

Benchmarking Industry-Science Relations - The Role of Framework Conditions

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Foreword

The European Commission proposed benchmarking as an instrument to promote the continuous improvement of Europe's competitive performance in October 1996 in its Communication on "Benchmarking the competitiveness of European industry" (COM(96) 463 of 09.10.1996). In response to this Communication, the Industry Council in November 1996 called on the Commission and the Member States to "initiate a number of pilot projects to address key areas of competitiveness". Since then, a number of pilot projects on benchmarking have been carried out.

This pilot initiative on benchmarking framework conditions was launched jointly by the Commission and the Member States in April 2000 with Austria playing the co-ordinating role. The lead expert team, managed by the Institute of Technology and Regional Policy, Joanneum Research, Austria, prepared this report. The content of this report is the responsibility of the authors and the European Commission.

Further information about the European Benchmarking Initiative is available on the European Benchmarking Website at: <http://www.benchmarking-in-europe.com>

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Preface

The project "Benchmarking Industry-Science Relations: The Role of Framework Conditions" was jointly commissioned by the European Commission, DG Enterprise, and the Austrian Federal Ministry of Economy and Labour. The project started in April 2000. Eight EU member states participated in this project by delegating national experts to the expert group of the project, by accompanying the project via a steering committee of national delegates and by producing country reports.

National experts from the participating EU member states produced national reports on industry-science relations that served as the major empirical background of this report. A 'lead expert team' from Austria co-ordinated the research and benchmarking work. They received highly valuable conceptual advice from the methodological facilitators appointed by Enterprise DG of the EU and effective organisational support from the Benchmarking Co-ordination Office (BCO). The project produced several outputs which were stored on the project extranet on the European benchmarking website (www.benchmarking-in-europe.com):

- Material on methodological issues for benchmarking industry-science relations (conceptual model, definition of indicators, database, questionnaire, structure of national analysis).
- Eight National Reports on industry-science relations (Austria, Belgium, Finland, Germany, Ireland, Italy, Sweden & UK).
- Outline of the approach of the project and early findings which were presented at the EU conference on Benchmarking 15-16 March in Brussels.
- Final Report on the role of framework conditions for industry-science relations. (this report is available for downloading from the European benchmarking website at: <http://www.benchmarking-in-europe.com>)

The authors would like to thank all members of the expert group and the steering committee for their considerable efforts and highly valuable contributions. They would also like to thank the methodological facilitators and the Benchmarking Co-ordination Office for their extensive support.

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Executive Summary

Background of the Study

Within the framework of the **EU-Benchmarking initiative** “Benchmarking the Competitiveness of European Industry”¹ a benchmarking project on industry-science relations (ISR) was carried out at EU level. It attempts to compare and assess the role of a set of framework conditions on the interaction between higher education institutions (HEIs) and public sector research establishments (PSREs - referred to as 'science') and the business enterprise sector (referred to as 'industry'), and to recommend areas for improvement. The benchmarking exercise covers **eight EU member states** (Austria, Belgium, Finland, Germany, Ireland, Italy, Sweden & the UK). **Two other countries**, the USA and Japan, are also considered as 'third country' comparisons.

In an increasingly 'knowledge-based' economy, the generation and use of scientific knowledge in the innovative efforts of enterprises is seen as one important dimension that determines the performance of a 'National Innovation System'. Hence, science and technology policy in recent years has devoted much attention to fostering Industry-Science-Relations (ISR) and in several countries, policy initiatives in this realm have been launched.

Against this background, this study compares and assesses the role of a set of framework conditions which influence ISR, that is, the relation between HEIs and PSREs on the one hand, and the enterprise sector on the other hand. Further, it identifies major programmes and policy initiatives and describes 'good practice' examples.

The approach applied in this study goes beyond a mere comparison of performance indicators and tried instead to describe, analyse and systematically compare the *processes* that lie behind the differences in performance. 'Policy learning' is only possible with knowledge about these processes and a broad discussion involving all 'stakeholders'.

A main aim of this study is to identify those framework conditions for ISR which either facilitate high levels of interaction or act as barriers to ISR, taking into account the following **areas of ISR**:

- collaboration in R&D (joint R&D activities, contract research, R&D consulting, co-operation in innovation, informal and personal networks),
- personnel mobility (temporary or permanent movement of researchers from industry to science and vice versa),

¹ COM(96) 463 final of 09.10.1996

- co-operation in training and education (further professional education, curricula planning, graduate education, PhD programmes),
- commercialisation of R&D results in science through spin-offs (disclosures of inventions, licensing patents, start-ups of new enterprises).

Among the variety of **framework conditions** governing industry and science interaction, we pay special attention to the following types:

- legislation and regulatory framework with respect to the different channels of ISR,
- institutional settings in public science, including incentive systems and institution-specific barriers,
- public promotion programmes and other policy initiatives aimed at stimulating ISR,
- intermediary structures implemented to foster interaction between industry and science.

This report attempts to **offer information to policymakers** on the following two key questions in the field of ISR:

- What types of generic mechanisms which either stimulate or impede ISR are in place in the countries considered?
- What is the practice of implementing or changing these generic mechanisms, which countries exhibit good practices, what are the key factors affecting policy success and how could one learn from the way others have addressed these mechanisms?

Main results

ISR are only one major element of innovation systems. Viewed in isolation, they cannot explain the difference in innovation and technology performance. Market conditions, financing, managerial and technology competencies of enterprises, along with different types of public infrastructures, to mention but a few, have to be considered as well. Policy considerations on ISR must be put into this perspective.

The level and pattern of ISR are largely determined by structural features of a national innovations system, i.e. the demand for and supply of knowledge as a result of industrial and scientific specialisation. ISR can only be understood and assessed against the background of these characteristics. Overly simplistic cross-country comparisons that do not take into account these differences are misleading.

Lower levels of ISR can be attributed mainly to a lack in demand on the enterprise side - a specialisation in innovation paths which do not require scientific knowledge or expertise (i.e. knowledge market is demand-driven) and to a lack of incentive structures and institutional factors on the science side. Typically, they do not reflect a lack in supply of scientific knowledge nor a willingness or readiness to co-operate on the science side.

Enterprises and science institutions use a variety of channels to exchange knowledge and technology. While intense co-operation through one channel (e.g. collaborative research) will stimulate the use of other channels (e.g. personnel mobility, co-operation in training or the start-up of new business ventures), interaction channels may also become substitutes. The intense use of informal contacts for example, may reduce the relevance of other modes of interaction, e.g. direct commercialisation of research results through spin-offs. Thus, low levels of interaction in some channels need not indicate ineffective knowledge transfer between science and industry. In order to properly assess the state of ISR in a specific country, all types of interactions must to be taken into account.

Looking at ISR on a national level is only useful as an entry point for further analysis. ISR differ largely by fields of technology and types of science institutions and enterprises. ISR are highly important, particularly in those fields of technology where new breakthrough innovations can be achieved and transferred to new products and processes (i.e. radical innovations) such as biotechnology, new materials & ICT. In these fields, high levels of ISR can be observed even in countries with low overall ISR intensity.

There is no single best practice model of ISR on a country level. However, in specific channels of interaction, various good practices in shaping framework conditions can be identified.

High levels of industry-science interaction occur when:

- industry demand is high as a result of the prevailing innovation strategies in the enterprise sector, and due to market incentives to engage in new technologies and apply new scientific knowledge,
- there are well-developed incentive schemes in science institutions to get engaged in ISR including individual remuneration, institutional mission and objectives, administrative and managerial support, balancing with other major objectives of science, i.e. education and fundamental research,
- there are special programmes which facilitate small and medium-sized enterprises (SMEs) by raising awareness in science, increasing innovation management capabilities and increasing R&D activities,
- legislation does not constitute as a barrier for interaction,
- there are public initiatives to foster ISR (via financial support, information provision, networking through intermediaries, training) on a sufficiently large scale,
- science and technology policy follows a stringent and long-term oriented approach of strengthening ISR, taking into consideration the various channels of knowledge interaction and technology transfer and fostering an overall favourable climate towards ISR.

Recommendations

There are a huge variety of good practice examples in framework conditions for ISR. In order to learn from these good practices, the following must be considered:

- Good practice is always specific to the market and institutional environment and addresses market failures and barriers stemming from this environment. Learning from good practice means firstly, learning to carefully identify these market failures and barriers and secondly, selecting a proper mechanism to tackle them.
- As a consequence, good practice should be related to specific fields of technology and the way in which knowledge production, knowledge exchange, and innovation takes place in these fields, and to the specific barriers to ISR that exist in them.

Bearing this in mind, some general conclusions on **good practice** in shaping framework conditions for ISR may be derived:

- ISR-related policy initiatives must be embedded in a comprehensive, stringent, and long-term oriented Science & Technology policy. ISR-related measures need a long-term perspective in order to achieve sustainable changes in behaviours and structures.
- ISR-related policies must take into account the various objectives of public science in economy and society. Good practice in ISR-related policies therefore, means a balance of technology transfer with education and fundamental research activities in public science.
- Joint research programmes which promote direct collaboration between industry and science are a well-established policy intervention mechanism which has a significant effect upon the level of ISR. In this area, good practice particularly refers to thematically focussed programmes which apply a bottom-up approach of defining joint research themes, have a long-term perspective of co-operation and rely, at least partially, on an 'infrastructure' approach, i.e. the establishment of institutions and/or facilities that are operated both by enterprises and science institutes and maintain co-operation after funding has ended.
- With respect to collaborative programmes, a competition-based approach of allocating funding has proved to be effective. Such an approach stimulates the involvement of a large number of applicants but restricts funding to promising 'best practice' cases which may serve as orientation points for other actors.
- Involvement of SMEs in ISR activities is a major issue in broadening the use of scientific knowledge in the enterprise sector. Good practice follows a two-side approach: First, absorption capacities of SMEs with respect to R&D, innovation management capabilities and the use of external knowledge and advice, should be strengthened and detached from any specific involvement in ISR. Secondly, SMEs with a sufficient in-house capacity for establishing science links may be stimulated to take up direct research and consulting contacts with science.

- Fostering the direct commercialisation of research results in public science is an important policy issue especially in fields such as biotechnology, genetic engineering, new materials, and new information and communication technologies. Good practice in commercialisation covers, amongst others: the provision of supportive infrastructure that reduces transaction costs and information asymmetries in using IPRs (patent licensing offices); advisory support and pre-seed capital for start-ups; and several awareness measures that raise the perception of researchers in the commercial potential of the research results they have achieved.
- Reforms of institutional settings in public science are particularly successful when the following issues are considered: implementing ISR as part of the institutions' mission; considering ISR activities in evaluations; providing both individual and organisational incentives; and linking industry and science through advisory boards.
- In many countries, a successful way of strengthening ISR was to establish transfer-specialised institutes either in universities or within public research laboratories. Key success factors in these institutions include: keeping together basic and applied research within one research team; regular auditing of the research strategy in order to cope with changes in economy and society; direct transfer between researchers and industry (i.e. avoiding intermediaries); and individual remuneration of successful transfer activities.
- Personnel mobility and interaction in graduate education have received attention in some countries as being a major issue in ISR. Good practice is often related to: exchange programmes which specifically address the personnel needs of SMEs; joint graduate education programmes that involve enterprises in the definition of the theme of a thesis, and allow students carrying out practical R&D work in the enterprise; and qualification programmes for industry researchers in HEIs.

ISR-related policies in most countries currently pays a lot of attention to certain issues (such as IPRs, academic start-ups, joint research, personnel exchange) while other areas of similar relevance (such as co-operation in curricula planning, vocational training, institutional reform and individual incentive systems) have had less attention and should be addressed more intensely by policy. More specifically:

- Interaction in education and vocational training (further professional education) becomes more and more important in a knowledge-based economy.
- In the field of higher education in the natural sciences and engineering, redesigns of curricula should involve both academia and industry.
- Policy should assign clear roles for the respective institutions in the science system. As there is a trade-off between ISR and public goals of education and knowledge generation, policy must strike a balance between the goals for each type of institution.

A. Methodology of Benchmarking ISR Framework Conditions

A.1 Introduction

This report summarises the main findings of a benchmarking project on industry-science relations (ISR) and the way in which framework conditions affect them. Industry-science relations, i.e. the various interactions between the private business enterprise sector (referred to as 'industry') and the public science sector (higher education institutions and public sector research establishments) have gained increasing attention in the last two decades or so. Smooth interaction between these two groups of actors in innovation systems is regarded as a major element for the success of innovation activities, industrial competitiveness and employment and growth. At regional, national and international levels, several initiatives have started to identify bottlenecks in ISR and to foster knowledge interaction and technology transfer.

The distinctive mark of this study is threefold: firstly, it applies a comprehensive macro-approach to the way ISR work in several countries, considering various channels of ISR and various types of actors. Secondly, it attempts to shed light on the role of framework conditions, i.e. those structural, cultural and policy-related conditions which define capacities and capabilities for ISR in industry and science, which guide individual behaviour by setting incentives and barriers, and which might be altered only in the longer term. Finally, it employs a benchmarking approach to this field, i.e. it identifies the key elements shaping ISR, defines key performance indicators and systematically compares national experiences in order to find good practice and to learn from the way ISR work in other countries.

The benchmarking exercise is based upon detailed information from eight EU member states: Austria, Belgium, Finland, Germany, Ireland, Italy, Sweden, and the UK. For each member state, national experts delivered a report which followed a unique, customised structure and used a common methodology, including structured expert questionnaires and standardised data definitions. Furthermore, the USA and Japan are considered as third countries in the benchmarking exercise and information on ISR in these countries is derived from the huge body of literature available.

The main aims of the benchmarking project are:

- (i) to develop a methodology for benchmarking framework conditions for ISR;
- (ii) to characterise in depth the distinct national models of ISR, i.e. the level of ISR, the pattern of interactions and the relevant framework conditions in each of the participating countries. This includes characterisation of knowledge production structures, the performance of ISR for different types of interaction and the policy-related framework conditions;

(iii) to identify those framework conditions for ISR which either facilitate a high level of interaction or act as barriers to ISR, taking into account the following areas of ISR:

(Throughout the report, a number of concepts and notions are used which denote central aspects of the benchmarking exercise. For clarification, these are defined below)

- *"Science"* refers to publicly financed higher education institutions (HEIs: universities, polytechnics and colleges) and public sector research establishments (PSREs: public research laboratories, governmental research institutes, academies of sciences and other publicly financed research organisations).
- *"Industry"* refers to the business enterprise sector and covers both the manufacturing and service sector.
- *"Industry-Science Relations" (ISR)* refers to different types of interaction between the industry and science sectors which are directed at the exchange of knowledge and technology. This includes direct and indirect transfer channels such as personnel mobility, graduate mobility, joint research projects, contract research and consulting, licensing, prototypes, spin-offs (start-ups by researchers from science), training for industry researchers, informal contacts (including the use of publications), personal networks, training of students at firms etc.
- *"Framework conditions for ISR"* covers all those factors which affect the behaviour of actors and institutions in industry and science, which are involved in knowledge and technology exchange activities. For analytical reasons we distinguish between two broad types of framework conditions: the *"knowledge production structures"* covers some general features of a national innovation system such as size, industry structure, R&D orientation, sector specialisation, market characteristics, and cultural and social attitudes. *"Policy-related framework conditions"* refer to those factors which are strongly shaped by policy decisions or may directly be designed by policymakers such as legislation, public promotion programmes and initiatives, the institutional setting in public science and the publicly established or supported infrastructure of intermediaries in the field of ISR.
- The term *"institutions"* is used to denote different types of organisations in public science characterised by different institutional settings such as mission, organisational structure, financing, stakeholders etc.

The report consists of three main parts. Part A describes the background of the project and the methodology employed. Part B summarises the national reports on ISR for each of the ten countries covered. Part C sums up and synthesises the results by comparing the national models of ISR, highlighting good practices for various channels of ISR and drawing conclusion for the design of ISR policies.

A.1.1 Why Benchmark Industry-Science Relations?

To say that scientific research is an important factor in modern industrial development and long-term economic growth is to state the obvious. Universities and science contribute substantially to the competitiveness of industries (see Mansfield 1995, 1997, Mansfield and Lee 1996). The contribution is greatest in the case of so-called science-based industries, i.e. industries with a high proportion of research input out of the total factor input (see McMillan et al. 2000, Meyer-Krahmer and Schmoch 1998). However, it is also substantial and apparently increasing in a growing number of other industries (see OECD 1999, 2000a).

In most economies, technology policy has sought to bring the worlds of scientific and commercially oriented research closer together. Innovation and technological development depend increasingly on the ability to use new knowledge produced elsewhere and combining it with the stock of knowledge available in a particular enterprise. For this purpose, absorptive capacities, transfer capacities and the ability to learn by interaction are crucial success factors in innovation (see Cohen and Levinthal 1989, 1990, Foray and Lundvall 1996). New and commercially useful knowledge is the result of interaction and learning processes among various actors in innovation systems, i.e. producers, users, suppliers, public authorities, and scientific institutions (see Lundvall 1988, 2000). Universities and other public research institutes, as major producers of knowledge, are increasingly expected to contribute to this process.

The rationale of this expectation is obvious. In Europe, the recognition of a gap between high scientific performance and industrial competitiveness has recently been labelled the 'European paradox' (see Pavitt 2000). If science matters in economic development, a decline in competitiveness raises the following question: either the science system fails to make the kind of research contributions upon which advanced industrial economies have become increasingly dependent or, industry lacks the ability and/or absorptive capacities to use effectively the new knowledge produced in the science sector.

In most European countries, a large share of research is carried out in universities and public research institutions. In order to reap large commercial benefits from this research, an efficient interface between public research and commercial exploitation is warranted.

Taking a broad view, science (i.e. higher education and public sector research establishments) contributes to innovation in industry via four major channels:

- (i) Industry receives inputs from science in the form of well-trained individuals. Although these individuals may require further training (which may also be supplied by higher education institutions), university education is the backbone of the production of human capital engaged in research activities in firms. Personnel mobility of researchers between science and industry (and vice versa) contributes, not only to the dissemination of coded knowledge, but also to the exchange of tacit knowledge.

- (ii) Knowledge produced in science institutions is disseminated as coded knowledge through publications, conferences and patents, and serves as a stock of knowledge which is available to the public and might be used by industry as a 'public good' input to commercial research. However, the use of the public good knowledge requires certain adoption and absorptive capacities. The increasingly complex and specialised nature of modern science makes it difficult to use potentially fruitful knowledge, especially by SMEs.
- (iii) Universities and public research institutions are increasingly involved in co-operative R&D projects with industry. Although these collaborations are varied in type, they are all characterised by an exchange of knowledge among participants with science usually in the role of the most important supplier of basic knowledge.
- (iv) In recent years, the creation of technology-based enterprises by researchers from science or by graduates has received increasing attention (see OECD 2000b, Bania et al. 1993). So-called start-ups or spin-offs are regarded as an important instrument for rapidly transferring new technological developments and innovative business ideas created in science, to commercial use.

The intensity of the interaction and co-operation between universities and industry which will be observed presently (see Schmoch 1999, Hicks 2000, OECD 2000a) owes much to the following two, interrelated factors (see OECD 1998):

- Increasing budgetary stringency forces policy makers to make tough choices in the allocation of resources which affect the science system. Universities and other public research institutions are forced to seek external sources of income and are thereby encouraged to carry out research work financed by industry. Indeed, there is a clear trend of a growing share of funding of HERD by the business sector while the total public share is steadily declining (see Table A.1.1).

Table A.1.1: HERD^a by Funding Source 1983 - 1997 for 7 EU countries^b (in %)

	<i>Total public share</i>	<i>General university funds (GUF)</i>	<i>Direct government funds</i>	<i>Foreign</i>	<i>Business</i>	<i>Other Income</i>	<i>Private non-profit organisations</i>
1983	94.0	68.3	25.7	0.6	2.9	1.1	1.5
1985	92.7	65.2	27.5	0.7	3.7	1.3	1.7
1989	89.9	60.2	29.7	1.4	5.4	1.2	2.1
1991	89.4	61.7	27.7	1.6	5.5	1.2	2.3
1993	87.7	60.1	27.6	2.5	5.8	1.4	2.7
1995	85.6	59.0	26.6	3.2	5.7	1.8	3.7
1997	84.6	57.9	26.8	3.5	6.4	1.7	3.8

a Higher education expenditures on research and development

b Denmark, France, Germany, Italy, Ireland, the Netherlands, the UK; figures represent the weighted average.

Source: OECD (1998, 2000), calculations by the authors

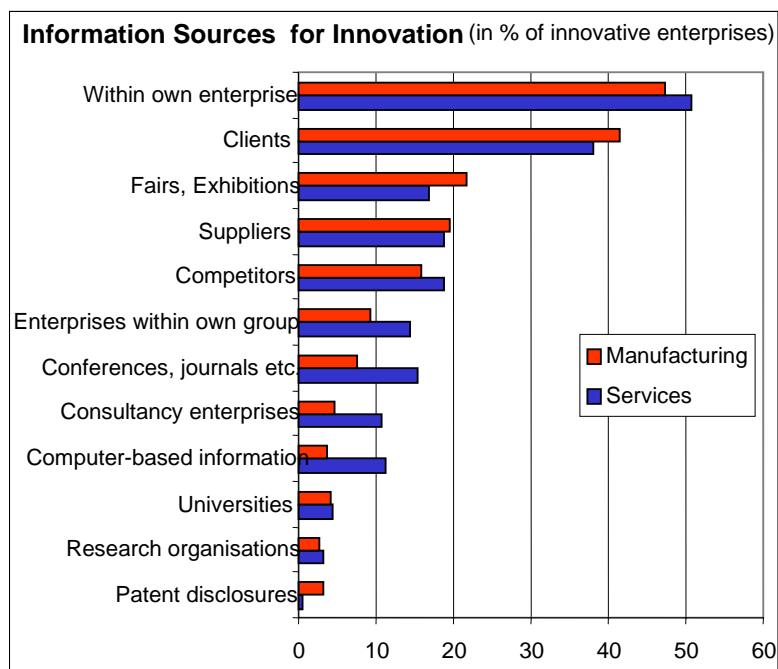
- At the same time, growing "knowledge intensification" (see OECD 1996, 1997) of industrial production makes scientific knowledge more valuable to industry. So-called 'science-based technologies' (biotechnology, information technologies, new materials) are defined as fields with frequent reference to scientific knowledge. This trend is also indicated by a growing number of citations of scientific literature in patent documents (Schibany et al. 1999).

In practice the contributions of science to innovation and the relation between research institutions and enterprises is not as straightforward as a linear view of the innovation process would imply. The functioning of the science system is governed by rationale and different institutional settings which are different to those prevailing in the enterprise sector. Furthermore, there are considerable differences between national science systems, which results in divergent objectives and attitudes towards the role of science in innovation and industrial competitiveness. Depending on these national designs of innovation systems, the exchange of knowledge between science and industry takes place through different channels and is affected by various factors - not all of them necessarily functioning smoothly.

The linkages between science and industry, and the effectiveness and efficiency of these linkages for a smooth exchange of knowledge and successful innovation, are many-faceted and difficult to measure and evaluate. Historical development, cultural and social attitudes, political decisions and objectives, institutional settings and economic specialisation and structures, result in a country-specific pattern of industry-science relations (ISR). These country-specific features cannot be captured accurately by a single set of quantitative indicators. Consequently, these different national settings make it extremely difficult to compare the structure and performance of ISR by a single analytical method such as for example, econometric modelling. In particular, one has to take into account the very different framework conditions for ISR. In order to capture the variety of these framework conditions and their impact on ISR performance, a *benchmarking approach* seems appropriate.

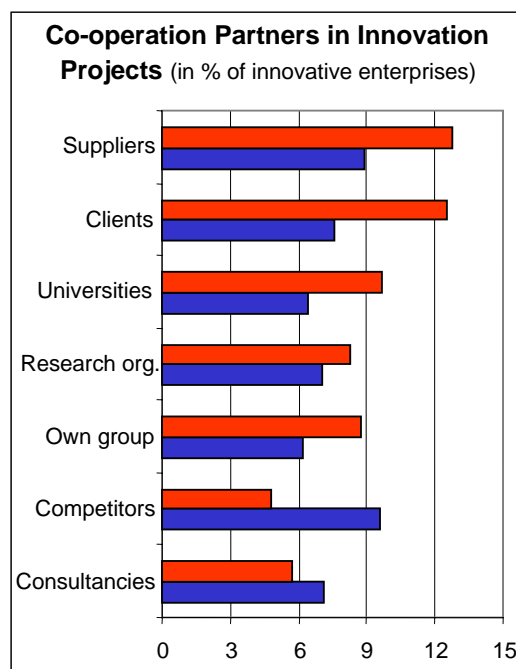
Benchmarking ISR attempts to provide an insight into how to improve relations within a national system of innovation, in order to increase innovation performance and as a result, industrial competitiveness. It is important to bear in mind however, that there is only a loose link between the performance of ISR and the level of innovation activities and innovation success, and that there are many more variables affecting the performance measures of an innovation system. This may be illustrated by the empirical evidence derived from the Community Innovations Surveys (CIS). Only a small fraction of innovative enterprises use science, i.e. universities and public research labs, as an important information source in their innovation projects (see Figure A.1.1). In 1996, only 4 and 3 percent of innovative enterprises used information from universities and public (including non-profit) research organisations respectively, for designing their innovation projects. Compared to internal sources (e.g. in-house R&D, information from marketing departments, enterprises within the own firm's group) and to market stimuli (clients, competitors, suppliers), science plays no major role for driving innovation activities in the majority of enterprises. This pattern is a robust finding throughout the EU member states.

Figure A.1.1: Information Sources in Innovation: Results from the Community Innovation Surveys 1996



Source: Eurostat New Cronos (CIS2), calculations by the authors

Figure A.1.2: Co-operation Partners in Innovation: Results from the Community Innovation Surveys 1996



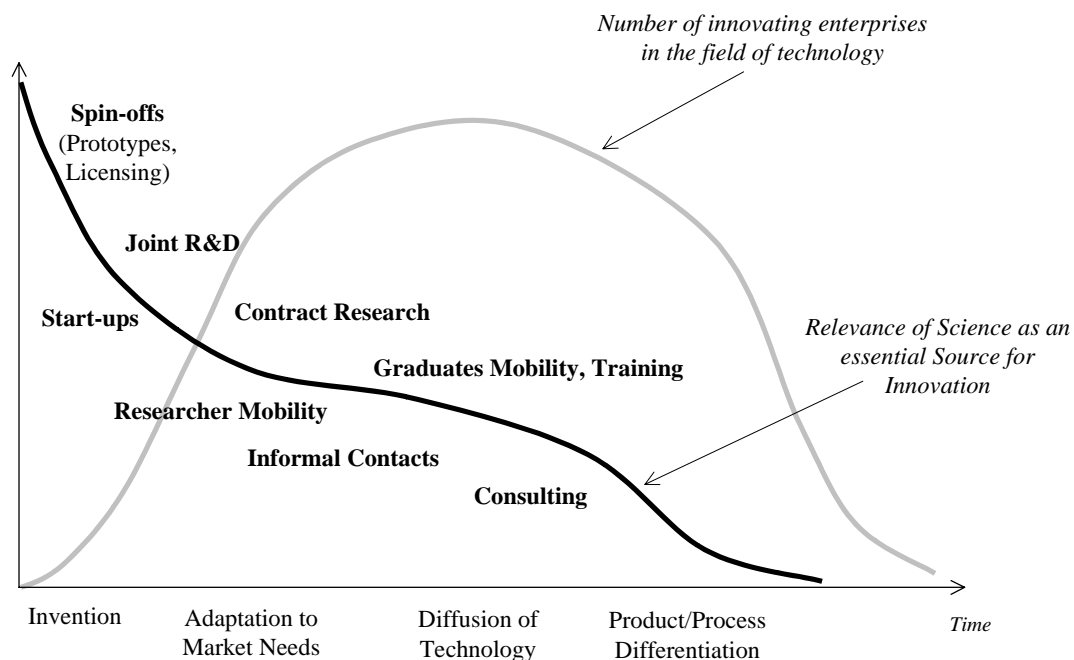
Source: Eurostat New Cronos (CIS2), calculations by the authors

Universities and public research labs however, are more important as a co-operation partner in innovation projects, for example, in carrying out certain types of R&D even if the information

source for starting and directing the innovation comes from another source. Figure A.1.2 reveals that science has almost the same significance as a co-operation partner in innovation as suppliers or clients. Nevertheless, only 6 to 10 percent of all innovative enterprises in Europe (in the reference period 1994 to 1996) have carried out innovation activities in co-operation with science, where the co-operation takes a variety of forms and need not be restricted to collaborative research.

The low direct significance of science in industrial innovation is easy to explain when looking at the type of knowledge typically offered by science and the demand for such knowledge in the innovation cycle (see Figure A.1.3). Science institutions initially offer new technical and methodical knowledge, which is mainly needed in innovation activities which are oriented towards developing new technologies, new materials, new devices and products which are very new to the market. These activities take place in the early stages of the innovation process i.e. before market entry and in a stage of low competition. As such innovation activities are characterised by high uncertainty and low demand for the outcomes of innovation activities, only a few pioneering firms are engaged in such activities. In part, these pioneers are start-ups by researchers who wish to commercialise a new product, technology or business method. But there may also be well established enterprises which use new scientific knowledge in order to establish new business activities by acquiring prototypes or licenses, or by adopting new scientific knowledge via joint research activities or researcher mobility.

Figure A.1.3: Science as a Source for Innovation in the Innovation Cycle



Source: presented by the authors

However, the vast majority of innovation activities are located in latter stages of the cycle, i.e. in the re-design of already existing products to market needs, in the diffusion of new technology to new areas of application, and in the adoption of new technologies invented

elsewhere to own production and organisation. For all these activities, heavy interaction with clients and suppliers and careful observation of market developments, particularly that of competitors, are critical success factors. Thus, ISR in innovation projects are relevant only to a small fraction of enterprises, as is revealed by Figure A.1.1.

Nevertheless, theoretical and empirical work in innovation economics suggests that on a broader perspective, the use of scientific knowledge in setting up and maintaining industry-science relations, positively affects innovation performance as measured by the share of sales due to new products or services (see Kline and Rosenberg 1986, Kline 1985, Dodgson 1994, David and Foray 1995, Cohen and Levinthal 1989, OECD 2000a, Rothwell 1992). Of course, ISR are just one factor amongst a variety of determinants influencing an enterprise's innovation performance, such as

- absorptive capacities of the enterprises (e.g. in-house R&D, qualification of employees, innovation management capabilities, technology skills),
- market structure and demand characteristics (e.g. market dynamics, degree of competition, user-producer-relations, lead market characteristics of the home market, price elasticity of demand),
- industrial networks (e.g. networks with technology suppliers, sector-specific spillovers),
- factor markets (e.g. price of labour and capital, shortage in supply of qualified labour),
- technology dynamics and the potential for complementary application of technologies,
- innovation policy and regulation (e.g. promotion programmes, institutional and legal barriers and incentives, public financing, public procurement).

Industry-science relations, including technology licensing, start-ups, knowledge spillovers through informal contacts, and the provision of highly qualified labour, are therefore only one aspect among many which drive innovation activities in an economy.

For the benchmarking ISR exercise, these results have some important consequences. Firstly, ISR performance should not be related too closely to innovation performance. Secondly, when looking at framework conditions for ISR on the demand side (i.e. firms), one has to bear in mind that only a small fraction of firms are relatively close partners in ISR. Thirdly, framework conditions for ISR may have a particularly strong effect on innovation performance in the early stage of the innovation cycle and in the course of technological breakthroughs, where the integration of new scientific knowledge in industrial innovation is of special relevance.

A.1.2 The Limits and Scope of Benchmarking ISR

In general, the benchmarking approach attempts to analyse the factors determining the performance of a certain process by comparing various ways of carrying out the process. A standard or 'best practice' is identified by examining how the highest level of performance is

achieved. From best practices, one could learn how to improve one's own process and increase one's own performance (see Bogan and English 1994). While benchmarking was originally introduced as a management tool for comparing industrial processes and learning from those enterprises with the best performance, caution must be exercised when applying this method to a field like ISR and the role of different national framework conditions. "Countries are characterised by systemic differences and therefore what is best practice in one country or region will not be best practice in another. Therefore the more modest aim to develop 'good' and 'better' practices through 'learning by comparing' is more adequate" (Lundvall and Tomlinson 2001, 122). This approach is labelled "intelligent benchmarking" and focuses on the development of "a common understanding and shared objectives which make it more meaningful to benchmark some specific aspects of the innovation system" (Lundvall and Tomlinson 2001, 131), rather than comparing a set of quantitative indicators. In our work, we have tried to avoid the traps of a "naive benchmarking" approach, while still making as much use as possible from quantitative indicators.

Benchmarking as a tool for learning and improving practice was first introduced at the level of enterprises. Benchmarking exercises in enterprises follow a multi-stage approach (see O'Reagain and Keegan 2000), which traditionally consists of: a definition stage (which process or series of processes should be analysed); the identification of the world's best (identifying best practices in the process including key performance indicators); a comparison stage (comparing own operation and performance in a process with that of the world's best); and a learning stage (improving the processes in order to achieve the same performance as the best). As benchmarking is intended to be a continuous learning process, the exercise should be repeated regularly.

The objective of our benchmarking exercise is to analyse the role of a certain set of framework conditions for innovation performance and competitiveness, i.e. interaction between industry and science in the context of innovation activities. O'Reagain and Keegan (2000) proposed the application of their benchmarking procedure to such an analysis, in the same way as it is applied on the enterprise level, i.e. to select areas of improvement, to identify best practices in these areas, to develop a set of indicators (benchmarks) in order to position a process analysed vis-à-vis best practices, to study the best practice processes in great detail, pay particular attention to the conditions under which best practice is achieved, and to derive, with recommendations, how to adjust framework conditions to the best practice case. These recommendations should then be used as an input in dialogue with concerned actors.

The applicability of such a procedure to the benchmarking of framework conditions in the area of ISR is limited however, due to several reasons. In general, the process under analysis is very different from that in a traditional benchmarking exercise carried out at the enterprise level. On the enterprise side, the focus is on well-defined industrial operations in production, distribution or organisation within an enterprise, which may be compared to very similar operations in other enterprises acting in the same market. In our case, we look at behaviour, decisions and social interactions of economic actors acting on very different markets and

under very different institutional and organisational settings. Benchmarking industry-science relations has to be dealt with at a much more detailed level than enterprise-based benchmarking, as it must include the framework conditions under which interactions take place, including features of the innovation system and policy objectives in the fields of innovation and research policy.

There are also considerable differences in the objectives of benchmarking at the enterprise level and at the level of policy-driven framework conditions (see Lundvall and Tomlinson 2001). Benchmarking framework conditions in general attempts to identify the impact of the regulatory, institutional and policy framework on certain outcomes of economic and social processes, and, by which means and in which direction framework conditions should be improved in order to maximise economic performance, welfare or other policy objectives. These performance measures, however, are affected by a broad set of factors and policy designed framework conditions are only one among many. In general, performance is driven by decisions of economic actors which first of all, rest on market stimuli. While benchmarking at the level of the organisation is restricted to distinctly defined and directly observable processes, benchmarking framework conditions deals with complex processes which are characterised by a large set of partially interrelated determinants, not all of which are easy to measure and where only some of the relationships between process elements are well known. Thus, benchmarking framework conditions faces the difficulty of identifying the marginal effect of framework conditions on performance and of considering the indirect effects of framework conditions, and their changes, on other factors affecting performance (such as incentives for economic actors, market structures etc.).

Furthermore, policy framework conditions are heavily dependent upon the institutional and social setting within a society. As this setting is the result of historical development, differences in framework conditions reflect long-term differences in social, economic and political developments. Transferring best practices (i.e. the way the institutional, regulatory and policy framework is designed) in order to achieve a certain performance may be difficult as a best practice in a certain country (i.e. in a certain institutional environment and systemic setting) may not be compatible to the institutional and social setting in another.

In addition to these general limitations in applying the benchmark approach towards the area of framework conditions and policy regulations, there are further methodological challenges when looking at the way framework conditions influence the performance of industry-science relations (ISR):

- ISR are **not one single process of interaction** between actors in an innovation system but cover a huge variety of relations, each being determined by partially different variables. A certain framework condition may affect different types of relations in different ways. In some cases, the promotion of a certain interaction channel will crowd out the use of another one. As each type of interaction is suitable for a certain type of knowledge to be transferred, this may impair the overall flow of knowledge between industry and science.

As a consequence, benchmarking of framework conditions for ISR must be differentiated by type of relation.

- Framework conditions for ISR comprise a **diverse set of regulations, institutions, promotion measures, incentive schemes** etc. Each type of framework condition exerts a different effect upon ISR and effects can be mutually strengthening, neutralising or counteractive. Thus, it is quite difficult to isolate the separate effect of a certain framework condition on the performance of ISR and to identify best practice in framework conditions. Moreover, many framework conditions are almost 'joint productions' where it is not possible to adjust one element without changing other ones too. For instance, introducing a certain type of public research organisation with strong technology orientation into a national innovation system may demand reforms in legislation concerning personnel mobility, wage system, IPR, contract research etc. which will also affect the already existing public research organisations and could be counterproductive for them.
- ISR are **specific to certain economic sectors and fields of technology**. The nature of the linkages will vary along with market conditions, demand characteristics, technology characteristics, and national and international industry networks. Framework conditions for a certain type of ISR may have very different effects on ISR performance in different sectors and technology fields. For example, framework conditions for start-ups with respect to venture capital provision, pre-seed financing, enterprise creation regulations and support for consulting, operate differently in young technology fields such as biotechnology, than in well established fields with high market competition and a cumulative technical progress such as machinery or technical services. This, of course, leads to huge differences in entry barriers and influences the potential to commercialise new scientific knowledge via spin-offs. Therefore, benchmarking should be differentiated by sector or fields of technology but one must be careful when transferring best practice in framework conditions for ISR between sectors.
- There is a significant **time lag in the marginal effects of framework conditions on ISR performance** and this varies by type of interaction, by type of framework condition, and by the field of technology considered. This makes it extremely difficult to associate a change in general framework conditions to an observable change in ISR performance. Benchmarking mostly has to analyse historical situations in framework conditions while the actual situation and current trends are of little relevance for understanding the current situation in ISR performance. Furthermore, most data on ISR - as far as it is actually available - is published after a considerable time lag. Therefore, international benchmarking has to **rely on somewhat 'historical' data** of key performance indicators which show the way ISR has operated some years ago. In a rapidly changing environment, technology policy depends on current information and trends and has to learn from relatively recent experiences in order to adjust its strategy and measures to the current situation.

- The promotion of ISR by policy (i.e. the framework conditions designed by policy to stimulate ISR) follows **two main objectives which are only in part, going in the same direction**. On the one hand, ISR ensures that public investments in higher education spill over to the enterprise sector and makes these investments economically productive. On the other hand, ISR are regarded as a tool for enterprises to raise their competitiveness and technology performance by using complementary sources available in public research for their innovation efforts (i.e. acquire external knowledge). Following both objectives may not go together smoothly and may even be counteractive. For example, heavy promotion of technology transfer activities by public research institutions may crowd out other knowledge sources relevant to enterprises which have higher productivity than firm innovation, or, high application oriented science may lead to an under-investment in long-term oriented research activities and to a lack in supply of basic knowledge relevant to radical innovations, in newly emerging fields of technology.
- Good performance of ISR is not a policy objective in itself, rather ISR are regarded as an intermediary input in the innovation process and should contribute to a higher level of innovation, productivity, international competitiveness, and growth. Thus, the performance of ISR must be related to its impact on these output measures, both at the level of enterprises and the economy as a whole. However, the performance of **ISR affects economic performance variables only to a low extent**, while many other factors are of considerably higher relevance. As a consequence, in benchmarking ISR care must be taken not to overestimate the impact of ISR performance on innovation and competitiveness. Furthermore, the relation between innovation performance and ISR performance is likely to be re-occurring, i.e. a high level of innovation activities and a strong market position in new technologies will positively affect the demand for knowledge interaction with science and stimulate ISR on various levels.

A.2 Conceptual Framework of the Benchmarking Exercise

A.2.1 Basic Concepts for Benchmarking ISR

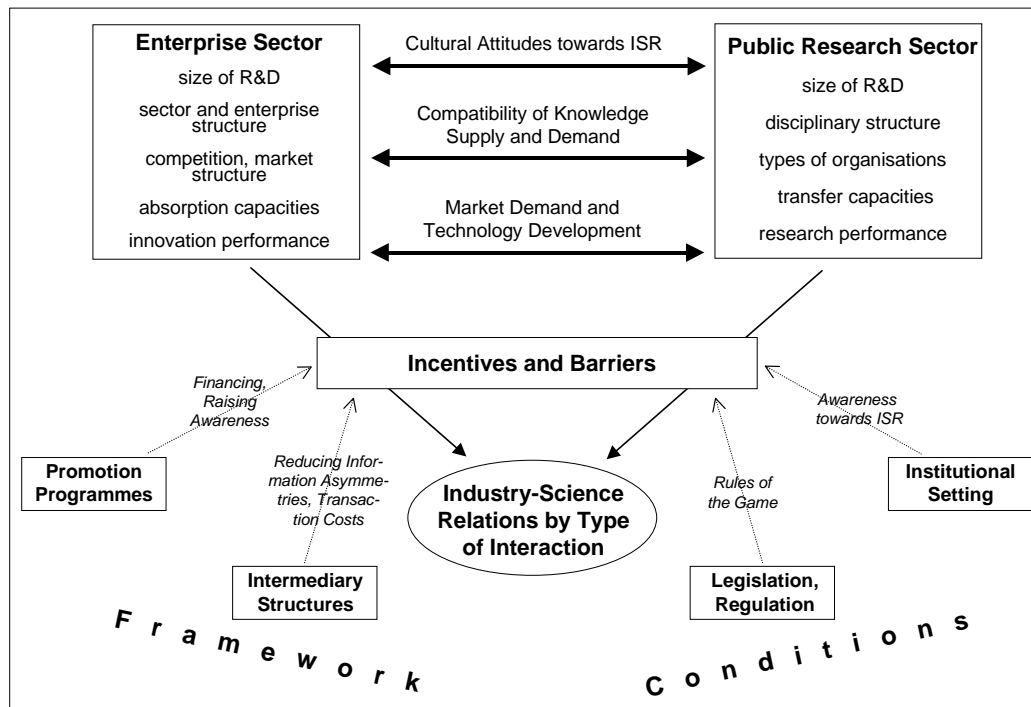
For benchmarking framework conditions for ISR, we start with a general model of industry-science relations. The model refers to a market conceptualisation of ISR, i.e. ISR are regarded as the result of market decisions by actors on the 'knowledge market'. Due to the economic characteristics of knowledge, this market is characterised by particular features such as: high information asymmetries between market actors and low market transparency; high transaction costs for knowledge exchange due to a certain set of prerequisites demanded on each side of the market actors (i.e. transfer and absorption capacities); high spillovers to other market actors (i.e. a low level of appropriation of benefits of the knowledge acquired); restrictions for financing knowledge production and exchange activities due to risk-averse and short-term oriented financial markets; the existence of joint products (i.e. knowledge is not arbitrarily divisible); and sometimes, the need for collaborative production of knowledge which loosens the distinction of user and producer on the knowledge market and demands a reciprocal interaction in knowledge exchange. These market features result in a particular incentive structure for market actors, in specific barriers to market interaction, and in a high importance of the shape of policy designed framework conditions to compensate for market failures and to stimulate knowledge transfer.

In our model of ISR, we distinguish therefore, between three groups of variables affecting the ISR performance in a certain country (see also Bozeman 2000 for a similar approach). First, characteristics of the main market actors (enterprises and public science institutions, i.e. higher education institutions - HEI, and public sector research establishments - PSRE) represent demand and supply on the national knowledge market. The coherence of demand and supply structures determines the potential demand for interaction and shape incentives and barriers for market actors. Second, framework conditions such as public promotion programmes, intermediary infrastructures, legislation and regulation, and institutional settings, may either stimulate ISR by reducing barriers and setting behavioural incentives, or impede ISR by erecting barriers or by setting disincentives. Third, performance indicators for ISR measure to which extent industry and science interact with each other in various channels and in different fields of technology (see Figure A.2.1). A detailed analysis of both structural characteristics and policy framework conditions in areas with a high ISR performance allows us to identify good practices and areas where learning can take place.

The structure and performance of the enterprise sector determines the demand for industry-science relations and is the prerequisite for any level of ISR in an economy. Here, we consider: the composition of the sector (i.e. the relative size of research in different fields of technology); enterprise structure (relevance of large corporations versus SMEs, relevance of foreign-owned enterprises); market structures within each field of technology (degree of competition, level and quality of demand); absorptive capacities (i.e. skills, innovation

management capabilities of enterprises); and innovation performance with respect to the specialisation of certain stages in the innovation cycle and the level of innovation activities. A low R&D potential and an unfavourable structural setting for innovation activities will significantly reduce the demand for scientific knowledge and thus, the relevance of ISR for the enterprise sector.

Figure A.2.1: A Conceptual Model for Analysing Industry-Science Relations



Source: presented by the authors

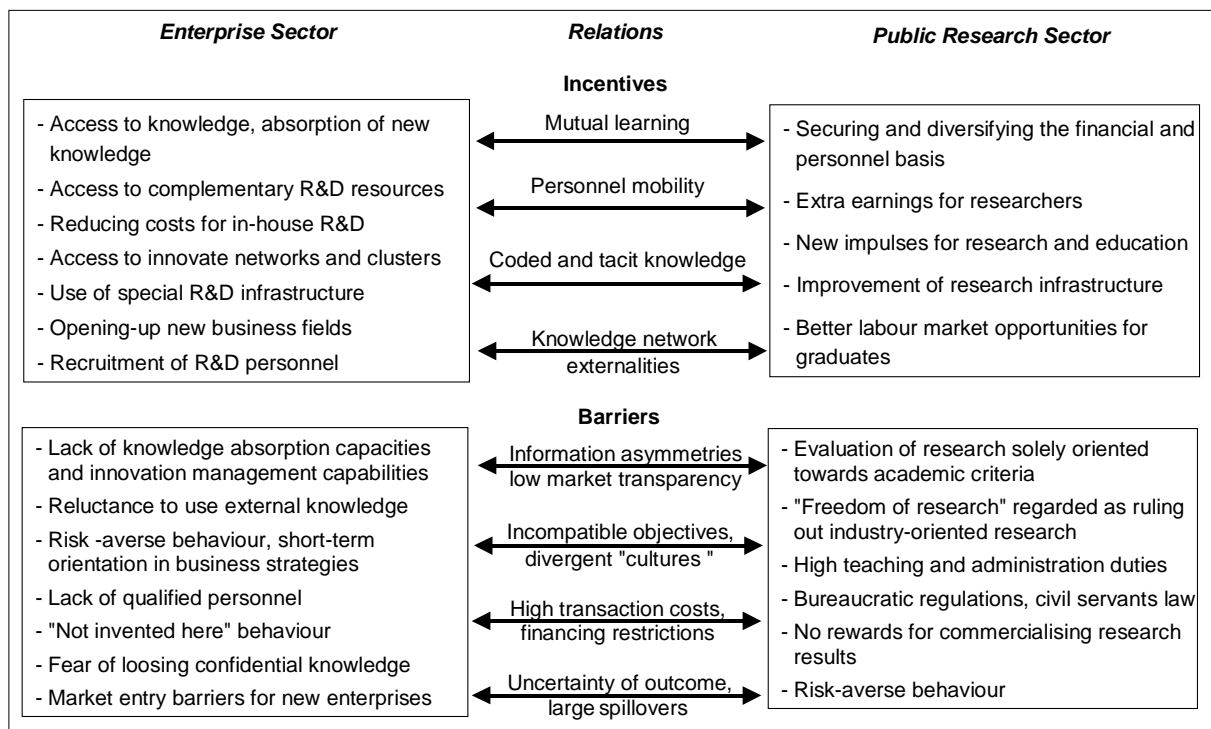
On the other side of the 'knowledge market', the structure and performance of the public research sector determines knowledge supply and knowledge transfer capacities. Major variables here are: the disciplinary structure (i.e. the share of different scientific disciplines in total research activities); the types of organisations (relevance of various types of public research institutions such as universities, polytechnic colleges, public research labs, joint industry-university labs, as well as the relation between civil and military research); the transfer capacities governing the research orientation and research mission (long-term, pure basic research, oriented basic research, short-term applied research); as well as the mode of financing, personnel qualification and personnel capacities; and the research performance with respect to scientific excellence and patent applications.

The level of ISR is strongly affected by the extent to which demand for knowledge interaction and absorptive capacities in industry meets knowledge supply and transfer capacities in science. Here, the congruence between technology specialisation in the enterprise sector and disciplinary structures in science plays a crucial role. Furthermore, the specialisation of enterprises within the innovation cycle (i.e. invention, adaptation, diffusion and product differentiation stages) and the orientation of research performance in science on industry

needs, affect the level of ISR. Market demand and technology development trends in the various fields of technology also play a major role as they represent major information sources and competitive pressures for firms to direct and strengthen their innovation activities. Finally, there is the impact of cultural and social attitudes towards the role of science in society and the degree to which it should be oriented towards technology transfer to industry and adjust its scientific efforts and themes of research on industry needs, which may be regarded as a particular feature of a national innovation system and not directly affected by policy measures.

Matching knowledge supply and demand is a necessary condition for establishing ISR in innovation activities. The extent to which this potential is utilised depends on how incentive structures and barriers work inside an innovation system and the way they influence the behaviour and decisions of market actors. Figure A.2.2 shows major incentives for and barriers to, ISR in the enterprise sector, in the public research sector, and in the relation between both sectors.

Figure A.2.2: Incentives for and Barriers to ISR



Source: presented by the authors

Of course, the main incentives are the income for public research institutions from research collaboration with enterprises, and the access to knowledge for enterprises, which may act as a competitive advantage. Other incentives are in the field of education and personnel recruitment, network building, and mutual learning. The barriers to ISR are dependent upon: certain behavioural features of the market actors (such as risk-averse behaviour, idiosyncratic behaviour, innovation management capabilities); market inefficiencies (such as a lack of qualified personnel or in financing sources); market failures (information asymmetries, lack

of transparency, transaction costs, spillovers, uncertainty etc.); and incentive structures which are not favourable for ISR (such as evaluation solely oriented towards academic criteria or short-term orientation in enterprise strategies due to short-term oriented financial markets).

Publicly designed framework conditions for ISR affect these incentives and barriers in two different ways. On the one hand, some are the direct result of certain framework conditions such as institutional settings in public research organisations, evaluation procedures applied, regulation of labour and financial markets, or legislation on ISR-relevant issues. On the other hand, policy attempts to design framework conditions which reduce market failures in the knowledge market, remove the barriers inherent to knowledge interaction, and thus stimulate ISR. We distinguish four sets of such framework conditions:

- (i) *Legislation and regulation* (i.e. the legal framework) may act as incentive in encouraging ISR (e.g. transfer-oriented IPR-regulation) but may also impede ISR (e.g. civil servants law complicating personnel mobility, taxation of contract research incomes).
- (ii) *Public promotion programmes* often provide financial resources for ISR and thus compensate for high transaction costs, spillovers, uncertainty of R&D results, and a lack of financing by risk-averse capital markets. Furthermore, programmes attempt to raise public awareness towards ISR and change individual behaviour and attitudes which are not favourable for ISR.
- (iii) *Intermediary structures* are established in various forms in all countries covered in this analysis. They cover both physical and immaterial infrastructure such as technology centres, incubators, consulting networks, information networks and databases devoted to fostering ISR, and represents those framework conditions which may directly be designed by policy.
- (iv) *Institutional settings* in Higher Education Institutions (HEIs) and Public Sector Research Establishments (PSREs) determine the incentives and barriers for researchers in public science to engage in ISR, including: evaluation criteria and procedures; individual remuneration; financing sources and schemes for R&D; institutional missions and organisational cultures; recruitment policies; auditing and strategic planning; administrative support etc.

A major conceptual element of our benchmarking approach is to analyse structural variables, framework conditions and ISR performance specific to various types of knowledge interaction between industry and science. Both empirical and theoretical work has shown that there are very different types of knowledge exchanged in innovation processes, and that there are differences in the effectiveness of various kinds of channels for exchanging a certain type of knowledge (Foray 1994, 1997, Smith 1995). Thus, while both industry and science normally rely on a broad set of channels when interacting with each other, the relative importance of the channels will vary with the type of innovation activity carried out, the type of knowledge demanded, the absorption and transfer capacities in enterprises and science, the type and

extent of market failures prevailing on the knowledge market etc. Table A.2.1 presents several types of interactions in ISR and qualifies these types by three dimensions which define their suitability to knowledge transfer: the degree of formalisation, the extent to which tacit knowledge may be transferred, and whether a personal interaction takes place.

Table A.2.1: Types of Knowledge Interactions between University and Firms

<i>Types of knowledge interaction</i>	<i>formalisation of interaction</i>	<i>transfer of tacit knowledge</i>	<i>personal (face-to-face) contact</i>
Employment of graduates by firms	+/-	+	-
Conferences attended both by industry and science	-	+/-	+
New firm formation by researchers from science	+	+	+/-
Joint publications	-	+	+
Informal meetings, talks, communications	-	+	+
Joint supervision of PhDs and Masters theses	+/-	+/-	+/-
Training of employees of enterprises	+/-	+/-	+
Mobility of researchers between industry and science and v.v.	+	+	+
Sabbatical periods for researchers at both sides	+	+	+
Collaborative research, joint research programmes	+	+	+
Lectures at universities held by employees of enterprises	+	+/-	+
Contract research and consulting	+	+/-	+
Use of public research facilities by industry	+	-	+/-
Licensing of patents held by science to enterprises	+	-	+/-
Purchase of prototypes developed at science	+	-	+/-
Enterprises reading of publications, patent disclosures etc.	-	-	-

+: interaction typically involves formal agreements, transfer of tacit knowledge, personal contacts

+/-: varying degree of formal agreements, transfer of tacit knowledge, personal contacts

-: interaction typically involves no formal agreements, no transfer of tacit knowledge, no personal contacts

Source: Schartinger et al. (2001)

We concentrate our benchmarking analysis on those types of knowledge interactions between industry and science which are based, at least to some degree, upon formal and personal interaction and allow for the transfer of tacit knowledge which is regarded as a critical success factor in learning and successful innovation (see also Schmoch 1999, Abramson 1997, Cohen et al. 1995, Schartinger et al. 2000, 2001, Schibany et al. 2000). These include:

- *Collaborative research*, i.e. carrying out R&D projects jointly by enterprises and researchers in science.
- *Contract (commissioned) research and technology consulting*, i.e. the placing of R&D contracts by enterprises in science institutions and the use of technology advice by enterprises.
- *Personnel mobility*, i.e. the permanent or temporary move of researchers from science to industry and vice versa;
- *Co-operation in graduate education* such as temporary practical studies in enterprises or the joint supervision of thesis.

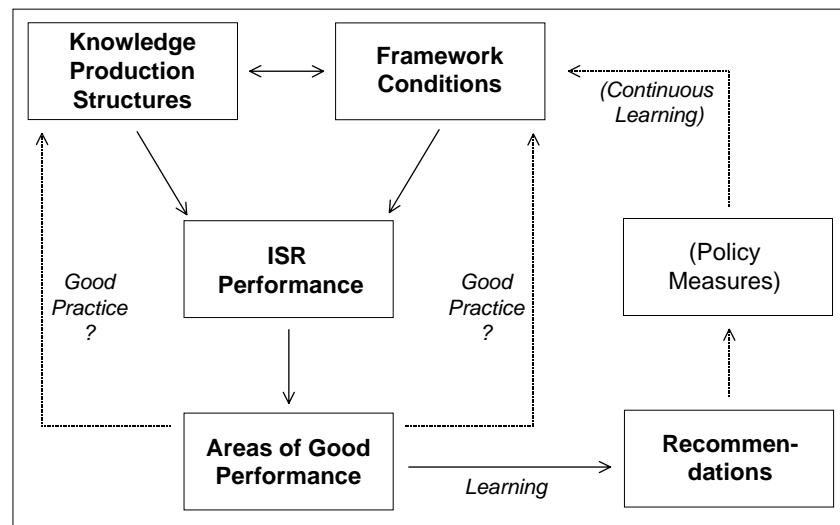
- *Vocational training for employees*, i.e. further education for enterprise staff in research and innovation related topics.
- Use of *Intellectual Property Rights (IPRs) by science* both as a tool for indicating technological competence and as a base for licensing technologies to enterprises and receiving royalties.
- *Start-ups of technology-oriented enterprises by researchers in science*, i.e. transfer of new research results into commercial value by creating new enterprises.
- *Informal contacts and industry-science networks* on a personal or organisational basis, including informal consulting and information exchange, Alumni meetings, mutual memberships in advisory boards, sponsoring of professorships by industry etc.

Of course, there are additional ways of exchanging knowledge between enterprises and public research organisations which represent important transfer channels and these will be considered in the benchmarking exercise on a qualitative level. These include, amongst others: the employment of graduates in enterprises (who may transfer new knowledge from universities to industry); the reading of articles and scientific papers; joint scientific publications by researchers from enterprises and public research institutions (which often coincides with collaborative research projects); and lectures by employees of enterprises at universities.

A.2.2 Layout of the Benchmarking Process

The benchmarking approach applied in this project is modelled on the procedure shown in Figure A.2.2. Based on standardised methodology and analytical structure, national experts produce reports on the performance of ISR, the structure of knowledge production and the prevailing policy-related framework conditions for ISR in their countries. This information is used firstly, to produce uniform 'national models of ISR' to identify those framework conditions that foster the exchange of knowledge and technology between industry and science. Secondly, it is used to compare national approaches to the shaping of framework conditions in several critical areas of ISR, such as IPRs, start-ups from public science, personnel mobility, training & education, joint R&D efforts, science-based industries, and the involvement of SMEs in ISR. A detailed analysis of both structural characteristics and policy-related framework conditions in areas with a high performance in ISR allows identification of good practices and areas where learning may take place. Special emphasis is placed on the way in which good practices depend upon specific barriers and incentives that prevail in certain national innovation systems. The exchange of this information, and the discussion among policy makers and experts on the experiences each country has had in shaping framework conditions for ISR, shall stimulate learning and adoption processes and ultimately, contribute to a continuous learning process.

Figure A.2.2: Procedure of the Benchmarking Exercise on ISR and the Role of Framework Conditions



Source: presented by the authors

Indicators of ISR

For each country considered in the benchmarking exercise, indicators are measured on the structure and performance of knowledge supply and demand in the business enterprise and the public science sector ('knowledge production structure'). The following indicators are used (see Table A.2.3):

- R&D performance with respect to R&D intensity of the business enterprise sector (BERD as a percentage of GDP), the higher education sector (HERD as a percentage of GDP), and the government sector (GOVERD as a percentage of GDP); change in total R&D intensity during the 1990s (GERD as a percentage of GDP)
- Enterprise structure with respect to the significance of large enterprises and foreign-owned enterprises in business enterprise R&D performance
- Absorption capacities in SMEs with respect to their R&D and patent activities
- High-tech orientation of the business enterprise sector with respect to the share of high-tech, medium to high-tech and IT services in total BERD; patent application intensity in high-tech areas and in global markets; share of the enterprise sector in total basic research
- Disciplinary orientation in public science with respect to the share of natural sciences and engineering in total HERD and GOVERD respectively
- Excellence of science with respect to impact factors of scientific publications in natural sciences and engineering

- Financing structure of R&D with respect to basic R&D financing of the higher education sector (universities and colleges) via 'general university funds'; share of government financing of business enterprise R&D; significance of venture capital investment

Table A.2.3: Indicators of Knowledge Production Structures Relevant to ISR

<i>Variable</i>	<i>Indicator</i>	<i>Year</i>	<i>Source</i>
R&D Performance	BERD in % of GDP	1998*	OECD
	HERD in % of GDP	1998*	OECD
	GOVERD (incl. non-profit private) in % of GDP	1998*	OECD
	Change in GERD as % of GDP in the 1990s (in %-points)	1988-98*	OECD
Size Structure and Firm Ownership	Share of enterprises > 10,000 employees in BERD in %	1997*	OECD
	Share of BERD carried out by domestic enterprises in %	1997*	OECD
R&D Activities by SMEs	Share of continuously R&D performing innovative small manufacturing enterprises (20-50 employees)	1996	CIS2
	Share of continuously R&D performing innovative medium-sized manufacturing enterprises (50-249 employees)	1996	CIS2
Patent Activities by SMEs	Share of innovative small manufacturing enterprises having applied a patent (20-50 employees)	1996	CIS2
	Share of innovative medium-sized manufacturing enterprises having applied a patent (50-249 employees)	1996	CIS2
High-Tech Orientation of Enterprise Sector	Share of BERD performed in high-tech in %	1998*	OECD
	Share of BERD performed in medium- to high-tech in %	1998*	OECD
	Share of BERD performed in IT-services, private R&D in %	1998*	OECD
	Number of high-tech patents applications at EPO per 1 million of population	1998	OECD
	Number of Triade patents per 1 million of economically active population	1998	FhG-ISI
	Share of enterprise sector in total basic research in %	1997	OECD
Disciplinary Orientation of Public Science	Share of natural sciences in total HERD in %	1999*	nat. rep.
	Share of engineering in total HERD in %	1999*	nat. rep.
	Share of NSE in total R&D personnel at PSRE in %	1999*	nat. rep.
Excellence of Public Science	Impact factor of scientific publications in natural sciences (citations per publication)	average 1995-99	ISI-NSIOD
	Impact factor of scientific publications in engineering (citations per publication)	average 1995-99	ISI-NSIOD
Financing of R&D	Share of HERD financed outside GUF in %	1998*	OECD
	Government funding of BERD in % of GDP	1998*	OECD
	Venture capital investment in % of GDP	1999	EVCA
Market Dynamics in New Technologies	Turnover at ICT markets in % of GDP	2000	EITO
	Share of new products in turnover in % (manufacturing only)	1996	CIS2
	Diffusion of internet in % of population	1999	ITU
	Mobile telephone subscribers in % of population	1999	ITU

* For some countries and some indicators, data is available for earlier years only. In the case of availability of 1999 data, the more recent information is used.

OECD: Main Science and Technology Indicators; Basic Science and Technology Statistics; Science, Technology and Industry Scoreboard; ANBERD and STAN databases

CIS2: Community Innovation Surveys II (1997-1998, reference period 1994 to 1996), Eurostat

FhG-ISI: Fraunhofer-Institut for Systems Technique and Innovation Research, Karlsruhe, Germany

ISI-NSIOD: Institute for Scientific Information, National Science Indicators on Discette

EVCA: European Venture Capitalist Association

EITO: European Information Technology Observatory

ITU: International Telecommunication Union

nat. rep.: national statistics, provided by national experts within this benchmarking exercise

Source: compiled by the authors

- Market dynamics in new technologies with respect to overall propensity to adopt new technologies (using the internet & mobile phones as benchmarks); significance of information and communication technology (ICT) markets; turnover of new products as a share of total manufacturing turnover (as a substitute for the average length of product cycles, i.e. innovation dynamics)

A country's *performance in ISR* is measured for several types of interactions, using the following indicators (see Table A.2.3):

- *Research collaboration*: the share of R&D financing in higher education institutions (HEIs) and public sector research establishments (PSREs) which stem from industry (i.e. the significance of financial flows from business enterprises to public science institutions in the course of collaborative and commissioned research and R&D consulting); the share of industry's R&D financing in public science as a percentage of total R&D expenditures in industry (i.e. the significance of R&D outsourcing to, and co-operation with, science); the significance of faculty consulting (i.e. technology consulting in enterprises by individual researchers outside formal institutional agreements)
- *Co-operation in innovation*: the number of enterprises who co-operate with HEIs or PSREs in the context of innovation projects; the number of enterprises who use HEIs or PSREs as an information source for their innovation activities (i.e. the significance of public science as a contributor to industrial innovation)
- *Researcher mobility*: the number of researchers in HEIs or PSREs who have moved to industry research within a certain period of time, and the number of industry researchers who have moved into the public science sector (i.e. the degree of mobility between the two sectors)
- *Co-operation in training and education*: income from vocational training activities (professional continuing education etc.) in HEIs; the number of participants in vocational training in relation to the R&D capacities of HEIs; the share of students carrying out practical work in enterprises as part of their study (e.g. placements, jointly supervised thesis)
- *Use of IPRs in public science*: the number of patents applied for by HEIs and PSREs (or by individual researchers working in these institutions) in relation to the total number of researchers in HEIs and PSREs; the share of royalty incomes to HEIs and PSREs from their total R&D expenditures
- *Start-ups from public science*: the number of new, technology-oriented enterprises created by researchers from HEIs or PSREs, or by the institutions themselves, in relation to the total number of researchers

- *Informal contacts and personal networks*: a qualitative assessment by national experts on the relevance of informal contacts, and personal or organisation based networks such as Alumni meetings, membership in advisory or scientific boards, sponsorships, and other types of networking that facilitate knowledge exchange on an individual basis

Table A.2.4: Indicators of the Performance of ISR

<i>Variable</i>	<i>Indicator</i>	<i>Year</i>	<i>Source</i>
Contract and Collaborative Research	R&D financing by industry for HEIs in % of HERD	1998*	OECD
	R&D financing by industry for PSREs in % of GOVERD	1998*	OECD
	R&D financing by industry for HEIs/PSREs in % of BERD	1998*	OECD
	Significance of R&D consulting with firms by HEI researchers	mrya	nat. rep.
	Significance of R&D consulting with firms by PSRE researchers	mrya	nat. rep.
Co-operation in Innovation Projects	Innovative manuf. enterprises co-operating with HEIs in %	1994-96	CIS2
	Innovative manuf. enterprises co-operating with PSREs in %	1994-96	CIS2
	Innovative service enterprises co-operating with HEIs in %	1994-96	CIS2
	Innovative service enterprises co-operating with PSREs in %	1994-96	CIS2
Science as Information Source for Industrial Innovation	HEIs used as inform. source by innov. manuf. enterpr. in %	1994-96	CIS2
	PSREs used as inform. source by inn. manuf. enterpr. in %	1994-96	CIS2
	HEIs used as inform. source by innov. service enterpr. in %	1994-96	CIS2
	PSREs used as inform. source by inn. service enterpr. in %	1994-96	CIS2
Mobility of Researchers	Share of researchers in HEIs moving to industry p.a. in %	mrya	nat. rep.
	Share of researchers at PSREs moving to industry p.a. in %	mrya	nat. rep.
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	mrya	nat. rep.
Training and Education	Income from vocational training in HEIs in % of R&D expenditures	mrya	nat. rep.
	Number of vocational training participants in HEIs per R&D employees in HEIs	mrya	nat. rep.
	Share of students carrying out practices at enterprises during their study (placements, master thesis, PhD programmes etc.) in %	mrya	nat. rep.
Patent Applications by Public Science	Patent Applications by HEIs (and individual HEI researchers) per 1,000 employees in NSEM in HEIs	mrya	nat. rep.
	Patent Applications by PSREs (and individual PSRE researchers) per 1,000 employees in NSEM at PSREs	mrya	nat. rep.
Royalty Incomes by Public Science	Royalties in % of total R&D expenditures in HEIs	mrya	nat. rep.
	Royalties in % of total R&D expenditures at PSREs	mrya	nat. rep.
Start-ups from Public Science	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	mrya	nat. rep.
	Number of technology-based start-ups at PSREs per 1,000 R&D pers.	mrya	nat. rep.
Informal contacts, personal networks	significance of networks between industry and HEIs (exp. assessment)	mrya	nat. rep.
	significance of networks between industry and PSREs (exp. assessment)	mrya	nat. rep.

* For some countries and some indicators, data are available for earlier years, only. In the case of availability of 1999 data, the more recent information is used.

mrya: most recent year available

OECD: Main Science and Technology Indicators, Basic Science and Technology Statistics

CIS2: Community Innovation Surveys II (1997-1998, reference period 1994 to 1996), Eurostat

nat. rep.: national statistics or assessments by national experts, provided by national experts within this benchmarking exercise

Source: compiled by the authors

Within the conceptual model underlying the benchmarking exercise, it is assumed that the knowledge production structures prevailing in an innovation system represent the potential for

ISR. The extent to which this potential is utilised depends heavily upon the framework conditions in individual situations, i.e. the incentives and barriers as a result of the legal framework, institutional structures, supporting institutions and policy measures. These may explain why ISR performances could be high despite unfavourable structural features of an innovation system, or why they might be lower than one would expect due to the structural characteristics of the knowledge production system. In order to capture these factors and identify good and bad practices, five areas of so-called 'policy-related framework conditions' are distinguished and described for each country following a uniform structure:

- (i) *legislation and regulation*, i.e. laws and other legal direction affecting either industry or science in ISR,
- (ii) *public promotion programmes* and other *science and technology policy* measures aimed at removing barriers to interaction due to 'market failures' in the fields of knowledge production and technology exchange,
- (iii) *intermediary structures* such as technology transfer units, physical infrastructures, and consulting networks,
- (iv) *institutional settings* (with respect to incentives to, and barriers for, ISR) in public science institutions and in the business enterprise sector,
- (v) *cultural attitudes* towards ISR with respect to awareness of ISR among different groups of actors, idiosyncratic behaviour, cultural values and traditions which encourage or hinder ISR.

Knowledge production structures, ISR performance and policy-related framework conditions are outlined in the national reports. A lack of quantitative information is compensated for by expert interviews based on a standardised questionnaire that allows for qualitative comments and assessments (see Appendix D.2). The country-specific results provide the starting point for a cross-country comparison of structural characteristics, framework conditions and ISR performance. For countries with a particularly high performance in a certain type of ISR, we analyse the knowledge production structure and policy-related framework conditions in more detail. Based on expert interviews and expert assessments, examples of good practice in shaping framework conditions are identified for each country in "*areas of good performance*". The good practices are described with respect to their dependence on the overall setting of the national innovation system and the specific barriers and incentives which are dominant (in terms of the type of interaction). Special attention is paid to those characteristics and mechanisms of good practice that may overcome major barriers and provide stimulating incentives, and from which one could learn how to shape framework conditions under certain features of an innovation system.

The final step of our benchmarking exercise is the learning from the good practices identified. We conclude with recommendations on how to improve and strengthen ISR, paying particular emphasis to the following areas:

- collaborative research in bottom-up defined fields of technology,
- supporting research commercialisation in public science through the creation of new firms (start-ups),
- the role of IPRs in the dissemination and commercialisation of new research results,
- facilitating interaction in the field of human capital, i.e. researcher mobility between industry and science and co-operation in vocational training and education,
- supporting SMEs in tackling their general disadvantages in ISR,
- fostering ISR in science-based industries,
- reforming institutional settings in public science through setting proper incentive schemes for transfer activities.

B. National Models of ISR

B.1 Austria²

B.1.1 Knowledge Production Structures in Austria

R&D investments in Austria - compared to GDP - are rather low by international standards. In the second half of the 1990s, R&D expenditures have significantly increased however, and the R&D intensity (R&D expenditures as a percentage of GDP) has grown from 1.5 % in 1993 to 1.8 % in 1998. In terms of financing, the main source of growth has been funds from abroad, including both EU funds (framework programmes) and R&D financing by foreign enterprises. However, a more recent survey on R&D activities in Austria in 1998 suggests that R&D activities financed from abroad were underestimated in 1993.

Table B.1.1: R&D Expenditures in Austria (1993, 1998) by Financing and Performing Sectors (in million €)

Performing Sector	Financed by (1993)			Total million €	Total %	% of GDP
	Enterprises	State*	Abroad			
Enterprise Sector	1,107	126	54	1,287	56	0.83
PSREs*	6	203	2	211	9	0.13
HEIs	16	786	3	805	35	0.52
Total (million €)	1,128	1,115	60	2,303		
Total (%)	49	48	3		100	1.48
Financed by (1998)						
Total (million €)	1,475	1,410	770	3,655		
Total (%)	40	39	21			1.80

* including the small non-profit private sector

Source: 1993 data: OECD (2000), based on the full survey of R&D in Austria in 1993, calculations by the authors

1998 data: Statistics Austria, based on the full survey in Austria in 1998, calculations by the authors

Enterprises are the main R&D performers in Austria accounting for 56 percent of total R&D expenditures. The enterprise sector finances about 86 percent of its own R&D activities and 40 percent of total R&D activities in Austria. The government finances a significant share, 10 % of total BERD. The second most important R&D performing sector is the HEIs, with a share in total GERD of 35 %. The small PSRE sector accounts for only 9 % of Austrian R&D expenditures.

HEIs in Austria receive 83 percent of their annual budgets through basic financing and only 17 percent through competitive funding on a project basis. The main source of competitive funding in HEIs is the Austrian Science Fund (FWF) with a focus on natural sciences. 95 percent of public financing sources in HEIs stem from the national government. In 1993, only

² This chapter is based on the national report on ISR in Austria (Schartinger, Gassler and Schibana 2001) as well as on Schartinger et al. (2000a,b, 2001).

minor amounts came from enterprises, regional governments or abroad. This has significantly changed in recent years however, with a large increase in financing from abroad since Austria has become a member of the EU. PSREs receive a rather high share of their annual budgets (about two thirds) through the acquisition of research projects and only one third through basic financing. However, the majority of funds - basic or competitive - stem from various public sources and about 10 % come from the enterprise sector or from abroad.

Table B.1.2: Financing Structure of R&D in HEIs and PSREs in Austria (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs (1993)</i>	<i>PSREs (1999)</i>
Basic Financing (GUF)	83	~ 35
Project Financing and other financing sources	17	~ 65
National Government	95	~ 60
Regional Governments	2	~ 20
Other Sources (enterprises, internal financing, abroad)	3	~ 10

Source: OECD (2000), own survey and calculations by the authors

R&D expenditure in the Austrian enterprise sector focuses on the high technology sectors and other technology sectors.³ These two categories accumulate about 70 % of business R&D expenditure. They are characterised by extensive R&D investments as a percentage of value added respectively. There was an enormous shift in the sectoral distribution of R&D expenditures between 1993 and 1998. In 1993, the focus of business R&D expenditures was on technology sectors outside the high-tech-sectors and on other manufacturing sectors, which combined, accounted for two thirds of business R&D expenditures. So, whereas at the beginning of the 1990s, Austrian industry concentrated its R&D activities on incremental technological change and relied heavily on its customer relations as a source of information, now high-tech sectors which are generally assumed to have stronger science linkages, have gained greater importance.

Table B.1.3: R&D Expenditures in the Austrian Enterprise Sector by Sectors 1998

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	36	0,37
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	35	0,36
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	14	0,15
IT-Services (NACE 64, 72, 73)	7	0,07
Other Services (NACE 50 to 99, excl. IT-Services)	8	0,08

Source: ÖSTAT (2000), calculations by the authors

R&D in the Austrian service sector accounted for 15 % of total GERD in 1998, which meets the OECD average. The highest R&D expenditures per capita are found in IT services, data processing and telecommunications, and more in various business and consulting services.

3 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

But only a very small fraction of the service sector (commercial research institutions) reaches the levels of the manufacturing sectors. Despite its relative weight in the Austrian economy, no research activities are found in tourism. But it must be noted that the character of service innovation differs from that in manufacturing, therefore R&D-intensity should not be mixed up with a sectors propensity to innovate.

The sector of small enterprises (SMEs) in Austria employed about two thirds of all employees in the Austrian enterprise sector in 1995 and accounted for 18 % of all R&D expenditures in the enterprise sector in 1998 (see Table B.1.4). However, results from CIS2 reveal that in Austrian enterprises with under 250 employees use universities as an information source more often than the European average. Over 50 % of all R&D expenditures in the enterprise sector are spent by enterprises with more than 1000 employees which accounts for about 20 % of all employees in the enterprise sector.

Table B.1.4: R&D Expenditures in the Austrian Enterprise Sector by Size Classes of Enterprises 1998

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 250 employees)	18
Medium-sized Enterprises (250 to 999 employees)	30
Large Enterprises (1,000 to 9,999 employees)	~ 26
Very Large Enterprises (10,000 employees and more)	~ 25

Source: ÖSTAT (2001), calculations by the authors

Some 67 percent of businesses reported the introduction of product or process innovation between 1994 and 1996. More than half of these reported the introduction of innovation in both products and processes. This tendency by Austrian businesses to utilise innovation is clearly above the European average of 51 percent. When compared by size class, Austria has also achieved an above average quota of innovation in comparison with the other EU countries. The differences become less pronounced with an increase in the size of the business.

In terms of investments in innovation, SMEs in the manufacturing sector and medium-sized enterprises in the service sector have markedly higher innovation expenditures as a share of turnover, than the European average (see Table B.1.5). Innovation intensity remains below EU averages, mainly in the areas of electric and optical machines, as well as energy and water supply. Furthermore, innovation intensity is above average in the oil and chemistry, rubber, plastics, mineral products and glass, and metal production and processing, and metal products sectors.

In Austria, the share of turnover due to new or improved products in total is similar to the EU average. The share of turnover from new or improved products is clearly above the EU average in very small manufacturing enterprises. Larger enterprises with more than 250 employees rank slightly below other European businesses of comparable size. These businesses therefore appear to be very efficient innovators despite the fact that they lag behind in innovation-specific expenditure. Austrian medium-sized enterprises also remain slightly below the comparative European average. Given the above average innovation-specific

expenditure of Austrian medium-sized enterprises, there is a definite need to improve the efficiency of these innovation processes.

Table B.1.5: Relative Innovation and R&D Performance of SMEs in Austria

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.04	0.96	1.07	0.88
Innovation Expenditures as a Share of Turnover*	1.89	1.41	0.90	1.54
Share of Turnover due to Innovative Products*	1.98	0.99	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	0.48	1.07	0.64	0.81
Share of Enterprises with Medium R&D Intensity**	1.11	1.40	0.49	0.46
Share of Enterprises Engaged Continuously in R&D**	1.02	1.27	0.60	0.97
Share of Enterprises Having Applied for a Patent**	1.42	1.35	0.40	1.21

* Figures show the relation of Austrian SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Austrian enterprises to all EU enterprises: $(SME_{x_{Aj}}/SME_{x_{Ej}})/(x_{Aj}/x_{Ej})$, x being the variable considered, A being Austria, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Austria to SMEs in the weighted mean of all EU countries (except Greece): $SME_{x_{Aj}}/SME_{x_{Ej}}$, x being the variable considered, A being Austria, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

In the higher education sector, Austria shows a clear focus on medical sciences in terms of R&D personnel, followed by natural and social sciences (see Table B.1.6). Only 12 % of the R&D personnel in the public science sector are attributed to engineering. In contrast, PSRE figures reveal a clear focus on natural sciences, followed by social sciences and humanities. In the total public science sector, engineering disposes of the least amount of R&D personnel. This is critical considering that engineering may contribute mostly to technological problem solving in the innovation processes of the enterprise sector.

Table B.1.6: R&D Personnel in the Austrian Public Science Sector (HEIs & PSREs) by Fields of Science (in %)

<i>Sector</i>	<i>HEIs (1999)</i>	<i>PSREs (1993)</i>	<i>Total</i>
Natural Sciences	24	34	26
Engineering (incl. Agricultural Sciences)	12	8	11
Medical Sciences	32	10	29
Social Sciences	18	25	19
Humanities	14	23	15

Source: ÖSTAT (2000), calculations by the authors

The public science sector in Austria consists of the following main institutions (see Table B.1.7 for a summary):

There are 12 main universities (including two technical universities) and the universities of Arts and Humanities. They are, by a large extent, the main R&D performers in public science in Austria, accounting for nearly 80 % of total R&D expenditure in public science. They

receive basic funding from the federal government and their legal framework is affected mainly by national laws. The 12 main universities educate 93 % of all students in Austria while universities of Arts and Humanities educate 3.5%. The main universities are situated in seven locations and were divided into 843 departments in 1997 while the universities of Arts and Humanities were divided in 55 departments in 1993. Detailed surveys revealed that on average, university researchers engage 50 percent of their work hours in research and development activities and 30 percent in medical sciences due to the attendance of patients. In terms of professorships authorised and financed by the government, the main Austrian universities reveal a specialisation in technical sciences, followed by social sciences and humanities.

Polytechnic colleges educate the remaining 3.5 % of all students in Austria. Polytechnic colleges were first established in 1994 as an alternative to classical university education. As universities, they fulfil education and research tasks. As technology transfer is a considerable part of their mission, education is characterised by practice orientation and shorter courses of studies (3 years plus practice). The prerequisites for access to polytechnic colleges are the same as for students in the main universities but increasingly, they must undergo a selection process. The demand for polytechnic colleges has grown very quickly with an annual growth rate of students enrolled of over 30 %. In contrast to universities, polytechnic colleges are set-up and sustained not only by the federal government, but also by regional and local governments, membership organisations or legal persons of civil law.

The most recently established university level institution in Austria is the Danube University Krems, based on its own federal law of 1994. At Krems, teaching began at the beginning of the academic year 1994/95. Research agendas are partly complementary to, and partly overlapping with, the general universities. Education is dedicated exclusively to the realm of post-graduate professional and continuing education and offers application oriented course programmes.

The Austrian Academy of Sciences is regarded as part of the HEI sector and unites functions of the 'classic society of scholars' with those of the largest extra-university institute for basic research in all fields. It is financed primarily by federal subsidies and employs a staff of 600 researchers.

Within the PSRE sector, there are several federal institutions and agencies that carry out research: the Central Institute for Meteorology and Geodynamics and the Geological Survey of Austria; the Federal Environment Agency; and the Federal Institute of Public Health. Fifteen departmental research institutes are installed in the fields of agriculture, forestry and the management of water resources - some of them also have an educational function.

The state owns shares of certain co-operative research enterprises, e.g. 51 percent of the Austrian Research Centre Seibersdorf and 100 percent of the Research and Testing Centre Arsenal. Both enterprises co-operate closely with another registered company - The Joanneum Research, which is owned by the federal province of Styria. In order to optimise

the market position after the opening up of Eastern Europe and Austria's EU accession, Research Austria was founded as an umbrella organisation for these three large research institutions.

Table B.1.7: Main Characteristics of Major Institutions in the Austrian Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Main Universities	~ 70	12 universities	research and education	basic and applied research	low to high, highly varying among dept.
Universities of Arts and Humanities	~ 4	50-60 institutes	research and education	basic research	low
Polytechnic Colleges	< 1	19 colleges	education and technology transfer	applied research	high
Danube University Krems	< 1	19 departments	research, education and consulting	applied and basic research	low
Academy of Sciences	~ 5	57 research units in 11 research fields	complementary to universities	basic research	low
Federal Research Institutions and Agencies	~ 5	about 20 agencies and institutes	research in public interest	applied research	low to medium
Austrian Research Centres Seibersdorf & Arsenal Research	~ 7	11 research units, 4 subsidiary companies	applied research mainly in natural sciences and engineering	applied research	high
Joanneum Research	~ 3	20 institutes	applied research mainly in natural sciences and engineering	applied research	high
Austrian Institute for Economic Research (WIFO)	~ 1	8-9 divisions, various research topics	economic forecasts, policy consulting	applied research	low
Institute for Advanced Studies (IHS)	< 1	4 departments, 60 researchers	economic forecasts, policy consulting, education	basic and applied research	low
Others	~ 3				

Source: own survey and calculations by the authors

The Austrian Institute of Economic Research (WIFO) analyses Austrian and international economic developments. They provide short and medium-term forecasts and studies on competitiveness, quality of location and European integration, and thereby supply the information required both for economic policy and for strategic decisions in enterprises.

A number of other PSREs and non-profit research institutes deal particularly with social sciences and the humanities, and are financed by government funds and by earnings from research projects assigned to them by public authorities. They also offer advice on science policy issues. One of the larger of these institutes is the Ludwig Boltzmann Society, which is an umbrella organisation covering more than 100 smaller research institutes with a focus on the medical field and social sciences. The Austrian Institute for International Politics, the International Research Centre for Cultural Sciences, and the Institute for Advanced Studies

which in addition to its research function also provides post-graduate studies and further education, are other main actors.

B.1.2 The Level of ISR in Austria

The level of ISR in Austria is described by a set of indicators and assessments on the significance of various interaction channels. Table B.1.8 lists the indicators used and the main results. It also indicates those areas in which ISR in Austria may be regarded as above average with respect to EU standards.

Data on financial flows between the enterprise sector and the public science sector in Austria show rather low inter-sector linkages in terms of contract research. Enterprises finance merely 2 % of all higher education expenditures on R&D and 2 % of all government expenditures on R&D. The business expenditure on R&D used to finance research at universities or PSRE is even below 2 % (1.7 %). With respect to sectors of economic activity, it is mainly the chemical and pharmaceutical, machinery and equipment sectors, the basic metal industry and energy and water supply sectors, that finance research in a variety of fields of research.

There is a growing trend towards the co-operation between the science and enterprise sectors in Austria. In comparison with the innovation survey from 1990, more recent studies show an increasing tendency towards co-operation. This is remarkable considering that Austrian universities are almost exclusively publicly funded. Although there have been cuts in public funding, it is quite difficult to interpret this relatively high co-operation rate with universities and public research institutes in Austria as a consequence of these cuts (i.e. that universities are being 'forced' to become more entrepreneurial and commercial oriented). Instead, strong co-operation links between some specific university departments and commercial firms in Austria seem to reflect personal relationships and initiatives of the firms, more than as a result of canvassing by universities in order to acquire additional funds.

Concerning the use of different information sources, the Austrian enterprise sector highly correlates with the EU average. Around 5 % of the innovative companies rank universities as an information source which they consider highly important. The significance of these as sources of information does however, vary depending on the size of the firm. The larger the company, the more important are HEI and PSRE as sources of information. Small companies tend to have problems tapping sources of information close to the sciences. If they are part of a conglomerate they tend to look for information within it. Enterprises in the manufacturing sector tend to turn to HEIs rather than to PSRE for additional information. Conversely, the extent to which enterprises in the service sector use HEIs or PSRE as a source of information is negligible.

The mobility of researchers from science to industry is rather low in Austria. This is especially true for HEI. Career paths in the university system are rather linear. University researchers start as university assistants and develop their careers from there. They either get

a permanent appointment or drop out of the system. Because of this career path, universities usually do not recruit researchers externally but develop these jobs internally. (This does not apply for full professors.) Mobility restrictions between universities and industry in Austria also arise from the specific culture of the university system and are based on rather pragmatic issues. Many of the university researchers, who make use of the chance to temporarily leave university for external research or teaching purposes, have lifelong employment contracts. Hence, they are eager to be able to return to their jobs after the termination of their external contracts. Additionally, due to large wage differences between HEIs and PSREs on the one hand and industry research on the other, there is little mobility in the other direction, from industry to science.

In many cases, researchers at PSREs are not civil servants. Therefore, compared to industry, the differences in employment regulations are not as significant as they do not enter lifelong employment contracts as university researchers. There is little empirical information on the mobility of researchers from PSRE to industry. Expert assessments indicate low mobility however.

Universities usually offer vocational training programmes on a decentralised basis, i.e. on the initiative of individual departments or faculties. About 11 % of all university departments in Austria were engaged in vocational training for the enterprise sector in the period from 1995-1998. The university field of research which is most actively engaged in vocational training in relation to its size, is traffic and transport systems, followed by the fields of research of economics and engineering. The sectors of economic activity most frequently engaged in vocational training with universities in Austria are the chemical and pharmaceutical sectors, medical, precision and optical instruments, and the vehicle industry.

The awareness in HEIs and PSREs concerning the protection of intellectual property through patent applications has increased. Both institutions are now less willing to automatically leave the rights to the research, to the contract partner, in the case of research co-operations. However, there is no reliable information in Austria on the annual amount of patent applications in HEI or at PSRE.

Income from royalties is not a major means of financing, either at PSREs or in HEIs. It is likely that royalty income heavily depends on very few patents. At HEI, royalties belong to individual researchers and therefore empirical data is not available.

With respect to start-ups by public science researchers, it may be said that nearly 80 new companies were set up by university researchers in Austria in the period of 1995-1998 (i.e. 26 per year, excluding graduates). The majority of these university researchers were in technical and scientific disciplines, followed by the social sciences and economics. In terms of business profile, three quarters of the new companies provide production-related services, 14 percent belong to the sector of the small-scale manufacturing industry, and 12 percent provide other services. This corresponds to the findings of surveys of new technology-based

companies in Austria, which also show the service sector to be significantly more dynamic than the manufacturing industry.

The existence of personal networks seems to be the main determinant for the establishment of science-industry-linkages in Austria. As PSREs are very dependent on contract research, they must dispose of a rather widespread and stable net of personal contacts in order to acquire external funds. HEIs, which receive a rather high share of basic funding, are less aware of the necessity to cultivate personal relations.

Table B.1.8: Indicators and Assessments of ISR in Austria at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % of HERD	2.0
	R&D financing by industry for PSREs in % of GOVERD	2.0
	R&D financing by industry for HEIs/PSREs in % of BERD	1.7
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	high
	Significance of R&D consulting with firms by PSRE resear.	low
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	12.6
	Innovative manuf. enterprises co-operating with PSREs in %	7.1
	Innovative service enterprises co-operating with HEIs in %	5.8
	Innovative service enterprises co-operating with PSREs in %	2.5
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	4.7
	PSREs used as inform. source by innov. manuf. enterpr. in %	1.1
	HEIs used as inform. source by innov. service enterpr. in %	0.6
	PSREs used as inform. source by innov. service enterpr. in %	0.7
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in %	medium
	Share of researchers at PSREs moving to industry p.a. in %	medium
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	low
Vocational Training (Source: national statistics, assessments)	Income from vocational training in HEIs in % of R&D exp.	low
	Number of vocational training participants in HEIs per 1,000 R&D employees at HEI	low
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in NSEM	low
	Patent Applications by PSREs per 1,000 employees in NSEM	medium
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	low
	Royalties in % of total R&D expenditures at PSREs	low
Start-ups from Science (Source: national statistics, assessments)	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	~ 4
	Number of technology-based start-ups at PSREs per 1,000 R&D personnel	~ 1
Informal contacts and personal networks (Source: national statistics, assessments)	significance of networks between industry and HEIs	medium
	significance of networks between industry and PSRE	high

* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD, own surveys and calculations by the authors

B.1.3 The Policy-Related Framework Conditions for ISR in Austria

Cultural attitudes: In Austria, the main contribution of universities to industrial technological change has long been seen as the provision of qualified graduates. In contrast, PSREs were often seen as a means to create a comprehensive knowledge base in technologies that were considered key to technological development in general. Enhancing science's direct contribution to industrial needs and hence, the financial contribution by the business sector,

and increasing the shares of competitive funding to HEIs and PSREs budgets, were not stated goals of technology policy until late in the 20th century.

It is not part of the culture in Austrian enterprises to address universities as potential sources of information in their innovation processes in the first place. However, enterprises are inclined to turn to universities for technological or other support, if they have built up personal relationships and mutual trust with specific institutions in the past. This social capital is often established through graduates.

University departments have experienced a shift in expectation towards them but until now, there has not been a legal or financial necessity to attract more third party funds in general or from industry. However, a small number of university departments have always entertained industry linkages on a regular basis. The majority of university departments that do not interact with industry may be subdivided into the following groups: (1) those who are basically ready to co-operate but are passive and are waiting for firms to take the initiative; (2) those who are interested in principal but feel prevented by external factors (budget or bureaucracy); and (3) those who are not interested in co-operation.

Legal framework: Generally, the legal framework conditions in Austria do not actively support the development of industry-science relations but they do not prevent them either. The University Organisation Act from 1993 ascribes partial legal capacity to universities, faculties and departments. This law entitles them to carry out research contracted by third parties as long as regular teaching and examination activities are not impaired. And it generally entitles universities, faculties and departments to enter into selected kinds of contracts, engagements and memberships, e.g. purchase contracts, lease contracts, the employment of additional staff via employment contracts etc. The payment for contract research activities may exceed the costs thereby incurred. This implies that universities, faculties and institutions may realise profits from their research contracted by third parties. But these profits are committed to the fulfilment of the predefined tasks of universities which is mainly research and teaching. There are two laws that state explicitly that university budgets should not financially support projects contracted by third parties. Personnel as well as real costs have to be met by the project revenues.

Legal regulations, which are likely to have an effect upon the mobility of university researchers, may be found in the Remuneration Act and in the Civil Servant Law. Relevant regulations institutionalise differences between science and industry, which is assumed to make the mobility between the two sectors more difficult. Analysis of the Remuneration Act from 1956 shows that the length of system affiliation is the main criteria for remuneration of university employees. Researchers to be employed at an Austrian university enter a fixed remuneration scheme consisting of 10 - 18 salary grades, depending on the position of the researcher (professor, associate professor, university assistant). The general inflexibility of the university remuneration scheme is, of course, very alien to industry and constitutes a major factual and cultural difference between science and industry in Austria. There are no

incentives in the remuneration scheme to promote ISR or in the compulsory criteria for career advancement.

Another difference between science and industry in Austria is the fact that university researchers may acquire tenured positions, i.e. guaranteed lifelong employment at the university. However, the Federal Minister of Science may grant university researchers a temporary leave from their official tasks for teaching and research purposes, which includes research and teaching in the private sector. These research and teaching activities must have a connection with the research and teaching activities at the university. These temporary leaves and sabbaticals are mainly used for research studies in other (e.g. foreign) universities.

Public Promotion Programmes: In the main, the Federal Government in Austria offers a variety of programmes aimed towards increasing the level of ISR (see Table B.1.9). Almost all programmes aim towards reducing institutional barriers to collaboration resulting from the inconsistency of the objectives of universities and firms and the inconsistency of the criteria for success. The objectives of all of programmes are similar as they offer incentives to overcome these inconsistencies. However, some public promotion programmes leave the processes of a mutual approach and the reduction of institutional barriers, entirely to be organised by universities and firms. After successful convergence, small amounts of lump-sum payments are dispersed to the respective target groups.

Instead, more recently established public programmes (Kplus, Kind, and Knet) encompass comprehensive measures in order to establish long-term structures of collaboration. The focus lies on pre-competitive and high-level research. Platforms for collaboration are implemented and financed for a number of years in order to provide a wide scope for the establishment of personal relations between partners, and to support the formation of a joint language, a joint culture and common goals. Also, spin-off programmes now receive increasing attention in public promotion. Although a programme exists to foster spin-off formations of new firms for several years, this has obtained funds below the critical masses. Now a programme with comprehensive measures (AplusB) will be implemented in the near future, which signals the significance that is now assigned to high-technology science-based young firms in Austria.

Intermediary structure: Most of the main universities (i.e. eleven out of twelve) in Austria do have technology transfer offices (TTOs). The offices differ in their proclaimed aims. The aim that appears most often and most prominently is the provision of information services. Each of these transfer offices is engaged in the collection of data on research projects at the respective university. All information on research projects is then gathered into a central database on research projects (AURIS) which is publicly accessible through the world wide web. Furthermore, most of the TTOs at Austrian universities have the function of being a public relations unit i.e. they formulate press releases and organise events, conferences and exhibitions for university departments or faculties. In the main, at universities with a strong technology focus, the TTOs see technology transfer as a primary aim. Related activities include the establishment of contacts between firms and university departments, consulting in

contracts, patents and other legal issues, and the training of university researchers (e.g. in project management).

Table B.1.9: Major Public Promotion Programmes in the Field of ISR in Austria

<i>Name of Programme (responsible authorities)</i>	<i>Public Funding (million € '99)</i>	<i>Main Approach</i>	<i>Type(s) of ISR Mainly Addressed</i>
Impulse projects (FWF)	1.21	Financing of the wage costs of postdocs up to two years for research projects involving PhDs and a firm (preferably SMEs) that should markedly raise the level and quality of R&D activities of the firm	Joint R&D projects
Programme for Biomedical Technology (BMVIT)	0.59	Financing of selected projects in biomedical technology that involve the collaboration between researchers, producers and applicants of biomedical technology at early stages of the development processes	Joint R&D projects
K-plus (TIG, BMVIT)	9-11 (federal funds)	Establishment of collaborative competence centres with a specified time frame, which are selected for funding in a competitive process according to specific quality criteria	Joint research labs
Industrial Centres of Excellence (Kind) and Networks of Excellence (Knet) (BMWA)	14.53	Association of several locally dislocated nodes of excellence in business and science with a synergetic thematic orientation, jointly run by enterprises and HEIs/PSREs	Joint research labs
Christian Doppler Society and CD Laboratories (BMWA)	1.82	Establishment of the CD Laboratories, member firms of the CD Society invest on a long-term base in specific basic research fields and participate in the labs	Joint research labs
Scientists for the Economy (BMBWK)	0.04	Lump-sum payment for firms, which employ a university researcher. University researchers are granted temporary leave from their official university tasks and may return to their position afterwards	Researcher mobility
Scientists Establish Firms (BMBWK)	0.31	Lump-sum payment for university researchers, which is disbursed after the formal foundation of a firm	Start-ups
AplusB (TIG, BMVIT)	1.45	Support for the creation of incubators, business plans and to accommodate potential founders in newly created centres, support for the organisation of events to raise the awareness towards start-ups	Start-ups
TecMA (BMWA)	1.08	Organisational support and cost-free evaluation of the patenting or marketing opportunities of inventions developed by Austrian researchers	IPRs, Licensing
Young Researchers' Programme (FFF)	5.54	Support for research activities of young researchers in joint projects with companies (SMEs), thereby increasing the extent of co-operation between science and industry	personnel mobility, joint R&D projects
Polytechnic Colleges for the Economy (FFF)	0.3	Fostering joint research projects between polytechnic colleges and firms and at increasing the capacities and networks of polytechnic colleges for future research collaborations with firms	Joint projects with graduates

Source: own surveys and calculations by the authors

The target groups of university TTOs seem very often to be researchers from within the universities. They must be motivated, informed and trained in order to co-operate with people

from outside the universities - not only from industry but also other universities, public authorities and foreign research organisations. However, some of the TTOs also explicitly mention industrial firms as target groups and want to be considered as a first contact point for interested firms.

In the long run, every polytechnic college is supposed to have a technology transfer office but this has not yet been the case as polytechnic colleges were only introduced in 1994 and are still very much in the development process. The objective of polytechnic colleges is not only the provision of practice-oriented knowledge to students but they also have a clear mission to carry out application-oriented research. In both respects, every kind of co-operation with the industry is very welcome. Currently, only the most established polytechnic colleges have some kind of TTO. One of these polytechnic colleges establishes and maintains contacts with firms via an association of 140 members who are also proprietors of the polytechnic college. Each of these members has to provide placements or practice for the students, which is part of the course of studies at polytechnic colleges. Furthermore, the association aims material and immaterial support of courses of studies at polytechnic colleges, public relations, support in the conceptualisation and financing of research projects, and organisation of discussions and presentations. As it has emerged from several interviews, this model of an association which institutionalises firm contacts will be copied by various other polytechnic colleges in Austria.

The large PSREs (e.g. Austrian Research Centres Seibersdorf or Joanneum Research) do have technology transfer offices, often at several locations. Target groups are private enterprises, mainly in the respective location. On the one hand, these TTOs provide services such as consultation for private firms. On the other hand, they mediate services by the research organisations.

ACR (Austrian Co-operative Research) is an umbrella organisation of privately organised co-operative research organisations and industrial firms. It consist of 18 full members (non-profit research organisations) and 8 associate members (profit-oriented industrial firms). Full members have about 700 employees in total and a turnover of 51 million Euros. Activities of ACR comprise referee and examination activities, control of quality and certification of products, knowledge and technology transfer through consultation, training, events and documentation. ACR does not only provide services for its members but also serves as a platform for information on research and technological development for other firms in Austria, particularly SMEs.

B.1.4 ISR in the Field of Human Capital in Austria

On a decentralised basis, interactions between industry and science in the field of higher education take place in various ways. However, only few, outlined below, are institutionalised.

Recently, the first attempt was made to institutionalise co-ordinating structures for considering industry needs and changes in industry demand, in higher education programmes

(curricula, new courses etc.). For every new course of studies at universities, a committee is established to plan and conceptualise the curriculum. The Law of University Studies states that curricula must be presented, not only to the Ministries and Governments of Federal provinces as employers, but also to associations of industries, chambers of commerce and individual relevant chambers of professions (e.g. chamber of physicians), or other organisations relevant as sectors of economic activity and professions. These organisations are to submit propositions of change within a certain period of time. The propositions must be documented but they do not have to be reflected in the curricula.

Using their own motivation, some committees (especially in engineering) may, and often do, go far beyond this legal requirement in the Law of University Studies.

Co-operation in graduate education is rather widespread. Universities co-operate with industry by means of joint supervision of Masters and PhD theses. Polytechnic colleges co-operate with industry by means of obligatory practice or placement by students in the firms. In Austria, these are most pervasive types of interaction between HEIs and enterprises. It enables enterprises to establish and maintain personal contacts and to acquire personnel that are equipped with advanced levels of training and expertise, as they bring with them 'tacit' skills, have experiences of tackling complex problems and are often part of a network of researchers.

Teaching at universities and colleges by firm employees varies considerably among university faculties and departments. In total, at least 16 % of all university departments have lectures by firm employees, particularly in technical, natural and social sciences. At Polytechnic Colleges, contacts with firms are particularly dense as over one third of all lecturers are firm employees.

More than quarter of all university departments in Austria (27 %) offers vocational training for firm employees. Those university fields of research which most actively engage in vocational training are traffic and transport systems, followed by the fields of research of economics and engineering. Except for economics, educational science and jurisprudence, the most active fields of research are the technical sciences.

There are some large firms (e.g. from the chemical and pharmaceutical, electronics or automobile industry) which finance professorships or even whole research units at universities but this type of interaction is rare.

Some programmes (e.g. Young Researchers Programme) have an effect by providing financial support for the employment of graduates. It supports research activities of young researchers (from universities or polytechnic colleges) in joint projects with companies (SMEs), thereby increasing the extent of co-operation between science and industry. Young researchers may define research topics for PhDs or Masters theses in co-operation with their supervisors from university and a firm. The programme facilitates the establishment of R&D facilities in firms and enables many young researchers to find jobs in the field of industrial

research. An evaluation carried out in 1996, showed that 30 % of the researchers supported by the programme were able to find a job in the firms in which their projects were carried out.

Table B.1.10 shows some general features of tertiary education. It depicts the fact that the majority of first degrees awarded were in social sciences and humanities/arts. In international comparison, Austria sets itself apart with a low number of graduates for this discipline. This is partially due to the two-stage system (first degree, post-graduate degree) and consequently, longer the time needed to complete degrees. Also responsible is the fact that knowledge and skills gained in other schools of higher learning are not accounted for in university study. Rather than investing in a concentrated university education, Austria tends to invest heavily in the secondary school system which has resulted in a broad secondary education with high standards. In the tertiary education segment, Austria is behind most OECD countries. This is displayed in the relatively low share of the population with a university education. The OECD average is 11 % while in Austria only 7 % of the population have a university diploma. The reason for this is that in most other EU countries, a course of study can be finished in a much shorter time. Long courses of study as a result of a two-stage/degree system also contribute to the low number of graduates, aged 24 or younger (10.2 percent). However, a change in the laws governing university study provides for the creation of an academic diploma (baccalaureate) after three years of study. With this, young graduates can take their university diploma and their knowledge and put it to work in the economy sooner.

Table B.1.10: Higher Education by Disciplines in Austria 1998/99 (in %)

<i>Field of Study</i>	<i>Students</i>	<i>Study Beginners</i>	<i>Graduates (diploma) 1997/98</i>	<i>Unemployed Graduates</i>	<i>Gainfully Employed (1991)</i>
Natural Sciences	11	11	14	13	13
Engineering (incl. Agric.)	18	17	20	15	11
Medicine	8	7	8	9	16
Social Sciences	34	34	35	46	36
Humanities and others	29	30	23	17	24
Total number (1,000)	229.9	26.6	14.3	5.3	199.0

Source: ÖSTAT, Austrian Labour Market Service (AMS), www.bmwf.gv.at/3uniwes/04unistat/index.htm, calculations by the authors

A factor that seems to be of importance for the personnel mobility between industry and science are long-term oriented and stable relationships in graduates' mobility between universities and firms. Furthermore, there seems to be a broad agreement that personal contacts based on joint projects and contract research play a very important role for the mobility of university researchers and graduates to industry. Also, if professorships or departments are financed by industry, this raises the probability of mobility significantly because university researchers can often become alienated by industry in this way. On the contrary, researchers from industry rarely leave their job for an employment at a university. If they move to a university, they do this only for a limited period of time in order to write their dissertation and return to industry afterwards.

There are no institutionalised methods of personnel mobility from industry to public research in Austria. Personnel mobility between science and industry is mainly organised on an individual basis. The most important information channel for jobs in R&D are personal contacts based on joint projects and contract research. Advertisements in newspapers and magazines are a further important mechanism for researchers' mobility.

Retirement regulations differ between the universities, some PSREs and industry in Austria. At universities, fully qualified professors have the status of civil servants and are therefore not members of any public pension funds (but will receive further 'wage payments' by the state after retirement). If university assistants gain extra-university practical experiences, Austrian pension law provides that only 50 percent are acknowledged for the pension annuity. At the largest PSRE, retirement regulations are, in general, similar to the private enterprise sector. At PSREs which are directly assigned to public authorities, researchers often also fall under civil servants law.

Wage differences between the public and the private sector are significant in Austria as in other countries. This is particularly true for younger people because of the seniority system in wage payments in the public sector (where wages automatically increase by age) and especially for researchers in fields of science in which there is a large demand from industry.

B.1.5 ISR in Austria: A Summary Assessment by Type of Interaction

In Austria, the main transfer of knowledge between the enterprise and the university sector still occurs through the mobility of people equipped with scientific knowledge. Asked what the general benefits from universities are, a vast majority of the firms responded that they value highly skilled personnel as the main output from universities and consider the employment of graduates as important access to academic knowledge.

The most frequent type of interaction between the enterprise and the university sector, apart from the employment of graduates, is the joint supervision of Ph.D.s and Masters Theses. This is the result of various studies on the part of innovative firms as well as on the part of universities. The joint supervision of Ph.D.s and Masters Theses results in graduates being not only equipped with scientific knowledge but also acquainted with the needs of the firm or its business sector. Hence, this may very well be perceived as a strategy used by the enterprise sector to acquire qualified personnel.

Contract and collaborative research: This type of interaction is most important for PSRE but of lower importance for universities. PSRE have a strong incentive to attract additional resources from industry in order to compensate for decreasing funding from basic (institutional) financing. For HEI, this incentive is considerably lower as they receive a very high share of basic funding. However, in the course of the reorganisation currently discussed at universities, this is likely to change. About 65 % of R&D expenditure at PSREs are financed by contract research whereas in HEIs this share is at 17 %. Correspondingly, the

shares of R&D expenditure financed by industry are lower in HEIs (2 %) than at PSREs (5 to 8 %).

If framework conditions, such as public promotion programmes or the legal framework, have an effect upon the extent of contract and collaborative research in Austria, it is mainly that of creating awareness. However, framework conditions such as project financing by the Federal government, the provincial governments and the Commission, for joint R&D activities with industry in thematic or technology-specific programmes or specific legal regulations, do not determine the quantity of contract and collaborative research. It is past experiences in research projects with the enterprise sector, that are crucial for university departments to get involved in interactive relations with the enterprise sector. Satisfaction with past interactions on a personal, technological and on a research level, and the formation of social capital, lessens individual and institutional barriers and renders contract and collaborative research between the public research and the enterprise sector, more likely.

Personnel mobility: Personnel mobility between science and industry is rather low in Austria. This may be attributed to the following framework conditions:

- Wages for researchers are significantly lower in HEIs and PSREs, mainly due to rigid wage scheme and budget constraints in public science. This prevents mobility from industry to science and stimulates mobility from science to industry only to low extent.
- There are legal regulations which institutionalise differences between science and industry and are therefore assumed to make the mobility between the two sectors more difficult. In particular, that university researchers may acquire tenured positions, i.e. guaranteed lifelong employment at the university, presents a great barrier to mobility.
- There are further unfavourable framework conditions too, such as the pension system in public science and the low acknowledgement of non-academic activities for scientific careers.

Training and education: Training and education are seen by the enterprise sector as the main benefits from HEIs. There is however, little involvement of HEIs in further education and vocational training for enterprises. In these areas, specialised institutions outside the HE system offer services to enterprises.

IPR in science: The awareness of HEIs and PSREs concerning the protection of intellectual property through patent application has increased. However, incomes from royalties are not a major means of financing, neither at PSREs nor in HEIs. In HEIs, this fact is associated with the prevailing IPR regulation, i.e. individual university researchers are free to decide whether to commercialise a patent or not.

Start-ups from science: The annual number of all start-ups by researchers from universities may be estimated at about 25 in total. Almost 60 % of these are in the producer-related service sector. The producer-related service sector includes a wide variety of activities such

as economic, technical and legal consultations, and other services. The share of technology-based start-ups is comparably small and the same applies for PSRE. A main barrier to start-ups from science is perceived in the lack of entrepreneurial climate at universities and a lack in managerial knowledge, especially in the case of researchers from natural sciences and engineering. With the implementation of a new programme, the awareness towards the creation of new firms shall be raised.

Networking between industry and science: It may be seen, both from enterprises and from public science institutions, that previous experiences and personal networks between researchers from both sides are important channels for knowledge exchange. These previous experiences do not only refer to informal contacts but also, to a high degree, to previous collaborations. That the common educational background of researchers from industry and science is of great importance may be shown in that graduates often pave the way for co-operation.

Involvement of SMEs in ISR: In Austria, there are several public promotion programmes that specifically aim towards markedly raising the level and quality of R&D activities in SMEs. In SMEs, absorptive capacity necessary for the successful use of scientific knowledge and expertise is often lacking. Hence, there are various types of benefits from HEI that vary significantly with firm size. Small firms appreciate the benefit of highly skilled graduates and of universities directly supporting the development process, less than large firms do. In addition, small firms value the benefit of consulting services by universities less than large organisations do.

Science-based industries: The high-tech sector with strong science links in innovation (computer & software, telecommunication, pharmaceuticals & biotechnology, instruments, and aircraft) has grown a great deal in Austria in recent years. Its share in intramural business R&D expenditure has risen from about 20 % to about 36 %. This has completely changed the specialisation of the Austrian industry which traditionally had a focus on medium- to high-tech and low-tech sectors, and concentrated on incremental innovations.

B.1.6 Good Practice in Framework Conditions for ISR in Austria

In the following, the K-plus and the K-ind programmes are presented as examples of good practice in stimulating joint research efforts with a long-term perspective based on a competition and a bottom-up approach of defining thematic focuses.

K_{plus} - Collaborative Research Facilities

Focus

The purpose of the Kplus programme is to improve the co-operation between scientific institutions and the industry in Austria and to conduct top quality research in internationally competitive dimensions. Kplus funds collaborative research facilities jointly run by enterprises and research institutions (universities, government research labs etc). Research carried out in the centre should be pre-competitive. Individual projects run by the centre should involve multiple partners.

The selection process of the centres introduced a novelty into Austrian technology funding schemes, insofar as it is a *competitive process* between different proposals. Calls for proposals are launched regularly. There is no pre-selection of technological/scientific areas or types/status of applicants. Consortia bidding for the grant are formed in a self-organised way between business and academia. Proposals are evaluated on the basis of:

- their scientific and technological quality,
- their ability to 'cluster' existing scientific and economic competence into 'critical masses',
- their estimated economic benefit for Austrian companies and
- the quality of their business plans.

The main instrument of the evaluation process is peer-review.

Target groups

Industrial enterprises and research institutions which carry out high quality research with high potential for economic application.

Volume

To ensure the formation of critical masses, some 'target size' indicators are used: centres should have an annual funding of 2,2 to 4,4 million Euro and between 25 to 50 staff.

Duration

Centres are established for a period of 4 years, with the possibility of an extension (following an interim evaluation) for another 3 years. There is no a-priori set limit for the duration of the whole programme but at the start, it was estimated that around 20-25 centres would be a ceiling for Austria.

Institutional setting and organisation

There is considerable leeway for the organisation of internal relations between the partners. Most centres are organised as limited companies. There is a requirement for a minimum number of 5 industrial participants, in order to avoid 'single firm centres' and unfair preferential treatment, which might effect competition.

Instruments used

In addition to the subsidies, some help is provided in the preparation phase of the proposal and the establishment of the organisation of the centre. Management advice is also provided throughout the duration of the project. Subsidies are in the form of grants with up to 35 % from the T.I.G. Enterprises bear a minimum of 40% of the costs and the remaining 25 % stems from other public sources.

K_{ind} - Industrial Competence Centres

The main objective of the programme is to lay the ground for the formation of industrial clusters by providing a durable framework for co-operation, which should lead to the "building of trust and a shared knowledge base". "Awareness activities" and "search for partners" are not explicit activities of the programme. The programme has no active role in organising the network either, although it outlines some minimum formal requirements. Otherwise, the organisation is left to the participants. Neither does the Ministry take an active role as a partner in the centre/network, although some regional governments do.

Focus

K_{ind} supports the establishment of R&D centres jointly run by enterprises and research institutions (universities, government research labs etc), while K_{net} supports the co-operation of geographically dislocated/dispersed research facilities along common themes.

Target groups

All industrial enterprises with their own R&D department and research institutions. SMEs without their own R&D might participate as 'associate' partners at the level of individual projects. The centre/network should have a transfer component that is, technology transfer activities are encouraged. Planned technology transfer activities are a positive selection criterion.

Volume

Three centres are operative at the moment, for which 6,5 million Euro was provided in 1999 (total project costs 20 million Euro). 4 centres are currently (2000) in a preparation phase, with the start of fully-fledged projects expected in 2001.

Duration

1999-2002 (period of initial funding with projects expected to run until 2006). The funding period is limited to 4 years, with the possibility of a 3 years extension.

Institutional setting and organisation

The co-operation can take various forms, ranging from the more loose "association" to the establishment of a formal RJV as a limited company.

Instruments used

Subsidies in the form of grants, up to 60 % of total (eligible) project costs. Enterprises bear a minimum of 40% of the costs. Of the 60 % of public funding, a maximum of 40 % can come from the Programme, the rest can be provided from other public (e.g. regional) sources.

B.2 Belgium⁴

B.2.1 Knowledge Production Capacities in Belgium

As in most EU countries, the enterprise sector dominates the Belgian R&D system, accounting for 68 % (or 1.06 % of GDP in 1995) of all R&D expenditure. In science, HEIs account for a share of 27 % while PSREs play a minor role in the Belgian R&D system (5 % in total R&D expenditures, see table B.2.1). The Belgian economy shows a rather low R&D orientation with total R&D expenditure amounting to 1.57 % of GDP in 1995. In recent years, R&D activities have increased only slightly.

Table B.2.1: R&D Expenditures in Belgium 1995 by Financing and Performing Sectors (in million €)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total</i>	
	<i>Enterprises</i>	<i>State*</i>	<i>Abroad</i>		<i>%</i>	<i>% of GDP</i>
Enterprise Sector	1,927	102	106	2,135	68	1.06
PSREs*	13	117	38	168	5	0.08
HEIs	92	696	75	863	27	0.43
Total (million €)	2,031	915	220	3,166		
Total (%)	64	29	7		100	1.57

* including the small private non-profit institutions sector

Source: OECD (2000), calculations by the authors

R&D in enterprises is mainly financed by internal sources. The institutions in public science are financed both by basic financing provided by the State, and by project-based financing via scientific funds and research project funding. Basic financing via the General University Fund accounts for only one third of total R&D expenditure by HEIs, i.e. R&D activities in this sector depend heavily on external sources, most of which are acquired on a competitive basis (Table B.2.2). During the 1990s, the public financing share (by regional governments, i.e. the Flemish and Wallon government) of HEIs' R&D has slightly decreased. At PSREs in 1995 most money for R&D came from the regional government. This situation has changed however, with the growth of industry-oriented PSREs in Flanders, showing a share of basic government financing of 53 % in 1998.

Table B.2.2: Financing Structure of R&D in HEIs and PSREs in Belgium 1995 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (GUF)	35	n.a.
Project Financing and other financing sources	65	n.a.
Regional Governments	80	92
Other Sources (enterprises, internal financing, abroad)	20	8

Source: OECD (2000), calculations by the authors

⁴ This chapter is based on the national report on ISR in Belgium (Clarysse et al. 2001).

Within the enterprise sector, R&D expenditure is concentrated in just a few industrial sectors. Table B.2.3 shows that the bulk (41 %) of R&D takes place in areas which are technology-driven but outside the narrower "high-tech sector"⁵ (i.e. machinery, vehicles, electrical equipment, and chemicals). The sectoral concentration of R&D is quite high. The chemical & pharmaceutical industry accounts for more than one third of all private business R&D expenditure alone, although its share in the value-added of the Belgian business sector is only 5 %. This industry shows, by a large degree, the highest R&D intensity (R&D expenditures as a percentage of value added), i.e. 13 %. R&D in the service sector is rather low. However, recent studies show that this low share may be a significant underestimation due to data collection problems. In 1997, the service sector's share in BERD was reported to be 17 %.

Table B.2.3: R&D Expenditures in the Belgian Enterprise Sector by Sectors 1995

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	30	0.31
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	41	0.42
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	17	0.17
IT-Services (NACE 64, 72, 73)*	7	0.07
Other Services (NACE 50 to 99, excl. IT-Services)*	5	0.05

* too low due to a lack of data recording

Source: OECD (2000), calculations by the authors

The overwhelming majority of business R&D is spent in large enterprises. Small enterprises (< 100 employees) account for only 19 % of total business R&D. About 40 % of all business R&D is performed by very large enterprises, i.e. consisting of more than 10,000 employees. These are international oriented enterprises (for example Solvay) with huge R&D activities.

Table B.2.4: R&D Expenditures in the Belgian Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	19
Medium-sized Enterprises (100 to 499 employees)	17
Medium-sized to Large Enterprises (500 to 999 employees)	12
Large Enterprises (1,000 to 9,999 employees)	~12
Very Large Enterprises (10,000 employees and more)	~40

Source: OECD (2000), calculations by the authors

Although SMEs have only modest significance for the R&D performance of the Belgian business enterprise sector, they represent nevertheless the vast majority of enterprises in Belgium (as in other EU countries). Thus, their awareness of the potential benefits of contacts and co-operation with the science sector is crucial for the absolute level of ISR (as in other EU countries also). Information on innovative performance can be obtained from the results

5 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

of the recent community innovation survey (CIS2). However, the results of CIS2 should be interpreted with care. The framing of questions proved to be different from one country to another. This has had a severe impact on international comparability. In particular, the estimations of the share of innovative enterprises in Belgium seem to be far too low when compared to respondents from other EU countries.

In Table B.2.5 information is provided on the innovative performance of Belgian SMEs in relation to the EU average. The results are rather mixed. For some indicators (especially the share of turnover due to innovative products or share of enterprises with continuous engagement in R&D), Belgian SMEs (both very small as well as small enterprises) perform better than the EU average. The overall picture suggests that absorptive capacities at Belgian SMEs are rather high, especially in the very small enterprises segment.

Table B.2.5: Relative Innovation and R&D Performance of SMEs in Belgium

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.12	0.87	0.94	1.28
Innovation Expenditures as a Share of Turnover*	1.48	1.06	0.67	2.64
Share of Turnover due to Innovative Products*	1.67	1.27	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	1.05	0.69	0.45	2.08
Share of Enterprises with Medium R&D Intensity**	0.86	1.28	1.94	2.40
Share of Enterprises Engaged Continuously in R&D**	1.41	1.41	1.28	1.93
Share of Enterprises Having Applied for a Patent**	1.26	0.64	1.20	2.36

* Figures show the relation of Belgian SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Belgian enterprises to all EU enterprises: $(SME_{x_{Bj}}/SME_{x_{Ej}})/(x_{Bj}/x_{Ej})$, x being the variable considered, B being Belgium, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Belgium to SMEs in the weighted mean of all EU countries (except Greece): $SME_{x_{Bj}}/SME_{x_{Ej}}$, x being the variable considered, B being Belgium, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

The public science sector in Belgium consists of universities, polytechnics and several PSREs. The regional governments of Flanders and Wallonia are formally responsible for the public science institutions. Table B.2.6 summarises some major institutional aspects of the public science system in Belgium:

- As of today, there are 17 universities in Belgium, employing about 25,000 personnel and with about 132,000 enrolled students (1999). Universities differ in terms of size and range of teaching and research spectrum. The three biggest universities (Katholieke Universiteit Leuven, Rijksuniversiteit Gent and Universite Catholique de Louvain) employ 50 % of the total university personnel in Belgium and account for about 53 % of all university students. Some universities are specialised in certain technology fields (for

example agriculture and mining). These universities are significantly smaller, both in terms of personnel as well as enrolled students (150 to 500 personnel and about 1,000 to 2,000 students).

- Taking into account the distribution of research personnel, the majority work in the natural sciences (33 %), followed by engineering (24 %). The opposite holds true for the distribution of enrolled students. Here, the main bulk is concentrated in social sciences (43 %). This somewhat contrary picture between the share of students and the share of researchers suggests that faculties in the social sciences are much more focused on teaching duties when compared to faculty members in engineering and natural sciences. Interestingly, this pattern cannot be found in any other EU country (at least to such a large extent).

Table B.2.6: R&D Personnel and Enrolled Students in the Belgium Higher Education Sector by Fields of Science 1999 (in %)

<i>Sector</i>	<i>R&D personnel</i>	<i>Enrolled students</i>
Natural Sciences	33	15
Engineering (incl. Agricultural Sciences)	24	7
Medical Sciences	15	21
Social Sciences*	19	43
Humanities*	9	14

Source: VLIR (2000), Cref (2000)

- In addition to the universities, there are 59 polytechnic schools in Belgium whose main focus is on education. In 1999, the total R&D personnel at these schools was only 214, 128 in Flanders and 86 in Wallonia. The R&D expenditure at polytechnic schools was about 13 million Euro in 1999. The main financing sources are direct regional government appropriations (67 %) and intermediaries, i.e. other public financing agencies (25 %). Financing by enterprises accounts for only 3 to 4 %.
- Besides the university system, Belgium has several public (or semi-public) research institutes with varying objectives, structures and size. In total, their significance in the public science sector is limited but some institutions are highly specialised on ISR activities and therefore play a major role for industry-science links. Particularly in *Flanders*, these institutions play a prominent role in the regional innovation system. The three most prominent are IMEC, VIB and VITO:
- IMEC, Interuniversity Institute for Microelectronics (founded in 1984) employs about 1000 people and has a total financial budget of about 75 million Euro. Its mission is in the field of microelectronics, conducting research, promoting technology transfer and stimulating spin-offs (IMEC has its own VC fund).
- VIB, Flanders Interuniversity Institute for Biotechnology (founded in 1995) employs about 700 people with an annual budget of about 30 million Euro. The mission of VIB is

to promote biotechnology in a broad sense (research and development, technology transfer including stimulating spin-offs, public awareness of biotechnology). VIB combines eight university departments and five associated labs.

- VITO, the Flemish Institute for Technological Research (founded in 1991) employs 450 people with a budget of about 40 million euros. The mission of VITO is to conduct contract research and to develop new products and processes in the fields of energy, environment and materials for the public and private sectors. An important objective is to encourage the sustainable use of energy and raw materials.
- In *Wallonia*, centres of excellence in specific fields of technologies have been created including: BCR (biotechnology); CEDITI and MULTITEL (information technology); MATERIAL NOVA (new materials); and Centre de Recherches Metallurgique (steel). However, these centres are less prominent in the field than their Flemish counterparts. The Wallonian strategy is more programme-orientated and puts lower emphasis on the establishment of independent research centres.

Table B.2.7: Main Characteristics of Major Institutions in the Belgian Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities	17 universities, incl. 7 larger, general universities and 10 smaller, specialised universities	higher education and research	basic research	high share of funding from business sector
Polytechnic Schools	59 schools	education, consulting	applied research at a low level	low
IMEC	Inter-university Institute, "PPP model" (universities, Flemish government, Association of Flemish Employers)	(contract) research in the field of microelectronics	mainly applied research	high share of contract research, high level of international orientation
VITO	Independent research centre owned by the Flemish government	contract research and development in the field of energy, environment and materials	applied research	high share of contract research
VIB	Inter-university institute	applied research in biotechnology; technology transfer, creating spin-offs; promoting biotech for a broader audience	applied research and new technology development	lower orientation on contract research if compared to IMEC and VITO
Sector-specific Centres of Excellence (Wallonia)	public research institutes with strong sectoral focus	applied research in distinct fields of technology (biotechnology, information technology, new materials, metallurgy)	applied research	divergent

Source: own survey and compiled by the authors

- There are several other small PSREs and semi-public research institutes such as: the International Institute of Cellular and Molecular Pathology (ICP); the Societe de

Recherches et de Developpement Industriel (SOREDI); the Institution pour le Developpement de la Gazeification Souterraine; and the Wetenschappelijk en Techn. Centrum van de Belgische Textiel (Centexbel).

In summary, the knowledge production structures in Belgium may be characterised as somewhere in between, going in no particular direction, and neither very favourable nor very unfavourable to ISR. In science, a quite distinguished and large variety of different institutions exists. Their objectives cover the whole range from a mainly higher education orientation to basic research to applied research, with the focus explicitly on contract research. In particular, the PSREs sector in Flanders has an explicit focus on technology transfer in the broad sense (including joint research, stimulating diffusion, promoting and supporting spin-offs, increasing public awareness for new technologies etc.). However, financing of R&D by the public sector (as a share of GDP) is comparatively low and is decreasing. Consequently, this leads to the fact that universities have to cope with budgetary constraints which seem to have become even more severe in the latter years. The Belgian enterprise sector has no pronounced high-tech orientation. Rather, R&D is concentrated in technology sectors which are not characterised as highly science-oriented. BERD (as a percentage of GDP) is quite below that of the leading EU countries such as Sweden, Finland or Germany. However, R&D in the business sector is performed, to a large extent, by large companies with significant in-house R&D capacity. These companies, such as Solvay, are a driving force for ISR in Belgium.

B.2.2 The Level of ISR in Belgium

The level of ISR in Belgium is described by a set of indicators and assessments on the significance of various interaction channels. Table B.2.9 lists the indicators used and the results achieved. It also indicates those areas where ISR in Belgium may be regarded as above average with respect to EU standards. There is no uniform pattern of ISR - rather, interaction between industry and science differs largely by the type of interaction and by the type of actor involved in industry and science. The main results are discussed below.

Contract research carried out by science institutions for industry and collaborative research between industry and science is revealed through financial flows from enterprises to HEIs and PSREs for R&D activities. Enterprises are a very significant funding source with almost 11 % of total R&D funding in HEIs. Belgian universities receive much more funding from the business sector than most other EU countries do. In 1995, only a very small part of R&D at PSREs (about 2 %) was associated with contract research. In industry, the share of R&D financing by enterprises for HEIs and PSREs as a % of BERD is clearly above the EU average. Thus, according to this data source, the level of interaction between science and the business sector seems to be rather high when compared with the EU average.

However, the results of the CIS2 obtain somewhat different results. The share of innovative enterprises (both from the manufacturing as well as from the service sector) co-operating in innovation projects with HEIs, is below the EU average. According to CIS2 results, Belgium

is the only country with greater co-operation with PSREs than the EU average. Additionally, the CIS2 results show that HEIs and PSREs are not regarded as an important source of information in the innovation process of Belgian manufacturing firms (the opposite is true for service firms). However, the interpretation of these results should be taken with care, as the international comparability of the CIS2 data cannot be fully guaranteed.

Table B.2.8: Indicators and Assessments of ISR in Belgium at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % of HERD	10.6
	R&D financing by industry for PSREs in % of GOVERD	2.1
	R&D financing by industry for HEI/PSREs in % of BERD	4.9
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI researcher	low
	Significance of R&D consulting with firms by PSRE research.	low
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	13.4
	Innovative manuf. enterprises co-operating with PSREs in %	8.5
	Innovative service enterprises co-operating with HEIs in %	15.3
	Innovative service enterprises co-operating with PSREs in %	6.0
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	6.7
	PSREs used as inform. source by innov. manuf. enterpr. in %	4.8
	HEIs used as inform. source by innov. service enterpr. in %	2.0
	PSREs used as inform. source by innov. service enterpr. in %	2.7
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in %	~ 3
	Share of researchers at PSREs moving to industry p.a. in %	~ 5
	Share of HE graduates at industry moving to HEI/PSREs p.a. in %	0.4
Vocational Training (Source: national statistics, assessments)	Income from vocational training in HEIs in % of R&D exp.	high
	Number of vocational training participants in HEIs per 1,000 R&D employees at HEI	high
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in NSEM	low
	Patent Applications by PSREs per 1,000 employees in NSEM	~ 15
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	low
	Royalties in % of total R&D expenditures at PSREs	low
Start-ups from Science (Source: national statistics, assessments)	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	high
	Number of technology-based start-ups at PSREs per 1,000 R&D personnel	~ 3
Informal contacts and personal networks (Source: national statistics, assessments)	significance of networks between industry and HEIs	low
	significance of networks between industry and PSRE	high

* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD, calculations by the authors

Recently, a Belgian study for the mobility of human resources in science and technology (HRST) was conducted on the basis of the labour force survey⁶. Mobility is defined as the move in employment between two points of time. In this study, four different types of mobility are identified:

- (i) immobility of persons between different employers;
- (ii) mobility in the labour regime (from employee to independent or vice versa) or moving from full time to part time employment;

6 Steunpunt WAV (2000). First Exploration of the Belgian HSST Data.

- (iii) mobility in or out of employment (e.g. finding a job or going into retirement);
- (iv) other mobility patterns (e.g. a non-active person enrolling in the unemployment-system).

As Table B.2.9 shows, almost 44 % of all HRST personnel experienced some type of employment mobility in the time period 1993 and 1997. The most frequent type of mobility was between firms. Thus, it can be argued that changing occupation between firms is a very important channel of knowledge transfer. Interestingly, the rate of mobility seems to have a declining trend over time. At the beginning of the time period, the rate was considerably higher in all types of mobility than at the end of the period. Then, with only one exception, this rate declined steadily.

Table B.2.9: Mobility of HRST-personnel in Belgium in 1993-1997 by types of mobility

<i>In percent of sample</i>	<i>inter-firm mobility</i>	<i>within workforce</i>	<i>in or out of work</i>	<i>other transitions</i>	<i>stability (no mobility)</i>
dec '93 - dec '94	7.4	4.2	6.0	2.5	79.9
dec '94 - dec '95	8.3	4.0	5.5	2.2	79.9
dec '95 - dec '96	6.5	4.1	4.7	2.1	82.5
dec '96 - dec '97	3.2	2.5	2.7	1.1	90.5
Period 1993-1997	19.1	9.1	11.4	4.0	56.4

Source: KSZ, HRST-dataset (Steunpunt WAV)

For the period 1995-1996, there is also information on sector specific mobility rates (inter-firm mobility) and on available inter-sector interactions in mobility. With 25,4 % R&D, institutions experience the highest mobility rate of all sectors (the average for the total workforce is 1,5 %). However, the majority (47,6 %) of the mobile R&D employees stay in the same sector. Only 11,2 % change to the business enterprise sector. With respect to the total number of HRST persons employed, this results in a mobility rate from PSREs to industry, of about 5 % (this figure, however, also includes mobility from private and semi-public R&D institutions). The respective mobility rate of HRST persons from HEIs to industry is 3 %. Both figures are high by international standards and indicate a significant R&D personnel mobility between industry and science in Belgium. The mobility by HRST personnel from industry to the public science sector is considerably lower. Annually, only about 0.4 % of all HRST personnel in the business enterprise sector move to HEIs or PSREs. Thus, personnel mobility takes place mostly in the direction from science to industry and seldom the other way around.

HEIs and PSREs play a significant role in vocational and further training for enterprises in Belgium. According to the expert interviews, teaching by firm employees at universities, vocational training programmes for industry and long-term relationships in graduate mobility seem to be very significant channels of ISR. However, some interviewees mention that there is a shortage of teaching by firm employees in the natural sciences and in engineering. Most teaching by firm employees takes place in the field of business practices (entrepreneurship, management, etc.). A lot of interviewees are in favour of work placements for students in

order to strengthen the relationships between industry and science. However, the current structure of the curriculum in the engineering faculties and the exact sciences does not allow for these kinds of work placements. There are some programmes that foresee internships during summer holidays but these are not integrated into the basic curriculum.

Patent applications by HEIs and PSREs account for only a small share of total national patenting in Belgium. Capron and Cincera (2000) estimate the share of patents by Belgian applicants originating in a non-market environment, at about 5 %. Between 1980 and 1996 there were only 357 patent applications at the EPO by Belgian HEIs or PSREs (including government agencies). Most of these patents (71 %) originated from PSREs. However, within the PSREs sector, patent applications are highly concentrated on just one institution, namely the Centre de Recherches Metallurgiques. Universities account for 35 % of patent applications. Table B.2.10 gives a detailed overview of patenting activities of the various institutions in the science sector in Belgium.

Table B.2.10: Number of patent applications at the EPO by different non-market institutions between 1980 and 1996

<i>Type*</i>	<i>Name of institution</i>	<i>Number of patent applications</i>
P	Centre de Recherches Metallurgiques	126
P	Interuniversitair Microelektronica Centrum (IMEC)	35
P	Stichting REGA	22
P	SCK/CEN	19
P	International Institute of Cellular and Molecular Pathology (ICP)	16
P	Vlaamse Instelling voor Technologisch Onderzoek (VITO)	14
P	Others and miscellaneous	23
<i>P</i>	<i>Subtotal Public Research Institutions</i>	<i>255</i>
U	Leuven Research & Development (Katholieke Universiteit Leuven)	23
U	Universite Catolique de Louvain	16
U	Universiteit Gent	10
U	Universite Libre de Bruxelles	9
U	Universite de Liege	4
<i>U</i>	<i>Subtotal Universities</i>	<i>62</i>
G	La Region Wallone	27
G	Belgium State - Scientific Policy Office	13
<i>G</i>	<i>Subtotal Government Agencies</i>	<i>40</i>
Total		357

* Type: P: Public Research Institute; U: University; G: Government Agency
 Source: Capron and Cincera (2000, 181)

Given the small size of the PSREs sector in comparison to the HEIs sector, PSREs are much more patent active than universities. Based on recent numbers of patent disclosures by the three Flemish research institutes VIB, IMEC and VITO, one may estimate that annually, there are about 15 patent applications per 1,000 researchers in the PSREs sector, which is high by EU standards. At universities, patent intensity is clearly below 5, even when one takes into account an increase in the late 1990s in disclosures by Belgian universities.

There is no data available on royalties income in public science. In HEIs, this type of income is negligible. At patent active PSREs, patents seem to be used more as a strategic tool for

signalling competence and knowledge to potential industrial partners, rather than as an important source for R&D financing.

A recent study by Degroof et al. (2001) has described the phenomenon of research based start-ups of enterprises in Belgium. These are defined as spin-offs from university laboratories or public/private R&D laboratories. Corporate spin-offs are not included in the definition. In order to be considered as a spin-off, there had to be a clear technology transfer from the parent organisation to the new start-up, embodied by either a licensing agreement or a financial participation by the parent organisation of the company. According to this study, the number of spin-off enterprises has increased exponentially in Flanders since the mid-nineties and in Wallonia as well since the end of the 90s. As of today, over 100 spin-offs exist in Flanders and almost 50 are found in Wallonia. There are a number of explanations for this increase in the late nineties. First, there were some successful and visible IPOs in the middle and late nineties of companies such as Innogenetics, Eurogentec, Ubize, etc. These IPOs did not only motivate other scholars to create a new start-up, they also attracted pre-seed capital funds. This might be seen as a second main explanation - the emergence of pre-seed capital funds has been shown by Clarysse et al. (2000) to be an incentive for entry to spin-off activity. Third, changes in the Belgian legislative framework made it easier and clearer to start up companies for academics. The IPR legislation was made clearer (at least in Flanders, see below), the universities were motivated to develop their interface services (see below), stock options were recognised as a legal remuneration system, and finally, Business Angel networks received financial support from the government.

Not surprisingly, informal contacts and personal and organisational networks are considered very significant for ISR by almost all interviewed experts. Personal contacts based upon past joint projects may lead to a sustained network and to new joint projects in the future. Given the uncertainty naturally associated with research projects, this behaviour may be attributed as risk reducing and to be quite logical. However, according to expert assessments, networks play a more significant role for PSREs than for HEIs.

In summary, Belgium shows an impressive record of ISR when taking into account the rather low investment in R&D both in the enterprise and public science sectors. The main channels of interaction are research collaboration, personnel mobility, training, and start-ups. The small PSREs sector is quite strongly engaged in patent activities, as far as technology specialised research institutes are concerned. The Belgian enterprise sector plays a comparatively significant role in financing university research. This indicates that the enterprise sector has the absorption capacity as well as the willingness to contract out research to the science sector or to conduct joint research projects with universities.

B.2.3 The Policy-related Framework Conditions for ISR in Belgium

The Belgian institutional framework is quite complex compared to other EU countries. Belgium has a federal government responsible for federal issues regarding ISR. It can be divided into the French and Flemish community, each responsible for some parts of ISR (i.e.

the higher education sector). Finally, in matrix format, there are three Regions - the Walloon, Flemish and Brussels-Capital Region - which also share some responsibilities (e.g. technology policy). Only in Flanders, do the Flemish Region and Flemish Community have a common government and administration. The legal environment differs between these regions to a considerable extent. Thus, it is necessary to discuss the legal framework separately for the two Communities.

Despite the complex policy structure, the institutional framework is characterised by divergent 'cultures' between industry and science which are reported as a major obstacle for ISR. In science, there are almost no incentives to engage heavily in ISR and the disincentives are numerous. Involvement in ISR does not lead to a reduction in administrative and teaching duties, the evaluation system is based on scientific publications in which ISR involvement plays no role. Also, although royalty earnings are possible, they are highly taxed and earnings (i.e. personal remuneration) from contract research cannot be attributed to the individual professors but belong to the university. The latter is quite different in Leuven R&D (see B.2.6). Here, university professors have the right to take 50 % of total profit generated by contract research, while the other half has to be reinvested. A major incentive in HEIs is the possibility to recruit researchers associated with the contract research project. Thus, it is possible to form greater research teams at university institutes than current budget constraints would otherwise allow.

The differences in R&D objectives are also reported as an impediment to ISR, although this is not specific to the Belgian situation. Although patent-driven and industry-driven research can be carried out at universities, it is not the main focus of university research, nor is it adequately appreciated in evaluation and decisions on the distribution of research grants. However, differences in objectives may also enrich the co-operation. Universities get funding in order to carry out fundamental research, without which, it would be impossible for companies or scientific institutions to develop applied research that can lead to joint research contracts.

The institutional setting in PSREs seems to be more favourable to ISR activities, particularly in technology specialised research institutes oriented towards a well-defined research area and group of industrial clients. Section B.2.6 gives an example of such an organisation and the main features of the institutional setting.

The legal framework of intellectual property rights is currently changing in the *Flemish Community*. The decree of 22 February 1995 determined that research results which can lead to validation (including patents, licenses and other IPRs) must be divided between the university or research centre and the principal of the contract, and that each individual contract includes the results of negotiations between parties. Article 103 of the decree of 29 August 1998 determines that IPR from research carried out by university researchers belong to the university, excluding the possibility of negotiating contracts with third parties (and thus dividing IPR between industry and the university). Even though the university obtains the IPR on the research and the university has an exclusive right on the exploitation of the

research results, the researcher can claim the rights if the university fails to exploit them within 3 years after filing the research results. This excludes the possibility for researchers to obtain the rights on their own research results (unless the university fails to exploit these results). The same regulations are used for research projects carried out at the governmental research centres in Flanders, VIB and IMEC. The research organisations and not the researchers, get the IPR. For research contracts between research organisations and industry, the division of IPR depends on how much know-how was needed in the research organisation prior to the start-up of the joint research project. Contract negotiations will determine whether the research centre or company obtains the rights.

The decree of 1995 also determines the criteria that need to be fulfilled before a university can invest in spin-offs. Financial participation is only possible if the research results that lead to the creation of a spin-off, and other intangibles, are validated. The university can accept shares in exchange for these intangibles but it can never own the majority of voting rights. For research financed by the Community, it still owns the rights but, as is the practice for many years, agrees to let the university exploit its research results. Research contracts with the Region of Flanders (only for universities located in Flanders) are contractually settled between the industrial partner, the IWT (Flemish Institute for Science and Technology - a semi-autonomous, one-stop institution for the implementation of industrial R&D policy and for dealing with all R&D programmes and activities with an economic impact in which the Flemish Government is involved), and the university. Recently, the Flemish Council for Science Policy (Advisory organisation) advised on the voting of a decree which stipulates that the universities own the results of the research they carry out, regardless of the party that finances the research (i.e. industry or government).

The former legal basis for research contracts between universities and third parties was established in 1991 (decree on education) and was complemented by the decree of 22 February 1995. This decree states that all costs directly linked to the execution of contract research, namely the use of infrastructure, services or personnel from a university, are at the expense of the principal of the contract. It also determines that all research contracts must be approved by the university administration. There are no other regulations for Flemish universities so most have their own internal regulations governing these matters. These internal regulations determine the minimum overhead costs that must be applied in these contracts, the method of payment and the possibility of personal remuneration for researchers.

The legal framework for IPR changed recently in the **French Community** as well. Before the decree of 1997, IPR from research at universities belonged to the French Community. The decree of December 1997 determined that universities obtain the rights on the research carried out. For research that was carried out before 1998, and for which the results are owned by the Walloon government, IPR can be transferred from the government to the research group or university who wants to exploit the results obtained. The Walloon government is authorised to interact with companies that will exploit the research results by participation, by giving convertible loans or guarantees. With respect to contract research,

joint research projects and start-ups from public science institutions, there are no specific regulations which apply in the French Community.

In Belgium, IPR is a federal issue. There is no subsidy for carrying out evaluation of the patenting or marketing opportunities of the proposed invention. In the Flemish Community, the Dutch speaking universities can make use of a small budget set aside for their disposal by the Flemish government (1.2 million Euro in total). They can, amongst others, use this money to promote licensing or pay patent applications. We refer to the next section for a detailed analysis of this. In Wallonia however, costs for protecting research results obtained from research in universities or research labs financed by the Walloon government, are paid by DGTRE. After the patent evaluation is carried out and marketing opportunities are mapped by the Ministry of Economic Affairs, the Walloon region pays all costs (including first filing, national patents, patent demand at the PCT, European patents, taxes on these patents, costs of patent attorneys, and translation costs) up to a maximum period of 6 years.

Table B.2.11. provides an overview on major regulations in the fields of IPR and spin-offs in HEIs and PSREs in the two Belgian Communities.

Table B.2.11: Overview of IPR and Spin-off Related Regulations in Belgium

<i>Name of regulation</i>	<i>Year of implementation</i>	<i>Contents/Incentives/Barriers</i>
Flanders		
<i>IPR at universities and public research labs</i>		
Decree on scientific or social services concerning the relations of universities with private institutions	1995	Art. 6 IPR: to be determined in contract
Decree IX on education, art. 103	1998	Art. 169 IPR: belongs to university
<i>Joint R&D projects and contract research</i>		
Decree on scientific or social services concerning the relations of universities with private institutions	1995	Art. 4: contract determines regulation
<i>Spin-offs</i>		
Decree on scientific or social services concerning the relations of universities with private institutions	1995	No majority stake in spin-offs
Wallonia		
<i>IPR at universities and public research labs</i>		
Decree of 05/07/90	1990	IPR belong the Walloon government
Decree of 17/12/97, title III, art. 14	1997	IPR belong to universities
<i>Joint R&D projects and contract research</i>		
No specific regulation		
<i>Spin-offs</i>		
No specific regulation		

Source: Capron and Cincera (2000, 181)

Another obstacle to ISR seems to be the shortage in capital and financing in science in Belgium. For instance, there is a lack of funds to create technology transfer offices at universities, which are consequently understaffed. Furthermore, universities in Flanders are not allowed to take a majority stake in spin-offs. The current budgetary restrictions for universities results in short term actions. As a result, the financing of research projects is often too small to encourage a research team to excel in a certain domain. The universities

have a rather small budget which they can use to finance larger projects (in the range of 1 million Euro). However, these projects are often 'politically' attributed to faculties so that they remain an insufficient support to a research programme.

As a result of various barriers to ISR stemming both from market characteristics and institutional and behavioural peculiarities, the regional governments of Flanders and Wallonia have introduced various promotion programmes relevant to ISR. Table B.2.12 gives a summary of some of the most important programmes. In addition to the programmes listed in the table, there are further important policy initiatives in the field of ISR, such as providing intermediary and supportive infrastructures (which are described in a separate subsection), and providing an efficient set of public research institutes which act as partners to enterprises in innovation projects. Such institutions (e.g. VIB, VITO, and IMEC) have been listed in B.2.1. Among the promotion programmes, the following deserve special attention:

- In 1998, the Flemish Government decided to launch a specific financing programme aimed towards stimulating fundamental research projects in strategic technologies, and was a result of an interaction between the academic institutes and economic agents in Flanders (STWW). Last year, this programme was slightly modified (technological projects with both societal and economic impacts could be proposed without thematic limitation), re-named GBOU, and the methods of obtaining financing were made easier. The GBOU projects have the following objectives: economic or societal impact have to be shown; this impact is to be expected only in the medium or long term; the research remains generic so that more than one application area can be defined, with one or more related economic sector; and it happens in interaction with economic and/or societal actors outside the academic domain. The industrial partners in these projects cannot obtain direct funding from GBOU. However, further along the technological trajectory (when commercialisation nears) they can make use of the traditional subsidies from the IWT.
- The KIV programme was established in 1997 and aims to stimulate SMEs with a limited innovative capacity, to recruit highly educated people to work on innovation projects, coached by a research centre. The programme was established because SMEs seemed to lack the structural capacity to carry out these projects. It gives a wage subsidy for one year and the external coaching by the research centre is remunerated. Projects are handed in by research centres or intermediary structures and are evaluated by IWT. Until fall 2000, 75 proposals were received and 69 selected for funding. The greatest difficulty with this kind of programme seems to be the availability of people willing to carry out these innovation projects in SMEs.
- The HOBU fund, stimulating and supporting technological research in Flemish polytechnics, has been operational since 1997. It has two goals. First of all, its objective is to give an impulse to the commercialisation of technological research at Flemish polytechnics. Secondly, it aims towards giving smaller companies the opportunity to stay acquainted with the technological developments in their sector. The HOBU fund gives support to Flemish polytechnics to carry out technological research projects with potential

commercial or socially valuable results. A project must be relevant for at least 3 companies (preferably SMEs), who will be actively involved in the project. The polytechnic searches for technological opportunities for the companies involved. The project takes a maximum of 2 years and gets a maximum budget of 0,3 million Euro.

Table B.2.12: Selected Public Promotion Programmes in the Field of ISR in Belgium

Programme (executing agency)	Region	Public Funding p.a. (million Euro)	Starting year	Main approach	Type(s) of ISR Mainly Addressed
STWW/GBOU (IWT)	Flanders	16.2	1998	stimulating fundamental research in strategic areas in public science	technology transfer, collaborative research
KIV (IWT)	Flanders	1.2	1997	wages subsidies to SMEs for hiring research personnel, financial support to HEIs/PSREs for providing consulting services to SMEs	personnel mobility, consulting, training, contract research
HOBUS fund (IWT)	Flanders	4.2	1997	support to polytechnics for carrying out technological research projects for SMEs	contract research, technology transfer, consulting, training
FIRST Doctorat (DGTRE)	Wallonia	1.1	1989 ¹	support to PhD students for carrying out a doctoral thesis jointly with an enterprise	personnel mobility, technology transfer
First Europe (DGTRE)	Wallonia	2.8	1989 ¹	support to PhD students for carrying out a doctoral thesis jointly with an enterprise, including a research period abroad	personnel mobility, technology transfer
FIRST Spin-off (DGTRE)	Wallonia	1.1	1989 ¹	support for HEIs researchers to establish a new firm	start-ups
Interface Offices (DGTRE, Flemish government)	Belgium	2.3	1998	support for technology transfer offices in HEIs to strengthen valorisation of research results	IPR-use, start-ups, technology transfer
PhD programmes (IWT)	Flanders	15.5	1981	support to young researchers to carry out R&D projects relevant to industry	personnel mobility, technology transfer

¹ First Doctorat, First Europe and First Spin-off were derived from the initial programme First Universities that was established in 1989.

Source: EU trend chart project, own survey and compiled by the authors

- DGTRE was established in 1989 from the programme 'FIRST' (Formation and Impulse to Scientific and Technologic Research), in order to stimulate exchange between science and industry. The programme has three objectives. First, to increase of scientific and technological potential of university research. Second, the valuation and transfer of this potential to Walloon companies, and third, the formation of high-level executives specialised in new technologies. The FIRST programme consists of three initiatives called FIRST Spin-off, FIRST Doctorat and FIRST Europe, and outlined below.
- FIRST Doctorat offers 20 scholarships annually to PhD students who want to develop their PhD in co-operation with industry. The research results must contain the possibility of a positive impact on the economic and social development of the Walloon region while

the research proposal must be initiated by an Walloon university in co-operation with a Walloon research centre or company, and must lead to a PhD. Scholarships are granted for a period of 2 years but can be extended by another 2 year period. The Walloon region and the company or research centre that collaborates with the university during the research period pays part of the remuneration of the researcher. The Walloon region takes care of 50 % (for large companies) or 80 % (for SMEs) of the scholarships, and pays an extra of 5,000 Euro a year to the university involved. The company or the research institute pays the rest. In turn, the company or research institute obtains the rights over the research results but if it fails to validate these results, the university has the right to take them over.

- First Europe is a very similar programme for PhD students but the researcher must spend at least 6 months of their research period at a European university. The costs (remuneration of researchers, and travel and subsistence costs) are completely covered by the Walloon region and the European Social Fund. Each year, a maximum of 40 scholarships can be granted.
- FIRST Spin-off offers 20 scholarships to researchers each year. During the project, they work on the completion of an innovation project, carry out an economic and technical feasibility study, and write a business plan for the creation of a spin-off. The researcher must participate in management. Financing covers the remuneration and courses of the researcher and is fully covered by the Walloon region. The programme is described in more detail in B.2.6.
- In Flanders, the IWT PhD scholarships support young researchers to carry out a research project that might result in an industrially applicable concept. The scholarships are granted for a period of 2 years and are renewable for another 2 year period. The researcher gets an income of approximately 1,340 Euro per month, and a 'bench-fee' of 3,718 Euro per year to cover other costs. In 1999, 162 scholarships were started and 134 were renewed.
- Both in Wallonia and Flanders, universities are developing their interface offices. These offices receive some public support from the regional governments. Although the structuring of most interface services is still in its infancy, there is one good practice to be found in Flanders - Leuven R&D (see B.2.6). Interface activities are activities that promote the co-operation between Flemish universities and companies value university research and help to establish spin-off companies by the university. The promotion of co-operation between Flemish universities and companies focuses on the organisation of contacts, search for partners and juridical and financial assistance for the establishment of contracts. Valuation of research results includes educational initiatives concerning validation, active searching for commercial potential results, market research, and protection of IPR and coaching the establishment of a validation plan. The promotion of the establishment of spin-off companies includes business plan coaching, coaching for investments, and financing and management training.

According to the assessment by national experts, the intermediary infrastructure to strengthen interaction between science and industry lacks effectiveness. Although in Flanders universities are established with technology transfer offices (TTOs), their size (usually only one or two persons) is far below the necessary critical mass to cover all the responsibility (negotiation and management of patents, validation of research, monitoring spin-offs etc.). The institutional framework in Belgium induces a large population of different intermediaries that play a role in ISR. There are three types of intermediaries that can be distinguished: financing institutes for R&D; bridging institutes at regional and sectoral level; and private-public incubator initiatives. The following is a selection:

- IWT (Institute for the Promotion of Innovation by Science and Technology in Flanders): IWT was established in 1991 as a semi-autonomous, one-stop institution for the implementation of industrial R&D policy, to deal with all R&D programmes and activities with an economic impact, in which the Flemish Government is involved. The annual budget is 148 million Euro (2000). The institute supports and stimulates industrial research and technology transfer in the Flemish industry. The IWT has two main functions. First, to offer financial support for research, technology advice, partner search and information about international subsidy options. Second, to promote the validation, diffusion and support of scientific and technological knowledge. In this function, the institute deals with the development of new initiatives and provides information and expertise. Furthermore, it enhances networking and co-ordinates the government policy with regard to bridging institutes and interface services.
- DGTRE (General Directorate for Technologies, Research and Energy): In Wallonia, the financial support for R&D is not managed by a separate institute as in Flanders but by the regional administration, namely DGTRE, which supervises and finances industrial projects. The DGTRE budget is used for carrying out S&T activities, the organisation of technology watch, involvement in international programmes, and carrying out sector analysis.
- The Research and Innovation Service of Brussels-Capital: The Research and Innovation Service (RIS) supports R&D projects in which the firms located in Brussels are involved. The RIS is a part of the administration and is very comparable to DGTRE in the Walloon Region.
- Interface offices: Both in Wallonia and Flanders, universities are developing their interface offices. As aforementioned, in Flanders, these offices receive some public support while in Wallonia, universities have to look for their own funds. Although the structuring of most interface services is still in its infancy, there is one 'good practice' model to be found in Flanders - Leuven R&D. This model is described in B.2.6 in more detail.
- Regional Development Agencies (GOMs): Each Flemish Province hosts a GOM. They are public bodies that promote the socio-economic development of their province. Their aims and activities include the active promotion of the province's socio-economic

development and companies in the province. The GOM's active field is based on co-operation between the public and private sectors. In their management structure, there are representatives from the public sector (provincial and city government, as well as local associations) and the private sector (employers' organisations). They play an important role in technology diffusion towards SMEs. The GOMs have created a common "Technology Innovation Cell", which tracks the potential of new products, processes and services in companies.

- Collective Research Centres: These centres occupy a central place in the applied research context of the Flemish Community and Belgium as a whole. Their objective is to meet the specific scientific and technological research requirements of the industry in the sector they represent. The largest of these centres are connected to industries which have historically played an important role in the Flemish economy - the textiles, metallurgy and metallic constructions, and building industries. In total, they employ about 1,200 specialist researchers. Although their money comes mainly from the compulsory contributions of companies in the industry, they increasingly engage in joint R&D projects with industry and participate in programmes such as the KIV programme (managed by the IWT). The Flemish research institutes VIB, VITO and IMEC have created a central organisation, VLOOT, to undertake ad hoc common projects in which the competencies of each individual centre can be used.
- TADs (Regional Technology Advisory Centres): These centres are an initiative of the Flemish Government to support companies with technological advice and information about technological developments. In fact, they are virtual centres located in most regional development agencies (GOMs) and in several collective research centres. Their activities are co-ordinated by the IWT.
- Regional Development Agencies: In Wallonia, there are nine Regional Development Agencies which together, manage about 130 industrial zones. As in Flanders, these Agencies play a major role in the promotion of the socio-economic development of their region. Unlike in Flanders, they do not engage in innovation advice, although this is currently changing.
- Walloon Innovation Relay Centre (CRIW): This centre has been created on the initiative of the DGTRE in collaboration with the six Walloon EURO-Info-Centres and the five Walloon European Business and Innovation Centres (see below). CRIW promotes innovative projects, technology transfer, European partnerships and "technology watch".
- In 1999, the Walloon Region started a new information service on innovative enterprises. This "Index" includes information from about 1,000 firms on certification, technologies, R&D activities and participation in EU programmes. The Index shall increase the opportunities for collaboration, favour the participation in EU Framework Programmes, and develop new perspectives on the commercialisation of research results.

- Business and Innovation Centres: BICs are Business and Innovation Centres that are recognised by the EC. Belgium has 8 BICs, of which seven are in Wallonia and one in Flanders. These were established with financing from the European Fund for Regional Development and local authorities. Even though most experts were convinced that the first BICs established did not reach their goal, they do think that some of the BICs established so far might become a good practice in the future. The first BIC was created in 1984 in Luik (Socran). An analysis of 2 BICs, namely EEBIC (European Erasmus Business Innovation Centre in Brussels) and Innotek (BIC Geel) shows that cooperation between industry and science is one of their most important achievements.
- Almost each university in Belgium has an 'incubator' which provides offices and a 'science or research park'. As described above, the incubator function of a university is much broader than offering office space to new spin-offs. In addition to office space, university seed capital funds are created and activities initiated to coach these start-ups. As these activities are described elsewhere in this report, refer to the section on Leuven R&D (interface services) and to section III.
- There are quite a number of private incubation initiatives in Belgium. Examples of these initiatives include Silicon Forest, E-Merge, Minds, Powerlaunch, Sailtrust and Starlab. Starlab deserves some more attention. It is a private, blue-sky research lab that employs about 80 people carries out blue-sky research, is involved in the creation of consortia with industry and the creation of spin-offs. It is described in more detail in B.2.6.

One main conclusion of the Belgian legal framework is its high complexity due to the federal-regional nature of the Belgian political system. Nevertheless, the situation has become clearer in the last few years (for example, with respect to IPR, if parties from universities and business are involved). A various set of different institutions and programmes fostering ISR have been established in recent years. They address the whole range of ISR but lay a special focus on mobility and researcher training programmes. Another major feature of the Belgian ISR system is the huge variety of intermediaries attempting to foster ISR. Broadly defined, they include special research institutions in science and industry, public financing institutions, commercialisation offices in HEIs, incubators (both public and privately run), business and innovation centres, information services, and technology consultants. Experts feel that this large supply of intermediaries is rather inefficient although there are some good practice examples.

B.2.4 ISR in the Field of Human Capital in Belgium

At the end of the 1990s, the total number of graduates by different disciplines amounts to about 32,000 persons per year. Not surprisingly (given the distribution of students) the great bulk of graduates are in the social sciences (43 %), followed by medicine (20 %). 11 % of all graduates can be found in engineering which is considerably higher than the relative share of engineering students (7 %). The opposite holds true for the natural sciences. While their share of students is 15 %, their relative share of graduates is only 8 % (Table B.2.13).

Of the 7,300 unemployed graduates, 46 % of them are from the social sciences. Thus, this is not much higher than the relative share of graduates. The highest discrepancies are to be found in the humanities (share of graduates: 17 %; unemployment share: 25 %) and - in the opposite direction - in medicine (20 % versus 8 %).

Table B.2.13: Higher Education by Disciplines in Belgium 1998/99 (in %)

<i>Field of Study</i>	<i>Students</i>	<i>Graduates (first and second cycles)</i>	<i>Unemployed Graduates</i>	<i>Gainfully Employed (1991)</i>	
				<i>Manufacturing</i>	<i>Services</i>
Natural Sciences	15	8	12	7	8
Engineering (incl. Agric.)	7	11	9	56	17
Medicine	21	20	8	4	23
Social Sciences	43	43	46	25	34
Humanities and others	14	17	25	8	19
Total number (1,000)	132.0	32.0	7.3	54.1	312.0

Source: various national sources, calculations by the authors

Based on the Census of 1991, the total number of graduated employees amounts to 366,100 people (which is about 10 % of total employment). A huge bulk (85 %), work in the service sector. Thus the service sector concentrates a considerably higher share of graduates than it has to total employment. This pattern is generally common in the EU. One reason is that the public sector alone (government, education and health sector), absorbs about 41 % of all employees with graduates. This orientation towards the public sector is particularly high in medicine (71 %), natural science (54 %) and humanities (49 %). For the latter two scientific fields, the education sector is of particular importance.

In Belgium, the majority of engineers work in the manufacturing sector. On a more detailed level it can be seen that 6.5 % of all engineers are working in just one (sub) sector, namely chemistry. This points to the dominant role of the chemical sector in the Belgian innovation system. Another support for this is that 7 % of all natural sciences graduates work in the chemical sector too.

Based on expert assessments, ISR in the field of human capital in Belgium may be characterised as follows:

- Teaching by firm employees at universities, vocational training programmes for industry and long-term relationships based on graduate mobility seem to be significant type of interactions in the field of training and education. The number of firm employees teaching in the domain of exact science in universities in Belgium, is rather low, as business people tend to prefer teaching in entrepreneurship and economics courses, and at Business Schools.
- The current structure of the curriculum in the engineering faculties and the exact sciences does not allow or enhance work placements by students. The FIRST programme as well as the IWT PhD programme, supports this type of interaction for PhD students but not for undergraduates writing their master thesis. There are some study programmes that foresee

internships during summer holidays but these are not integrated in the basic curriculum. A recent research report (Clarysse et al., 2000), mentions that introducing these internships would require a lot of additional effort by the professors. It is probable that the academic staff should be largely increased because coaching of internships is much more intensive than ex cathedra lecturing. In addition, universities would have to attract professors who not only excel in scientific work but also know the business environment. This seems difficult in the current university structure.

- There is quite a significant interaction between public science and industry in the field of curricula planning. Examples of study programmes that were organised at universities and public research labs in co-operation with industry are the Postgraduate in Telecommunications at IMEC and the Programme in Informatics at UCL (Catholic University of Louvain-la-Neuve).
- Mobility of R&D personnel is high in Belgium, at least from science to industry. There are also several promotion measures aiming - at least partially - to stimulate this type of interaction. Mobility from industry to science is low due to significant differences in salaries.
- Offering university chairs to R&D managers from the business sector is considered by experts to be considerably significant and may be viewed as an important type of ISR with respect to mobility of research managers.
- Personal contacts based on joint projects and contract research are seen as a very significant channel of interaction too.

B.2.5 ISR in Belgium: A Summary Assessment

Contract and collaborative research: Industry's share in financing of R&D in HEIs is remarkably high in Belgium, i.e. interaction by the way of commissioning R&D projects to universities and carrying out research projects jointly, is an important channel for knowledge and technology transfer. There are several driving forces for this pattern. First, Belgian universities face a low level of basic funding and public funding sources decreased during the 1990s. Thus, there is pressure to look for additional funding for R&D. Second, the scientific disciplines most relevant to industrial R&D, i.e. natural sciences and engineering, show a strong orientation towards research activities, while teaching occupies a lower share of their resources compared to other disciplines. There is some indication that at least some natural science and engineering departments maintain close and regular research contacts with the enterprise sector. Third, despite a generally low level of R&D activities in the business enterprise sector, there is a group of large, R&D intensive enterprises in the advanced technology sector (above all in chemicals but also machinery and metals), which have both the resources and capabilities to interact intensively with public science institutions. There are however, no major financing programmes for joint R&D activities.

Personnel mobility from public science to industry is high in Belgium. This high level is stimulated, firstly, by significant differences in salaries and a high demand by industry for well-qualified personnel. Secondly, fluctuation of higher educated science and technology personnel seems to be generally high in Belgium and thus, demand for replacement at enterprises is significant. Thirdly, public promotion programmes in the field of ISR pay special attention to personnel mobility as an effective channel of technology transfer. Finally, a close interaction between industry and science in the field of training and education, and the corresponding development of personal networks between researchers in both sectors, favours personnel mobility too.

Training and education: There are no quantitative figures on the extent of interaction in training and education but expert assessments suggest quite intense interaction. HEIs (especially polytechnic schools) contribute to vocational training measures for enterprises and there are also promotion measures to increase, amongst others, training interactions between HEIs and SMEs (KIV). Industry is also involved in curricula planning and there are special programmes for promoting PhD students carrying out research relevant to enterprises.

IPR: IPR are used frequently and intensively by PSREs while universities show a weak patenting record until the end of the 1990s. A major reason might be the regulatory framework which does not provide specific incentives to researchers in HEIs for invention activities. Property rights on inventions belong to the universities (or, until 1998 in Wallonia, to the regional government). There is some financial support for HEIs to cover costs of patent applications and commercialisation but only a few universities have the size, research quality, disciplinary structures and professional commercialisation offices, to use IPR in an effective way. The high patent intensity in the PSREs sector is caused by a few specialised institutes acting in fields of technology where patenting is an important competitive issue.

Start-ups: The level of start-ups from science is high in Belgium, both in HEIs and PSREs. Spin-off activities in the field of new firm formation are supported by infrastructure provision (incubators and consulting services) as well as by direct financial support, especially in the very early stages. The FIRST Spin-off programme is perceived as a good example of an effective promotion programme in this area.

Involvement of SMEs in ISR: There is little evidence for a particularly strong involvement of SMEs in ISR in Belgium. Their share in total business R&D activities is low. There are some policy initiatives in Flanders to stimulate SMEs to use more intensively scientific knowledge in innovation activities, including the employment of scientists (KIV programme).

Science-based industries in ISR: Fast growing new technology sectors such as biotechnology, software, microelectronics and new materials, have a less prominent weight in total business R&D than in other European economies. In 1995, the Flemish government started a new research institute dedicated to the area of biotechnology (VIB) in order to strengthen research in this area and to attract complementary activities by enterprises. VIB has developed well and seems to achieve the high expectations. Furthermore, IMEC, a research institute

belonging to the Flemish government and specialised in information technology is a major scientific actor in its field. Nevertheless, it will still take a significant amount of time until science-based industries take a more central role in the Belgian innovation system than they do today.

B.2.6 Good Practice in Framework Conditions for ISR in Belgium

In Belgium, one may identify several examples of good practice in framework conditions for ISR. The following have been selected for presentation:

- Leuven R&D as an example of an efficient interface organisation
- VIB and IMEC as public research organisations specialised in certain technologies and with a strong focus on technology transfer
- First Spin-off as an example of a promotion programme with the aim of fostering research spin-offs from universities and public research labs
- Starlab as an example of a private research firm with an interdisciplinary focus, promoting spin-offs and research consortia.

Leuven R&D

The Technological Transfer Organisation at the Katholieke Universiteit Leuven, called Leuven R&D, can be considered as a good practice in the functioning of an interface service. The interface is run by an internationally well connected business manager with a track record. It has built up considerable experience in the filing and managing of patents, it provides technical incubation to various sorts of research groups involved in applied research projects, it closely collaborates with a university seed capital fund to spin-off an average of 5-7 spin-offs annually, and has created Leuven INC., a non-profit organisation which manages the networking between the different spin-offs in the region. Finally, it manages a science park and an incubator. Start-ups currently in the incubator are expected to grow into the science park.

To realise the investment in these spin-offs, the university created, in a collaboration with KBC and FORTIS (two leading banks in Belgium), a university seed capital fund (Gemma Frisius). After a year and half of experience in investing in spin-off firms via the seed stage fund, LRD came to the conclusion that it needed (1) to invest larger amounts of money in each company and (2) to push entrepreneurs to devise more ambitious projects. Initially, they invested between EUR 12,500 and EUR 62,500. Now they target investments in the range of EUR 250,000. They realise that, if the start up does not have enough equity to start with, it will be difficult to adopt a product orientation and automatically, the project will lack ambitions.

The Katholieke University of Leuven is also currently developing two science parks. It wants to encourage its spin-offs to locate in this park in the future. It also wants to attract international companies with complementary expertise to that of the spin-offs and the research labs of the university. In addition, Leuven R&D embarked in a public relations campaign within the university to make the researchers and the professors realise that the university is favourable to spin-offs and to inform them about the resources it can offer them. This includes articles in the campus press, a special course on entrepreneurship and specific presentations. Special attention was given to inform students about the high growth potential of new technology based firms and increase the awareness of IPOs as a form of funding. In Belgium, the dominant model for a small firm is very much the traditional 'SME' (Small and Medium Size Enterprise) characterised by low capitalisation, weak management, and slow growth. One aim with these awareness measures is to change this traditional view and to change the adverse attitude towards fast (but risky) growth among potential spin-off founders.

In 1999, the Leuven spin-offs represented about 150 million Euro in sales and employed over 1,000 people. In the same year, a new organisation was created by Leuven R&D, Leuven inc., whose mission is to promote networking between these different high tech firms and to organise training courses in high tech specific domains. Thus, also the social community has become increasingly active in this small environment.

VIB (Flanders Interuniversity Institute for Biotechnology)

VIB (Flanders Interuniversity Institute for Biotechnology) was established in 1995 by the Flemish government as an autonomous research institute specialised in biotechnology. VIB can build on a strong tradition in biotech research in Flanders and can count on the long-term commitment of the Flemish government towards biotechnology.

VIB was created in 1995 with three main objectives: research and applied research in biotechnology; the validation of research results in the form of technology transfer and spin-offs; and promoting biotechnology for the broad public. As of today, the institute realises 7 million Euro of revenues through its contract research and it employs over 700 researchers. VIB has 3 main objectives. First of all, it carries out high-level research. Therefore, it combines 8 university departments and 5 associated labs, representing a group of 700 researchers who are active in the domain of biotechnology. Over 50 patents have been applied for since 1995. So far, it has realised two venture capital backed spin-offs and is currently spinning of three new ones.

A second objective is the transfer of technology by licensing or by creating spin-offs. In order to evaluate the potential of technology transfer and validation, VIB uses a standard evaluation tool, namely "the record of inventions". Therefore, each research group has to report an invention or potential invention to the technology transfer group of VIB. In order to evaluate the commercial potential, VIB has established a valuation cell. This cell consists of 7 people that have a combined business experience of more than 30 years in several domains, such as bio-pharmaceutics, enzymology and plant genetics. The number of inventions reported to the cell increased during the past few years. In 1996, 22 inventions were reported, increasing to 59 by 1998. The valuation cell carries out patent screens and applies for patents if possible. The number of patent applications increased from 5 in 1996 to 20 in 1997 and 24 in 1998. The revenues from licensing amounted to 2,2 million Euro in 1997, and increased in the following years. It is still too early to estimate the economic impact of technology transfer by spin-offs. So far, VIB generated 2 spin-offs: Devgen and CropDesign. Both companies were established with a start capital of more than 2,5 million Euro, financed by both local and international risk capital providers. As well as looking for financing, VIB also looks for an experienced business manager to run the company if the initially technically oriented entrepreneur does not have the required management skills. At the moment, VIB has 3 spin-offs in the start-up phase.

The third VIB objective is to promote the image of biotechnology to a broad audience.

In 1999, the VIB has also set up a BIO-Incubator, which offers 2000 m² of office and laboratory space (soon to be extended to 3000 m²) for biotech start-ups. These start-ups do not have to be spin-offs from the research institute.

IMEC (Interuniversity Institute for Microelectronics)

IMEC (Interuniversity Institute for Microelectronics) was established in 1984 by the Flemish government in co-operation with the association of Flemish employers and universities. IMEC, established in Louvain (with associated labs in Gent and Brussels), has the mission to promote microelectronics in Flanders and to strengthen the industry-science relations. At the moment, 16 years after start-up, IMEC is known worldwide in the field of microelectronics. IMEC has a yearly budget of 75 million Euro at its disposal: 45 million is generated by contract research, the other 30 million BEF are subsidies from the Flemish government in the form of basic research grants. The income from contract research is distributed as follows: 43% comes from international industry, 32% from the Flemish industry, 20% from the European Commission, 2,5% from ESA (European Space Agency), and 2,5% from the government. IMEC employs about 1.000 people of whom 86% are directly involved in research and development.

The research at IMEC focuses on the development of production processes for the next generation of integrated circuits. Special focus lays on opto-electronic components, microsystems, solar cells and sensors. Next to this, research aims towards advanced integrated circuits with an increasing complexity (such as telecommunication technologies and multimedia). Finally, IMEC develops new packaging technologies that are the result of the increasing demand for small, portable and complex electronic products.

In 1999, IMEC established a new Microelectronics Training Centre (MTC) in order to strengthen its educational activities and to meet the worldwide need of well-educated people in the field of microelectronics.

Concerning technology transfer, IMEC co-operates with Flemish companies and tries to commercialise its technology by creating spin-offs. The technology transfer team consists of 20 people. IMEC also has established an incubation fund that gives funds to researchers to find out whether or not their idea can be used in a company, and whether or not a market for their product exists. Next to this incubation fund, IMEC has a VC fund (IT Partners) that has a first right of refusal for IMEC spin-offs. In 1999, IMEC handed in 45 patent applications of which 16 were filed. The number of contacts with Flemish companies increased from 22 in 1984 to 70 now. The first IMEC spin-off was established in 1986 and so far, 17 spin-offs have been created. Until 1997 there was little risk capital available in Belgium in order to start up spin-offs. Next to this, IMEC underestimated the costs related to 'business development'. Most of the spin-offs started with a capital between 3 and 10 million BEF and the management team mainly consisted of researchers who established their own company. In this starting period IMEC as its industrial partners had few experience in risk capital investments and the coaching of high tech starters. However, during its existence, IMEC learnt to estimate the needs of its spin-offs and the availability of risk capital increased in Belgium. At this moment, IMEC mainly focuses on the establishment of large start-ups (investments higher than 1 million Euro). In order to fill in for the lack of business experience of researchers, IMEC tries to recruit experienced managers to run its spin-offs. However, finding experienced managers who are willing to leave their current job in order to start in a high-risk company, remains difficult.

FIRST Spin-off

FIRST Spin-off is a programme to promote the founding of spin-offs by university researchers in Wallonia. It offers 20 scholarships to researchers each year. During the project, they work on the completion of a product, a procedure or a new innovative service concept, carry out an economic and technical feasibility study, and write a business plan for the creation of a spin-off. The researcher must commit to participate in entrepreneurship and management courses during the project (which normally takes 2 years, and is renewable for 1 or 2 years). At the end of the project, the researcher submits a report stating the scientific and technical results, and indicating the possibilities to start up industrial and commercial activities based on the research. As well as this, the report contains a business plan, financial plan and an estimation of the market. The researcher is succeeded by someone who has experience in the creation and management of companies. Financing covers the remuneration and courses of the researcher and is fully covered by the Walloon region. A lump-sum payment of 5.000 Euro is foreseen for the applying research institute. Conforming to the decree of 17 December 1997, research results belong to the university. However, if the researcher decides to start-up a company based on his research within 3 months after the end of the scholarship, the university has to attribute a license to the researcher that:

- is free during the first 5 years after company start-up;
- cannot be shared with third parties without the former approval of university;
- is exclusive on the condition that exploitation of results becomes effective in a time period that is to be determined by the university and the company. If the company fails to exploit the results before expiration of this period, the license becomes non-exclusive

Even though this FIRST Spin-off programme is probably one of the better programmes in Belgium initiated by government, it has some weaknesses. First of all, the researcher must have a technical background (engineer, exact sciences) in order to apply for a FIRST Spin-off scholarship. This means that they certainly have the technical capabilities to elaborate on the product, procedure or innovative service concept they have been working on, but that they also lack the commercial and financial background needed to write the business plan and to carry out the feasibility study. Entrepreneurship and management courses can teach them some basic principles, but they still lack the business experience, the business contacts needed with suppliers, clients, financiers, and the capabilities to build a team of entrepreneurs who have skills different to technical skills. A lot depends on the business person in charge of following up on their progress, the time they want to spend coaching the researcher, and their willingness to open up their network of contacts to the researcher. Some of the experts interviewed by us (particularly those from the industry or VC-environment) mentioned that the FIRST programme does not encourage collaboration of people with a technical degree with those with management experience. So, although it fulfils the objectives of being a pre-seed capital, it under-estimates the dimension of co-operation.

Starlab

Starlab is a privately held, blue-sky research lab with campuses in Brussels and Barcelona and was established in 1998 with a start-up capital of 12,9 million Euro. It is unique in the choice of its charter: the cross-fertilisation between Bits, Atoms, Neurons and Genes (BANG). The lab employs 80 researchers from 30 different nationalities. Its model consists of 3 pillars: blue sky research, consortia and creation of spin-offs.

Blue-sky research is solely funded by the government, whereas consortia are formed with financial help of industrial sponsors.

The company has a fund for spin-off companies (Starfund) and has recently established "Starseeders" which looks for ideas inside Starlab that can be transformed into new business ventures, and coaches the new ventures during the first phase after start-up. So far, Starlab has established 8 spin-offs. Some of these spin-offs are research groups that were moved from university to Starlab in order to further develop the technology, and were thus established with both Starlab and the universities as shareholders.

Probably most important within the framework of industry-science relations is the development of consortia. In these consortia, forward-thinking industrial players on the world business stage commit to a 5-year research project with Starlab's experts to guide the exploration of a chosen rich idea. The consortia are cross-sectoral and define a background for the exploration of a broad vision during which the sponsors give 'carte blanche' to the research team. Sponsors can however, guide the consortium via a steering committee and get full and royalty-free access to all its results (there is however, no commitment to obtaining results). One of the consortia established recently is the I-Wear consortium which researches into the theories, technologies, methods and techniques that will enable a vision of intelligent clothing. The consortium aims towards cross-sector collaboration, exploitation and the creation of new markets, and can be seen as a kind of network through which people from different sectors meet. Only exceptionally, spin-offs can be created out of these consortia because the research that is carried out has a long term and basic focus.

B.3 Finland⁷

B.3.1 Knowledge Production Structures in Finland

The R&D expenditure in Finland has grown in all main sectors over the last ten years and amounted to 3.9 billion Euro in 1999, which was 3,2 % of GDP (Table B.3.1). Until 2000, total R&D expenditure raised further to 4.35 billion Euro, i.e. 3.3 % of GDP. In comparison to other EU countries, both the level and growth of R&D expenditure in Finland are notably high. The main performer of R&D is the enterprise sector, carrying out 68 % of all expenditure. Between 1991 and 1998, business enterprise R&D expenditure almost tripled in nominal figures. The share of the HEIs in total R&D expenditure is about 20 %, and the share of the PSREs is 12 %. The private sector is also the biggest financier of R&D with a share of 66 % of the total R&D funding.

Table B.3.1: R&D Expenditures in Finland 1999 by Financing and Performing Sectors (in million Euro)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million Euro</i>	<i>Total %</i>	<i>% of GDP</i>
	Enterprises	State*	Abroad			
Enterprise Sector	2,439	167	38	2,644	68	2,18
PSREs*	66	370	34	470	12	0.39
HEIs	36	685	43	765	20	0.63
Total (million Euro)	2,541	1,222	115	3,879		
Total (%)	66	32	3		100	3,19

* including non-profit private institutions

Source: Statistics Finland (2001), calculations by the authors

Most of the R&D activities in the enterprise sector are financed by the internal funds of a company or enterprise group (90 %). The share of public funding of enterprises (6 %) is decreasing and clearly below the OECD average. Over half of outside funding of enterprise R&D comes from the Finnish Technology Agency (Tekes). Financing from abroad is of little relevance (4 %).

At the HEIs (universities), about half of R&D financing (46 %) is provided via the General University Fund. This share has decreased during the 1990s. Total government HEI appropriations (including financing of education and administration) remained almost constant in real terms between 1991 and 1999, while HEIs expanded in terms of students, graduates and personnel. Consequently, HEIs experience increased the pressure to look for outside financing. Among the outside R&D funding for HEIs, the Academy of Finland is the largest single financier, providing funds for research projects. Its funding was 98 million

⁷ This chapter is based on the national report on ISR in Finland (Kangaspunta 2001) and on Husso et al. (2000).

Euro which equals 24 % of the total outside R&D funding for universities. Amongst the outside financiers, the Tekes was quickest to increase its share, to current levels of 20 %. Foreign funding accounts for 11 % of total project-based financing of HEIs' R&D activities and domestic enterprises have a share of about 9 %. Non-governmental sources (own funds, domestic and foreign enterprises, private funds and EU sources) account for 13 % of the total R&D funding of HEIs.

At PSREs, the financing structure is quite similar to that in HEIs - 55 % of R&D is financed by basic funding. Within project oriented funding, non-government sources play a more prominent role, particularly concerning financing by domestic enterprises (31 % in total outside financing of R&D at PSREs) and from abroad (16 %).

Table B.3.2: Financing Structure of R&D in HEIs and PSREs in Finland 1999 (in %)

<i>Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing	46	55
Project Financing and other financing sources	54	45
Government	87	79
Other Sources (enterprises, internal financing, abroad)	13	21

Source: Statistics Finland (2000), calculations by the authors

The structure of the Finnish R&D expenditure in the enterprise sector places a strong emphasis on high-tech sectors⁸, where 51 % of all BERD is carried out. Medium- to high-tech sectors such as machinery, vehicles and chemicals, play a minor role in business enterprise R&D and their share of total BERD is only 15 % (Table B.3.3). The number of high-tech enterprises significantly increased between 1993 and 1998, from 281 to 389, with the majority of high-tech firms located in the electronics industry. This industry is also mainly responsible for the current increase in BERD.

Table B.3.3: R&D Expenditures in the Finnish Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	50.8	0.91
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	15.2	0.27
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	17.0	0.30
IT-Services (NACE 64, 72, 73)	9.0	0.16
Other Services (NACE 50 to 99, excl. IT-Services)	7.9	0.14

Source: OECD (2000), calculations by the authors

Private sector R&D expenditure is strongly concentrated in large enterprises with more than 1,000 employees. They carry out more than 55 % of all BERD (Table B.3.4). The major ten companies account for 53 % of the total private sector R&D expenditure. It has been

8 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

estimated that one single company, Nokia, accounted for about a third of total private expenditure on R&D in Finland in 1999. Consequently, there is also a strong sectoral concentration of business R&D in the electro-technical industry (machinery, equipment, electro-technical products, instruments and fine-mechanical equipment), which had a share of 53.8 % in 1999 and 55.3 % in 2000, and the metal and engineering industry (basic metals, metal products, cars and other transport equipment), their share being 12.8 % in 1999 and 11.6 % in 2000. Recently there was a significant increase in small firms carrying out R&D. Between 1995 and 1999, the number of enterprises with less than 50 employees carrying out R&D increased from about 900 to over 1,600, i.e. by almost 80 %. However, it is the large enterprise sector which accounts for the vast majority of R&D expenditure growth in the Finnish enterprise sector in recent years.

Table B.3.4: R&D Expenditures in the Finnish Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	14.3
Medium-scaled Enterprises (100 to 499 employees)	15.0
Large Enterprises (500 to 999 employees)	14.5
Very Large Enterprises (1,000 employees and more)	56.2

Source: OECD (2000), calculations by the authors

The SME sector represents about 89 % of all R&D performing enterprises, although its share in BERD was only 22 % in 1998. R&D activities in small enterprises (with less than 50 employees) are heavily supported by public funds, which amounted to 25 % of all R&D expenditure in these types of companies in 1999 (i.e. 68 million Euro). With respect to innovation activities reported by CIS2 data, there is a considerable gap in innovation performance between SMEs and larger enterprises, which is clearly greater than the EU average (Table. B.3.5)⁹.

In the Finnish manufacturing sector, innovation expenditure as a share of turnover as well as the turnover due to innovative products, are significantly lower in the SME sector. This result may be biased however, as the Finnish CIS2 strongly focussed on technology innovation, and the share of larger enterprises introducing such innovation may be higher than the relative share when all types of innovation are considered (see Leppälahti 2000). With respect to R&D intensity and patent activity, Finnish SMEs clearly perform better than SMEs in the EU average. SME performance in the service sector is above the EU standard for nearly all indicators.

⁹ In order to compare innovation performance as reported in the CIS2 among EU countries, one has to take into account national variations in the way innovation was defined (see Leppälahti 2000). Therefore, innovation performance indicators for SMEs are calculated with respect to the national average and the EU average, respectively, and these ratios are compared in order to position Finnish SMEs' innovation activities. With respect to R&D and patent indicators, there seem to be less serious definition biases, thus one can directly compare SME performance on a national level with SME performance on EU average.

Foreign firms play a minor role in the Finnish innovation system. They account for only 11.5 % of total BERD in 1996. On the other hand, the main Finnish R&D performing enterprises are internationally operating companies with a large number of foreign affiliates.

Table B.3.5: Relative Innovation and R&D Performance of SMEs in Finland

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	0.85	0.97	1.00	1.05
Innovation Expenditures as a Share of Turnover*	0.56	0.57	1.43	1.50
Share of Turnover due to Innovative Products*	0.54	0.79	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	1.84	1.54	1.85	0.81
Share of Enterprises with Medium R&D Intensity**	1.10	1.62	1.96	1.42
Share of Enterprises Engaged Continuously in R&D**	1.21	1.42	1.78	1.47
Share of Enterprises Having Applied for a Patent**	1.42	1.51	2.14	1.13

* Figures show the relation of Finnish SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Finnish enterprises to all EU enterprises: $(\frac{SME_{x_{Fj}}}{SME_{x_{EUj}}}) / (\frac{x_{Fj}}{x_{EUj}})$, x being the variable considered, F being Finland, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Finland to SMEs in the weighted mean of all EU countries (except Greece): $\frac{SME_{x_{Fj}}}{SME_{x_{EUj}}}$, x being the variable considered, F being Finland, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

Research in public science in Finland is concentrated on natural sciences and engineering while social sciences and humanities have a very low of total R&D staff in public science (21 %), compared to other EU countries. Engineering and agricultural sciences are the dominating fields of research in the PSRE sector, while natural sciences, engineering and medicine have the majority of research personnel in the HEI sector (Table B.3.6). Thus, the majority of public R&D is performed in areas with a high potential value for industrial innovation.

Table B.3.6: R&D Personnel in the Finnish Public Research Sector (HEIs & PSREs) by Fields of Science 1999 (in %)

<i>Sector</i>	<i>HEIs</i>	<i>PSREs</i>	<i>Total</i>
Natural Sciences	30	16	25
Engineering	21	37	26
Medical Sciences	20	14	18
Agricultural Sciences	3	23	10
Social Sciences*	18	9	15
Humanities*	8	2	6

Source: Statistics Finland (2000), calculations by the authors

The science side of the Finnish innovation system consists of different institutions, each having a particular organisational and financing structure, mission and research orientation,

and orientation towards technology transfer and firm interaction. Eight types of institutions are worthy of distinguishing:

- Finland has 20 universities. Three of them are universities of technology, a further three are schools of economics and business administration, and four are art academies¹⁰. In R&D statistics, the university sector also includes five central university hospitals which perform clinical research (11 % of total R&D expenditure in HEIs). All Finnish universities are state-run, with the government providing 89 % of their funding. High levels of outside financing can be observed in universities of technology. The basic objective of all universities is to carry out research, and to provide education based on the research. The underlying principle is the freedom of research, which gives the universities extensive latitude for independent decisions. Finnish universities typically have between five and nine faculties or departments under which there are numerous institutes or fields of responsibility (laboratories or professorships). Many universities are also partners in companies, such as science and technology parks, and technology transfer companies. Some universities have research institutes which cross the limits of the different faculties.
- In addition, in each university there are separate specialised institutes, including separate further education institutes. They typically provide chargeable services in research, training, consulting etc. tailored to meet the outside customers' specific needs. The specialised institutes are often multi-disciplinary units, involving partners from several faculties within a university or between different universities or research organisations. Institutes may have their own boards, on which industry or other interest groups are active. Institutes have their own budget and usually obtain outside financing from industry and other customers. They may carry out both basic and applied research. Institutes may have a national responsibility and often, also have a regional objective. Separate specialised institutes have offered a flexible way for the universities to respond to the demand by their interests groups. Today, there are about 140 such institutes at 19 Finnish universities. A good practice case is described in B.3.6.
- The 29 Polytechnics are more practically oriented. Most of them are multi-disciplinary, regional institutions (either municipal or private, and co-financed by the government and the local authorities) which give particular weight to contacts with business and industry. Polytechnics are being developed as part of the national and international higher education community, with special emphasis on their expertise in working life and its development. The polytechnics also carry out R&D relevant to their teaching and to working life but compared to universities, R&D activities are fairly low. Their share in total R&D expenditure in Finnish HEIs was 4 % in 1999 (i.e. 27.5 million Euro) but 73 % was financed by outside sources. The polytechnics were created gradually over the 1990s. The standard of former higher vocational education was raised and incorporated into multi-disciplinary polytechnics. Since the Polytechnics Act was passed in 1995, each year the Government accredited some polytechnics to operate on a permanent basis. The criteria

used in accreditation included proven excellence in experimental and development work. The national polytechnics network was completed in 2000. The polytechnics have two categories of teachers - principal lecturers, for whom the requirement is a postgraduate (licentiate or doctorate) degree, and lecturers, who must have a Master's degree. Both categories of teachers must have a minimum of three years of work experience in the field they teach, which may involve the completion of working experience in enterprises, although this may not be absolutely necessary.

- The largest public research institute is the Technical Research Centre of Finland (VTT) with about 2,850 R&D personnel and a turnover of c. 200 million Euro in 1999, which is 36 % (R&D personnel) and 43 % (R&D expenditure) of the total of the Finnish PSRE sector. VTT is an impartial expert organisation that carries out technical and techno-economic research and development work. VTT develops technologies in order to improve both the competitiveness of companies and the basic infrastructure of society, and to foster the creation of new businesses. VTT has eight Research Institutes (Electronics, Information Technology, Automation, Chemical Technology, Biotechnology and Food Research, Energy, Manufacturing Technology, and Building Technology) as well as an information service and a technology studies group. About three-quarters of the staff are located at VTT's main site, at Espoo.

Table B.3.7: Main Characteristics of Major Institutions in the Finnish Public Research Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D in %*</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>
Universities	60	20 universities, including 3 technical universities and 5 university hospitals	Carrying out jointly research and education	basic research
Separate Specialised Institutes at Universities	included in "Universities"	ca. 140 institutes at 19 universities	providing internal and external services, knowledge and technology transfer	applied research, but of little significance
Polytechnics	2	29 institutions	Education, technology transfer to industry	development
VTT	16	8 research institutes	Creating and applying technology to enhance industrial competitiveness	applied research
other PSREs	22	19 specialised research institutes, 11 ministries, other small institutes	divergent: public services, technology transfer, basic research	basic and applied research

* except R&D at Polytechnics

Source: compilation by the authors

- There are 19 other public research institutes, significantly smaller than VTT and mostly oriented towards a specific industry sector or field of research:

10 University-level education is also provided by the National Defence College, which comes under the Ministry of Defence.

- Agricultural Economic Research Institute and Agricultural Research Centre of Finland (MTT)
- Finnish Centre for Radiation and Nuclear Safety (STUK)
- Finnish Environment Institute (and Regional Environment Institutes)
- Finnish Forest Research Institute (METLA)
- Finnish Game and Fisheries Research Institute
- Finnish Geodetic Institute (FIG)
- Finnish Institute of Marine Research
- Finnish Institute of Occupational Health
- Finnish Meteorological Institute (FMI)
- Geological Survey of Finland (GSF)
- Government Institute for Economic Research
- National Public Health Institute (KTL)
- National Research and Development Centre for Welfare and Health (STAKES)
- National Research Institute of Legal Policy
- National Veterinary and Food Research Institute (EELA)
- The Defence Forces Research Centre (DFRC)
- The National Board of Antiquities
- The National Consumer Research Centre
- The Research Institute for the Languages of Finland
- The institutes listed above operate under the responsibility of the 11 Ministries and account for 91 % of the public sector R&D expenditure.

Furthermore, there are some other public institutes and private non-profit research institutes. Their significance in total R&D activities in Finland is less important however (other public institutes have 3 % while non-profit research institutes have 6 % of total public R&D expenditures).

In summary, Finland's knowledge production structures provide a favourable framework for developing strong ISR. The business enterprise sector is highly R&D oriented and concentrated on high-tech sectors traditionally regarded as science-based industries. R&D expenditures by enterprises have increased strongly over the last decade and thus, demand for interaction with industry grows. At the same time, the number of SMEs carrying out R&D is steadily increasing at a fast pace. In public science, R&D activities have increased during the 1990s as well, and have reached a high level compared to the EU standard. Here, an increased share of R&D financing was based on project and programme financing and the

share of basic (institutional) R&D financing is now 46 % (HEIs) and 55 % (PSREs). Public science institutions increasingly looked for additional funding from outside sources. Both in HEIs and PSREs, the focus of R&D is in natural sciences, engineering and agricultural sciences, thus providing a major potential source for co-operation and knowledge transfer to industry.

B.3.2 The Level of ISR in Finland

The level of ISR in Finland is described by a set of indicators and assessment on the significance of various interaction channels. Table B.3.8 lists the indicators used and the main results. It also depicts those areas where ISR in Finland may be regarded as above average with respect to EU standards. In most areas of ISR, Finland performs comparably well although there are some types of ISR interaction which are less intensively used by actors in the Finnish innovation system.

Contract research by public science institutions for enterprises (including consulting services), and collaborative research carried out jointly by industry and public science, are major types of ISR in Finland. University researchers mention these channels of interaction as being most important, while enterprises rank them as somewhat less significant than informal contacts and personnel recruitment. The significance of contract and collaborative research between industry and science is revealed by the financial flows from industry to science. In 1999, the domestic business enterprise sector financed R&D activities in HEIs and PSREs up to a total of 102 million euros. About two thirds of this amount went to PSREs, although their share in total public R&D performance is only 38 %. As a consequence, 14 % of all R&D expenditure in PSREs were financed by industry, whereas the respective ratio for HEIs is only 5 %. Among HEIs, the two largest technical universities show a high share of industry collaboration and account for a large part of domestic industry money going to Finnish HEIs (36 % in 1999). Nearly 4 % of all R&D money raised by the Finnish enterprise sector is used for financing contract and collaborative research in public science.

In 1999, VTT accounted for 82 % of all contract research carried out in the PSRE sector and the Finnish Institute of Occupational Health for a further 8 %. The volume of contract research in all other research institutes is small. VTT's share of the total volume of contract research in the public science sector (PSREs and HEIs) is 53 %. The total volume of contract research increased in the public science sector between 1997 and 1999 by 19 %. The growth was stronger in the university sector (36 %) than among the research institutes (11 %). Contract research at VTT grew by 9 % and continued to grow in 2000 with its volume reaching 77 million Euro (up from 63 million Euro in 1998). 49 million Euro (63 %) of the total income from contract research came from private companies in Finland. This is more than 20 % of the total turnover. The share of SMEs was 39 %.

Collaborative research is heavily promoted by Tekes financing schemes. In 1999, 62 % of all R&D projects in enterprises which had been co-funded by Tekes, also involved co-operation or sub-contracting to public science institutions. In this year, Tekes provided a total amount

for contract research in HEIs and PSREs commissioned by enterprises of nearly 32 million Euro, which is nearly a third of the total of HEIs' and PSREs' income from industry contract research. This is equivalent to 13 % of all Tekes funding for enterprises.

In addition, Tekes provides money for applied research in HEIs and PSREs (c. 125 million Euro in 1999), which is 12 % of total R&D funding in public science in Finland. These applied research projects act as 'indirect contract research' because of Tekes' policy to involve industry in these projects (e.g. via steering committees) and to encourage public science to transfer research results to the end users as early as possible.

A high level of co-operation between industry and science in Finland is also revealed by the CIS2 results. One in two manufacturing enterprises co-operate with HEIs in the course of their innovation activities and nearly 40 % of all innovative manufacturing enterprises co-operate with PSREs. In the service sector, these ratios are smaller but still among the highest in the EU. A notably higher share of large manufacturing companies had co-operation with science (76 % in manufacturing and 27 % in services) compared to SMEs. Nevertheless, the share of enterprises co-operating with public science is heavily driven by the behaviour of SMEs. Thus, the figures indicate a remarkable science orientation of the SME sector in Finland. Expert assessments suggest that the Tekes activities in promoting R&D at SMEs and strengthening contract and collaborative research between industry and science have a major impact on this pattern.

For innovative manufacturing enterprises, science is also an important information source for innovation, especially for large companies. In comparison to other EU countries, the share of Finnish manufacturing companies using HEIs and PRSEs as a source of information for their innovation projects, is clearly above the average. For innovative service companies, the importance of science as an information source is smaller than for manufacturing firms and is below the EU average. In general, HEIs are a somewhat more important source of innovation than PRSEs, which reflects the difference in size between the two sectors in Finland.

Research personnel mobility from science to industry is comparably high in Finland. According to a survey in 1995, 3.4 % of HE graduates who had worked at an HEI in 1994, moved to the business enterprise sector in 1995. At PSREs, the mobility ratio of HE graduates was 3.8 %. However, only 14 % of all HEI employees with a HE degree who moved away from a HEI occupation to an other sector, entered the business enterprise sector, while the vast majority moved inside the HEI sector or to other public services. At PSRE, 26 % of all outwardly mobile HE graduates went into business enterprises. Personnel mobility of employees with a HE degree from industry to public science is significantly lower. Between 1994 and 1995, 0.4 % of all HE graduates working in the private enterprise sector moved to public science and more than 90 % moved to the HEI sector. They represent 2.5 % of all business enterprise employees with a HE degree moving to another occupation. According to experts, an important factor for this biased pattern of research personnel mobility are the differences both in the level of salaries and in their growth rates, between industry and science. The level of personnel mobility is likely to be higher today, as 1994/95 was still a

period of economic recession with a rather low demand for highly qualified labour in the labour market. In 1998, the overall mobility rate of highly educated personnel returned back to the pre-recession level of 1989.

HEIs play a significant role in vocational training and offer various types of further education services. Universities provide *professional continuing education* to academically educated people for up-dating their knowledge and skills (In 1999, there were 133,500 participants). Within *open university* initiatives, adults may participate in teaching courses (In 1999, 77,500 participants). Universities are also engaged in employment training as an element of active labour market policy. In 1999, they reported 433,000 acquired student working days, which is 5 % of the total volume of employment training in Finland for that year. Furthermore, universities offer specific courses for companies' personnel training. Altogether, income from vocational training activities by Finnish universities totalled up to 79 million Euro in 1997, 64 % (50 million Euro) coming from business and public corporations. Compared to the total R&D budget, this is equal to nearly 9 %. Vocational studies are also offered by polytechnic colleges, especially for adults who wish to acquire a polytechnics degree. In 1999, 17,000 adults participated in this type of further education. Furthermore, polytechnics offer vocational specialised studies (3,000 students in 1999) and open polytechnic training (2,800 students in 1999).

With respect to patent applications, ISR relevant activities by universities are considered to be rather low. Because of the IPR regulation (see B.3.3), almost all patents are held by individual researchers, and thus universities are estimated to hold only a few dozen patents and receive almost no income from royalties. No data is available on the number of patents applications by HEI researchers but Aaltonen (1998), found that 20 % of R&D personnel at universities are engaged in patent or licensing activities, which is a remarkably high share.

At PSREs, VTT is responsible for the vast majority of patent applications and royalties. Here, it is considered a strategic tool. In 1999, VTT filed an application for 73 patents (24 per 1,000 researchers) and became the third most active applicant in Finland. So far, VTT has not separately calculated the development of income generated by licensing. The annual income from royalties and selling of IPR is estimated by VTT to be 0.6 to 0.7 million Euro (0.3 % of total R&D expenditure) but a three fold increase in the next couple of years is being aspired to. No summary information on other PSREs' patenting and licensing activity is available. It is most probable that the figures are not notable.

Although no comprehensive data is available on technology-oriented start-ups by researchers from public science in Finland, the existing information indicates a rather high level of start-up activity. In the HEI sector, data from the National Centre of Expertise Programme suggests that there were about 70 high-tech spin-offs per year in the period 1995 to 1998, but it is not clear how many of them had been real university-based start-ups (i.e. creation of a new firm by a university employee, the firm activity being based on new research results or the knowledge and competence acquired through university research). If one assumes that at least every second start-up fulfils the criteria of a university spin-off, the start-up ratio per

1,000 researchers at HEI would be about 2 to 3. A high level of start-up activity is also reported by Aaltonen (1998) who found that 11 % of university researchers had been engaged in spin-off activities but engagement included, for example, giving advice to start-ups. VTT reports 5 to 7 start-ups by their R&D personnel per year, i.e. c. 2 start-ups per 1,000 researchers. As start-up activities in other PSREs are rare, the average start-up intensity in PSREs in Finland may be about 1.

Finnish enterprises mention informal contacts as the most important channel of interaction with HEIs. Such contacts often take place within stable, long-term oriented networks of universities, PSREs and enterprises. In Finland, there are several policy initiatives to build up and maintain such networks, such as Centres of Excellence, Tekes Technology Programmes, Centres of Expertise and Cluster Programmes (see B.3.3). Networking and informal contacts are also enhanced by enterprise involvement in teaching (e.g. lectures by enterprise researchers and managers), by professorships sponsored by industry and by inviting enterprise representatives to take university professorships. Another way of maintaining informal contacts is to nominate members from outside the university, on universities' senates, including those from enterprises. In 2000, 5 universities had senate members from outside the university.

Table B.3.8: Indicators and Assessments of ISR in Finland at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (1999, Source: Statistics Finland)	R&D financing by industry for HEIs in % of HERD	4.7
	R&D financing by industry for PSREs in % of GOVERD	14.0
	R&D financing by industry for HEIs/PSREs in % of BERD	3.9
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	low
	Significance of R&D consulting with firms by PSRE research.	low
Co-operation in Innovation Projects (Source: CIS2, 1996)	Innovative manuf. enterprises co-operating with HEIs in %	47.3
	Innovative manuf. enterprises co-operating with PSREs in %	38.0
	Innovative service enterprises co-operating with HEIs in %	19.2
	Innovative service enterprises co-operating with PSREs in %	13.8
Science as an Information Source for Industrial Innovation (Source: CIS2, 1996)	HEIs used as inform. source by innov. manuf. enterpr. in %	6.9
	PSREs used as inform. source by innov. manuf. enterpr. in %	5.3
	HEIs used as inform. source by innov. service enterpr. in %	2.7
	PSREs used as inform. source by inn. service enterpr. in %	0.6
Mobility of Researchers (Source: national statistics, 1994/95)	Share of researchers in HEIs moving to industry p.a. in %	~ 3
	Share of researchers at PSREs moving to industry p.a. in %	~ 4
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	0.4
Vocational Training (Source: national statistics, 1997/99)	Income from vocational training in HEIs in % of R&D exp.	8.7
	Number of vocational training participants in HEIs per R&D employee in HEIs	16.3
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in NSEM	high
	Patent Applications by PSREs per 1,000 employees in NSEM (based on VTT figures)	~ 12
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	low
	Royalties in % of total R&D expendit. at PSREs (VTT only)	~ 0.3
Start-ups from Science (Source: national statistics, assessments)	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	2 - 3

	Number of technology-based start-ups at PSREs per 1,000 R&D personnel (based on VTT figures)	~ 1
Informal contacts and personal networks	significance of networks between industry and HEIs	high
(Source: national statistics, assessments)	significance of networks between industry and PSREs	high

* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD, national statistics, calculations by the authors

Another indicator for long-term oriented networks between industry and science is the co-publication of scientific papers, as this typically involves much co-operation and joint working on a certain topic over a significant period of time. In the second half of the 1990s (1996-1998), 4.2 % of all scientific papers written by Finnish authors had a co-authorship involving both firm employees and researchers from HEIs or PSREs. In HEIs, 4.5 % of all papers were written jointly with researchers from enterprises and at PSREs, this ratio was 5.0 %. Almost all scientific papers written by enterprise researchers are co-authored by a HEI or PSRE researcher.

In summary, the interaction between industry and science is rather strong in Finland. In order to exchange knowledge and technology, various channels are used. Of particular importance are contract research commissioned by enterprises, particularly to PSREs (which is very much concentrated on VTT), collaborative research and co-operation in innovation projects and vocational training. A special feature of the Finnish innovation system today is the strong involvement of SMEs in ISR, which was stimulated by policy initiatives during the 1990s. Finland's remarkable ISR record is associated with a strong re-orientation of the Finnish economy towards high-tech areas in information technologies after a heavy recession in the early 1990s (Statistics Finland 1999). Most of the considerable increase in R&D activities took place in this area and information technology enterprises seem to be a major driving force for ISR in Finland too.

B.3.3 The Policy-related Framework Conditions for ISR in Finland

Cultural Attitudes: There seems to be a rather high awareness that public science should contribute to industrial innovation. This was promoted by a coherent science, education and technology policy strategy during the 80s and 90s aimed towards increasing the knowledge base, improving the R&D and innovation performance of Finnish industry, and shifting the economy towards an information society. This ongoing technology policy is accompanied by various policy actions, many of them including measures to foster ISR. In universities however, there is still a strong tradition of autonomy in research and education, including a tendency to favour pure, curiosity-driven research and sometimes little awareness for commercially exploitative research results. However, many R&D intensive enterprises acknowledge the role of universities in carrying out basic research without direct commercial application purposes. Nevertheless, the government has made efforts to improve university performance in ISR (see below).

Legislation: There is no law in Finland that would explicitly regulate ISR but there are a number of laws that have to be taken into consideration. Some of them refer to regulatory settings in certain public science institutions and are discussed in a separate section below. In addition to laws, there are a number of relevant *decrees and decisions* by the Government that form part of the legal framework. Some regulations, for instance concerning the terms of finance, are based on regulations at EU level. Specific laws, which affect ISR in Finland, include regulations on intellectual property, civil service, terms of employment and public aid for business and include:

- The Act on Employer's Right to an Invention made by an Employee states that the IP of inventions made by employees, could to be transferred to the employer who then owns the invention. The Act covers the private sector organisations as well as most civil servants, including researchers in public research organisations such as VTT or those in the service of the Academy of Finland. However, researchers in universities or similar scientific institutions are not covered by the Act. Hence, the basic rule in the universities is that 'the researcher owns the invention'. In practice, the ownership and use of the intellectual property rights in HEIs and PSREs is strongly affected by the funding principles of the different financiers of research, as well as the policy and strategy of the university or the research institution. The policy of the Academy of Finland (SA) has been not to claim the rights for inventions, i.e. they are in practice, left with the researchers financed by SA. The ownership of the research results varies in programmes financed by Tekes. A participating company often claims rights to IPR. The principal policy of Tekes is to leave IP as the property of the organisation which has benefited from the funding. At universities, researchers often have to transfer their rights to the university before the funding contract can be signed by the university with Tekes, the EU or companies. This practice has become more common in recent years and has been influenced by Finnish participation in EU R&D programmes.
- The Act on Civil Servants defines the general terms of service for civil servants in Finland. Most public sector researchers are civil servants. The main responsibility of a civil servant is to carry out his official duties properly. For this reason, the Act limits the right of a civil servant to hold secondary occupations in addition to their office. A secondary occupation is defined as another office, or a waged work or task that the person has a right to refuse, as well as an occupation or business. The employee may not engage in secondary occupations which require the use of office time unless they have applied for it and the employer has given them the right to it. It is the duty of the civil servant to inform his employer about a secondary occupation subject to license, and to apply for a license. In practice, occupation and business require a certain continuity of the activity and a sufficient amount of repetition. Sporadic occupational tasks are not subject to limitations while participation on the board of a company is considered a secondary occupation.
- The Act on Civil Servants presents the following barriers for granting permission for a secondary occupation: (a) the civil servant may not become more challenged in the office

because of the secondary occupation; (b) the secondary occupation may not compromise the confidence in the civil servant's impartiality in office; (c) the secondary occupation may not bother otherwise appropriate execution of tasks; and (d) as a competing activity, the secondary occupation arguably damages the employer. Once the researcher has been given permission to hold a secondary occupation there are no restrictions as to the amount of remuneration. While the Act also defines the provisions concerning leave of absence, it is up to the employer to decide upon the length of leave of absence, except for certain cases where it is based on law.

- A general rule, which is based on the Act on Civil Servants and The Act on Contract of Employment, is that an employee must be loyal towards his employer ("The loyalty Principle"). An employee or civil servant may not engage in business that may harm the employer or competes with the activity of the employer. The contents and the extent of the loyalty requirement depend on the activity of the employer. For instance, it is the task of the universities to provide teaching, which leads to basic and scientific post-graduate degrees. It is not conceivable that university teachers and researchers could privately compete with the activities of the universities in these fields. The same holds largely true for basic research. Other relevant decrees include for example, those that define the criteria for the filling of professors' vacancies, qualification for university teachers or other staff.
- Various business-related laws may also be relevant for ISR, such as The Act on the Right to Carry on Business. Among others, some civil servants are denied engagement in business for reasons related to guaranteeing their impartiality. When thinking about what business is permitted and what is not, the consumer's point of view must be taken into consideration also. It is not acceptable that the line between official service and private business of a civil servant becomes vague. Competition laws also set requirements for academic entrepreneurship within universities. All conduct against good business practice is forbidden, as well as the provision of misleading information. Business secrets may not be exploited illegally or divulged. Other companies' business may not be harmed by an inappropriate manner of representation or by false information. In universities, problems may occur particularly at the interface of research work and business.
- The Act on the Principles of State Fees, and related decrees set the principles on which contract research has to be priced. Contract research is not considered as a public function and has to be provided on market conditions i.e. full compensation is required. Contributions 'in kind' are not allowed without providing work against its full value. Regulation concerning investment by PSREs and HEIs states that a government organisation receiving funding (even partly) directly from the state budget, may not invest in the private sector without the specific consent of the Parliament. On this condition, equity investments (for instance, in a joint research lab) are possible. In practice, such investments are rare. For example, VTT once made such an investment when VTT Technology Ltd, a technology transfer company, was started. Several universities have their own foundations, which are able to make equity investments. These funds are

separate from state funds. The New University Decree states that donated and bequeathed funds shall be administered separately to state funds. It is not quite clear to what extent the present regulation allows PSREs and HEIs to make capital contributions to private companies.

Despite the significant number of legal regulations on ISR, experts feel that legislation has a small inhibitory effect upon the performance in ISR in Finland. IPR regulations, civil servant law and mobility regulations are regarded to have neither a positive nor negative affect on ISR. The most commonly mentioned barriers to ISR stemming from legislation are perceived in the field of extra earnings for public science researchers and regulation on equity investment by public science institutions in enterprises.

Promotion Programmes: The government has started a large number of policy initiatives and measures to, directly or indirectly, foster ISR. A major approach is to actively finance R&D and research co-operation. In 1996, the Finnish government launched the *Additional Research Appropriation Programme*, with a volume for 1997-1999 of more than 500 million Euro, financed by privatisation incomes which stimulated R&D activities and research collaboration significantly (see B.3.6). The most important public financier of joint R&D between companies, universities and research organisations in Finland, is the National Technology Agency (Tekes) which focuses on the funding of applied research and product development. The Academy of Finland (SA) concentrates its funding on basic research. The importance and volume of *joint funding* of projects and programmes by Tekes and SA, has increased during the last few years. At the moment, the following programmes/measures are in operation and worthy of mention:

- Technology programmes have been the most important tools for Tekes to promote ISR. The technology programmes are planned co-operatively by companies, public science institutions and Tekes, and foresight is an important element in the programmes. Programmes have proved to be an effective form of co-operation and networking for enterprises and the research sector. Each programme has a steering group and a co-ordinator, their duration ranges from three to five years, and their volumes range from 5 million Euro to more than 100 million Euro. Tekes usually finances about half of the costs of programmes and the second half comes from the participants. During 2000, a total of about 60 extensive national technology programmes were under way. In 1999, Tekes provided 185 million Euro to fund technology programmes. The total volume of the programmes in operation was about 1,250 million Euro. More than 2,400 companies and about 860 public research units participated in the programmes.
- The Technology Clinics initiative was started in 1992 with the aim of bringing together technological service providers, SMEs and financiers of technological support activities. In each technology clinic, there are four organisations involved - the customer SME, Tekes, the clinic co-ordinator and the technological service provider (which is most often a public science institution). The financial support for SME projects can cover up to 60 % of the costs of the project and the remaining part is covered by the SME. There are six

generic types of technology clinics: *technology based clinics* that focus on a specific technology; *theme-based clinics* that aim towards promoting awareness of, and offering solutions to, a specific theme, problem or regulatory change; *cutting-edge clinics* which aim towards keeping Finnish SMEs at the forefront of technological development in some areas of technology, or possibly helping them increase their lead over international competition; *catching-up clinics* aim to help Finnish SMEs catch up with international standards in some areas of technology; *methodology clinics* aim to disseminate good management practices and methodologies in the SME sector; and *demonstration clinics* aim to offer demonstration services to a selected group of customers in a particular sector. In 1998, there were 16 clinics in operation and they carried out a total of about 180 assignments with about 0.85 million Euro funding from Tekes.

- The aim of the Academy of Finland's Centre of Excellence Programme's is to enable the emergence of research and training environments that can generate top international research with social relevance. The goal is to promote interaction between different types of research and foster a multi-disciplinary approach to research. A centre of excellence is a research and researcher training unit, comprised of one or more high-level research teams with shared, clearly defined goals and good prospects for reaching the international forefront in its field of specialisation. Centres of excellence are selected for a term of six years on a competitive basis, with evaluations provided by international experts. The first 12 centres were nominated for 1995-1999 and a further five units for 1997-1999. For the period 2000-2005, a total of 26 units from different fields were granted centre of excellence status. During the first three years, the Academy will be spending 21 million Euro in direct support of the units and 3.5 million Euro in core facilities funding. The centres also receive support from their host organisations (48 million Euro of universities basic funding and 12.5 million Euro of other funding). Tekes has been closely involved in the planning and implementation of the centres of excellence and supports the first three years of 11 units of the 2000-2005 programme at a cost of 5.2 million Euro. Funding from the EU is also important for many of the centres. Funding from the private sector is present in about a quarter of the centres but the amount is rather small.
- The Finnish Cluster Programmes comprise eight programmes under six ministries - *Wood Wisdom* (forest cluster), *The Well-being cluster*, *Food cluster*, *KETJU* (Logistics), *TETRA* (Transportation cluster), *NetMate* (the use of information networks in SME business), and *Workplace development* and *Environmental cluster*. The major goal of the programmes is to create new and permanent co-operation structures, improve the co-operative ability of the whole research system, and increase the relevance and flexibility of activities. Most programmes started in 1998 and will end in 2000 or 2001. The programme is described in more detail in B.3.6.
- Programmes for researcher mobility are rather rare in Finland. SA provides appropriations for the employment of post-doctoral researchers and for researcher training positions but this programme mainly focuses on universities and graduate schools. Tekes pays certain costs of researchers working abroad in R&D projects but also may bear costs

of researchers who are coming to work in Finland in R&D projects. By this measure, international co-operation in practice oriented projects should be promoted. For several years, Finland has had a tax relief for top foreign experts moving to Finland, i.e. they are taxed at a fixed rate of 30 %. There are also some institution specific schemes at universities and VTT described in B.3.4.

- The National Centres of Expertise Programme is one of the five periodic regional development objective programmes included in the Regional Development Act and Decree. The programme started in 1994 and will be continued until 2006. The programme tries to bring research, education and production expertise in a region into close interaction and shall enhance the profile of universities, regional specialisation and the division of tasks between regions. Centres of Expertise are regional operational units selected by a competition and using Technology Centres and Science Parks as an operational environment. Each Centre of Expertise has a scientific and technological focus. At the same time, networking and co-operation between the Centres is promoted. The total number of centres for 1999-2006 is 16 and the volume of financing for the projects included in the Programme amount to some 140 million Euro. There are 1,200 participating enterprises. Each Centre of Expertise is assisted by approximately four universities. 290 new enterprises have been established as a result of the Programme so far. The Programme has had an impact on the creation of some 8,000 new jobs. The frequency of co-operation between enterprises, universities and municipalities is reported to have increased five-fold.
- The TULI Programme for the promotion of science-based start-ups is operated by Tekes and promotes new ventures originating from university research through science park incubator companies. "TULI incubator companies" search for research results and new ideas produced within the research units they co-operate with, that could have business potential. These ideas are then processed further with the help of outside services (market research, business planning etc.). The Programme started in the early 1990s and was evaluated in 1996. By the end of 1996, 25 companies had been started or benefited otherwise from the programme through 11 different science park incubator companies. 441 project ideas had been appraised and 121 had been developed further. Tekes provides about 8 to 9 million Euro per year for TULI. A larger amount of new venture promotion takes place however, through Tekes normal financial and advisory services (capital loans scheme and Technology Programmes) when the customer is a new, start-up company. Between 1997 and 1999, Tekes spent annually between 80 and 110 million Euro in the promotion of new business ventures. Start-ups by researchers are also promoted by the Spinno Programme. It provides a network of experts in the service of the starting entrepreneur. Spinno is particularly targeted towards researchers working in universities and research institutes in Helsinki. It is administrated by the Innopoli Science Park and it is financed by the ESF, Tekes, Uusimaa, the Ministry of Trade and Industry and the Helsinki Region Centre of Expertise.

- The licensing of science patents by industry is promoted by the Finnish Foundation for Inventions, a private foundation financed mainly by The Ministry of Trade and Industry. It gives advice to individual inventors in the protection, development and utilisation of their inventions. It also assists the inventor in the search for partners for the development and commercialisation of the invention, and helps the inventor in negotiations with industry. It may also take part in the financing of the protection, development and marketing of the invention. The Foundation has a network of 18 advisory experts in the different regions of Finland. Six of them are located in universities. Their total annual budget is about 5 million Euro, 80 % of which is covered by public funds. About 2.5 million Euro is allocated directly to the protection, development and promotion of inventions, mostly in the form of conditional grants. Furthermore, there are institution specific activities in this area, both at universities and PSREs (esp. VTT).

Table B.3.9: Major Public Promotion Programmes in the Field of ISR in Finland

<i>Name of Programme (responsible authorities)</i>	<i>Public Funding per Year (million Euro)</i>	<i>Main Approach</i>	<i>Type(s) of Interaction Mainly Addressed</i>
Technology Programmes (Tekes)	~ 185	funding for joint large research projects in 60 technology fields	collaborative research
Technology Clinics (Tekes)	~ 0.85	funding for technology consulting to SMEs, developing a market for external technology assistance	technology transfer, consulting, training
Centres of Excellence (mainly SA, partly Tekes)	~ 10	leading public research to top international level in selected fields of research in order to strengthen the knowledge base	long-term oriented co-operation in high-tech areas, mobility
Cluster Programmes (several sectoral ministries, Tekes, SA)	~ 30	funding co-operative projects and networks of innovation actors in sectoral fields (research- producer-supplier-user chains)	networking, contract and collaborative research, mobility
Researcher Mobility Programmes (Tekes)	n.a., low	subsidies or tax relief to researchers moving abroad or coming from abroad	international researcher mobility
Centres of Expertise (Ministry of the Interior)	~ 20	building up regional networks in certain fields of technology involving enterprises, universities, municipalities and intermediaries	networking, start-ups, informal contacts, collaborative research, training & education
TULI (Tekes), Spinno	~ 9	promotion of start-ups from science by providing a supportive infrastructure which actively looks for spin-off ideas	start-ups
Programme for Increasing Education in the Information Industry Field (Ministry of Education)	~ 40	strengthening education relating to information industries	training & education
Research Training for Employed Persons	n.a.	compensation to enterprises in order to enable post-graduate training for researchers in business enterprises	training & education, mobility
Licensing Science's Patents by Industry (Finnish Foundation for Inventions, Ministry of Trade and Industry)	~ 4	providing supportive infrastructure (consulting, negotiation, information) to inventors in public science for licensing IPR	IPR

Source: own survey and compiled by the authors

- Training programmes: All universities have further education centres which provide various kind of vocational further education and training for individuals, as well as companies and other organisations. Programmes are financed by various sources (individuals, public authorities, companies/employers and EU structural funds). Companies' employees can also benefit from the so-called transfer education offered in the "Programme for Increasing Education in the Information Industry Field 1998-2002". This programme includes both ad hoc measures for promoting know-how and increasing the number of graduates in the near future, and permanent increases in the provision of university and non-university professional education. The measures will require a total of 205 million Euro of public funding. Furthermore, the government provides a state subsidy for the postgraduate research training of employed persons. This form of subsidy is intended for persons working in research institutes, the industry, business or public administrations other than universities. The recipient must have a postgraduate study programme approved of by a university. A pre-requisite to granting the subsidy is the fact that the researcher has an employment contract and is permitted to use a part of his/her working hours on a doctoral dissertation. The person in researcher training remains employed by his/her regular employer but the employer receives 1,514 Euro per month as compensation for a maximum of 18 months. The necessary research equipment is to be provided by the researcher's employer. There are further promotion programmes in the field of training and education such as the Graduate Schools, explored in B.3.4.

Institutional Setting: Universities (including Polytechnics) and PSREs each face a specific regulatory environment set out by several laws and government decisions but also shaped by their own internal directives. The institutional setting in HEIs and PSREs in Finland may be described as follows:

- The legal framework in which *universities* operate is defined, first of all, by the Constitution of Finland, which secures the freedom of sciences, the arts and the highest level of teaching. The Higher Education Development Act includes provisions on the objectives of the higher education system, appropriations and their allocation. The Universities Act ensures the autonomy of universities and prescribes their functions, operations and objectives in general terms only. Within these limits, each university may decide on the detailed organisation of its administration and the decision making power of its administrative bodies. The Universities Act also includes provisions concerning the evaluation of the outside effectiveness of the universities. The steering of the universities by the Ministry of Education is carried out by 'management by results' and is largely a strategic one. The same kind of legal frameworks exist for the Polytechnics. The highest decision-making body of a university is its senate. Usually, it also appoints all professors and other senior officials. To enhance co-operation between universities, businesses and the rest of society, universities are entitled to accept representatives of parties outside the institution as full members of university bodies.
- With respect to some areas of ISR, the institutional setting in universities does not appear to be very favourable. Temporary mobility of university researchers is hampered by civil

servants law (concerning leave of absence which usually depends completely on the consideration of the employer and the permission demanded by the employee for carrying out a secondary job), although the relative regulation is not regarded as a significant barrier by national experts. Universities are restricted in making equity investment in start-ups of other companies and researchers may face difficulties in start-up activities when competition laws or loyalty principles apply. In the field of IPR, inventions belong to university researchers. This may cause problems, for instance in the case of negotiations with companies in collaborative R&D projects, and may reduce appropriate commercialisation activities of inventions. This issue is currently being debated in Finland. Some argue that it is good from the commercialisation point of view that researchers own the rights as (large) companies like to negotiate directly with the researchers. Researchers may lack knowledge and experience for commercialisation and business development, which does not however, bother the large companies that negotiate with them. University administrations attempt to develop and test new principles for sharing IPR with the researcher and the university. Some universities have established innovation centres, others ask researchers to transfer their IPR to the university. Increasingly, universities provide value-added services for researchers for the commercialisation of IPR.

- The government made several steps to reform the university system. A major step in this regard is the Development Plan for Education and University Research. The plan for 1995-2000 emphasises, amongst other things, the promotion of university-enterprise partnerships. New university steering and management systems have been implemented, administrative autonomy of universities raised, and a decentralisation of decisions took place, giving more power to faculties and departments. At the same time, budgetary and regulatory control has given way to steering performance, backed up by a shift towards budgeting by results, and the development of evaluation systems. A key element in Ministry-university relations is the consultation procedure by which the Ministry and the universities jointly set the objectives for each university and agree on funding levels.
- In order to increase flexibility in external relations, almost all Finnish universities have established *separate specialised institutes*. They carry out, for example, vocational training activities, research, development and consulting for industry clients, or provide services to the general public, such as libraries etc. A good practice example of such an institute in the field of technology transfer and industry co-operation is given in B.3.6.
- The institutional setting for *PSREs* (position, aims, tasks, internal organisation and instruments) is defined by an Act, a Decree, Rules of Procedure and different Decisions by The Council of State concerning the organisation in question. These regulations may for example, oblige the organisation to promote technology transfer, the creation of new business or co-operation between companies, research organisations and universities. The leading PSRE in Finland, VTT, shows an institutional setting regarded as particularly favourable for strong industry links and is described in more detail in B.3.6.

Intermediaries in the field of ISR: A large number of intermediaries operate in Finland and they aim to support and promote knowledge and technology transfer between industry and science. The following types of intermediaries may be distinguished: Science and technology parks; technology transfer companies; industrial liaison offices and innovation centres at universities; and incubators, and these are outlined below:

- Science and technology parks offer premises, a technically developed infrastructure and a stimulating and innovative business environment. In addition to industrial companies and research units, different kinds of private, semi-public and public service organisations are located in the science parks. Each centre has its own general technology profile. Technology/science parks play an important co-ordinating or implementing role in various business development and regional development programmes. Shareholders of the parks are both private and public organisations. The Finnish Science Park Association (FISPA) has 10 member centres and 9 associate members, accommodating a total of approximately 1,000 enterprises, research, and education organisations, which employ more than 10,000 people. Within the National Centres of Expertise Programme, science and technology parks are used as locations for the centres. The Technology Centres implementing the programme have set up construction projects that will amount to a total volume over 150, 000 sq. m by the year 2002. These operations have resulted in new regional infrastructure (organisations, new enterprises and development units, premises and installations, equipment and service centres).
- There are seven technology transfer companies located in different technology and science parks. The companies are jointly owned by university foundations and other regional organisations. The National Fund for Research and Development (Sitra) is also an important shareholder in each of them. The task of the technology transfer companies is to promote the commercialisation of research results from universities and research institutes. The companies help their customers in evaluating the new research results, the patenting procedures, licence negotiations, and also take care of the development and marketing of patents when needed. The technology transfer companies also act as co-ordinators in important national and international research projects and programmes.
- All universities have industrial liaison offices and some run innovation centres. They attempt to promote research and technology transfer by helping researchers in applying for external research funding, drafting contracts and managing the research projects. Some research offices have more personnel and offer wider services. In these cases they are likely to be called research and innovation services units or innovation centres. The services offered cover a huge variety of consulting, information, training and organisation services.
- At the moment, there are 12 technology incubators located at different technology and science parks in Finland. They co-operate closely together and are usually also close to universities and research institutes. There are also however, other university incubators such as the New Business Centre of the Helsinki University of Economics and Business

Administration and Arabis, and the business incubator at the University of Industrial Art. Also the Polytechnics have incubators. Incubators get their backing from a variety of organisations in the public sector, organisations including large and medium sized companies, business associations and other organisations. Some incubators are so new that there are no companies in them yet. A couple of networked incubators are about to start in 2001. Technology incubators offer versatile services to companies that are just starting their activities as well as to companies that want to grow and internationalise. There are nearly 350 enterprises located in the 12 technology incubators, and between 160 and 200 new enterprises are estimated to start their businesses during the year 2001. FISPA is presently running a national project called *Technology Incubator 2001*. The main objective is to create a national business training model to support launching incubator companies as well as their growth and development.

- In the field of information services, the *Finnish Innovations* (Sfinno) project at the VTT Group for Technology Studies was introduced. It provides a unique database consisting of 1,482 Finnish innovations commercialised by 952 firms during the 1980s and 1990s. The database contains basic data on these innovations, including detailed survey data on the origin, development and commercial significance of 642 innovations.

In summary, policy-related framework conditions for ISR in Finland seem to be heavily shaped by a set of promotion programmes which give strong financial support for R&D activities, and lay particular focus on joint R&D activities, co-operation between enterprises and public science institutions, and establishing networks among various actors in the Finnish innovation system. This type of co-operation stimulating policy is at the centre of Finnish technology policy for two decades now and seems to have supported manifold relations between industry and science, resulting in high ISR performance in Finland. A major element of this technology policy strategy is a focus on information technologies, including education measures. Furthermore, technology clustering approaches and approaches focussing on the promotion of excellence in selected fields of research and technology, are other important features of this policy. Special attention is also paid to infrastructure provision as a base for inter-institutional networking. There are some legal regulations with respect to ISR (within civil servants law etc.) but their effect upon the practice of interaction and co-operation is reported to be low, i.e. the incentives for ISR set by policy override them.

B.3.4 ISR in the Field of Human Capital in Finland

In the field of education and training, there is quite a close interaction between industry and science. The new Universities Act which gave increased autonomy to universities, has had a positive effect upon the interaction between industry and science in the development of human capital. Industry influences the contents of university teaching through various channels: company representatives can be members on the administrative boards of the universities; some universities have established joint advisory committees on which industry is also represented; and industry sponsored professors have become more common at

universities. Professors unofficial contacts with industry however, are the most direct channel for industry to influence the major subjects at universities.

Industry carries out an annual survey (Osaamisluotain) to obtain companies' views about their demand for skilled personnel and training needs. The results of Osaamisluotain were an important impulse for the launching of the Programme for increasing education in the information industry fields 1998-2000. The Confederation of Finnish Industry has made plans to launch a foresight forum in the near future aiming at co-ordinating future studies and discussion related to education and training.

The structure of university degrees has been reformed in almost all fields of study. The new, more flexible decrees on degrees allows universities and students to design their studies more freely according to their own objective. Practical training can always be included in degrees. According to the universities' curricula, this is either compulsory or voluntary, depending on the field. In the past few years, the responsibility of the universities for job placement of graduates has been emphasised and has become one of the performance indicators of universities. Universities have, in recent years, established guidance and counselling services in order to promote working life relations and job placement. In polytechnic degrees, training in companies (20 credits out of 140 to 160) is compulsory. Furthermore, dissertation work and exercises for companies by students are particularly important mechanisms, particularly at technical universities and schools of economics but also at all other universities. In the field of post-graduate education, the graduate (doctoral) schools scheme is a major instrument. The first schools started their 4-year-operation in 1995. Since then, the graduate school system has been expanded to 95 schools in 2000. They are co-ordinated by universities and are financed mainly by the Ministry of Education and/or Academy of Finland and also a variety of other sources, including industry. Fifteen out of twenty universities have at least one graduate school. There were 1,287 students in the graduate schools in 2000, 1/5 of which previously worked outside the science sector. Many of the graduate schools work in close co-operation with the Centres of Excellence in research (see B.3.3). One of the aims of this instrument is to enhance the networking of universities, research institutions and industry. Evaluation results suggest that the level of intensive courses in the graduate schools was raised through co-operation between universities, research institutes and business, and co-operation between universities, research institutes and industry in the teaching of graduates has increased. Nevertheless, the main emphasis on graduate school students is to obtain competence in the academic world.

Over the 1990's period, adult education has emerged as an increasingly important component in national educational policy and planning. As a rule, adult education has close links with working life and the labour market but does not necessarily always relate to jobs and qualifications. Adults can choose between award-winning programmes, open instruction of curricular subjects (e.g. open university) and training for competence-based qualifications. Adult education is provided at all levels of education, from basic to university level education, by more than 1,000 institutions. Most adult learning takes place outside actual educational institutions, provided by the employer at the workplace or in the form of in-service training.

However, universities and polytechnics form a significant part of the adult education system in Finland and offer various types of courses and training services which are outlined below:

- Polytechnics offer plenty of possibilities for vocational studies for adults. More than 20 % of education supply leading to a polytechnic degree has been targeted towards adults. In 1999, some 17,000 adults were engaged in this type of education. The majority of adults already have a degree, usually from a vocational institute, and supplement them with polytechnics degrees. In addition to degree winning training, polytechnics organise 20-40 credit vocational specialising studies.
- All Finnish universities provide adult education opportunities. Adults may participate to normal degree winning university education through examination. Several fields offer masters courses tailored to meet the needs of working life. Scientific post-graduate possibilities are of course also available. Adult education at universities consists of seven complementary areas which together, form a complete entity: (a) professional continuing education (b) open university (c) employment training (d) regional and organisational development projects (e) development of teaching materials (f) research and publication (g) careers services. The main areas of activity have been the first three, (a) to (c) above.
- Professional continuing education provided by universities is primarily arranged by their continuing education centres. Each university has a continuing education centre which may have several affiliates operating outside the university town. The centres organise continuing education ranging from short courses, to 20-40 credit specialising studies. Education focuses on the application of the knowledge obtained through the latest academic research, and on the methods and models based on the most recent ideas. Continuing education centres typically work in close co-operation with the faculties and institutes of the university in question, and also co-operate with experts from other universities, both in Finland and abroad. The idea is to bridge the knowledge base of the university with the needs of individuals, business and various other organisations. In addition to education and training, continuing education centres carry out research and development projects with the aim of, for example, promoting regional development or internationalisation of its customers. The training is mostly chargeable. However, universities and polytechnics are also free to arrange non-academic vocational supplementary training, as in any other educational institute. The financing of the professional continuing education is based on the delivery contract between the institutions and the County Administrative Boards. In 1999, some 133,500 students participated in professional continuing education at universities. Of these, 14,500 were in specialist studies. Altogether, 5,000 courses were organised, out of which 700 were related to 20 credit specialising studies.
- Open university teaching has expanded rapidly. It provides an opportunity for all citizens, regardless of their basic education, to carry out university level studies. Finland does not have a specialised open university but universities organise the education in a distributed manner in co-operation with various adult education institutes. Different kinds of

multiform teaching methods have been developed for open university teaching. During the last few years, training through data networks particularly increased. In 1999, some 77,500 people participated in open university teaching. Moreover, all polytechnics also organise open polytechnic training.

- The provision of continuing education and apprenticeship training in the information industry fields is a major issue in the current policy debate and has resulted in a special "Programme for Increasing Education in the Information Industry Field". The programme is expected to increase the number of degrees in the information industry fields by one third between 1998 and 2002. The provision of continuing education and apprenticeship training will also be expanded. Mathematical and science education will be improved and measures are sought to attract more female students to the field. The Ministry of Education will explore ways to alleviate the shortage of competent teachers in the field. The industry will also contribute to the implementation of the programme. It will put equipment and experts at the disposal of educational institutions, offer internships and encourage their internships to graduate.

The high level of Personnel mobility between industry and science in Finland rests on three major elements: (1) long-term oriented and stable relations between enterprises or industrial sectors and universities in graduates mobility; (2) close co-operation in graduate education between universities and industry (including placements); and (3) the existence of co-ordinating structures for considering industry needs and changes in industry demand, in university education programmes. The mobility of researchers from science to industry and vice versa is mainly based on personal contacts (often as a result of joint research). While the level of mobility from public science to industry is high, mobility in the other direction is impeded by grave differences in salaries. In this field, national experts note the lack of effective programmes for the promotion of two-way mobility. In HEIs, human capital planning and mechanisms on research mobility, are currently under active development (alumni networks, recruiting offices, encouraging entrepreneurship etc.). International mobility of researchers is regarded as crucial for a small country like Finland and some promotion measures do exist (see B.3.3).

Sponsored and invited professors from industry have become more common in recent years. The sponsors typically form a consortium including private enterprises, communities and others. The minimum duration of a sponsored professorship is five years. In filling the invited professorship vacancies, the universities do not have to adhere to the open application procedure. Another successful form of university-industry co-operation is that of part time or adjunct professors, funded by the industry, who share some of their time with the university.

At VTT, leave of absence is the first step used for the exchange of researchers. This is supported by different funding methods (EU, Tekes, bursaries and fellowships). For the last three decades, VTT has had a specific system (*exchange study*) for encouraging the training of researchers in foreign research institutes and companies. Within the same frame, foreign researchers also work at VTT. In order to ensure feedback on the exchange study, VTT

expects the students to work at VTT for twice the amount of time they spent in exchange studies. The number of exchange students from VTT has been around 20 per year.

Human capital development receives high public and policy attention in Finland. The number of people with higher education is still increasing at a fast pace, which is indicated by a high ratio of HE students to the total number of the workforce with HE degrees (nearly 50 %), and a high ratio of HE graduates to higher educated employees (more than 5 %), (see Table B.3.10). The majority of students occupy studies in social and economic sciences and humanities. Unemployment among HE graduates is low, both with respect to the unemployment ratio within the total workforce with a HE degree (about 5 %) and with respect to current graduates (about 6 %).

Table B.3.10: Higher Education by Disciplines in Finland 1998/99 (in %)

<i>Field of Study</i>	<i>Students (1999)</i>	<i>Graduates (lower, higher, licenciates, 1999)</i>	<i>Unemployed Graduates (1998)</i>	<i>Gainfully Employed with HE (1998)</i>
Natural Sciences	15	16	7	8
Engineering (incl. Agricultural Sc.)	23	21	32	32
Medicine	7	9	11	11
Social Sciences	24	24	33	37
Humanities and others	31	32	18	20
Total number (1,000)	151.9	15.9	16.6	310.2

Source: Statistics Finland (2000), calculations by the authors

B.3.5 ISR in Finland: A Summary Assessment by Type of Interaction

Contract and collaborative research: Contract research carried out by public science and commissioned by industry, and joint R&D activities by industry and science, are major channels for ISR in Finland. On the side of public science, this type of interaction concentrates on a few types of institutions. In the PSRE sector, VTT is the main performer of such a type of interaction with industry, with a share of R&D financing by industry of about 40 %. In HEIs, it is the two largest technical universities as well as the separate specialised institutes at universities, that are most intensively engaged in this type of ISR. The average level of industry funding of R&D in HEIs is rather low however, and may reflect institutional and legal barriers in this type of institution, such as regulation concerning extra earnings. In industry, the bulk of money flowing to science comes from large, R&D intensive enterprises, most often located in high-tech sectors. Collaborative research between industry and science is strongly encouraged by policy initiatives, including Tekes' Technology Programmes and various networking programmes. In recent years, R&D activities and R&D co-operation at SMEs have been strongly and successfully promoted. During the 1990s, co-operation in research between industry and science has increased considerably, largely as a result of a coherent, long-term oriented technology policy strategy to strengthen R&D by providing large public funds and restructuring the Finnish economy towards information technologies.

Personnel mobility: The mobility of researchers from public science to industry is rather high in Finland, with a mobility ratio (mobile researcher per year in % of total researchers in the sector of origin) of 3 to 4 %. The ratio is higher at PSREs than in HEIs and at the latter, some legal regulations in civil servant law do exist which might be perceived as impediments, although they are regarded as having little relevance. Mobility seems to be driven mainly by a large demand in industry to enlarge their R&D activities. Special programmes for promoting mobility from industry to science are scarce. State subsidy for the postgraduate training of employed persons by the Academy of Finland was the only programme of this kind. Mobility from industry to public science is low as a result of significant differences in salaries

Training and education: ISR in the field of training and education is very well developed in Finland. HEIs receive a significant amount of income from training and education activities for adults, including professional training for employees of enterprises (the volume of these activities equals 8 % of total R&D expenditures at HEI). There are several education and training programmes offered by universities and polytechnics in order to meet the specific and divergent needs of their clients. Education in the field of information technology is a major policy issue and a separate programme was introduced by the government in this area. Vocational training and further education is carried out at universities in separate, specialised institutes, enabling a sufficient degree of flexibility. Interaction in the field of education also includes programmes for HE graduates working in industry which aim to up-date their scientific knowledge as well as providing doctoral programmes for industry researchers (such as the graduate schools programme). Further types of interaction concern student training in companies which is common in universities and compulsory in polytechnics degrees. Furthermore, foresight studies on the companies' skills needs (Osaamisluotain) and other tools are used by industry to influence the discussion of the development of higher education.

IPR in science: Patenting and incomes from licenses play a rather minor role in ISR in Finland. A major exception is VTT which is the third largest patent applicant in Finland and shows a high patent intensity (25 patents per 1,000 researchers). At universities, there are divergent views on whether the current IPR regulation hampers commercialisation of IP, as the individual researcher is the owner of an IPR. Several universities quite recently started to increase supportive measures for HEI researchers to make more use of IPR and licensing (e.g. consulting, financial support for patent application, innovation centres and incubators). Incomes from royalties in public science institutions are very low, even at VTT.

Start-ups from science: The level of start-up activities by researchers from public science seems to be rather high in Finland, although no exact data is available. Start-ups are promoted via supportive measures such as consulting services and incubators in science and technology parks. Tekes runs a separate programme on this issue, TULI, which provides financial support and aims to exploit the commercial potential of university results via spin-off formation, including the active search for spin-off ideas. Further supportive measures concern incubators and technology parks in public science institutions, and the Centre of Expertise programme.

Networking between industry and science: Building long-term oriented networks between innovative enterprises and public science institutions is a major approach of Finnish technology policy and is being pursued via several programmes and initiatives, such as the Cluster Programmes, Centres of Expertise, Technology Programmes, and National Centres of Excellence. Institutional reform at universities attempts to raise networking by opening university board membership to externals. Networking of enterprises and HEIs is also a major approach in the development of higher education and the design of studies. Finnish science and technology policy put a great emphasis on establishing a co-operative culture in R&D and innovation, and intense co-operation between industry and science is revealed by the CIS2 results. The largest PSRE, VTT, also follows a networking approach to maintain its close industry connection, including having industry representatives on its board.

Involvement of SMEs in ISR: SMEs carry out only a small fraction of business enterprise R&D. Nevertheless, involvement in R&D activities among SMEs has increased significantly over the past few years, largely because of public financial support (mainly via Tekes), which accounts for more than 30 % of R&D financing in small enterprises. More than half of all public financing for R&D at Finnish enterprises, goes to SMEs. The share of SMEs with continuous R&D activities and with patent activities is one of the highest in the EU. There is a separate programme, Technology Clinics, which aims to improve the absorptive capacities of SMEs and technology transfer from technology providers (public science, large enterprises and research enterprises) to SMEs.

Science-based industries: After the serious economic recession in the early 1990s, the Finnish economy rapidly re-oriented towards high-tech sectors, with information technologies as the leading sector. In 1998, more than 50 % of all business R&D was performed in the high-tech sectors and this share is still increasing. However, the high-tech sector is strongly shaped by one company, Nokia, which alone accounts for about one third of all business R&D in Finland. A major stimulus for the increased high-tech orientation was the launching of the *Additional Research Appropriation Programme* in 1996, which contributed to an increase of GERD (as a percentage of GDP) from 2.3 % in 1995 to 3.1 % in 1999, accompanied by a respective increase in BERD (as a percentage of GDP), from 1.45 % to 2.15 %. In 1999, a programme for strengthening education in information technology started. Technology Programmes, Cluster Programmes and Centres of Excellence and Expertise focus not only on information technology, but support other high-tech areas as well, such as biotechnology and new technologies in energy and environment.

B.3.6 Good Practice in Framework Conditions for ISR in Finland

There are several good practice examples for framework conditions favourable to ISR in Finland. The following four have been selected in this study:

- (i) The Technical Research Centre of Finland (VTT) as an example of an institutional setting at PSREs favourable to technology transfer to industry.

- (ii) The Digital Media Institute as one example of a separate specialised institute at universities, providing an interface between university and industry.
- (iii) The Additional Research Appropriation Programme launched by the government in 1996 as an example of how to create a positive atmosphere and environment for increased investment in R&D by all actors in the innovation system, including a closer and more intense interaction between industry and science.
- (iv) The Finnish Cluster Programme provides an example of a sector-focussed programme to build up networks and strengthen expertise in research and technology by bringing together various actors in a sectoral innovation system.

VTT: Technical Research Centre of Finland

VTT is an impartial expert organisation that carries out technical and techno-economic research and development work. VTT produces new applied technology in co-operation with domestic and foreign partners. The number of employees is about 3,000 and turnover is about 200 million Euro (1999). VTT is a not-for-profit organisation. The pricing of commercial activities is based on economic principles. Each year, VTT serves over 5,000 domestic and foreign customers. There is one main location at Espoo (2,250 employees) and five smaller sites in other Finnish regions with 20 to 300 employees.

VTT has eight Research Institutes:

- Electronics
- Information Technology
- Automation
- Chemical Technology
- Biotechnology
- Energy
- Manufacturing Technology
- Building and Transport

Furthermore, there is a division "Communities and Infrastructure" which provides information services (i.e. disseminates scientific, technical and techno-economic information and promotes the development of information services) and an internal services unit, including a Group for Technology Studies.

VTT's board members come from enterprises (Orion, Nokia), government (Ministry of Trade and Industry), interest groups (Trade Union, Confederation of Finnish Industry) and VTT (director general, representative of employees). VTT's staff is well qualified. With respect to the highest qualification level, 12 % have a doctors' degree, 7 % have licentiates, 46 % are other university graduates, and 22 % have a college degree (or similar). 82 % of the total staff are researchers, the remainder comprises of planning, office and management personnel.

Mission and Operating Principles

R&D at VTT is centred around three strategic principles: Customer and demand orientation, science-based innovation, and genuine co-operation (i.e. direct transfer to industry). VTT's strengths lie in a multidisciplinary expertise and a combination of long-term oriented research and technology development within the same unit of research. R&D is carried out in way which meets the specific demands of industry, i.e. scope, budget and timetable are practice oriented, results are reported clearly and concisely according to the needs of the customer.

VTT directs and develops its activities in close interaction with industry, research institutes and universities, as well as government authorities responsible for co-ordinating technology policy and the financing of R&D. VTT operates in accordance with Finland's technology, industrial and energy policies, and plays an active role in their formulation. In fulfilling its mission, the primary role of VTT's research institutes is to carry out research and development work, technology transfer and testing. R&D work is performed as projects.

Income and Funding

Most of VTT's income of total 200 million Euro derives from commercial activities which are in the main, contract research (including joint R&D projects) for industry (39 %). The share of income from so-called jointly funded activities (i.e. project based financing by public authorities) is 32 % and has increased in the last few years while the share of basic funding (29 %), and especially budget funding to research on VTT's own initiative, decreased. Basic funding is used mainly for long-term self-financed or jointly funded strategic research, i.e. basic or applied industrial research that increases VTT's core competencies and competitiveness in key areas and precedes commercial activities offering promising application opportunities in the future.

More than half of the external income is financed by public bodies, such as the Ministry of Trade and Industry, Tekes, and the EU. Over the last few years, the funding from abroad, including EU-funding, is gaining importance in the external income of the VTT. Industry accounts for about 34 % of the total VTT income, equivalent to 68 million Euro, with 5 million Euro coming from abroad. The majority of industry income is provided by manufacturing enterprises (59 %), especially from the electronics and electro-technical industries (i.e. Nokia). 32 % comes from the service sector, and other sectors (energy, construction etc.) are of little importance.

VTT is also a participant in international research projects. It's participation increased significantly in the last ten years, having a total number of 457 projects in 1999. The overwhelming majority of VTT international activities involves EU projects.

The table below shows size, funding and start-up activities by research institutes. The figures clearly indicate the integrated approach to research at VTT. At each research institute, there is a balance of basic funding for long-term, oriented research, project-based funding by public authorities for R&D projects with public interest, and industry funding for supplying industry with new research results and for ensuring effective technology transfer.

Research Institutes	Turnover (million Euro)	Employees	Basic Funding	Industry Funding (as % of total funding)	Project-based Public Funding	Number of Start-ups (1980-1999)
VTT Electronics	26	337	34	36	23	14
VTT Information Technology	17	246	34	31	24	10
VTT Automation	26	353	27	31	29	10
VTT Chemical Technology	24	328	29	33	26	1
VTT Biotechnology	17	304	31	27	28	2
VTT Energy	28	350	26	28	34	8
VTT Manufacturing Technology	25	314	27	25	33	14
VTT Building Technology	26	383	26	41	22	5
VTT Communities and Infrastructure	12	170	25	11	51	2
VTT Total (incl. others)	201	3,005	29	39	32	66

Source: *www.vtt.fi* (March 2001)

Additional Research Appropriation Programme

In 1996, the Government of Finland decided to allocate over 3 billion in proceeds from State property sales, to research and development. The purpose of this additional appropriation, disbursed between 1997 and 1999, was to intensify the operation of the national innovation system for the benefit of the economy, the business environment and employment alike. One key means to this end was to achieve a sufficiently narrow targeting of funds. An equally important aim was to allocate the research appropriation to end users by means of competitive bidding.

The Science and Technology Policy Council of Finland drew up a plan for the appropriation whereby the bulk of the funds were to be allocated to research and development through the appropriate channels in the science and technology administration, notably by increasing the resources allocated to Tekes and the Academy of Finland by means of competitive tenders. Targeted research funding for VTT and to universities was also to be stepped up. Moreover, additional funding was to be granted to R&D projects that aim to foster the development of the country's industrial clusters, the science and technology administration and individual business enterprises.

It was decided that when projects funded by State privatisation proceeds were implemented, the appropriation sum would be increased in stages over a period of three years. The original plan set the final allocation increment for 1999 at FIM 1,5 billion. The overall target sum for the allocation increment over the course of three years was FIM 3,35 billion. The original target in the additional appropriation programme was to raise the national appropriation contribution to R&D to 2,9 percent of GDP by 1999. This goal was reached and surpassed in 1998. In 1999, an appropriation increment of FIM 1,5 billion was introduced on a permanent basis.

The additional money was used for the following purposes:

- 54 % to Tekes for New business operations, Cluster programmes, Technology based services and Enhanced basic research
- 20 % to Academy of Finland for Centres of Excellence, Research programmes, Doctor-researchers programme and Internationalisation
- 20 % to universities for Equipment and other research conditions and facilities, Expanding existing and establishing new graduate schools, Expansion of training, Data transfer, information services and co-operation with industry, Bioteknia II
- 4 % to sectoral ministries for Cluster programmes and
- 2 % to VTT and Ministry of Trade and Industry for Cluster programmes and impact assessment.

The evaluation of the additional research programme was published at the end of year 2000. The evaluation team stated, among other things, that the programme seems to have had a positive impact on private research investment and implicitly in productivity, company profitability and employment. Additional funding has also had positive effects on regional development but only in the regions where research investment has been focused. Development of both the quantity and the quality of Finnish basic research had been very positive and rapid in the latter half of the 1990s. Networks of researchers expanded and co-operation with business enterprises increased both in Finland and abroad. The evaluation team stressed that in the future, policymakers should continue to set ambitious aims for research funding and strengthen the conditions for basic research. Old and new economies should also be better integrated. More focus should be placed on innovation (not only R&D) and future workforce competencies should be developed.

The additional appropriation programme included, amongst others, Technology Programmes funding by Tekes, research funding by the Academy of Finland, the Centre of Excellence Programme, the Cluster Programmes, Graduate Schools and the promotion of start-ups by Tekes (TULI).

Source: Prihti et al. (2000)

Digital Media Institute at TUT: An Interface between University and Industry

Tampere University of Technology (TUT) is one of Finland's three universities of technology and was founded in 1965. The university has developed a significant position in the Finnish higher education system. In the 1990s, TUT experienced a rapid growth in the number of students. By 1995, there were about 6,000 students in TUT and at the beginning of 2001, the number of students reached about 10,000, making it the second largest technical university in Finland.

By focusing on a set of key technology and technical sciences, it has formed a clear strategic profile, with some areas achieving world-wide international renown. The most important of these are materials technology, semiconductor technology, and signal processing. TUT offers certain programmes which are not available elsewhere in Finland including textile and garment technology, automation engineering, and materials engineering. There is also a department specialising in environmental technology. Characteristic of TUT is its close connection to industry, which is evident in the substantial amount of industry-commissioned research that it has undertaken throughout the years since its establishment.

TUT has a long and established co-operation with local industry. This comprises services such as basic and applied research, planning and product development, tests and measurements, Master's theses being made for firms' purposes, and customised education and training. Although charged for, these services are also within the reach of most of the SMEs. Compared to 1984, the finance from external sources in 1994 was over five times larger. In 2000, more than two thirds of the R&D budget was funding from external sources outside the basic financing, and about a third of external funding was provided by industry. TUT serves not only industry in the region, but in the whole country and increasingly, foreign firms. Nevertheless, Tampere University of Technology remains firmly rooted in its regional client base.

The reasons for this close co-operation with industry are numerous. First, the region has a clear sectoral agglomeration in the field of mechanical engineering, where firms have a similar kind of technology base. Secondly, the guiding principals of TUT have always been open and positive towards co-operation and they have directed research and services to those areas strongly represented in the region. Thirdly, and unusual for Finland, is that many of TUT professors have first gained experience within industry. As such, professors usually have many ongoing contacts with industry, 'they speak the same language', and they have a common understanding on the development issues. After becoming independent in 1972, TUT recruited a couple of young, active and well-qualified professors who were free of old-style traditions that were dominant in the Finnish higher education system up until then. At the same time, TUT formulated its key, strategic goal of developing close co-operation with industry.

The **Digital Media Institute** (DMI) is a separate research unit of Tampere University of Technology (TUT). The Institute was founded in 1985, when it was called the Institute for Research in Information Technology. In 1994, the research activities of the Institute were directed towards the area of digital media and it was renamed as the Digital Media Institute. Most researchers deal with digital media technology but there is also close co-operation with marketing, communication, sociology, information research, mathematics, psychology and educational studies. In these areas, a very important co-operation partner for the DMI is the University of Tampere. The heart of DMI is a thorough knowledge of signal processing algorithms which includes audio, image and video as well as biomedical signal pressing. The institute experienced a huge increase in staff during the 1990s, with about 120 researchers in 1995, rising to 400 in 2000.

The organisation of the institute is extremely simple and follows the matrix principle. DMI consists of 7 laboratories which belong to DMI from the point of view of research, but to TUT from the point of view of teaching. Thus, research and education is unified within the laboratories. This close relation between research and teaching is one of DMI's strong points. The majority of researchers are postgraduate students, directed by professors and senior researchers from TUT's Department of Information Technology. DMI is comprised of the following laboratories:

- Signal Processing
- Digital and Computer Systems
- Software Systems
- Telecommunications
- Hypermedia
- Information Technology in Pori
- Institute of Electronics

There were about 100 research projects in DMI in 1999. The budget for the institute for year 1999 was over 14 million Euro and has increased over the three last years by 30 to 40 % per annum. In 1999, funding of the projects came from Tekes (32 %), the TUT (20 %), the Academy of Finland (16 %), other public funds (14 %), Finnish enterprises (12 %) and the EU (6 %).

The signal processing laboratory has attracted the majority of income (53 %) while the other labs' share in total income is between 7 and 14 %.

The close interaction between research and education results in a remarkable education record of DMI and the TUT Department of Information Technology. In 1999, a total of 180 students graduated with a MSc and 15 with a doctoral degree. The Laboratories are focussed on undergraduate and postgraduate examinations in different ways. Most MSc students graduate from the Laboratory of Software Engineering while the Signal Processing Laboratory is strong in doctorates. DMI aims to narrow the difference in dissertation theses in future however. The Laboratories have provided encouragement to undertake doctoral thesis work e.g. by increasing the number of graduate school places. While DMI profits from the knowledge, competence and ideas of students, almost all graduates move to industry as both demand and salaries in industry are high.

Source: Howells et al. (2001), www.dmi.tut.fi (March 2001)

The Cluster Programmes

The Cluster Programmes are a policy initiative resulting from the government's Additional Research Appropriation Programme launched in 1996. They were formed to support R&D that strengthens selected industrial clusters in Finland by allocating funds to their development. The aim of these clusters is to transfer and accumulate knowledge in chosen fields by promoting co-operation among various actors, including both the producers and users of knowledge. They also aim to break boundaries between different sciences and fields and thus promote new innovations. Conceptually, the cluster programmes follow the innovation systems approach, stressing the importance of interaction among various actors in a sectoral innovation system.

The overall goals of the Cluster Programmes were specified by the Science and Technology Policy Council of Finland in 1997. The primary goal was to "generate new innovations, businesses and employment". Intermediate goals were to improve co-operation between authorities, public funding sources, legislators and the private sector. The Science and Technology Policy Council emphasised a "holistic" approach to the value chain so that private actions would add up to be a mutually beneficial process. Furthermore, 1997-99 cluster-specific funding was seen as a seed, which would "create new and permanent co-operation structures, improve the co-operative ability of the whole research system, and increase relevance and flexibility of activities". The council's main emphasis was on sectoral ministries and public financiers. However, they emphasised that one of the central practical goals of the programmes was that they should be attractive to companies.

The Cluster Programmes started in 1998 for three to four year periods. They consist of eight programmes: *Wood Wisdom* (forest cluster), *Well-being cluster*, *Food Cluster*, *KETJU* (Logistics), *TETRA* (Transportation cluster), *NetMate* (the use of information networks in SME business), *Workplace Development* and *Environmental Cluster*. The Finnish Cluster Programmes basically are public financial instruments. Each programme is organised under a sectoral ministry and each programme has its own publicly assigned and funded co-ordination. Moreover, there are several steering groups in each cluster, typically involving enterprises, public authorities, funding institutions and public science institutions. The financing of the Finnish cluster programmes is organised by increasing the appropriations of the sectoral ministries. "Earmarked" cluster-specific funds are only a part of funding and other public and private financing sources have been used in all programmes (see table below). However, public funding dominates in all programmes. In addition to ministries, TEKES and the Academy of Finland were major financiers. Reported financing is mostly domestic, with only 5 percent of funding being international (from different EU-sources).

In principle, the financial instruments were very straightforward. Public resources were allocated as grants to a set of projects. Access to programme resources is based on competitions. Each programme has its own eligibility criteria that focus on co-operation and networking, as well as scientific and industrial issues. Up to now, more than 300 projects have been funded, bringing together about 300 enterprises and as many organisations from the public sphere. 110 projects are industry-driven. The total finance of all six cluster programmes is 102 Million Euro, of which 24 % is earmarked cluster funding from the responsible sectoral ministries and 24 % is industry money. Most of the programmes have been organised on the basis of an open competition and in collaboration with other public financiers, particularly Tekes and the Academy of Finland.

Effectiveness of the cluster programmes

Based on a first evaluation carried out in 2000, the effectiveness of the Cluster Programmes with respect to its goals seems to be high, although several areas of critique have been mentioned. Overall, participants of cluster programmes were generally satisfied with the programmes, new and even innovative forms of co-operation were piloted, and public intervention was found important and effective. Concerning the cluster programmes, the evaluators found some of the definitions of the clusters rather vague. Another comment concerned the networking effect of the programmes. Positive effects on networking were identified at many levels (in Ministries and bodies responsible for the support of science and technology; interaction between sponsors and participants - for example municipalities, service providers and enterprises; and collaboration between research participants). The evaluators also discussed the participation of companies. Most cluster co-ordinators felt that the number of firms involved in projects could have been higher. The evaluators noted that several good explanations were offered for companies' rates of participation but probably the most important explanation lies in the strategic positioning of the clusters. Their strongest features, notably their engagement in public sector missions, have tended to position them upstream in the innovation cycle, away from where industry is most likely to participate. However, the evaluators did not necessarily recommend that clusters be started in more clearly industrial sectors (such as the telecommunication sector) because "the more the sector is industry-driven, the less the need for engagement of the public sector in this very active manner, except in circumstances such as development of standards and promotion of new firms". It was also mentioned that networking can take place even where there is no financial relationship. A more active participation of the companies and organisations other than university and other research units, such as trade associations, in project steering committees was

noticeable. Participation in such committees can give companies access to important information on the latest breakthroughs and developments in their area of interest. Furthermore, such participation may lead to further co-operation. Participating associations considered it their mission to disseminate the results to their client groups.

Several network-related aims were central motives for participation in the programme. Contacts with other researchers and research financiers were considered to be especially important. Public funding was seen as a positive signal to financiers, clients and those within their "own" organisation. Correspondingly, public funding was seen as a means to improve or strengthen a participant's position in an existing network. An important motive for participation was to look for access to a new network. On the other hand, statements that are typically important in "near-market" applications were not considered important here. In particular, risk sharing, client contact, financial costs and even proprietary rights, were ranked rather low.

Name	Start	Number of projects	Number of particip. companies	Number of particip. public units	Cluster spec. fund.	Other publ. funding (in million Euro)	Private funding	Grand total
Wood Wisdom	1998	113	12	49	2,5	17,2	14,7	34,4
Well-being cluster	1998	17	8	22	4,4	4,9	0,0	9,3
Food cluster	1997	12	17	12	2,0	2,4	0,1	4,5
KETJU	1998	30	60	10	2,3	4,1	7,7	14,1
TETRA	1998	48	29	42	1,9	7,5	1,3	10,6
NetMate	1998	10	n.a.	n.a.	1,6	0,4	0,2	2,3
Workplace development	1997	13	86	n.a.	5,0	8,4	0,0	13,5
Environmental cluster	1998	60	70	110	4,5	8,0	1,0	13,5
Total		303	282	245	24,2	53,0	25,0	102,2

Source: Pentikäinen, T. (2000)

B.4 Germany¹¹

B.4.1 Knowledge Production Structures in Germany

The enterprise sector is the dominant group of actors in the German R&D system, performing 69 % of all R&D expenditure. In science, HEIs and PSREs are similar in size. Compared to international standards, R&D expenditure is relatively high, amounting to 2.37 of GDP in 1999 (Table B.4.1). During the 1990s, R&D intensity in Germany fell significantly, partly as a result of the integration of East Germany and partly because of cuts in public R&D financing. The main R&D performer is the enterprise sector, accounting for 64 % of domestic R&D financing and 69 % of R&D expenditure in Germany. In public science, both the higher education sector and the PSRE sector are major R&D performers too (with respect to their R&D expenditures as a percentage of GDP), although their relative size compared to the enterprise sector is small)

Table B.4.1: R&D Expenditures in Germany 1999 by Financing and Performing Sectors (in million €)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total</i>	
	<i>Enterprises</i>	<i>State</i>	<i>Abroad</i>		<i>%</i>	<i>% of GDP</i>
Enterprise Sector	28,960	2,587	818	32,365	69	1.63
PSREs	133	6,530	114	6,777	14	0.34
HEIs	770	7,000	135	7,905	17	0.40
Total (million €)	29,863	16,177	1,067	47,047		
Total (%)	64	34	2		100	2.37

Source: BMBF (2000), calculations by the authors

R&D in enterprises is mainly financed by internal sources. In recent years, contract research within the enterprise sector has risen significantly and is about 15 % of total R&D expenditure of enterprises today. The state contributes 8 % to total BERD.

The institutions in public science are financed both by basic financing provided by the state and by project-based financing via scientific funds (especially the "Deutsche Forschungsgemeinschaft" - German Research Council) and research project funding by Federal and State Ministries. There are also some large private research foundations for public science institutions sponsored by large corporations (Volkswagen-Stiftung, Bertelsmann-Stiftung, Thyssen-Stiftung) as well as research programmes and funds in certain disciplines announced by large companies or industry federations (e.g. by the chemical industry). The HEIs acquire about one third of their total funds for research activities from such - mainly competition based - project financing, while at PSRE, this share is closer to one quarter. Financing for HEIs (the sum of basic and project financing) stems primarily from regional governments (i.e. the 16 Federal States, called "Länder") which are responsible for the higher education sector in Germany (Table B.4.2). The Federal Government, represented

¹¹ This chapter is based on the national report on ISR in Germany (Rammer 2001) as well as on the following sources: Schmoch et al. (2000), BMBF (2000), Legler et al. (2000), Czarnitzki et al. (2000).

by the Federal Ministry of Education and Research (BMBF), is the main financing source of PSREs, although some PSRE-institutions are jointly or solely financed by the Länder.

Table B.4.2: Financing Structure of R&D in HEIs and PSREs in Germany 1999 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing	67	77
Project Financing and other financing sources	33	23
National Government	17	66
Regional Governments	71	28
Other Sources (enterprises, internal financing, abroad)	12	6

Source: BMBF (2000), calculations by the authors

Within the enterprise sector, R&D expenditure is concentrated on technology sectors outside the high-tech sectors (Table B.4.3)¹². More than 50 % of all R&D activities takes place in these sectors which are characterised by a more cumulative pattern of technological change, high, but not extremely high, R&D investment as a percentage of value added, and innovation activities which rely strongly on industrial relations and networks (such as machinery, manufacturing of vehicles, chemicals and electrical machinery). Also however, the weight of high-tech sectors which are likely to have stronger science linkages, is considerably high. Its R&D expenditure as a share of GDP is for instance, still higher than the corresponding indicator for the sum of HEIs. R&D in the service sector is reported to be low but there is certainly a lack of data recording.

Table B.4.3: R&D Expenditures in the German Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in total BERD (in %)</i>	<i>R&D Expen- ditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	32	0.49
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	54	0.83
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	8	0.12
IT-Services (NACE 64, 72, 73)*	3	0.05
Other Services (NACE 50 to 99, excl. IT-Services)*	3	0.05

* too low due to a lack of data recording

Source: OECD (2000), calculations by the authors

The overwhelming majority of business R&D is spent in large enterprises. Small enterprises (with respect to the SME definition by the EU) only account for 11 % of total business R&D. About 50 % of all business R&D is performed by very large enterprises, consisting of more than 10,000 employees (Table B.4.4). The main business R&D performers in Germany are multinational corporations in the car industry, the chemical and pharmaceutical industry, the electronics industry and the aircraft industry. In general, these corporations run large R&D divisions both at German and at foreign locations, whilst also having central R&D

12 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

laboratories in Germany which maintain a manifold R&D network, both with other enterprises and with domestic and international science institutions. Some corporations spend extraordinary high amounts of money on R&D compared to the R&D expenditure in science. For example, DaimlerChrysler's R&D expenditure in 1999 was 7,575 million € which is only slightly lower than the total research expenditure in HEIs. More than 60 % of this amount was performed in Germany. Siemens spent about 5,600 million € (again, about 60 % in Germany) and the five largest pharmaceutical enterprises spent about 4,400 million € on R&D within Germany. The joint number of patent applications by Siemens and DaimlerChrysler exceeds threefold the total number of patent applications by HEI and PSRE in Germany in 1997.

Table B.4.4: R&D Expenditures in the German Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 250 employees)	11
Medium-sized Enterprises (250 to 999 employees)	10
Large Enterprises (1,000 to 9,999 employees)	30
Very Large Enterprises (10,000 employees and more)	49

Source: BMBF (2000), calculations by the authors

Although SMEs have little significance on the R&D performance of the German business enterprise sector, nonetheless, they do represent the vast majority of enterprises in Germany. Their behaviour concerning contact and co-operation with science determines the absolute level of ISR in Germany (as it does in other countries too). The level of ISR by SMEs strongly depends on their absorptive capacities and their involvement in innovation activities. According to various indicators on these variables provided by the CIS2, the German SME sector seems to perform rather well with respect to EU standards (Table B.4.5)¹³. In particular, very small firms perform better, both in the field of innovation and concerning R&D and patenting activities.

Foreign firms have a share of 17 % of total business enterprise R&D expenditure. With respect to their R&D intensity, they behave very similarly to their German competitors, i.e. their R&D expenditure as a percentage of turnover is very similar to the sectoral average, although in most sectors, is slightly smaller than those of German-owned enterprises (see Legler et al. 2000, 83ff).

A small part of R&D in the enterprise sector is performed by so-called "Institutes for Joint Industrial Research" (IfG). There are more than 100 such technology or sector specific institutes, united in the "Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF)" (Association of Industrial Research Organisations). Each IfG has a large number of

¹³ In order to compare innovation performance as reported in the CIS2 among EU countries, one has to take into account national variations in the way innovation was defined (see Leppälähti 2000). Therefore, innovation performance indicators for SMEs are calculated with respect to the national average and the EU average, respectively, and these ratios are compared in order to position German SMEs' innovation activities. With respect to R&D and patent indicators, there seem to be less serious definition biases, thus one can directly compare SME performance on a national level with SME performance on EU average.

membership firms, almost all being SMEs (with a total of about 50,000 SMEs) and carries out R&D projects where the results are used by the membership firms. Financing mainly stems from public sources (Federal Ministry of Economy and Technology - BMWi). The share of these institutes in total R&D performed in the enterprise sector is about 1 % (i.e. ca. 250 million €per year) but that is about 10 % of all R&D performed in the SME sector.

Table B.4.5: Relative Innovation and R&D Performance of SMEs in Germany

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.07	0.91	0.98	1.09
Innovation Expenditures as a Share of Turnover*	1.19	0.93	0.99	0.99
Share of Turnover due to Innovative Products*	1.44	1.04	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	1.27	1.41	1.06	0.76
Share of Enterprises with Medium R&D Intensity**	1.04	1.01	1.03	1.11
Share of Enterprises Engaged Continuously in R&D**	1.14	1.05	1.01	0.78
Share of Enterprises Having Applied for a Patent**	1.15	1.12	1.25	1.04

* Figures show the relation of German SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all German enterprises to all EU enterprises: $(\frac{SME_{xGj}}{SME_{xEUj}}) / (\frac{x_{Gj}}{x_{EUj}})$, x being the variable considered, G being Germany, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Germany to SMEs in the weighted mean of all EU countries (except Greece): $\frac{SME_{xGj}}{x_{Gj}} / \frac{SME_{xEUj}}{x_{EUj}}$, x being the variable considered, G being Germany, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

Research in the science sector in Germany is strongly oriented towards natural sciences, engineering and medicine. More than 75 % of all research activities takes place in these fields, nearly two thirds in natural sciences and engineering, which may be regarded as particularly relevant both to R&D and innovation activities in enterprises. Research in social sciences and humanities accounts for only 17 %. The PSREs are more strongly oriented towards the natural sciences and engineering than HEIs.

Table B.4.6: R&D Expenditures in the German Public Science Sector (HEIs & PSREs) by Fields of Science 1997 (in %)

<i>Sector</i>	<i>HEIs</i>	<i>PSREs</i>	<i>Total</i>
Natural Sciences	29	47	38
Engineering	21	28	24
Medical Sciences	24	7	16
Agricultural Sciences	4	6	5
Social Sciences*	9	6	7
Humanities*	13	6	10

* shares at PSRE only available for the sum of social sciences and humanities, a 50:50 distribution is assumed.

Source: BMBF (2000), calculations by the authors

The German public science sector consists of different institutions each showing a particular organisational and financing structure, mission and research orientation, and orientation towards technology transfer and firm interaction. A number of types of institutions are worthy of distinguishing and are outlined below:

- The general universities comprise about 170 institutions distributed rather equally over the whole territory of Germany and include all large, traditional universities. Universities are subordinate to Länder ministries from whom they receive basic financing. Their legal framework is mainly affected by regional laws although some general legal and organisational frameworks are set by a Federal law ("Hochschulrahmengesetz"). Their main objective is to carry out education and scientific research in an integrated way (the unity of research and education). Some smaller universities are specialised in arts, educational sciences or theology. Most universities are state-owned but there is an increasing (but still small) number of private ones too. Within the last few years, university reforms increased the autonomy of each institution including the area of financing. Cuts in university basic financing budgets during the 1990s forced universities to look for additional sources.
- There is a special organisational type in universities, called "An-Institute". They are legally defined as independent bodies in order to achieve sufficient administrative flexibility. Their main goals are to foster technology transfer and to perform research in application-oriented fields which does not fit into the administrative structures of universities (see Abramson et al. 1997, 288). They often take over the role of mediators between universities and industry and may be regarded as a good practice example of transfer oriented research institutes at universities (see B.4.6). They perform about 5 % of total R&D in the HEI sector.
- There are 13 Technical Universities which face the same legal and organisational framework as general universities do but with a somewhat different mission, as the transfer of knowledge and technology to enterprises is among their main objectives. This is seen in their high share of natural sciences and engineering in the disciplinary structure, an orientation towards applied research and a high level of firm interaction. They also play a crucial role in providing industry with highly qualified R&D personnel. At TU, the personnel mobility of researchers is not one directional from universities to firms but it is quite common to invite researchers from industry to take professorships (for which the wage gap between industry and science is less pronounced than in the case of younger researchers).
- Polytechnic Colleges, called Universities of Applied Sciences ("Fachhochschulen"), provide practice-oriented studies in engineering and business fields including one-year practical study periods at firms. The same legal framework applies as that of general and Technical Universities, i.e. Polytechnic Colleges are subordinate to Länder governments. The number of research activities is rather low but many colleges have strong ties to enterprises, especially SMEs, in the field of consulting and technical development. In the

Federal State of Baden-Württemberg, a separate consulting network of professors from polytechnic colleges, called Steinbeis-Stiftung, was established in order to promote technology transfer to SMEs. This network has now spread over the whole of Germany.

- The Helmholtz-Association of German Research Centres (HGF) is the largest institution in the PSREs, uniting 16 large, organisationally independent research labs. The basic financing of 90 percent, is provided by the Federal Government, and 10 percent by the Länder. So far, research financing was based mainly on general funds but a shift towards more project and programme financing was announced in 2001. The main objectives of HGF are carrying out long-term oriented basic research as well as research in key technologies (especially that with high degrees of public application such as space research, nuclear research and basic health research), and running large-scale R&D infrastructure (and provide this infrastructure to other users, such as the particle accelerator DESY). In April 2001, one research centre (GMD, 1,200 staff) was separated out and joined the Fraunhofer-Society.
- The Max-Planck-Society (MPG) consists of 76 institutes and is financed jointly (concerning basic financing) by the Federal Government and the Länder. The MPG is the descendant of the 1911 founded "Kaiser-Wilhelm-Gesellschaft" and its mission is to carry out top-level basic research by international standards in selected areas and thereby complete research at universities. The vast majority of research funds are provided via general grants. The MPG provides a high level of autonomy for researchers and is particularly engaged in new fields of research and in interdisciplinary research. Furthermore, the MPG offers PhD posts and acts as top-level qualification institution for young scientists.
- The Leibniz-Association of Research Institutes (WGL) comprises 84 organisational units. The main similarity between the institutes is that their basic financing is provided jointly by the Federal Government and the Länder governments which rests on an agreement on the joint promotion of research with respect to article 91b of the German constitution, decided in 1975 (so-called "blue list"). The research institutes are very heterogeneous concerning size, research topics and objectives. The WGL covers all fields of science, including humanities and social sciences. There are also non-research institution members of WGL, such as museums, libraries and thematic information centres. On the other side, some of Germany's top-level research centres (e.g. Heinrich-Hertz-Institute for communication engineering, Institute for New Materials, Institute for Innovative Semiconductors and the Institute for Semiconductor Physics) belong to the WGL. In 2000, an evaluation of all institutes was finalised and attempts to strengthen the profile of the WGL are under way.
- The Fraunhofer-Society (FHG) consists of 48 research institutes, each specialised in a certain field of technology within engineering. 90 percent of the basic financing is provided by the Federal Government, and 10 percent by the Länder (except 3 institutes oriented on military research and financed solely by the Federal Ministry of Defence).

The FhG was founded in 1949. Its main objective today is to promote technology transfer to industry, both via direct research collaboration and long-term oriented research in upcoming fields of technology. Key success indicators are the share of industry financing via contract research (which is currently nearly 40 % having strongly increased since 1994), and the number of patent applications (which in 1999, was 64 per 1,000 R&D personnel) and royalties (which were about 5 million € in 1999, i.e. 0.75 % of the total budget). In April 2001, a large research centre specialised on basic research in information technology (GMD, 1,200 staff) and belonging to the HGF network, was integrated into FHG.

- Most Federal Ministries run Departmental Research Institutions. There are a total of 52 institutes, most of them carrying out applied research and research services such as measuring, testing and standardisation. They include some large research centres such as the Physical-Technical Federal Establishment (PTB) and the Federal Establishment for Material Research (BAM) (both with more than 1,000 employees). Furthermore, there are some high level research institutes in this group, such as the Robert-Koch-Institute, the Federal Establishment for Breeding and Growing (BAZ) and the Paul-Ehrlich-Institute for Sera (PEI). Although their main objective is to provide research support for the Federal Government and public services in research related areas, there is quite a high level of interaction with industry within the institutes mentioned.

Table B.4.7: Main Characteristics of Major Institutions in the German Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D*</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
General Universities (including "An-Institutes")	44.9	ca. 170 institutions, of which 75 larger general universities	education and research	basic research	medium, highly varying among departments
Technical Universities	7.1	13 medium-sized and large universities	education and research in natural sciences and engineering	basic and applied research	high
"Universities of Applied Sciences" (Polytechnic Colleges)	1.8	ca. 160 small university colleges	education, technology transfer	development, consulting	medium to high
Helmholtz-Centres	15.9	16 large research centres	basic research, strategic research in key technologies	basic and applied research	medium to low
Max-Planck-Society	7.0	76 institutes	long-term oriented top-level research	pure basic research	medium to low
Leibniz-Association	5.9	84 institutes	heterogeneous	basic and applied research	medium, but highly varying among institutes
Fraunhofer-Society	4.7	48 institutes	research for industry, technology transfer	applied research, technical development	very high
Departmental	4.4	44 institutes	support for	applied	medium to high

Research Institutions of Federal Ministries	ministries, research with public interest, public duties	research, testing
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* 1999, partly estimates, the remaining share is performed in other institutions such as seven academies of sciences (financed by the Länder governments), departmental research institutions of Länder governments, museums, libraries, and other public research institutes outside the eight institutions.

Source: BMBF (2000), own survey and calculations by the authors

In summary, it may be said that the knowledge production structure in Germany is favourable for a high level of ISR. The enterprise sector is strongly oriented towards R&D activities. On the one side, there is a significant number of very large corporations who spend a considerable amount of money on R&D. On the other side, a large share of SMEs are engaged in R&D and innovation activities and thus, represent a substantial potential for interaction with science too. In the science sector, there are a large variety of institutions, some explicitly oriented towards technology transfer to the enterprise sector. The disciplinary structure, the even spatial distribution of HEIs and PSREs and the variety of research orientation (ranging from basic research to technology and management consulting), should provide an attractive supply of knowledge for enterprises.

B.4.2 The Level of ISR in Germany

The level of ISR in Germany is described by a set of indicators and assessments on the significance of various interaction channels. Table B.4.8 lists the indicators used and the main results. It also indicates those areas where ISR in Germany may be regarded as above average with respect to EU standards. There is, however, no uniform pattern of ISR. Rather, interactions between industry and science differ largely by the type of interaction and by the type of actor involved in industry and science.

Contract research by science institutions for industry, and collaborative research carried out jointly by industry and science, are revealed by financial flows from industry to science¹⁴. For HEI, contract research for industry is an important financing source. About 10 % of total R&D expenditure is financed by the enterprise sector. This share continuously increased during the 1990s, starting from 6 % in 1991. Particularly high shares are reported for Technical Universities. At PSRE, this ratio is significantly lower (2 %) but there are huge differences between institutions and disciplines. In natural sciences and engineering, the average share of industry financing in the four major institutions (HGF, MPG, WGL, FHG) is about 5 to 8 %, while at the FHG, it is around 40 % (including industry financing from abroad).

14 There is considerable inconsistency in the data, however. While HEIs report a total of 747 million € of R&D funding received from the domestic enterprise sector in 1997, German enterprises report only 341 million € given to HEIs for contract research. PSREs report a total R&D financing by domestic enterprises of 124 million €. Enterprises report that they finance 250 million € at PSREs. In the following, we refer to the figures reported by HEIs and PSREs.

In industry, large enterprises (with 1,000 employees or more) are the major financing source for contract and collaborative research in HEIs and PSREs, as they are actually the major R&D performers. While 80 % of BERD is performed by large enterprises, they account for only 70 % of R&D financing by enterprises in HEIs, but for 90 % at PSREs. This means that SMEs tend to use HEIs as partners in contract and collaborative research more commonly than PSRE. From a sector point of view, the following sectors are the main providers for industrial R&D funding for HEIs: Motor vehicles (25 %); pharmaceuticals (14 %); machinery (9 %); and aerospace (7 %). At PSREs, they are: motor vehicles (37 %); telecommunication equipment (21 %); machinery (5 %); telecommunication services; (6 %) and computer equipment (6 %).

Science is used by a significant number of innovative enterprises as an information source of innovation activities and as a co-operation partner in innovation projects. As a result of size differences between the HEI and PSRE sector, HEIs are more often used by innovative enterprises as an information source. Surprisingly, in the field of co-operation in innovation, manufacturing enterprises collaborate with PSRE-institutions more often than with HEIs. Innovation oriented interaction between industry and science in Germany is clearly above the EU average, with the exception of interactions between service enterprises and PSREs. Differentiated by types of science institutions, Technical Universities, general universities, Polytechnic Colleges and Fraunhofer-Institutes show the highest intensities as an innovative source for innovative enterprises (see Schmoch et al. 2000).

Researcher mobility from science to industry is comparably high in Germany (see B.4.4 for more detail). This is especially true for HEIs. One main reason is temporary employment contracts for research assistants. Usually, working contracts are limited to 5 years (both for graduates and researchers already with a PhD). At most institutes in the PSRE sector, a similar practice is used. Therefore, young researchers in HEIs and PSRE are forced to look for new job options and the industry sector is undoubtedly the most preferred target sector as it offers higher wages and represents the larger potential (as measured in the number of R&D personnel). Furthermore, older R&D personnel (i.e. aged 35 and older) often find it difficult to get a new research assistant job at a HEI. Due to serious wage differences between HEIs and PSREs on the one hand, and industry research on the other, there is little mobility from industry to science. Two exceptions should be mentioned however. First, at Technical Universities, it is quite common to invite top-level industry researchers to take a professorship (whereby industry R&D experience is regarded as a substitute for obligatory habilitation). Second, in Polytechnic Colleges, professors must have a minimum of two years work experience in industry, i.e. pure academic careers are not accepted at this type of HEI.

The role of HEIs and PSREs in vocational and further training is rather minor in Germany. Universities and Polytechnic Colleges normally offer vocational training programmes on a decentralised basis, i.e. on the initiative of individual departments or faculties. No exact information on the number of participants in vocational training courses offered by HEIs and PSREs is available but information derived from the Microcensus 1996 suggests clearly that less than 10 % of all vocational training (measured by the share of participants) take place in

HEIs. Amongst industry researchers who participate in vocational training, HEIs have a slightly higher share in vocational training institutions, at about 15 %. PSREs seem to offer vocational training courses only occasionally.

Patent applications by HEIs and PSREs have increased during the last 25 years. Today, the level of patent applications by science institutions in Germany is relatively high. HEIs applied for about 1,520 patents in 1997, the latest year for which figures are available. The number of patent applications by the four large PSRE institutions (HGF, MPG, WGL, FHG) was about 960 in the same year. Together, this is about 7 % of all national patent applications by German residents. In 1991, the respective numbers have been 1,020 (HEIs), 400 (PSREs), and 5 % (share in total). In relation to the R&D personnel in natural sciences, engineering and medicine, there are 19 patents per 1,000 R&D personnel in HEIs, and 20 at PSREs. Among the various institutions, significant differences can be observed with the FHG as the most patent intensive institution (55), followed by HGF (17), MPG (8) and WGL (7).

Table B.4.8: Indicators and Assessments of ISR in Germany at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % (1999)	9.7
	R&D financing by industry for PSREs in % (1999)	2.0
	R&D financing by industry for HEIs/PSREs in % of BERD	2.9
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	high
	Significance of R&D consulting with firms by PSRE resear.	low
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	10.4
	Innovative manuf. enterprises co-operating with PSREs in %	13.6
	Innovative service enterprises co-operating with HEIs in %	7.2
	Innovative service enterprises co-operating with PSREs in %	3.0
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	6.7
	PSREs used as inform. source by innov. manuf. enterpr. in %	2.9
	HEIs used as inform. source by innov. service enterpr. in %	5.6
	PSREs used as inform. source by inn. service enterpr. in %	2.7
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in % (1997-1999, NSE only)	~ 5
	Share of researchers at PSREs moving to industry p.a. in % (1997-1999, NSE only)	~ 3
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	n.a., but low
Vocational Training (Source: national statistics, assessments)	Income from vocational training for enterprises in HEIs	n.a., but rather low
	Number of vocational training participants in HEIs per 1,000 employees in HEIs	n.a., but rather low
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees (1997, natural sciences and engineering only)	19
	Patent Applications by PSREs per 1,000 employees (1997, natural sciences and engineering only)	20
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	n.a., rather low
	Royalties in % of total R&D expenditures at PSREs (1998; HGF, MPG, FHG only)	0.73
Start-ups from Science (Source: national statistics, assessments)	Number of R&D-oriented business start-ups in HEIs per 1,000 R&D personnel (1997-99)	3 to 4
	Number of R&D-oriented business start-ups at PSREs per 1,000 R&D personnel (1997-99)	2 to 3
Informal contacts and personal networks (Source: national statistics, assessments)	significance of informal contacts and personal networks between industry and HEIs	rather high
	significance of informal contacts and personal networks	heteroge-

between industry and PSREs	neous, high at some institutions
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* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD, BMBF (2000), Schmoch et al. (2000), Czarnitzki et al. (2000), calculations by the authors

Incomes from royalties are not a major financing source, neither for PSREs nor for HEIs. Although licensing activities has increased at several PSRE institutions within the last few years, their share of the total R&D budget is still below 1 % of the sum of all PSREs in Germany. At the HGF centres, royalties were equal to 0.51 % of total R&D expenditure in 1998, and increased to 0.62 % in 1999. At the FHG, the ratio was 0.60 % on average in the years 1998 and 1999 (for 2000, an increase of up to 2 % was expected), and at MPG it was 1.65 % on average for the years 1996 to 1998 (more than 50 % was received from the USA and Japan). Royalty incomes heavily depend on a few patents. At the FHG, patents are regarded more as a marketing element for establishing contract research with firms, by signalling which fields of technology they possess special know-how in, rather than using them as a financing instrument. In HEIs, royalties belong to individual researchers and therefore, no data is available.

Start-ups from HEIs and PSREs are reported to have increased during the last few years, partially stimulated by public promotion programmes by the Federal Government and by Länder governments. There are no reliable figures on the number of technology-oriented start-ups from science institutions. Estimations based on a recent survey suggest that there was a total annual number of 300 to 400 high-tech start-ups from HEIs, and 100 to 200 from PSREs, in the time period 1997 to 1999. Other studies report a total number of about 550 start-ups per year from HEIs and PSREs (see OECD 2000b). Within the Federal Government Programme EXIST, which promotes start-ups from science institutions in five regions, about 170 successful start-ups have been supported in the 2 and a half year period since the start of the programme. With respect to the total number of researchers in science, the start-up ratio is 3 to 4 per 1,000 R&D personnel in HEIs, and 2 to 3 per 1,000 R&D personnel at PSREs. The highest propensity to create a start-up is observed in Technical Universities.

Informal contacts and personal and organisational networks are highly important for the overall pattern of ISR in Germany today. In many fields of technology, there are dense networks between researchers in both industry and science, who know each other due to a common educational background and meet each other regularly at several occasions such as Alumni meetings, industry-specific conferences and fairs, advisory boards of funding institutions, scientific advisory boards of large corporations, standardisation boards, and regional events. Anecdotal evidence suggests that university institutes in the natural sciences and engineering, FHG-Institutes and some specialised WGL-Institutes, are particularly strongly engaged in such networks.

In summary, interactions between industry and science have increased during the last 20 years and have reached a high level today. Several channels are used for exchanging knowledge

and technology with contract research appearing to be the most prominent one. Personnel mobility, start-ups, patenting by public science institutions and informal networks are further major channels. A more detailed look into the German innovation systems shows that there are significant differences in ISR performance by type of actors (see Czarnitzki et al. 2000). In the HEI sector, Technical Universities show the strongest ties to industry. However, general universities and Polytechnic Colleges also have intense relations with industry, at least with respect to certain channels. Among the PSREs, the FHG has an outstanding position concerning most of the indicators considered which is only achieved by some specialised, industry-oriented research institutes (most of them belonging to the WGL). In industry, large companies from motor vehicle production, pharmaceuticals, telecommunication equipment and machinery sectors, are the major actors. They most often maintain an extensive network with several public science institutions, including all types of interactions considered above.

B.4.3 The Policy-related Framework Conditions for ISR in Germany

Cultural Attitudes: There is a long tradition of intense industry-science relations in Germany dating back to the 19th century and the development of high-tech oriented industrial sectors in the electronics, machinery, chemical and automobile industries. At this time, several technical universities were founded such as the TU Berlin (1879), the RWTH Aachen (1880) the TU Munich (1877), TU Karlsruhe (1885), TU Darmstadt (1877), TU Braunschweig (1878) and TU Dresden (1890). On the other side, the majority of general universities are still oriented towards a Humboldtian model of science giving special attention to freedom of research, curiosity driven research orientation (aimed towards increasing the general stock of knowledge in society) and the independence of individual researchers. As a consequence, different types of public research institutions with distinctively different objectives and ways of how they see themselves, co-exist today. While transfer to, and interaction with industry is part of the objectives of technical universities (as it is for polytechnic colleges), many researchers at traditional universities are said to follow a purely academic orientation, giving little priority to interaction with industry. The latter view on the role of science is also quite common in the general public, although awareness measures by the Federal and the Länder governments have changed attitudes in recent years.

Legislation: There are no specific laws either explicitly hindering or encouraging ISR. Three areas of legislation are commonly mentioned as hampering industry-science relations, all operating in science:

- (i) The Employment Law in HEIs, especially concerning retirement regulations for civil servants and other public employees, and the wage system, strongly affect personnel mobility from public research to industry. Professors in HEIs and some researchers at PSREs are traditionally civil servants, while other researchers in HEIs and most researchers at PSREs are other public employees. Movement of researchers from science to industry is hampered by a lack of transferability of pension titles between the public and private sector, resulting in decreasing incentives to move the older a

researcher gets in public science. Recently, it was announced that the transferability of entitlements to occupational pension plans between the public and private sector had eased. Both professors and researchers in HEIs (and almost all PSREs) are paid according to a single wage scheme with low flexibility, rare performance-related elements and a significantly lower wage level than in the business enterprise sector, making a move towards industry attractive for younger researchers (see B.4.4 for more details). In September 2000, the Federal Ministry of Education and Research announced a concept for reforming employment law in HEIs, including the introduction of temporary professorships ("Juniorprofessur") and a higher flexibility in wage payments to professors (i.e. a part of salaries should depend on performance indicators). New regulations are expected to pass parliament in autumn 2001.

- (ii) Regulations on intellectual property rights (IPRs) in HEIs are regarded as reducing the commercialisation of inventions made by university researchers. Professors have the privilege to decide whether to apply for new technological knowledge which they have invented, to be patented or not. This is in contrast to all other sectors of the economy (including PSREs) where inventions belong to the organisation of the employee who made the invention. University professors also receive all incomes from licensing a patent. This regulation may be viewed as an appropriate incentive scheme as it maximises private returns of patenting efforts. However, university researchers are sometimes lacking the knowledge and capabilities for assessing the commercial value of new technological developments and they sometimes shrink away from applying for a patent because of high costs and uncertainty of possible earnings. The Federal Government plans to alter IP regulation in HEIs by shifting the property rights to the HEI, fostering the establishment of effective commercialisation units and sharing royalties between the HEI, the commercialisation unit and the professor, in equal amounts. This proposed type of IP regulation in HEIs is in practice at all PSREs in Germany.
- (iii) The non-profit status of public science complicates the organisation of contract research and forces public research institutions towards organisational innovations. HEIs (and some PSREs) are in general, not allowed to earn profits and engage in entrepreneurial activities, including the investment in start-ups. In HEIs, income from industry research usually becomes a part of the university budget and carrying out the R&D project is considered a part of their regular activities. However, professors in HEIs may carry out contract research with industry as a secondary activity, as long as it does not exceed about one fifth of their total work time, or within an enterprise owned by the professors themselves. Other ways of dealing with the non-profit status is to concentrate research projects with industry in certain institutes, e.g. so-called "An-Institute" (see B.4.6). Although many actors feel uncomfortable with the current situation, any changes are viewed with caution as a new regulation may be either bureaucratic or reduce flexibility.

Institutional Setting: In B.4.1, the main features of the different institutions in public science in Germany are described. Four types of institutional settings especially favourable to ISR should be mentioned here:

- *Fraunhofer-Society* (see B.4.6 for more detail): The Fraunhofer-Society is a publicly funded, non-profit R&D organisation which regards technology transfer to industry as its major mission. The following 'critical success factors' may be identified: flexibility in carrying out R&D projects at the level of Institutes and research departments (each Institute being a profit centre); responsibility for transferring R&D results to industry application located at a very low organisational level (research groups and individual researcher); a high share of industry funding as an explicit evaluation criteria; a combination of long-term oriented research and direct application oriented R&D within one research team; advisory boards consisting of representatives from academia and industry; and balanced financing from industry (35-40 %), basic public funds (35-40 %) and project financing by Federal and Länder governments (15-20 %) and others (10 %).
- *Technical Universities (TUs) and Technical Faculties*: There are 13 TUs, and many large traditional universities have important technical faculties with similar structures to TUs. They bring together industry oriented research with practical and scientific education and are traditional partners for industry, both with respect to personnel recruitment and joint and contract research. TUs and technical faculties show the following characteristics which may be regarded as favourable for ISR: specialisation on natural sciences and engineering fields; technology transfer to industry as a 'third mission' (in addition to scientific research and education); maintenance of personal networks via Alumni and the call of industry R&D managers as professors (e.g. for a limited time period); practically-oriented education in co-operation with enterprises (including joint supervision of master thesis); and administrative and infrastructure flexibility with respect to industry projects.
- *Polytechnic Colleges (Universities of Applied Sciences - UAS)*: UAS's role in ISR in Germany is to provide short, practice-oriented tertiary education and offer innovation and technology consulting to SMEs. Although they carry out research only rarely or on a small scale respectively, they are an acknowledged partner in innovation activities by industry, mainly because of the following characteristics: professors must have working experience in industry before getting a professorship; UAS are strongly specialised in industry-relevant fields of technology; students are obliged to write their master thesis on industry-related subjects and in co-operation with enterprises; non-research oriented consulting for enterprises is a well-accepted activity for professors at UAS; and the diffusion of new management methods and new technologies to SMEs is part of the objectives of UAS (there is, for example, a consulting network of UAS professors has been established, the so-called Steinbeis-Foundation).
- *Specialised PSREs*: There are a number of PSREs specialised in industry-related fields of research and technology showing a strong transfer orientation and hence, intense ISR. In B.4.6, the newly established PSREs called Caesar is described in some detail. Other

examples are to the Heinrich-Hertz-Institute for Telecommunication (HHI), the German Centre for Artificial Intelligence (DFKI), the Institute for Semiconductor Physics (IHP) and the Institute for New Materials (INM). One may identify four critical success factors at such specialised PSREs: (1) decentralised responsibility for transfer activities; (2) regular strategic audits with respect to new technology developments and industry needs; (3) the integration of short-term and long-term oriented research within each research unit and the integration of technology transfer into strategic planning; and (4) joint public-private institutional set-up (co-funding by public and private partners).

In the field of science and technology policy, strengthening collaboration between industry and science has been a major issue for long time and a large number of policy initiatives have been started both by the Federal Government and the Länder governments. However, for a long time there was rather little co-ordination and responsibilities in the field of ISR are still split between two federal ministries (BMBF and BMWi) and the Länder governments (including HEIs, PSREs and innovation policy targeted at enterprises). In March 2001, a new *Action Programme* on strengthening knowledge and technology transfer between industry and science ("*Knowledge Creates Markets*") was announced jointly by the BMBF and BMWi, putting special emphasis on a stringent, integrated approach towards ISR (see B.4.6). Reforms focus on improving the incentive scheme in public science (including financing, institutional affiliation and individual remuneration), the commercialisation of public research results via patenting and start-ups, and increasing absorptive capacities at SMEs.

Promotion Programmes: Both the Federal Government and the Länder governments offer a variety of programmes which aim towards increasing the level of ISR (see Table B.4.9). There are some examples of effective programmes, outlined below, which are regarded as positively influencing the level of industry-science relations, although no comprehensive evaluation of the various programmes concerning their effects on ISR have taken place so far.

- Direct research promotion within thematic programmes is the major financing source for collaborative R&D projects in Germany and is by far, the largest public promotion programme exercise in the field of innovation. In the Federal Government, there are about 250 thematic programmes administered by the BMBF or the BMWi. In each thematic programme, there are several sub-programmes and tenders. Individual enterprises, public science institutions or consortia may apply for subsidies. Project proposals are evaluated on a peer review basis and the most promising projects are selected for public support. Typically, projects are of considerable size, last a good number of years and involve enterprises, HEIs and PSREs (so-called "Verbundforschung"). A special approach within thematic programmes is the so-called "Lead Projects". They follow a bottom-up approach of selecting thematic areas for public support (a competition of ideas). Currently, seven Lead Projects receive support, each for about 5 years and the total amount of public money spent on each project, is about 10 to 15 million Euro. Most Länder governments also offer technology specific programmes or programmes for the support of collaborative research.

- ProInno, InnoNet, INSTI and other innovation programmes aim to foster R&D and innovation activities by SMEs, including the promotion of R&D collaboration with public science, the exchange of R&D personnel, and increasing absorption capacities at SMEs. ProInno, for example, provides support to SMEs to employ R&D personnel and carry out co-operative R&D projects with public science institutions or with other enterprises. InnoNet is a newly introduced measure to establish research networks between SMEs and public science institutions. Subsidies are provided for HEIs or PSREs carrying out research within consortia which consist of at least four SMEs. INSTI is an initiative consisting of several sub-programmes and aims to foster the use of intellectual property rights in innovation by SMEs, including financial support, awareness measures, training for SMEs, reform of education in HEIs with respect to IPR, networking and others.

Table B.4.9: Major Public Promotion Programmes in the Field of ISR in Germany

Name of Programme (responsible authorities)	Public Funding (million € 1999)	Main Approach	Type(s) of ISR Mainly Addressed
Direct Research Subsidies in Thematic Programmes (BMBF, BMWI, Länder programmes)	~ 2,500 to 3,000	Subsidies to enterprises and HEIs/PSREs for carrying out research projects in certain thematic fields (currently ca. 250), including "Lead Projects" in strategic areas and "Centres of Competence" in certain fields of technology (biotechnology, medicine etc.)	Joint R&D projects, contract research
ProInno (BMW)	~ 110	Subsidies to SMEs for co-operative R&D projects with other enterprises or with HEI/PSRE, including personnel exchange	Joint R&D projects, Personnel Mobility
InnoNet (BMW)	~ 10	Subsidies to HEIs/PSREs for carrying out R&D together with at least 4 SMEs	Collaborative Research in Networks
InnoRegio (BMBF)	~ 50	Subsidies for establishing innovation networks in selected East German regions	Informal Networks, Personnel Mobility
R&D at SME and private R&D enterprises (New Länder only) (BMW)	~ 50	Subsidies to SMEs for carrying out R&D	Contract Research
Joint Industrial Research within the AiF-Network (BMW)	~ 90	Subsidies for members of the AiF (network of sectoral research institutes) for carrying out R&D projects relevant to SMEs	Collaborative Research
Technology Transfer Infrastructure (BMW, BMBF, Länder)	n.a.	Basic financing for technology transfer infrastructure in HEIs or on a regional level	Consulting, Contract Research, Personnel Mobility
Applied Research at Polytechnic Colleges (BMBF)	~ 8	R&D funding for researchers at polytechnic colleges	Contract Research, Consulting
INSTI-Network (BMBF)	~ 2.5	increasing the use of IPR with the help of awareness measures, networking, reform of HE, establishing innovation markets, subsidies to SMEs for using IPR	IPR, Training
IPR Promotion (BMBF, various Länder programmes)	n.a.	Consulting infrastructure (patent offices) for and subsidies to inventors at SMEs, HEIs and PSREs	IPR
Technology Consulting, Innovation Management (BMW, various Länder programmes)	~ 5	Subsidies to SMEs for costs of innovation management training and consulting	Training, Consulting, Personnel Mobility
Networks of Competence	~ 0.5	Internet platform for networks of various	Informal Networks

		actors in a certain field of technology with high international performance	
BTU, FUTOUR, tbg- and KfW-programmes for high tech start-ups (BMWI)	~ 500 to 1,000 (VC investment)	Subsidies, loans, equity investment, and re-financing for VC for high-tech start-ups	Start-ups
EXIST (BMBF), various Länder-programmes	~ 30	Infrastructure provision and pre-seed financing for HEI-/PSRE-based start-ups in certain regions	Start-ups
BioProfile/BioRegio (BMBF)	~ 15	Infrastructure provision for and subsidies to start-ups in biotechnology in certain regions	Start-ups
R&D personnel promotion (New Länder only) (BMWI)	~ 35	Subsidies to SMEs for temporary employment of researchers	Personnel Mobility
Innovation Assistant (various Länder programmes)	n.a.	Subsidies to SMEs for temporary employment of researchers	Personnel Mobility

Source: EU Trend Chart project, own surveys and calculations

- Start-ups of high tech enterprises are supported by a variety of policy measures, such as financial support via the provision of venture capital (BTU-programme and tbg-Programme) or by re-financing VC investment (KfW-programme), business angels networks, special promotion programmes for new firm creation by graduates and researchers in HEIs and PSREs (EXIST and various programmes at the Länder level), regional start-up initiatives within the thematic biotechnology programme (BioRegio and BioProfile), start-up contests in the field of multimedia, and many more.
- Awareness and networking programmes have received increasing attention in recent years. The "networks of competence" programme provides an Internet platform for networks of various actors in a certain field of technology with high international performance. Networks are selected on a competition basis. Technology-specific programmes and technology consulting promotion also attempt to raise the awareness of actors towards ISR and to reduce information asymmetries between actors.
- Joint industrial research centres carrying out R&D projects relevant to SMEs in a certain industrial sector are a long-standing support mechanism in Germany, introduced as early as 1952. There is an extensive network within the AiF providing research services and including collaborative research with public science institutions.
- Personnel mobility is promoted mainly by Länder programmes but the ProInno-Programme also offers support for employing researchers. Most Länder run so-called Innovation Assistant Programmes. They provide temporary financial support to SMEs for employing a graduate in the course of an innovation project.
- There is a special applied research programme for Polytechnic Colleges to increase their R&D activities. By this measure, R&D capabilities and competence in these type of institutions shall be strengthened in order to improve transfer activities and co-operation with enterprises in innovation projects.
- For the new Länder in Eastern Germany, there are several special programmes which address the main structural problems of this region. A major focus of many programmes is the strengthening of R&D and innovation in East German SMEs, which is achieved by

establishing and deepening links to public science and the large number of private non-profit R&D organisations in specific fields of technology, which have been established as a result of the transformation of large corporations in the former GDR (i.e. outsourcing of R&D departments). Such programmes include InnoRegio (establishing innovation networks in certain fields of technology on a regional base), researcher mobility programmes, special R&D promotion (including the promotion of collaborative research) and start-up promotion (FUTOUR)

Intermediary Structure: There are a large number of publicly supported intermediaries in the field of ISR in Germany today. Estimates are of about 1,680 organisational units, located in HEIs, PSREs, Chambers of Commerce or run as "independent" institutions or networks (see Table B.4.10). Their effectiveness is considered controversial among experts. While a large number of intermediaries show a mismatch between resources (which are most often, very low) and the scope of services offered (which normally cover a wide range of activities to support ISR), there are several good practice examples, too, including:

- The *Steinbeis Transfer Centres* represent a network of technology consultants for SMEs offering innovation consulting, technology development and training. There are more than 400 centres, most of them located in Baden-Württemberg and Bavaria, and in all other regions as well. Typically, a transfer centre is managed by a professor from a polytechnic college and most centres are affiliated to such colleges. Regional proximity, personal contacts with SMEs, practice and problem solving orientation and a rapid realisation of consulting and developing projects, are regarded as major success factors.
- Several universities established *independent commercialisation units* (operating as a business enterprise) for the licensing of patents and promoting start-ups, as well as for fostering knowledge transfer via training courses (e.g. TU Hamburg-Harburg, Ruhr-University Bochum and TU Dresden). Some Länder introduced a single *technology licensing bureau for all universities* within a Federal State (e.g. "Technology-Lizenz-Büro der Baden-Württembergischen Hochschulen GmbH" in Baden-Württemberg).
- At the Max-Planck-Society, there is a separate business unit which acts as a central technology transfer office for all 75 MGP-Institutes, called "*Garching Innovation GmbH*" (see B.4.6).

Table B.4.10: Intermediaries in the Field of Technology Transfer in Germany in 2000

<i>Affiliation</i>	<i>Type of Institution</i>	<i>Number of Intermediaries (estimates)</i>
Science	TTOs at Universities, Polytechnic Colleges	~ 250
	TTOs at Public Sector Research Establishments	~ 150
	Technology Testing and Controlling	~ 20
	Consulting and Development Centres	~ 110
	Application and Demonstration Centres	~ 100
Industry	Technology Consultants at local Chambers of Commerce	~ 240
	Innovation Consultants at local Chambers of Handicrafts	~ 60
Independent	Technology Centres, Innovation Centres, Incubators	~ 200
	Technology Agencies	~ 50

	Regional Technology Consultant Networks	~ 10
	Steinbeis Transfer Centres	~ 440
	Information Exchange Services	~ 50
Total		~1,680

Source: based on Reinhard and Schmalholz (1996, 107), additional investigations by ZEW

In summary, framework conditions for ISR in Germany seem to be driven strongly by the diversity of institutional settings and types of organisation in public science institutions, partly providing a favourable framework for the institutionalised transfer of knowledge and technology, and partly hindering interactions. Public promotion programmes in the field of ISR are designed to overcome inherent barriers to interaction between industry and science in the knowledge market. In recent years, policy initiatives have started to address some perceived weaknesses in the German ISR system, such as cultural attitudes in science, a critical industry orientation of science, or a lack in entrepreneurial spirit.

B.4.4 ISR in the Field of Human Capital in Germany

Interactions between industry and science in the field of higher education take place in various ways but only few of them are institutionalised and are outlined below:

- There are no institutionalised co-ordinating structures for considering industry needs and changes in industry demand, in higher education programmes (curricula, new courses etc.). Chambers of Commerce, industrial associations and other representatives of the enterprise sector may address their position directly to the Länder Ministries. Representatives of industry are members in the Scientific Commission ("Wissenschaftsrat") which is an advisory body to the Federal Government and the Länder governments. It makes recommendations on the development of higher education institutions and the research and science sector, with respect to structure and performance, financing, and general questions relating to the system of higher education, selected structural aspects of research and teaching, as well as management of specific fields and disciplines.
- In decentralised individual departments and enterprises, there is strong co-operation in graduates education by the means of joint supervision of master and PhD theses, and obligatory practices at enterprises. Both large and medium-sized firms use this type of interaction to transfer knowledge from public research to establish and maintain personal contacts, to carry out innovation projects and to recruit new R&D personnel. In technical sciences, writing a master thesis in firms or by arrangement with firms, is a very common form of writing a thesis and often opens up employment options at this firm for the students.
- Teaching at universities and colleges by firm employees is common in many studies although it varies considerably among HEIs and departments. At Polytechnic Colleges, contacts with firms are especially thick as professors need to have two-years previous working experience in the private enterprise sector in order to receive a professorship.

Thus, personal contact with firms is common, including the participation of firm representatives in study programmes.

- Important institutions for exchanging information, maintaining personal contacts between firm employees, graduates and university teachers and opening up job opportunities for students, are the alumni organisations. They exist at most German universities and organise various events which are used for informal contacts between industry and science.
- Many universities and colleges offer vocational training programmes for firm employees. Special courses for industry researchers are also offered by public research labs. Often these activities are organised via a separate organisational unit, a so-called "An-Institut" which may also carry out contract research for firms. Compared to other suppliers of vocational training (private enterprises and other education institutions), the significance of the supply by public research organisations is very low however.
- Some large firms (e.g. from the chemical and pharmaceutical, electronics and automobile industry or banking, insurance and media sectors) finance professorships or even whole research units at universities. This institutional infrastructure increases R&D resources in public research and builds the basis for long-term oriented and stable relations between the financing firm and the university departments. In many cases, these departments also act as an origin of graduate mobility.
- Many Länder governments offer so-called Innovation Assistant Programmes which provide financial support for the (temporary) employment of graduates from universities and colleges, in the context of innovation projects by SMEs.

Table B.4.10 shows some general features of tertiary education by fields of science in Germany. Compared to the high share of natural sciences, engineering and medicine sectors in the total R&D budget at HEI, about 75 percent (see Table B.4.6), their share in education is significantly lower. Today, nearly two thirds of new students choose to study in the field of social sciences or humanities, while engineering accounts for only 15 percent of new students. This is remarkably low compared to the share of gainfully employed academics with a degree in engineering (which is 25 percent) and may produce a shortage in highly qualified engineering personnel in the coming years. The decision to study in a particular field made by students seems to be highly affected by the labour market situation for graduates in the various fields, at the time of beginning a study. As demand varies at least partially with the business cycle, so does the labour market situation and the number of students beginning various studies. The corresponding variation in the number of graduates is lagged by about six years however, and the demand situation may be the opposite to that at the time the decision was taken. Today, such a phenomenon may be observed in the field of informatics. Since about 1995, firms have reported a high demand for personnel with informatics knowledge. In 1998 and 1999, the number of beginners in informatics increased dramatically, and in 2000, this development continued.

Table B.4.10: Higher Education by Disciplines in Germany 1998/99 (in %)

<i>Field of Study</i>	<i>Students</i>	<i>Study Beginners</i>	<i>Graduates (diploma)</i>	<i>Unemployed Graduates</i>	<i>Gainfully Employed with HE (1995)</i>
Natural Sciences	15	16	13	13	14
Engineering	17	15	21	32	25
Medicine	6	4	6	6	9
Agricultural Sciences	2	2	3	3	3
Social Sciences	31	33	35	25	29
Humanities and others	29	30	22	21	20
Total number (1,000)	1,801	390	203	198	4,767

Source: Statistisches Bundesamt (2000), Mikrozensus 1995, calculations by the authors

While students are free to decide which subject they want to study at which HEI, there are restrictions on the maximum number of new students per year, for certain studies. For such studies, students have to apply for a study place either directly at the HEI or - for some studies with a Germany-wide "numerus clausus" (NC) - at the Central Office for the Allocation of Study Places ("Zentralstelle für die Vergabe von Studienplätzen" - ZVS) in NC studies. The main criteria for receiving a study place is the grades obtained on the high-school leaving certificate, but the time a student has already waited for a study place, is considered as well. In winter term 2000/01, 11 studies have a German wide NC, including business administration, biology, food chemistry, medicine, pharmaceuticals, psychology and law. Technical studies normally do not have a Germany-wide NC.

A major criticism by industry on the German HE-System is the length of time of study. The minimum time for most university studies is 9 semesters while at polytechnic colleges it is three years. The average duration of study at universities is between 12 to 14 semesters however. Due to restrictions in the number of study places and some other factors, students in Germany start their study at a comparably high age, and the average age of graduates completing their study, is about 30 years old. Industry representatives thus urge the introduction of baccalaureate studies with a maximum of 6 semesters at universities.

Personnel mobility between industry and science takes place in both directions, i.e. from public research institutions to industry and from industry to public research. Three framework conditions strongly affect the level of personnel mobility between the two sectors in Germany - (1) regulations in the field of employment law with respect to retirement regulations; (2) wage differences between industry and science; and (3), certain institutional settings which either encourage or hinder personnel mobility.

Retirement regulations differ between the institutions of public research. At universities, full professors have the status of civil servants and are therefore, not members of any public pension fund (but will receive further "wage payments" by the state after having retired). A move to the private enterprise sector or to other public research institutions is unattractive, as their working time as professors is not considered for their pension entitlement in public pension funds. At the four large public research lab organisations (HGF, MPG, FhG, WGL), retirement regulations are in general, similar to the private enterprise sector. At research

institutions directly assigned to Federal or Länder Ministries, researchers also often fall under civil servants law.

Wage differences between the public and private sectors are significant in Germany, especially for younger people, because of the seniority system in wage payments in the public sector (where wages automatically increase by age), and especially for researchers in fields of science where there is a large demand by industry. The vast majority of researchers in public research organisations fall under the BAT wage system ("Bundesangestelltentarif" - Tariff for Employees at Federal Institutions) which has four different payment levels for graduates. As individual extra payments are not common (and sometimes are even not allowed by Länder laws), an adjustment of wages to the labour market situation is not possible. Thus, wage differences for young graduates holding strongly demanded qualifications (such as informatics, electronics and certain aspects of business administration) may reach a factor of 1.5 and more.

There are some types of institutionalisation of personnel mobility from industry to public research. At polytechnic colleges, candidates for professorships must have previous working experience in the private enterprise sector of at least five years. In many cases, young researchers or managers from firms move to these colleges as professors and thus, establish personal linkages between the college and their former employer. At Technical Universities, time spent in industry research is often demanded from candidates for professorships. The same is true for senior researchers at the FhG. At general universities and public research labs with a basic science orientation (such as MPG and some WGL institutes), pure academic careers are the rule and increase the likelihood of receiving a professorship or a permanent working contract as a senior researcher.

At universities and at many public research labs (such as MPG), the vast majority of young researchers are only offered temporary working contracts with a maximum length of 5 years, often connected with a PhD study. Afterwards, they are forced to look for alternative jobs which stimulates personnel mobility to the firm sector too.

Personnel mobility between science and industry is mainly organised on an individual basis. The main information channel for jobs in R&D are newspapers, website homepages of firms and public research departments, and above all, personal contact with professors, heads of institutes and R&D managers at firms. The local employment agencies of the Federal Office for Labour ("Bundesanstalt für Arbeit") are engaged in arranging working possibilities for unemployed graduates and they do actively advertise their services to firms. There is, however, no centralised database on the demand for, and supply of, researchers in Germany.

There are some institutionalised forms of personnel exchange, but their quantitative significance should not be overestimated. Amongst others, the following are notable:

- company-university agreements of personnel exchange on a temporary basis (mainly from the university to enterprises),
- sabbaticals for university professors to carry out research projects together with firms,

- offers of chairs at technical universities to R&D managers at firms.

The level of personnel mobility from public science institutions to industry is quite high but it differs significantly by type of institution and reflects the diverse objectives (in terms of education and research orientation) and different regulatory frameworks at these institutions. In natural sciences and engineering - which are most relevant with respect to personnel mobility in the field of R&D - universities have the highest intensity of personnel mobility and this is mainly due to the practice of temporary working contracts for research assistants (annually, 5 to 6 percent of all university researchers move to industry research). At Polytechnic Colleges, this ratio is much lower. At PSREs, this mobility ratio is about 3 to 4 percent.

B.4.5 ISR in Germany: A Summary Assessment by Type of Interaction

Contract and collaborative research: Both enterprises and public science institutions regard this channel of interaction as the most important one for ISR. About 10 % of R&D expenditure in HEIs are financed by industry while at PSREs, this share is significantly lower (2 %), and also, some public research labs reach shares of 30 % and more. Contract and collaborative research between industry and science in Germany is strongly driven by four forces:

- Firstly, HEIs and PSREs have a strong incentive to attract additional resources from industry in order to compensate for decreasing funding from the General University Funds and basic (institutional) financing.
- Secondly, a high R&D potential and sufficient absorptive capacities at a few dozen very large companies, provides a significant demand for this type of interaction.
- Thirdly, project financing by the Federal government and the Länder governments for joint R&D activities with industry in thematic or technology-specific programmes, is a major stimulus.
- Fourthly, there are several institutions in science which are strongly oriented towards contract/collaborative research with industry, such as the Fraunhofer-Society, Technical Universities, Polytechnic Colleges (with respect to consulting) and specialised PSREs.

In conclusion, framework conditions with respect to legislation and intermediaries seem to have little effect (either positive or negative) for this type of interaction.

Personnel mobility: Personnel mobility from science to industry is high in Germany, with about 5 % of all HEIs researchers and 3 % of all PSREs researchers moving to industry each year. This high level of mobility may be attributed to the following framework conditions:

- Wages for researchers are significantly lower in HEIs and PSREs, mainly due to a rigid wage scheme and budget constraints in public science. This stimulates mobility from science to industry.

- Young researchers in public science (both in HEIs and most PSREs) usually only get temporary working contracts. There are also a large number of researchers working on completed research projects in public science. As further employment within the same institution is restricted or at least not common, young researchers are forced to move to other employers, which are often in industry.
- At some types of public science institutions such as Technical Universities, Polytechnic Colleges and the Fraunhofer-Society, the employment of R&D managers from industry as professors or heads of department is common.
- There are however, unfavourable framework conditions too, such as the pension system in public science and a lack of acknowledgement of non-academic activities for scientific careers.

Training and education: HEIs are the main provider of highly qualified labour for industry. There is however, little involvement of HEIs in further education and vocational training for enterprises. In these areas, specialised institutions outside the HE system offer services to enterprises. There are no explicit mechanisms to co-ordinate demand and supply for highly qualified labour in Germany. Rather, there is a free labour market with high inter-regional mobility and cyclical unemployment of, and shortages in, graduates of certain disciplines, partly as a result of high fluctuations in the number of new students in industry relevant studies. In highly demanded fields of study, the number of study places is limited but such regulation mainly affects the availability of teaching resources in HEIs rather than the expected demand by industry.

IPR in science: Both HEIs and PSREs increasingly use IPR. The number of patent applications per researcher in natural sciences, engineering and medicine has risen by 40 % (HEIs) and 120 % (PSRE) in the period 1987-1997, and is now at about 20 patent applications per 1.000 R&D personnel, both in HEIs and PSREs. About 7 % of all patent applications at the German Patent Office stem from public science, which is considerably high when taking into account the size and structure of the German business enterprise sector and its specialisation in fields of technology where patenting is a key business strategy. Royalties from patents however, are not a significant source of income for public science in Germany. In HEIs, this fact is associated with the prevailing IPR-regulation, i.e. patents belong to individual professors who are free to decide whether to commercialise a patent or not. Professors are supported by specialised technology transfer bureaux which are run by individual universities or a regional network of universities. IPR-regulation in HEIs will be changed in the near future however, giving the right of commercialisation to the universities and enlarging the support infrastructure. At PSREs, patents belong to the organisation, and most PSRE institutions run their own licensing bureau. Here, royalties have increased during the second half of the 1990s.

Start-ups from science: The annual number of start-ups by researchers from HEIs may be estimated at about 3 to 4 per 1.000 researchers while at PSREs, this figure is somewhat lower.

Start-ups are facilitated by a quite well developed private Venture Capital market, VC programmes by the Federal Government (such as BTU) and specific promotion programmes for university spin-offs by the Federal Government (EXIST) and by five Länder governments. Furthermore, there is public promotion for start-ups in biotechnology via the BioRegio programme (five regions) and its successor, the BioProfile programme (competition is still underway). A main barrier to start-ups from science is perceived as the lack of an entrepreneurial climate at universities and a lack in managerial knowledge, especially in the case of researchers from natural sciences and engineering. With the establishment of specialised professorships for entrepreneurship and start-ups, managerial skills of students and the awareness towards the creation of new firms, shall be raised.

Networking between industry and science: Both enterprises and public science institutions report that informal contacts and personal networks between researchers from both sides are important channels for knowledge exchange. Such informal contacts may take very different forms: Alumni meetings in HEIs; meetings in advisory boards and scientific committees; occasional contact at industry fairs, exhibitions, conferences; participation in standardisation committees etc.; regional forums and events; and many more. A main basis for such networking is often a common educational background of researchers from industry and science and personal contacts dating back to the time of study or working experiences in HEIs and PSREs by industry researchers. At industry, it is mostly medium-sized and large companies which are involved in such networks.

Involvement of SMEs in ISR: In SMEs, absorptive capacities necessary for the successful use of scientific knowledge and expertise, are often lacking. The share of SMEs either performing R&D on a continuous basis or showing patent activity is rather low compared to EU standards. Therefore, several public promotion programmes attempt to remove these barriers to interaction, either by providing funding for R&D or by offering consulting services in order to improve innovation management capabilities. In 1995/97, SMEs (i.e. enterprises with less than 500 employees) accounted for 17 % of all R&D contracts to public science in Germany. This was 4.2 % of their total R&D expenditures, which is slightly above the average share of R&D contracts to public science in total BERD (3.9 %). SMEs main partners for co-operation in science are universities, polytechnic colleges and Fraunhofer-Institutes. In Eastern Germany, there are also good contacts to sector specific, non-profit privately owned research companies.

Science-based industries: Compared to other large, industrialised countries, the high-tech sector which has strong science links in innovation (computer & software, telecommunication, pharmaceuticals & biotechnology, instruments and aircraft sectors), is of a lower significance in the German economy. Its share of total BERD is about 30 %. The German economy is rather specialised on medium- to high-tech sectors such as motor vehicles, chemicals, electrical machines and (non-electrical) machinery, which account for more than 50 % of BERD. In science, there are however, several institutions specialised in research highly relevant to science-based industries. Research in computer & software, microelectronics and biotechnology is carried out at some of the large public research centres,

at many Fraunhofer-Institutes, at Max-Planck-Institutes and at specialised research centres. In recent years, spin-offs from these institutions in terms of start-ups of new enterprises, of licensing patents to enterprises and of joint research activities, have increased in number. In the field of biotechnology, Germany is the European leader with respect to patent applications today.

B.4.6 Good Practice in Framework Conditions for ISR in Germany

Six examples of good practice in shaping framework conditions favourable to ISR have been selected. In the main, they refer to different types of institutional settings and are outlined as follows:

- (i) The Fraunhofer-Society as an example of an institutional setting at PSREs favourable to technology transfer to industry.
- (ii) The newly established "Center of Advanced European Studies and Research" (Caesar) which represents a transfer oriented type of PSRE with a new type of organisation and incentives.
- (iii) The patent and technology transfer office at the Max-Planck-Society, called "Garching Innovation" which represents effective supportive intermediary infrastructure at large, basic research oriented PSRE.
- (iv) The so-called "An-Institute" at universities offering a flexible organisational approach to carrying out joint R&D with enterprises and other transfer oriented activities such as training and seminars.
- (v) The EXIST-Programme by the Federal Government which aims to promote start-ups from HEIs and PSREs within a regional network approach.
- (vi) The new action programme by the Federal Government on strengthening ISR - "Knowledge Creates Markets" - is a joint initiative by the BMBF and the BMWi which represents an attempt by an integrated, stringent policy approach to foster interaction between industry and science.

Fraunhofer-Society: A Model of Institutionalised Technology Transfer

The "*Fraunhofer-Society*" (FHG) consists of 48 research institutes, a total staff of about 7,200 (on full-time contracts in 2000) and an annual budget of (2000) 760 million Euro. Founded in 1949, the FHG is organised as a recognised non-profit organisation specialised in applied research in engineering. Amongst its members are well-known companies and private patrons. The basic financing was 220 million Euro in 2000, 90 percent of which was provided by the Federal Government and 10 percent by the Länder (except 3 institutes oriented on military research and financed solely by the Federal Ministry of Defence).

The Fraunhofer-Institutes focus their research efforts in eight fields:

- Materials technology, component behaviour
- Production technology, manufacturing engineering
- Information and communications technology
- Microelectronics, micro-systems technology
- Sensor systems, testing technology
- Process technology
- Energy and building technology, environmental and health research
- Technical and economic studies, information transfer

The success of the Fraunhofer model, as reflected by steadily increasing budgets, is based on a variety of strategic elements, including the decentralised management and substantial autonomy of the institutes, which are pre-requisite for flexible adaptation to the needs of the research market. Another element is the direct linkage between the level of institutional funding to success in contract research, which is a major incentive for market orientation and entrepreneurial behaviour. Indicators for success include their high share of contract research for industry (nearly 40 %), the number of patent applications (1999: 64 per 1,000 R&D personnel), royalties (1999: 5 million Euro, i.e. 0.75 % of the total budget) and spin-offs (40 to 50 start-ups by researchers in 1998 to 2000, i.e. 6 to 7 start-ups per 1,000 R&D personnel).

Furthermore, the success of the Fraunhofer model rests on a balanced mix of the three sources of support: institutional funding (35-40 %), public projects (20-25 %), and contract research for industry (35-40 %). On the one hand, a higher share of institutional funding would imply a decreasing interest of the institutions in industrial contracts, and thus, a diminished orientation toward industrial needs. On the other hand, a considerable decrease in public funding would reduce scientific competence and call the institutes' transfer function into question. The financing structure allows both for oriented (strategic) basic research in new fields of research and for using the results of this research for application oriented R&D which meets industry needs. The institutional linkage to universities is another vital element in maintaining a high standard of scientific competence. Some Fraunhofer-Institutes are managed by researchers who hold a part-time professorship at a nearby university at the same time.

In the German debate on research policy, success with industrial contracts is often seen as the defining feature of the Fraunhofer model, and the close linkage to science is overlooked. Both elements however, are important to guarantee effective technology transfer in the long run. Therefore, managing the balance between scientific and technological competence is a major challenge for the FHG, which is met by regular control of all elements of technology transfer for each institute. In 1998, a systemic evaluation of the FHG took place. The results reinforced the main success factors of the Fraunhofer model: integration of strategic and applied research, decentralisation of transfer responsibilities, strategic planning and audits at the level of institutes. Major recommendations include the increase in flexibility of the wage system (which is today rather rigid due to the application of the BAT-tariff) in order to attract highly qualified researchers, to re-orient the disciplinary structure towards life sciences, material sciences and communication technologies, and to increase networking with other PSREs in Germany (MPG, HGF, WGL).

In 2001, the Research Centre for Information Technologies (GMD), so far one of the 16 large research centres within the HGF-network, will be merged with the Fraunhofer-Society. In 2000, the GMD had about 1,170 employees and an annual budget of about 95 million Euro. As a result of the merger, the FhG will become the leading German PSRE in the growing field of information technology, both carrying out basic research (GMD) and applied research at seven FhG-Institutes.

The Fraunhofer-Society also runs some specialised institutes offering particular transfer services:

- *Fraunhofer Alliances*: Fraunhofer-Institutes pool their expertise in co-operative alliances, appearing jointly on the market to offer their customers a broad range of services. There are currently eight Alliances: Information and Communication

Technology, Life Sciences, Microelectronics, Surface Technology and Photonics, Production Technologies, Materials and Components, Polymer Surfaces, and Simulation Technologies (FAST).

- *Application Centres*: They are run by a Fraunhofer-Institute and provide a research infrastructure to university professors who are carrying out contract research for industry. The competence of the Fraunhofer-Institute and the university are combined to offer more customer oriented research services, especially for SMEs in the region with whom university professors often have better contact. Today there are seven such centres.
- *Innovation Centres*: There are two such centres (telecommunication technologies and recyclable polymers) which are constituted as limited enterprises and do not receive any public financing. The purpose of Innovation Centres is to facilitate and speed up the transfer of new developments at Fraunhofer-Institutes to industry. This function is carried out through the manufacture of short-run series for market introduction, pilot and field tests.

Source: Schmoch et al. (2000, 154ff), Evaluierungskommission FhG (1998), Abrahamson et al. (1997, 287ff), www.fhg.de (March 2001)

Center of Advanced European Studies and Research (Caesar)

Caesar is a research centre in the field of natural sciences founded in 1995 by the Federal Government and the state of North Rhine-Westphalia and commenced work in 1999. It is a new type of private foundation with a capital endowment of its own and major organisational freedom. It is geared to the technologies of the 21st century and focuses on projects with explicit market orientation. Technology transfer to industry is a major objective of Caesar. Its main characteristics are the following:

- Caesar takes up seminal research topics on an interdisciplinary basis at the interfaces between information sciences and physics, chemistry, biology and medicine. Both in terms of research topics and staff, Caesar has a strong international orientation.
- Major consideration is given to market orientation of research topics, including a view to its industrial application from the beginning.
- Caesar is to develop and test new mechanisms for converting research results into industrial innovation. This includes the consistent protection of research results by patents and assistance in raising capital and operational support in setting up new businesses.
- Flexibility in the choice of topics and staff is to be ensured by imposing a strict time limit on the projects and by efficient project control, i.e. project management at the operational and strategic levels.

Caesar attempts to reach these goals by:

- conducting multidisciplinary research projects supported by an efficient operational and strategic project control,
- assembling temporary teams of researchers employed by Caesar, as well as staff members from other research organisations and industry,
- establishing research teams based on scientific excellence neglecting international and interdisciplinary boundaries,
- developing new mechanisms for commercialisation including the substantial support of start-up-companies,
- becoming a nucleus for co-operative activities and a focal point for knowledge networks.

Organisation of Research

Caesar will continuously search for new topics and shift its research focuses. Organisation-by-project requires continuous development and self-examination with respect to scientific relevance and market orientation. By way of example the founding committee has identified three broad topics for the initial phase:

- (i) Material science and nanotechnologies
- (ii) Coupling of biological and electronic systems
- (iii) Ergonomics in communications

Research teams are the core units within Caesar. They are formed on an ad-hoc basis to tackle specific projects - generally lasting no more than five years. The project goal is defined jointly by the team leader and the Board of Directors, and this goal determines the team's size and budget. Teams include scientists employed by Caesar, scientists from the region and industrial fellows.

Since the basic research themes of Caesar are, by definition, at the interfaces between different scientific fields, the teams are transdisciplinary and the research methodology will not be rooted in any one discipline but will develop as part of the research. This method of operation is the leitmotiv of the projects selected for Caesar and is being organised via research in triplets. Each thematic focus will be worked out by three teams with different viewpoints:

- The model and simulation group is responsible for setting the research via model building and supports the experimental stage via simulations. Mathematicians, computer scientists and research oriented scientists from other fields are working in these groups.
- The experimental group carries out the necessary experiments. Natural scientists are in this group.
- An engineering group is responsible for the transmission of the results to the market and there will be application oriented natural scientists and engineers.

The co-operation among these three groups is indispensable for the success of the projects. Each team is led by a person who must be an outstanding scientist who is able to lead a mixed group of researchers from various disciplines. Also,

younger scientists with an international reputation are to be considered when filling these posts. The team leader will be responsible for monitoring and spending the budget, which will be determined jointly by the Board of Directors and the team leader before work starts. The team leader will also choose team members, in agreement with the Board of Directors.

The three team leaders of a thematic focus - a triplet - work collectively and are co-directing the triplet with the same rights. The teams focus on innovations which can be applied to industry - industrial representatives are invited to participate in Caesar projects. The Board of Directors and the team leaders - and also industry if external funds are involved - co-operate in providing a budget for each team. The team leaders control their budgets and are bound by structural elements of public control such as annual accounting, cover limit and staffing schedules.

The teams progress is measured by an oversight process which includes not only measuring expenses, monitoring milestones and consumption of resources, but also includes a scientific assessment. By making the research progress transparent the oversight process is to assist the management and the teams. It is not meant to limit freedom or supervise the staff but rather to guide and promote foresight.

The team leaders report at least annually on the progress and results of their research. When half the project period has elapsed, or earlier, the scientific director, with external support, will carry out a progress review which can result in the reorganisation or re-orientation of the project or even, in its early termination. The Advisory Council is involved in this procedure.

The Foundation Council consists of representatives from policy (Federal Government, Länder Government and Local Government), science and enterprises (Bayer and Telecom). In the Scientific Advisory Council, there are both representatives from universities and public research labs, and from enterprises (Siemens, BMW, IBM and BST).

Today, Caesar has a staff of about 100, a third being senior researchers. There are currently 12 research teams. Within the next few years, the number of employees shall increase to 350. The total capital of the Foundation is 383.5 million €, 91 % was provided by the Federal Government and the remaining part, by the Länder government of North Rhine-Westphalia. Nearly 100 million € are used for investments. Financing is provided by interests from the foundation capital but the majority will come from research project funding, both using public (national and EU) and private (industry) sources.

Interaction with industry is carried out in several ways:

- Participation of industry representatives in the Foundation Council and the Scientific Advisory Council (Bayer, Deutsche Telecom, Siemens, BMW and BST).
- Presentations at fairs, conferences and lectures.
- Contract research for enterprises.
- R&D projects carried out jointly by Caesar and enterprises.
- Temporary personnel mobility from enterprises to Caesar.
- Start-ups by scientists.
- Personal networks between scientists and researchers from enterprises.

Source: www.caesar.de, March 2001

Garching Innovation - the TTO at the Max-Planck-Society

The "Garching Innovation GmbH - Technologien aus der Max-Planck-Gesellschaft" (GI) handles technology transfer for the Max-Planck-Society (MPG). The main task of GI lies in seeking out inventions and know-how in the Max-Planck-Institutes and exploiting them by the conclusion of sales, licence and option agreements with industry, at home and abroad. GI investigates these inventions, estimates their economic potential and advise the institutes on the scope of protection of patent applications and the territories in which protection should be sought. GI also supports start-up activities by researchers at MPG.

With respect to industry, GI informs interested commercial enterprises on the actual state of research at MPG and promotes contacts with the business world. It assists companies in concluding scientific co-operation and consulting agreements, as far as these relate to inventions and know-how from the institutes of MPG.

Economically exploitable research results arise in almost all areas of the Max-Planck-Society. The fields of operation of GI can be subdivided as follows:

- New Materials
- Apparatus and Sensors
- Medical Technology
- Diagnostic and Pharmaceutical Compounds
- Biotechnology and Genetics
- Plants
- Software

Garching Innovation was founded in 1970. At present, GI has 13 employees, including a managing director, four scientists, two economists, and a lawyer. An advising board, to which experts from research, scientific administration and industry belong, assists GI and its parent, the MPG, in important questions concerning the structuring of the company and on licence policy. GI is financed by the general budget of MPG, which mainly stems from institutional funds from the government.

Garching Innovation is a mediator between research and industry. It advises the institutes when inventions are made and instructs external patent attorneys to formulate and file patent applications on behalf of the Max-Planck-Society. It is GI's aim to conclude agreements with industrial partners. For this, GI tries to find suitable partners for their projects. The negotiation of appropriate licence conditions is the task of GI in agreement with the institutes. Knowledge of companies and individuals, as well as visits to many exhibitions and conferences, are the basis for successful contacts. A comprehensive archive of concluded agreements serve as a foundation for future work.

Success Indicators

Garching Innovation has taken care of about 1,600 inventions since 1979 and has exploited 905 of them. The total net revenue runs to about 154 million DM, half of which originates abroad. In 1996, the MPG held a total of about 800 inventions. Patent applications are filed for between 100 and 120 new inventions each year. In 1998, 72 licence and option agreements were concluded. They netted MPG around 8.7 million € in licence fees. The income from licence agreements has risen considerably in recent years. The statistics are however, still determined by outstanding individual inventions. Further substantial contributions to turnover are expected from GI's industrial partners and will determine the picture in the future.

Through their contacts with industry, GI acquired research funding of 12.6 million € for the institutes of the MPG between 1993 and 1998 (which is about 0.3 % of total R&D expenditures during this period). The foundation of innovative businesses, with GI participating in their creation in different ways, is of increasing significance, although the absolute number of start-ups from MPG supported by GI is still small.

Year	Number of patent applications	Number of licence, option agreements	Royalties in million €	Number of Start-ups	R&D expenditures at MPG in million €
1993	69	69	3.7	2	731
1994	92	46	3.8	1	750
1995	83	51	6.0	1	810
1996	120	54	25.0	2	892
1997	167	69	11.7	8	885
1998	134	72	8.7	5	956
1999	n.a.	n.a.	n.a.	4	1,026

Source: www.garching-innovation.mpg.de, March 2001

"An-Institutes": Flexible Organisation for Technology Transfer at HEI

While universities are the most preferred partner by the science sector for innovative enterprises in Germany, the administrative framework and bureaucratic procedures at universities may impede interaction. This concerns, for example, the employment of research assistants, the purchase of research equipment and the financial questions concerned with the non-profit-status of public science in Germany. One way to overcome restrictions on ISR imposed by university regulations is to establish external institutes.

A special type of such external institutes are the so-called "An-Institutes". An-Institutes are legally defined as independent bodies of universities in order to achieve sufficient administrative flexibility. They may have a completely private or semi-public status. In most cases, they are non-profit institutions and thus, pay reduced taxes. Important common characteristics of all An-Institutes are that they are officially acknowledged by universities and operate under a co-operation agreement. Some Federal States (Länder) have official rules and regulations for An-Institutes.

The main goals of An-Institute are to

- foster technology transfer and application-oriented research and development;
- perform research in areas that are the focus of university research; and
- perform research that does not fit into the administrative structures of universities.

An-Institutes are "mediators" between universities and industry. Because of their legal independence, they have short decision paths and can react to market demands and opportunities in a flexible way. Furthermore, they can establish a business-oriented budgeting and accounting system. For example, they can freely use their budgets for special remuneration of their staff, for public relations activities, or for the professional training of their researchers. For interested companies, especially SMEs, the research areas and competence of An-Institutes are more transparent than those of large universities with a variety of faculties, and international institutes. This is a special advantage that helps An-Institutes to get involved in regional networks and attract attention.

At the same time, An-Institutes have close relations to universities and thus, good access to basic research. In most cases, the directors of An-Institutes are also regular (part-time) professors at universities and are engaged in teaching. An-Institutes are able to offer students attractive research possibilities and thus, can attract the brightest students which may be another competitive advantage for interaction with industry.

Some critics fear that university research activities are being shifted too strongly to An-Institutes, and consequently, universities may lose external funds from industry. In reality, universities generally profit from the industrially oriented activities of An-Institutes and acquire additional funds through the co-operation agreements.

The various An-Institutes differ not only in their legal status, but also in the scope of their research. Some An-Institutes have narrow markets linked to a special industry, for example VLSI design for the microelectronics industry (Institut für Mikroelektronik [IMS], University of Stuttgart). Others have broad markets, for example, software systems for the manufacturing industries (Oldenburger Forschungs- und Entwicklungsinstitut für Informatik-Werkzeuge und -Systeme [OFFIS], University of Oldenburg). The institutes with broad markets normally have multiple directors. As a general rule, An-Institutes carry out research in areas close to so-called 'science-based industries' such as information technology and microelectronics.

The various legal status correspond to their diverse budget structures. In some Länder, e.g. Baden-Württemberg, the An-Institutes receive one-third from contract research for industrial clients and one-third from projects for public clients, such as the BMBF, the European Commission, the Länder and others. In this regard, the model of the An-Institutes is comparable to that of Fraunhofer-Institutes. However, many An-Institutes receive no public contribution to their institutional base and thus, depend almost totally on private and public contracts. In some cases, industrial partners provide some institutional funds.

The main problem for An-Institutes is survival in a market that is dominated by competitors from large institutions with superior organisational skills and networks (e.g., Fraunhofer-Society), more generous basic funding (e.g., large public research centres), or hidden overheads (e.g., universities). Therefore, only An-Institutes with a special competence profile, close linkages to industrial partners, and dynamic structures, have the potential for long-term survival.

The activities of An-Institutes at universities represent a considerable portion of technology transfer. In 1997, their total number of R&D personnel was about 4,500. In 1999, their total budget was 442 million Euro, 88 % of which (390 million Euro) was devoted to R&D. Assuming that at least one third of this amount was financed by industry, the industry income by An-Institutes is 13 % of the total R&D financing by industry at HEI in Germany.

Source: Abrahamson et al. (1997, 287ff), BMBF (2000)

EXIST: Promotion Programme for University-based Start-ups

The German EXIST-programme is an example of a start-up promotion from universities using a regional network approach and supporting only a selected number of projects which serve as 'best practice' examples. Through the identification of critical success factors, university start-up initiatives in other regions can use the supported projects as models. Furthermore, the 'best practice' examples should stimulate competition among HEI by providing framework conditions conducive to start-ups.

The EXIST programme has four main objectives:

- (i) to establish a culture of entrepreneurship in teaching, research and administration at HEI,
- (ii) to increase the knowledge spillover into economic value added
- (iii) to foster the transfer of business ideas and entrepreneurial potential at HEI and PSRE into real business activities
- (iv) to increase the number of technology-based enterprises and innovative services, combined with the corresponding labour market effects.

The EXIST programme started in December 1997 with the launching of a competition. The aim of the competition was to find the best concepts for achieving the objectives mentioned above by building a network of relevant regional institutions (university, public research organisations, technology transfer, firms, public authorities etc.). To qualify for participation, at least three different partners from a region had to work together, including at least one higher education institution. A total of 109 proposals for regional networks were brought to a jury which selected 12 most promising proposals. In many cases of rejected proposals, the participation in the competition was enough to start the process of networking, improving framework conditions and drawing increased attention to new firm formation as a professional option for graduates. Thus, the programme affected university start-ups even in the pre-promotion stage and without spending any public money. This effect was proved by an analysis of 47 regions.

In a second round of competition, five proposals were awarded prizes as the best regions (Wuppertal, Karlsruhe, Stuttgart, Ilmenau-Jena and Dresden). In December 1998, these five regions started the realisation of their network concepts. The approaches, starting conditions and main emphasis of the five regional networks differ widely and reflect the heterogeneity in public higher education and in regional economic structures. Each approach builds on the specific potential in the region and covers very different numbers of participating institutions (from 15 to 60). All networks have central contact agencies which give advice, help establishing contact between network members and distribute information.

The EXIST programme gives financial support for different purposes. First, the network itself is sponsored by the EXIST funds. Second, scientific support and on-going evaluation is financed within the programme. Third, countrywide publicity on activities and success within the five networks is a major mechanism for stimulating similar start-up initiatives in other regions. Forth, direct individual support to new firm founders is provided by the sub-programme EXIST-Seed.

EXIST-Seed provides support in the very early phase of new firm creation, i.e. the formulating of business ideas and the development of enterprise concepts. The target groups are students, graduates and young academic staff, either individuals or teams up to three persons. Financial support is available for start-up activities in the phase before a full business plan has been developed i.e. the focus is on encouraging the successful translation of a business idea into a business plan. Financial support covers the entrepreneurs' livelihood, the funding of consulting services, expenses incurred prior to the setting-up of a business and expenses for filing patents. A pre-requisite is that the university provides a mentor and a workplace and guarantees that the entrepreneur may use the university's infrastructure. Furthermore, the entrepreneur must be assisted by the regional EXIST network. Funding may be granted for up to one year and up to 20.452 Euro per annum for students, and 38.347 for academic staff (including a lump sum). After six months, the progress of the project is assessed by the mentor and the administrating agency of the Programme.

In 2000, a new sub-programme called EXIST-HighTEPP (High Technology Entrepreneurship Post-Graduate Programme) started. It shall improve the entrepreneurially oriented education at HEI and aims to increase the academic potential in the field of management of start-ups, and to offer a high-quality education for managers of young, technology-oriented enterprises. The sub-programme runs at three universities (Jena, Bamberg, and Regensburg) and focuses on biotechnology and information technology. A major approach is that both managers and natural scientists get experiences in the other fields, hence fostering interdisciplinary learning. The sub-programme also includes placements at companies.

Further cross regional measures are being developed by EXIST and will be open to other networks and regional initiatives, such as incentives for professors to support university-based start-ups, training for lecturers and consultants who give advice

to start-up companies, setting up and testing model structures in industrial property rights and a "virtual academy for company founders" for the target group of new media. These measures are always centred on model projects (also outside the five EXIST-networks). The results and lessons learned by the model projects are made available countrywide.

The public funding for EXIST was about Euro 7.5 million per year in the first years (1998-1999). In 2000, funding was doubled to about Euro 15 million annually. The on-going evaluation of the EXIST programme shows that there is a strong demand for start-up related qualification and further education measures in each of the five regions. In some regions, new curricula were introduced particularly dealing with new firm foundation. A network analysis in the five regions came to the result that in most regions, new network connections among the participating actors and institutions had been built up. Until the beginning of 2001, nearly 200 start-ups received support in the five EXIST regions. An especially high level of success is reported from the Karlsruhe region (KEIM) and Stuttgart region (PUSH).

Source: www.exist.de

Action Programme "Knowledge Creates Markets"

Announced in March 2001 by the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Economics and Technology (BMWi) jointly, this action programme aims to foster industry-science relations on a broad scale, by addressing various channels of interaction and stressing the important role of an appropriate incentive scheme in public science, and to increase sufficient absorptive capacities and awareness towards science on behalf of industry.

In the document, the Federal Government notices that Germany has excellent framework conditions for using the potential of the knowledge based economy, i.e. the competence in public research and enterprises are high, export performance is strongly based on the integration of high-tech in traditional products, and new firm creation accelerates structural economic changes. There is also a high willingness among science and industry to put new technological and organisational developments into practice. However, the level of interaction between industry and science is perceived to be lower than one would expect, and there is a high potential for further co-operation. Therefore, knowledge and technology transfer between industry and science must receive the highest priority in the sense of a fruitful public-private partnership. The action programmes are intended to foster these interactions by providing several types of incentives and by reforms to the framework conditions for co-operation. The programme addresses four central fields of activity:

- commercialisation of research results,
- promoting start-ups by scientists and in the field of new technologies,
- setting incentives and favourable framework conditions for transfer activities and establishing partnerships between industry and science,
- supporting enterprises in building up and strengthening their innovation competence.

The programme consists of 26 action areas, most of them comprising different individual measures:

1. Establishment of a supportive commercialisation infrastructure for universities and public research establishments in the field of patenting and licensing on a regional level.
2. A reform of intellectual property regulation for professors at higher education institutions.
3. Promoting qualification measures at universities and public research establishments in the field of patenting and research results commercialisation.
4. Providing funding for patent applications by higher education institutions.
5. Support for the introduction of a period of grace for novelties on a European level.
6. Building up communication and co-operation platforms among intermediaries in the field of technology transfer.
7. Introduction of a uniform Internet platform on science and technology, offering a one-stop information service on research activities and transfer activities in public science and research in Germany.
8. Financial and consulting support to scientists at all German universities and public research institutes, planning to create a new enterprise.
9. Creating a favourable climate for start-ups in public science institutions, including start-up labs, business angels, disseminating good practice in promoting start-ups from science, increasing the consideration of start-ups as part of the commercialisation of research results in public science institutions.
10. Introducing a general framework for improved co-operation between public science institutions and public venture capital financing institutions.
11. Enlarging the number of professorships for entrepreneurship at universities, introducing new courses with respect to the management of a start-up.
12. Increasing co-operation among public science institutions, partially by reforming the institutional affiliation of research institutes, such as the merger of the GMD research centre for information technologies with the Fraunhofer Society.
13. Incorporating industry perspectives in long-term research planning in public science, especially in the large public research centres, including a stronger programme-oriented public financing of the HGF centres (project financing instead of basic financing).
14. Promoting industry-science research co-operation also in the field of long-term oriented, strategic research, including stronger financial contributions by enterprises to more basic oriented research, and the participation of enterprises in the definition of such research activities in public science.

15. Incorporation of technology transfer within the mission of public research institutions, both within the HGF-network and Federal departmental laboratories.
16. Strengthening regional innovation networks in the New Länder, including a new measure on innovative regional growth poles and regional innovation forums which should bring together industry and science in order to develop joint innovation strategies.
17. Involving SMEs in international co-operation and thematic research programmes by offering special consulting services and by systematically exploring the barriers existing at SMEs, including a "innovation dialogue" for SMEs.
18. Systems evaluation of the public promotion of collaborative research between SMEs and public science institutions by the Federal Ministry of Economics and Technology in order to increase efficiency in this line of policy activity.
19. Increasing the ability of Polytechnics (Fachhochschulen) to engage in transfer activities (especially with SMEs) by increasing the funding for R&D at Polytechnics.
20. Increasing the individual benefits of transfer activities by scientists, including the reform of employment regulations at higher education institutions in the field of the wage system, i.e. introducing variable elements of salary, and disseminating successful models of other types of individual reward for the engagement in transfer activities.
21. Improving innovation competence at SMEs as a precondition for interactions with public science institutions by promoting the development of continuous learning mechanisms in enterprises, the strengthening of individual occupational competencies, and the introduction of network-oriented learning in SMEs.
22. Reducing information deficits in SMEs concerning the supply of training and consulting services by establishing a new Internet platform on the German education system, including all public education and training institutions in Germany. Furthermore, it is checked whether quality circles among these institutions and the evaluation of their services might reduce information asymmetries existing at SMEs.
23. Introducing innovation related issues as part of examinations for the title of masters, fostering the introduction of innovation management in education of apprentices and the training of employees in the handicraft sector.
24. Making new information and communication technologies, and electronics more available to all fields of traditional handicraft by further developing occupational and technology centres for handicraft to form a national network of thematic competence centres in certain fields of technology. Furthermore, the number of technology consultants for the handicraft will be increased.
25. Increasing the supply of vocational training courses by higher education institutions (within the new system of master courses) and support for the introduction of new education courses in the field of innovation management.
26. Accelerating the transmission of new research results into higher education courses by initiating and promoting models of a new qualification network consisting of higher education institutions, public research centres and industry. It is intended that public research centres and enterprises will complement courses offered by higher education institutions in the field of application oriented qualification.

The programme represents an example of a comprehensive policy approach towards fostering ISR, taking into account the huge variety of potential channels for the exchange of knowledge and technology. A main distinctive feature of the Action Programme is that it addresses framework conditions that guide individual decisions on ISR, such as institutional incentives and barriers, absorption capacities at enterprises, and infrastructure and platforms for bottom-up co-operation initiatives.

Implementation approach

The action programme will be implemented on the basis of individual measures. Time horizons and financing modes differ from measure to measure. There is no programme-specific budget and no central authority responsible for the implementation of all actions. Rather, a decentralised implementation approach is followed. The action programmes also take up some that exist already and which will be re-designed in the context of the Action Programme.

Source: www.bmbf.de

B.5 Ireland¹⁵

B.5.1 Knowledge Production Structures in Ireland

Ireland reports a significant increase in R&D activities. At the beginning of the 1990s, R&D expenditure as a percentage of GDP was about 0.9, while in 1997 this ratio was 1.4. In recent years, the fast growth in R&D activities has continued. Today, Ireland is in 11th place out of 26 OECD countries with respect to this indicator and this brings the country on a par with the European average.

Table B.5.1: R&D Expenditures in Ireland 1997 by Financing and Performing Sectors (in million €)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total</i>	
	<i>Enterprises</i>	<i>State*</i>	<i>Abroad</i>		<i>%</i>	<i>% of GDP</i>
Enterprise Sector	619	40	20	679	73	1.01
PSREs*	12	57	6	75	8	0.11
HEIs	11	125	37	172	19	0.26
Total (million €)	643	221	62	926		
Total (%)	69	24	7		100	1.38

* Including the very small private non-profit institutions sector.

Source: OECD (2000), calculations by the authors

The enterprise sector is by far the dominant group of actors in the Irish R&D system, performing 74 % of all R&D expenditure. In aggregate terms, R&D activity in Irish industry continued to grow during the 1990s. Total business expenditure on R&D in 1997 was €643 million or 1.01 % of GDP. In science, HEIs are twice as large as PSREs, the PSREs sector being of little relevance to the Irish R&D system (Table B.5.1). R&D at enterprises is overwhelmingly financed by the enterprise sector itself, while the government is the main funding source for HEIs and PSREs. R&D financing from abroad was rather low in 1997 but shows an increasing tendency. The financing of R&D in HEIs is mainly based on project financing, while money from the General University Fund (i.e. grant-in-aid by the Higher Education Authority) accounts for 42 % of total R&D financing (Table B.5.2). At PSREs, about two thirds of R&D money comes from basic financing via the Exchequer Fund. Both for HEIs and PSREs, the national government is the main funding source for R&D.

Table B.5.2: Financing Structure of R&D in HEIs and PSREs in Ireland 1999 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (GUF)	42	~ 65
Project Financing and other financing sources	58	~ 35
National Government	66	76
Other Sources (enterprises, internal financing, abroad)	34	24

Source: Forfás (2000), own survey and calculations by the authors

¹⁵ This chapter is based on the national report on ISR in Ireland (Evertsen 2001).

In industry, it is estimated that there were approximately 1,250 enterprises with some involvement in research and development in 1997 - of these, over 70 percent are Irish-owned and about 30 percent are foreign-owned. However, the scale of R&D activity within these enterprises is very low in many cases and particularly so for the indigenous group. Most Irish-owned R&D performers are SMEs and the absolute size of R&D expenditures is low. Therefore, Irish-owned enterprises account for only 36 % of total business R&D in Ireland, while foreign-owned enterprises are responsible for 64 %. However, the industrial and technological skills and R&D capacities are most realistically reflected by the Irish-owned sector. The foreign-owned sector enterprises benefit from their location in Ireland but obtain their primary entrepreneurial impetus and R&D capability from their countries of origin.

Furthermore, Irish-owned and foreign-owned enterprises are specialised in different industrial sectors. Foreign-owned enterprises dominate in the high-tech sectors such as pharmaceuticals, office machinery & computers, communications equipment and medical & optical equipment, while Irish enterprises dominate in the traditional sectors, including food, wood & wood products, paper and printing, non-metallic minerals and basic metals. However, average R&D intensity of indigenous manufacturing is similar to that of foreign-owned manufacturing (1.1 % versus 1.2 %). Given the different sectoral mix, this seems surprising but can be explained by the fact that indigenous manufacturing has an average R&D intensity (compared to international standards) in 'low-tech' sectors where R&D intensities are generally low, while the R&D intensity of foreign-owned 'high-tech' sectors, is low by international standards. Only one in five foreign-owned enterprises in Ireland can be described as a 'research performer'.

As Table B.5.3 demonstrates, the majority of R&D expenditures within the Irish enterprise sector are concentrated on the high technology sectors¹⁶ (46 percent), with foreign-owned enterprises as the main actors. Compared to the EU average, the share of R&D performed in low-tech sectors is rather high. There is also a significant share of business R&D carried out in 'high-tech services' such as software.

Table B.5.3: R&D Expenditures in the Irish Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in Business R&D Expenditures (in %)</i>	<i>R&D Expen- ditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	46	0.47
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	21	0.21
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	20	0.20
IT-Services (NACE 64, 72, 73)*	11	0.11
Other Services (NACE 50 to 99, excl. IT-Services)*	2	0.02

Source: OECD (2000), calculations by the authors

¹⁶ High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

Despite the large number of R&D performing SMEs, R&D activities in industry are concentrated on a small number of enterprises. Only 60 enterprises annually spend more than IR£ 1 million on R&D and together, they account for two thirds of total BERD.

Table B.5.4: R&D Expenditures in the Irish Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	32
Medium-sized Enterprises (100 to 499 employees)	57
Large Enterprises (500 to 9,999 employees)	11
Very Large Enterprises (10,000 employees and more)	0

Source: OECD (2000), calculations by the authors

Nevertheless, the SME sector is of crucial importance to ISR in Ireland. The behaviour of SMEs concerning contact and co-operation with science determines the absolute level of ISR in Ireland. However, SMEs are often said to lack absorptive capacities in order to recognise, adopt and process new knowledge and technologies produced in public science. According to different indicators on SMEs' absorption capacities as provided by the CIS2, the Irish SME sector seems to perform rather well with respect to EU standards (Table B.4.5)¹⁷.

Table B.5.5: Relative Innovation and R&D Performance of SMEs in Ireland

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.10	0.94	1.14	0.69
Innovation Expenditures as a Share of Turnover*	1.22	1.54	2.67	0.64
Share of Turnover due to Innovative Products*	1.42	1.21	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	2.38	2.03	1.29	3.55
Share of Enterprises with Medium R&D Intensity**	1.55	1.33	0.83	0.17
Share of Enterprises Engaged Continuously in R&D**	1.46	1.25	0.56	0.94
Share of Enterprises Having Applied for a Patent**	1.10	0.99	0.19	0.95

* Figures show the relation of Irish SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Irish enterprises to all EU enterprises: $(\frac{SME_{xIRj}}{SME_{xEj}}) / (\frac{x_{IRj}}{x_{Ej}})$, x being the variable considered, IR being Ireland, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Ireland to SMEs in the weighted mean of all EU countries (except Greece): $\frac{SME_{xIRj}}{SME_{xEj}}$, x being the variable considered, IR being Ireland, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

17 In order to compare innovation performance as reported in the CIS2 among EU countries, one has to take into account national variations in the way innovation was defined (see Leppälähti 2000). Therefore, innovation performance indicators for SMEs are calculated with respect to the national average and the EU average, respectively, and these ratios are compared in order to position Irish SMEs' innovation activities. With respect to R&D and patent indicators, there seem to be less serious definition biases, thus one can directly compare SME performance on a national level with SME performance on EU average.

Table B.5.5 makes clear that the share of firms that have introduced new products is above the EU average in the small firms, as is the share of innovation expenditure in turnover and the share of turnover due to new products. The share of firms with high or medium R&D intensity is above the EU average in the manufacturing sector but not in the service sector.

In Ireland, the manufacturing sector shows low R&D intensities in general, and also when compared to the OECD average in each sector. However, the share of firms with high or medium R&D intensities is above the EU average in the manufacturing sector. This evidence points to the fact that R&D is carried out in most enterprises at a low intensity, and that large, R&D intensive companies are missing in Ireland.

Research in public science in Ireland is strongly oriented towards the natural sciences and engineering (Table B.5.6). More than 60 percent of all research activities in HEIs take place in these fields, which may be regarded as especially relevant both to R&D and innovation activities at enterprises. Research in social sciences accounts for almost 20 percent of R&D expenditures in HEIs. Instead, research in the medical and agricultural sciences and humanities combined, account for only 20 percent. For the PSREs sector, no recent data is available. In 1994, about 80 % of all R&D expenditure went to the natural sciences, engineering, medicine and agricultural sciences sectors.

Table B.5.6: R&D Expenditures in the Irish Public Science Sector by Fields of Science (in %)

<i>Sector</i>	<i>HEIs (1998)</i>	<i>PSREs (1994)</i>
Natural Sciences	37	
Engineering (incl. Agricultural Sciences)	24	81
Medical Sciences	8	
Agricultural Sciences	3	
Social Sciences	19	19
Humanities	9	

Source: Forfás (2000) OECD (2000), calculations by the authors

The structure of the Irish HEIs sector is made up of Universities, Institutes of Technology (Technical Colleges) and other Third Level Colleges (Colleges of Education) (see Table B.5.7 for more detail). There are only a few PSREs in Ireland, most of which are involved in specific sectoral interests. The knowledge production at tertiary level in Ireland is based on Private and Public Institutions. Both are governed by their own Government acts. In addition, a number of private Colleges provide specialised training and education.

There are eight¹⁸ Universities in Ireland. Universities and other designated institutions are funded directly by the Higher Education Authority (HEA). The government is the main provider of HE research funds in Ireland, through both direct and indirect sourcing of funds. Indirect funds are the single largest funding source for higher education research in Ireland, accounting for 43 % of the total, but they do not provide support for incremental costs associated with individual research projects. Direct funding of research projects comes from

18 Including one Pontifical University.

government departments and their agencies (including Enterprise Ireland¹⁹, Health Research Board, the Marine Institute, COFORD (Forestry and Timber) and Teagasc²⁰).

Table B.5.7: Main Characteristics of Major Institutions in the Irish Public Science Sector (HEIs & PSRE)

<i>Institution</i>	<i>Share in Total Public Science R&D (1998)</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities	61	8 universities, including 1 Pontifical University	education and research	basic, strategic and applied research	divergent
Institutes of Technology	5	14 institutes	technological education and applied research	strategic applied research, consulting	medium to high
Technology Service Centres and PATs	8	26 centres at third level colleges	technology transfer	applied research, consulting	high
Teagasc (incl. Agriculture and Food Centres)	26	120 locations in Ireland, 9 thematic R&D centres	advisory, training, research	applied research	high

Source: Forfás (2000), compilation and calculation by the authors

There is quite a variation in the sources of research income that are received by the different fields of science. In the area of social sciences and humanities, 68 % and 85 % of their research income respectively, comes from an indirect government source. In contrast to this, the natural sciences, engineering and medical sciences are not as dependent on these indirect government funds. These three areas have seen a combined real increase of €29.3 million since 1992 from the EU and direct government sources. The monies under direct government sources have a high portion (75 % on average) of Community Support Framework funds included in them.

As the interaction with the business sector intensifies, universities are increasingly involved in applied and technical tasks. Applied research has increased by €50.9 million (125 %) in real terms since 1992 and experimental research has also increased by €12.1 million in real terms. There is a strong bias in the engineering and agricultural sciences towards the applied/experimental end of the research spectrum, with nearly 80 % of research being carried out in this area. Basic research has also increased significantly over this period by €37.2 million (81 %) in real terms, although its share of the total has decreased from 45 % in 1992 to 41 % in 1998. Applied research increased from 40 % in 1992 to 45 % in 1998.

Upon a co-operative initiative by the three universities on the Atlantic seaboard - University College Cork (NUI Cork), National University of Ireland, Galway (NUIG) and University of Limerick (UL) - the Atlantic University Alliance (AUA) was formed in May 1999. The

19 Enterprise Ireland: Agency concerned with the development of Irish Industry sector.

objective of the AUA is to facilitate the effective transfer and commercialisation of technology within industry, and between industry and university. It provides an integrated approach to assist the economies of the western, mid-western and southern regions. The aim of the AUA is to harness the collective strengths and resources of NUI Galway, NUI Cork and the University of Limerick, to facilitate innovation within companies and to meet the training requirements of industry, especially the indigenous industry within the three regions served by the Universities.

There are fourteen Institutes of Technology (IoTs) in Ireland. The IoTs represent a major development in the provision of higher technical education and play an important role at regional level in providing for recurrent educational needs by way of full-time and part-time, day and evening programmes. Institutes of Technology do not have the same track record as the Universities in supporting industry-relevant research - legislation allowing the Institutes to participate in R&D activities was only introduced in 1992. Consequently, ISR activity within the Institutes of Technology is in its infancy by comparison to the university sector - the major factor being that staff have to carry out any R&D in addition to their administrative and lecturing tasks. No allowances are made to reduce these obligations. Currently, discussions are taking place to allow a certain amount of overheads to be charged to a research project, facilitating the employment of supplementary staff to fulfil administrative and lecturing obligations. IoTs are an important partner for SMEs in innovation. TecNet is a network formed by the IoTs to promote co-operation in this respect.

There are 26 technology specific Technology Service Centres, housed in most of the Institutes of Technology and Universities around the country. These are campus-based centres, focused on specific technology areas, which provide a range of services to industry, for example: research and development, technology consulting, testing, industrial training and technology demonstration. The Centres are built on existing strengths and expertise in the colleges. There is a wide range of scientific and technological expertise available in the HEIs sector that is a valuable resource for industry. However, the full potential of the resource cannot always be realised while access to it depends on ad hoc interactions between industry and individual scientists and technologists in a college. Technology Service Centres are expected to ensure a well planned and professionally delivered service, which is responsive to the needs of industry and commercial in its approach.

The work of the Technology Service Centres is perceived as central to raising the level of innovation in Irish enterprises so that they can compete successfully in world markets. The Centres complete over 1,200 contracts every year and generate an income of around €2.5 million. Over 300 Irish-owned enterprises use the services of the various Centres each year. The Centres themselves provide employment for about 100 engineers and researchers. The public funding which each Centre receives is for a limited period only but enables them to get established and develop independent sources of income. Each Centre is expected to become

20 Teagasc: Agency concerned with the development of Irish Agriculture sector and includes the National Food Centre.

financially viable within about three years. The back up and support of their host colleges is essential to the continued success of the Centres.

The PAT (Programme for Advanced Technologies) run centres of expertise (PATs) within the Universities that provide a joint research lab facility. They are considered to have made a significant contribution to promoting spin-offs from collaborative research. The PATs are designed to manage the commercialisation of technology and ideas developed within universities.

The PSREs sector is not very relevant to the Irish research and innovation system, except to some extent in the Agriculture and Food sector. Teagasc is a semi-state body that provides integrated research, advisory and training services for the agriculture and food industry in Ireland and employs over 1,500 people at 120 locations throughout Ireland. The National Food Centre is involved with the development of food safety and food products, and the Health Research Board deals with national health aspects. Often the research at PSREs is not focused on commercialisation but their main mission is to provide public services.

In summary, the knowledge production structure in Ireland has developed well in the past decade, and Ireland has experienced a remarkable growth in R&D activities. In the main, this growth may be attributed to foreign-owned firms in high-tech sectors who used a favourable business climate to establish new production sites. Despite their high-tech orientation, the level of R&D performance by foreign-owned enterprises is lower than the EU average in these industries. At the same time, more and more indigenous manufacturing enterprises - almost all being SMEs - have become more intensively involved in R&D activities. The growing knowledge orientation of the Irish industry is faced with a rather small public science sector, the HEIs being the main R&D performer. However, universities and colleges traditionally had a strong focus on education and academic oriented basic research activities. While the education of graduates who become R&D personnel in industry remains a major contribution to industrial innovation (and the growing shortage of highly qualified personnel raises the importance of this area of ISR even more, see B.5.4), the growing demand for knowledge interaction in industry contributes to the fact that HEIs become increasingly involved in applied research and technical tasks.

B.5.2 The Level of ISR in Ireland

The level of ISR in Ireland is described by a set of indicators and assessments on the significance of various interaction channels. Table B.5.8 lists the indicators used and the main results. It also indicates those areas where ISR in Ireland may be regarded as above average with respect to EU standards. There is however, a lack of quantitative data and for many areas of ISR, the level of interaction is only available on the basis of expert assessment. While those indicators with available quantitative information (i.e. financial flows from industry to science, and co-operation in innovation projects) show Ireland's performance in ISR to be rather good, expert assessments for other channels of interaction suggest a low level of ISR.

Research co-operation between industry and universities has increased dramatically over the past few decades. Although industry still accounts for only a small share of university research funding (on average 6 percent), there has been a significant change in the traditional framework of interactions between universities, the private sector and governments. Research co-operation between industry and science is fostered by a variety of co-operative research programmes, ranging from specific collaborative research projects to specialised research centres featuring partnerships among industry, institutes and universities. Most of these programmes have been introduced by the government in recent years.

Recently, there are increasing levels of contract research in universities financed by companies. Irish HEIs finance about one third of their R&D expenditures through sources other than the national government and receive basic financing below 50 percent (see Table B.5.2), thus there is pressure to acquire additional funding from industry. In 1997, 6.4 % (in 1999, 6.5 %) of all R&D expenditures in HEIs came from industry, which is above the EU average. The small PSREs sector attracts a significantly greater share of their funding from industry (15.4 %). Within HEIs, almost half of all contract research income appears in the field of engineering, where industry's share in total R&D financing is 12.5 %.

Co-operation between innovative manufacturing enterprises and public science institutions is relatively common in Ireland. In the CIS2, enterprises stated to have co-operated in innovation projects with HEIs significantly more often than with PSREs (13.8 percent vs. 6.3 percent). Moreover, innovative manufacturing enterprises in Ireland use PSREs more often as an information source in innovation processes than the European average, while innovative Irish enterprises in the service sector rely more heavily on HEIs. As these figures are determined by the behaviour of SMEs, this points to a rather strong use of science as a source of innovation by Irish SMEs, even in the mid-1990s (to which period the figures refer to). One may expect that science links may have further increased within the last few years as a consequence of the increased effort by Irish and EU technology policy to foster such linkages.

In general, personnel mobility by researchers from science to industry is very low, as the academic would perceive this as possibly compromising their career in the academic institution. This is because research (and research outputs such as number of publications and post graduates) is rewarded heavily in the promotion of the faculty while working with industry has a low significance in awarding promotions. Graduate exchanges have been very positive at some HEIs as a result of the co-operative education programme and actually creates researcher retention difficulties. Industry mobility into research is low due to high salary differences between science and industry. Temporary transfer from industry to science appears to be on the increase but this may only be due to faculty shortages in science in 'high-demand' areas such as information and computer technologies. In contrast, industry does not appear to attach a great significance to teaching at colleges as part of contributing to the academic curriculum.

Vocational training by HEIs for the industry researcher and other highly qualified personnel was low in Ireland for a long time, mainly because of a low demand by the indigenous

industry which is specialised in traditional, 'low-tech' sectors. With an increasingly high-tech orientation during the last decade, the interaction between industry and science in regard to matching supply and demand for highly qualified labour has strengthened, including activities in the field of continued professional development, but ISR in this area is still in its infancy.

The use of IPR by public science institutions in Ireland, both in regard to patent applications and royalties from IP, is supposed to be low. There are no quantitative indicators available however. In the case of collaborative R&D projects involving both public science institutions and enterprises, individual arrangements based on formalised agreements are common. Often, the enterprise receives the ownership of IP. With the growth of the software industry in Ireland, copyright issues receive increasing attention in science too.

Table B.5.8: Indicators and Assessments of ISR in Ireland at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (1997, Source: OECD-BSTS)	R&D financing by industry for HEIs in % of HERD	6.4
	R&D financing by industry for PSREs in % of GOVERD	15.4
	R&D financing by industry for HEI/PSREs in % of BERD	3.4
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	low
	Significance of R&D consulting with firms by PSRE resear.	low
Co-operation in Innovation Projects (1996, Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	13.8
	Innovative manuf. enterprises co-operating with PSREs in %	6.3
	Innovative service enterprises co-operating with HEIs in %	3.6
	Innovative service enterprises co-operating with PSREs in %	2.5
Science as an Information Source for Industrial Innovation (1996, Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	5.0
	PSREs used as inform. source by innov. manuf. enterpr. in %	7.4
	HEIs used as inform. source by innov. service enterpr. in %	5.8
	PSREs used as inform. source by innov. service enterpr. in %	2.1
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in %	low
	Share of researchers at PSREs moving to industry p.a. in %	low
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	low
Vocational Training (Source: national statistics, assessments)	Income from vocational training in HEIs in % of R&D exp.	medium
	Number of vocational training participants in HEIs per 1,000 R&D employees at HEI	medium
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in NSEM	low
	Patent Applications by PSREs per 1,000 employees in NSEM	low
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	low
	Royalties in % of total R&D expenditures at PSREs	low
Start-ups from Science (Source: national statistics, assessments)	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	low
	Number of technology-based start-ups at PSREs per 1,000 R&D personnel	low
Informal contacts and personal networks (Source: national statistics, assessments)	significance of networks between industry and HEIs	low
	significance of networks between industry and PSRE	low

* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD, surveys and calculations by the authors

Also, there are no statistical data on the number of start-ups by researchers from HEIs or PSREs. Assessments by national experts suggest the level is rather low. Nevertheless, the general mind-set on IPR and spin-offs from research has changed both within the public science sector and industry. Therefore, a growing use of this type of ISR may be expected in the coming years.

The development of long term relationships and stable networks based on personal contacts between a HE department and an enterprise, is seen as a major element for raising the efficiency and effectiveness of ISR, as transfer of knowledge and technology often demands intense communication on a personal level, the establishment of confident relations and trust between the partners involved. In the past, such networks have been less significant than in many other countries, mainly due to industrial structures, the strong academic orientation of HEIs, and a lack of specialised PSREs. In recent years, networking seems to have gained importance in Ireland too.

In summary, data on ISR in Ireland is scarce and expert assessment reports a low but growing level of interaction between enterprises and public science institutions. The rather low level of ISR corresponds to the knowledge production structure, i.e. an Irish-owned enterprise sector specialised in low- and medium tech areas, a foreign-owned enterprise sector importing the bulk of R&D used in Irish production from the corporation's headquarters from abroad, and a small public science sector in terms of R&D expenditures as a percentage of GDP. However, the Irish government pursues a strategy to upgrade the technology orientation of industry by various promotion programmes, especially by providing additional money for R&D activities both for industry and science. As a result, ISR are becoming more important in recent years, and a continuation of this policy is expected to strengthen industry-science links in future even more.

B.5.3 The Policy-related Framework Conditions for ISR in Ireland

Cultural Attitudes: Due to the dominance of traditional, small-scale manufacturing in the Irish economy over many decades, demand for ISR was low in industry. Consequently, there was no tradition in HEIs to get intensively involved in ISR. Furthermore, evaluation criteria in HEIs still strongly focus on scientific performance while technology transfer activities to industry are rated lower. In the PSREs sector, commercialisation of research results has a rather low priority too. The general mind-set with respect to ISR is undergoing a significant change today however. Awareness for technology transfer has improved in HEIs, with a large increase in applied research activities being a prominent indicator for this process.

IPR-Regulation: Currently, there are no global regulations which govern intellectual property rights issues in the case of collaborative research between industry and HEIs. However, these are under development. In public science, IP as a result of research belongs to the organisation and individual researchers do not receive any special compensation for their invention activities, e.g. they do not get any royalties from patents licensed to other parties. In the case of collaborative R&D between enterprises and public science institutions, formal agreements are generally entered into as part of the collaboration. The agreement conditions are mainly institution specific and are adjusted to company requirements. The current approach to IPR is seen as very positive by the HEIs whilst industry has expressed some reservation and find it a factor which may restrict ISR. Policy makers and ISR support groups do not consider the current IPR situation to be adverse however, and do recognise that

some formalisation is required. One aspect of any regulation is that academia fully understands and applies such agreements, whilst focusing on R&D.

Over the last decade there has been a distinctive shift in emphasis from patenting to copyright owing to the growth in the software development industry in Ireland. Consequently, there is a need for greater availability of expertise to deal with legal issues pertaining to software development. A perceived lack of adequate protection of a range of copyright IPRs, including legislation to counter copying of computer programs/software, protect databases and ensure recognition performing rights, particularly in the arts, has motivated the introduction of a new Copyright & Related Rights Bill 1999. It substantially updates Irish Copyright law to take account of the many changes that have taken place, particularly in relation to technological developments, since the last substantial piece of Copyright legislation in 1963. The Bill also consolidates and modernises most of the previous legislation and gives effect to a number of European Directives which have not yet been implemented in Ireland. The legislation also gives effect to some international obligations arising as a result of the WIPO Copyright Treaty and the WIPO Performances and Phonograms Treaty of December 1996. The scope of the Bill will be of interest to a wide range of persons in industrial sectors however. It should be of particular interest to the computing, internet and other high technology industries (including the E-commerce community) as certain provisions of the Bill address important copyright issues for these industries which have, to date, not yet been addressed by the legislature. The Bill also provides for new rights which will transform the conduct of Intellectual Property right holders and connected industries. These new rights include the following: rental and lending rights; database rights; satellite broadcasting and cable retransmission rights; moral rights for authors; and making available right.

There are no regulations governing the mobility of researchers from science to industry, and neither is it an issue of any significant concern. The new full-time recruitment restrictions as dictated by government policy can adversely affect the employment of industry researchers into HEIs. In the case of the IoTs, a more flexible contract for Institutional academic staff to facilitate their involvement in industry-relevant R&D is essential. Currently, the lecturing obligations of staff in the Technological Sector are between 16-18 hours per week for 35 weeks. There is no scope for a reduction of hours for supervision of other classifications of research personnel or for academic staff members to carry out research and development work themselves. There are no formal policies within the Higher Education sector that support the mobility of staff between industry and the Institutes of Technology. Indeed, the recent Labour and Employment Agreement (PCW) that introduced recruitment at Assistant Lecturer Level only (except in proven exceptional cases), actively discourages Institutes from releasing more senior staff members since many of the Institutes are experiencing severe difficulties in recruiting high quality lecturers for their full-time programmes at Assistant Lecturer grade in the current economic climate.

Financing-related regulations: The current level of tax relief, i.e. a non-tax relief, does not provide an added incentive to industry to engage in ISR. The major incentive for ISR collaboration is currently provided through the provision of co-finance of ISR collaboration

by Government Departments and Agencies. The income-tax-free status of IP royalties is currently a bonus for both the HEIs and industry researchers. However, public service employees involved in R&D do not receive royalties and cannot therefore, benefit. At the moment, this is not an apparent disincentive to research at the public research institute, Teagasc, for instance.

Technology Policy: Since the late 1950s, Ireland has pursued an activist industrial development strategy aimed at both attracting foreign direct investment and stimulating growth in export-oriented Irish-owned companies. The strategy has been focused on the internationally traded sector and thus, mainly on manufacturing, although since 1990, internationally traded services have played an increasingly important role. During the 1990s, this policy showed a shift towards technology policy with the main aim to transform the traditional Irish economy into a knowledge-based economy, and by doing so, raising income and wealth. Together with a significant support by the EU structural policy programmes, some remarkable success was achieved. Such a policy produced a favourable environment for enterprises and public science to strengthen their R&D activities, including closer links between both sectors. For the next decade, this process should be accelerated. In 1999, the Irish government decided to earmark about € 2.5 billion for research, technology and innovation activities as a cornerstone of the National Development Plan for the period 2000 to 2006 (see B.5.6.).

Public Promotion Programmes: The provision of public financial support is seen both as a significant and effective stimulant to collaborative R&D between HEIs and industry. Financial support programmes are operated by various state agencies. With the exception of Enterprise Ireland, all of these are sector focused. Table B.5.9 summarises major aspects of those programmes most relevant to foster ISR in Ireland, and more detail is provided below.

- The Research Technology & Innovation Scheme (RTI) provides financial support to enterprises for carrying out R&D and technological innovation. The scheme has proven invaluable in the past when the share of public contribution was very high (up to 40 - 50 %). With a current contribution of 25 to 45%, the RTI scheme is regarded as a good scheme as far as encouraging ISR is concerned.
- The Innovation Partnerships programme (formerly the Applied Research Grant Scheme) provides a major incentive for industry to develop collaborative research activities with Irish universities and IoTs. It facilitates industry to have applied and innovative research carried out in HEIs on industry's behalf. The current approach is viewed as satisfactory, and its major strength is seen in the high percentage of public funding available (up to 75 %).

Table B.5.9: Major Public Promotion Programmes in the Field of ISR in Ireland

<i>Name of Programme (responsible authorities)</i>	<i>Public Fun- ding (million)</i>	<i>Period</i>	<i>Main Approach</i>	<i>Type(s) of ISR Mainly Addressed</i>
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	€ 1999)			
Research Innovation Fund (Enterprise Ireland)	4.5	2000 - 2006	funding of commercially oriented strategic R&D in colleges	pre-collaborative research
RTI (Enterprise Ireland)	25.3	2000 - 2006	funding of R&D and innovation projects at enterprises	contract research
Innovation Partnerships (formerly "Applied Research Grant Scheme") (Enterprise Ireland)	3.1	2000 - 2006	subsidies to colleges for R&D carried out jointly with HEIs	collaborative research
R&D Technological Skills Programme Strand 1 (HEA)	n.a.	n.a.	strengthening R&D at IoT	training & education, personnel mobility, contract research
TecNet (Technology Network)	0.33	1999 - 2001	facilitating partnerships between IoTs and enterprises	technology transfer, consulting, contract research
CORD (Enterprise Ireland)	2.7	2001, annual repeat	funding for start-ups from HEIs by financing feasibility studies and business plans	start-ups
Atlantic University Alliance (Enterprise Ireland)	0.33	1999 - 2001	raising absorptive capacities at SMEs by providing consulting and training services	technology transfer, start-ups
Technology Centres Programme (Enterprise Ireland)	~ 3.5	1999 - 2000	establishing intermediary infrastructure in HEIs for technology transfer	technology transfer, consulting, training, testing
Programme for Advanced Technology (7 Programmes) (Enterprise Ireland)	72.5 (from 2000 on: ~ 103)	1995 - 2000, extended to 2006	establishing centres of expertise at universities, providing technology transfer services and joint research labs	collaborative research, technology transfer, IPR use
Regional Business Incubation and R&D space	4.2	2001 - 2006	establishing incubators at IoT	start-ups
Techstart (Forbairt)	n.a.	1998 - 1999	funding for implanting technology and engineering expertise in SMEs	raising absorption capacities at SMEs
Techman (Forbairt)	n.a.	1998 - 1999	funding for implanting technology and engineering experts in SMEs	raising absorption capacities at SMEs
COFORD (Govt. Dept. of the Marine and Natural Resources)	6.4	1995 - 2000, extended to 2006	Funding of R&D in forestry and timber research	technology transfer, personnel mobility, contract research
Marine Institute (Govt. Dept. of the Marine and Natural Resources)	n.a.	2000-2006	Funding of R&D in marine and fisheries research	technology transfer, personnel mobility, contract research

Source: surveys and calculations by the authors

- The R&D Technological Skills Programme Strand I has a similar focus to the Applied Research Grant Scheme, although the latter has an increased emphasis on the provision of highly trained research graduates in advanced technological areas that industry requires to become and remain competitive. However, it does not insist on an industrial monetary contribution and is specifically focussed on building research capability within the Institute of Technology sector. The programme provides research and development training for graduates for the specific purpose of promoting development capability and thus, advancing links between HEIs and industry. Specific emphasis is given to industrially relevant research projects or projects which are filling a gap in the research knowledge.

- Another programme is the Technology Transfer Initiative under the aegis of the Atlantic University Alliance, which aims to promote and develop new ways of interacting between academia and industry, to build sustainable competitive advantage for industry and to establish new high tech campus companies. The Initiative will target 1,400 enterprises across the southern and western regions. About two thirds of these companies are classified as "Standard Technology Companies", and the need for innovation and the potential for growth are high. The Technology Transfer Initiative will help these firms by putting the routes in place for technology information and acquisition, identifying barriers to university-industry co-operation and putting together regional and sectoral networks of firms.
- TecNet - The Technology Network - was established in 1999 by the Council of Directors of the IoT and is jointly funded with them by Enterprise Ireland. The primary objective is to provide industry with comprehensive R&D, consulting services and technology transfers by utilising the skills and facilities available within the IoT sector. TecNet can support SMEs by providing a mechanism through which industry can tap into the IoTs' resources and specialised expertise on a networked basis to stimulate ISR and economic growth. When companies need to undertake projects requiring external expertise, TecNet can facilitate a partnership between the Institutes and local industry for their mutual benefit. This provides a framework for exploring and identifying needs and developing and refining solutions (based on personal communications between scientists and SMEs).
- Enterprise Ireland operates a dedicated programme "CORD" for start-ups from HEIs. The programme provides funding for the setting up of start-up in the form of financial support for a feasibility study and a business plan. The annual budget assigned to this programme €0.6 million. The average grant issued (50 % of the total cost) is generally €19,000. During 2000, 30 projects were approved and implemented 10 % of which are expected to materialise into High Potential Start Ups (HPSU) companies. In addition, further soft financing is provided by the supplementary financing of assigned mentors, and support for IPR and marketing.
- There are several policy initiatives to build up an effective technology transfer infrastructure at Irish HEIs. The Technology Centres Programme has built up the technical services infrastructure by establishing 26 technology specific Technology Service Centres in most of the IoTs and universities around the country. The Technology Centres Programme supports campus based centres, focused on specific technology areas, which provide a range of services to industry, for example: R&D, technical consulting, testing, industrial training and technology demonstration. The Programme for Advanced Technologies (PAT) run centres of expertise within the universities that provide some joint research lab facility and can support university researchers in managing the commercialisation of technology and ideas. In January 2001, a new support initiative was launched Regional Business Incubation and R&D space. This programme is, in particular, directed at Institutes of Technology in an effort to promote ISR. It will be operational until 2006 and has an assigned budget of €25.4 million. It is expected that approximately 10-

incubation units will result from this programme leading to the setting up of HPSUs. The provision of support for these intermediary structures and facilities are regarded by both academia and industry to be of significant importance and effectiveness to promote ISR.

- Techstart and Techman were two government programmes operated by Enterprise Ireland during 1989 - 1999 with the objective of supporting the introduction and implementation of technology into SMEs in particular. Both support programmes provided the company with access to skills and technology / engineering resources. The requirement for the expertise was identified in a detailed strategic development plan for the company. Both programmes are outlined in more detail below:
 - Techstart was aimed at companies, which had outdated or limited technological expertise. It provided assistance to employ a young technical graduate or diploma holder who could bring more relevant skills to the company. Furthermore, it also aimed to provide financial support for the placement of the graduate by linking this expert to an external source of expertise upon which they could draw for advice and assistance, e.g. a college or technology centre. The programme provided a 50 % employment subsidy of up to €6,348 and a further €2,500 to buy technical expertise from a college or other resources. The financial support was annual for a maximum of two years.
 - Techman aimed to assist SMEs with good development potential to make significant technological advances by: (1) the placement of a technically qualified person to carry out significant work in key areas in the company; and (2) supporting an effective working link between the company and an appropriate college or research centre. Under this initiative, co-funding was provided on a sliding scale over a three-year period. During year one, 50 % of the graduate's salary was funded up to a maximum of €12,700. During year two and year three, up to a maximum of €6,350 and €3,200 respectively. In addition, a further subsidy of up to €6,350 was provided for external consulting.

Intermediaries: The support for an intermediary structure is regarded to be of great significance to promote ISR and is considered to be effective in ISR promotion. Several dedicated initiatives have been set up specifically targeting Universities, Institutes of Technology and Industry, as follows:

- C.H.I.U. (Conference of Heads of Irish Universities) represents the Heads of the seven Irish universities. It aims to promote the development of university education and research by formulating and pursuing collective policies and programmes. A joint Council of the C.H.I.U. and IBEC (Irish Business and Employers' Confederation) was established, to develop and promote co-operation in areas common to enterprise and universities to the benefit of each sector, the economy and social and cultural life in Ireland.

- Enterprise Ireland is a government organisation charged with assisting the development of Irish enterprise. Its core mission is: "to work in partnership with client companies to develop a sustainable competitive advantage, leading to a significant increase in profitable sales, exports and employment". The clients are mainly Irish manufacturing and internationally traded services companies employing ten or more people, and overseas food and natural resources companies operating in Ireland. Enterprise Ireland also administers national and EU supports for building technological innovation capability and co-operation between industry and higher education educational institutions. The development is carried out both at national and regional level on behalf of both the Government Department of Enterprise, Trade and Employment and the Office of Science and Technology. Through the regional office network of 13 offices, individual SMEs are assisted in their development in a structured approach, amongst which R&D and technical development is included. Assistance is provided in the form of financial support and advisory / consultancy.
- The Industry Research & Development Group (IRDG) is the lobby group for research, development and innovation-oriented companies in Ireland. It is a company limited by guarantee with its own board of directors and is entirely funded by member's annual subscriptions. IRDG is an affiliate of The Irish Business and Employers Confederation (IBEC) and the IRDG chairman is a member of IBEC's National Executive Council. The Group includes companies of all sizes, Irish as well as Foreign-owned, in all manufacturing sectors. The main objectives of the Group are to identify the needs of members, to advise and assist them on research and technology development matters and to lobby Government, Government Agencies and the EU on their behalf.
- Most of the Institutes of Technology and universities have established Technology Service Centres. These are campus-based centres, focused on specific technology areas, which provide a range of services to industry, for example: research and development, technology consulting, testing, industrial training and technology demonstration. They are supported via a special programme (see above). Furthermore, there are centres of expertise at each university financed via the Programme for Advanced Technologies (PAT). They provide some joint research lab facility and supportive services for the commercialisation of technology and ideas developed within universities. In addition, each HEIs set up an Industrial Liaison Office to facilitate ISR activities. The "Head of Development", a senior management post, is responsible for the overall strategic development of research within each institute. The Industrial Liaison Officer, reporting to the Head of Development, is responsible for promoting and developing collaborative links with industry.

B.5.4 ISR in the Field of Human Capital in Ireland

In Ireland, the interaction between industry and science in regard to matching supply and demand of graduates is only in its infancy, as industry has only become more high tech oriented during the last decade. Very few university academic staff have had real industrial

experience, and indeed, very few industrially based engineers and scientists contribute to university programmes.

In general, faculty personnel mobility is very low from science to industry, as the academic would perceive this as possibly compromising their career in the academic institution. This may be due to the rewarding system in HEIs: research (and research outputs such as number of publications and post-graduates) is rewarded heavily in the promotion of faculty while working with industry has a low significance in awarding promotions. Furthermore, representatives from public science report that difficulties in the portability of pensions may restrict mobility. In the HEI sector, there is a view that the academic staff contracts should be reviewed in order to permit the employing institutions to provide incentives for participation in ISR.

Graduate exchange has been very positive at some HEIs as a result of the co-operative education programme and actually creates researcher retention difficulties. Industry mobility into research is low due to salary differences between science and industry. Temporary transfer from industry to science appears to be on the increase but this may be only due to personnel shortages at science in 'high-demand' areas such as information and computer technologies. In contrast, industry does not appear to attach great significance to teaching at colleges being a part of contributing to the academic curriculum. There are well-developed programmes for undergraduate student placement in industry but in general, there is limited mobility at post-graduate or researcher level. The PATs and the Applied Research Programme has had some impact. Funding from the EU Framework Programme has helped to forge links with mainland EU based enterprises but there has been limited mobility in the view of experts.

Sabbaticals to industry are not considered to be very attractive to researchers. There is little incentive for mobility between industry and HEIs as there is often a collision of cultures, and the longer one spends on either side the more difficult it is to transfer, even on a temporary basis. There is also the 'out of sight out of mind syndrome' i.e. if one moves off campus, or lab she/he may be forgotten about and overlooked for promotion etc. It appears that people choose early in their career, which direction to take after which, there is no movement. The sponsorship of academic chairs by industry only has a limited significance in enhancing ISR in Ireland today.

In the promotion of ISR in the field of education, training and mobility, various measures are currently discussed in Ireland in order to ensure effectiveness. The development of a longer-term relationship between industry and science would be regarded as the most important factor. This could be supported through an improved co-ordination between science and industry to obtain a better understanding of industry needs and through vocational education programmes for industry in HEIs. Structures to support both the matching of industry skills requirements and the hiring of graduates in industry, could provide a significant ISR incentive. Until recently, Enterprise Ireland operated such promotional programmes,

Techman and *Techstart*. Both these programmes provided financial incentives to companies to employ new graduates.

There is a high demand for graduates in the IT sector as well as in other fields of natural sciences and engineering. The so-called Science & Technology graduates experience very good job opportunities and significantly higher salaries than graduates from other disciplines. Given the buoyant job market in Ireland at present, it has become increasingly difficult for HEIs to attract highly qualified graduates to undertake postgraduate programmes and step into a university career. Consequently, more consideration needs to be given to repositioning research as a career. Furthermore, the share of S&T students and graduates is rather low (Table. B.5.10), and activities to raise awareness in favour of these studies may be required.

Table B.5.10: Higher Education by Disciplines in Ireland 1998/99 (in %)

<i>Field of Study</i>	<i>Students</i>	<i>Graduates (degree awarded)</i>
Natural Sciences	19	18
Engineering	9	9
Medicine	13	11
Agricultural Sciences	2	2
Social Sciences	24	26
Humanities and others	33	34
Total number (1,000)	98.6	22.4

Source: HEA (1999), calculations by the authors

As a result of the high industry demand for high-qualified labour in Ireland today, unemployment among HE graduates is low. A recent survey shows that among the HE graduates from 1999, only 1.5 % was seeking employment in 2000. More than 50 % gained employment and about 40 % carried out further studies or training.

B.5.5 ISR in Ireland: A Summary Assessment by Type of Interaction

Contract and collaborative research: In 1999, 6.5 % of all R&D expenditures by HEIs were financed by industry as contract or collaborative research. In the small PSREs sector, industry financing of R&D is even more important and accounts for 15 % of total R&D expenditure. A major driving force for joint research activities is public financial support to enterprises for R&D activities. A major restricting factor for research collaboration is the small size, strong academic orientation and the absence of world-class research capability in the Irish public science system. Technology-based industries increasingly expect public authorities to put such capabilities in place i.e. to provide the fundamental science from which they will generate the next generation of products. At present, research expenditures in public science institutions amount to 0.4 % of GNP. There is considerable scope to increase this level of investment so that growth in public R&D complements the required increases in business sector investment in R&D. Quite recently, the government proposed the establishment of €63 million to develop a world-class research capability in the niche areas of information and communications technology and biotechnology.

Personnel mobility, training and education: Personnel mobility from science to industry is reported to be low in Ireland. There are some regulatory barriers in public science but cultural differences and the lack of incentive schemes for researchers in HEIs and PSREs, may be the more important factors. In the area of training and education, there seems to be only little co-operation, and both industry and science representatives feel that interactions should be strengthened in this area. Human capital development is becoming increasingly important in Ireland with the rapid growth of the IT industry. A shortage of graduates has led to an increase in wages for S&T graduates. Increasing differences in salaries for researchers in public science and industry may drive mobility from science to industry, but it may also weaken the position of HEIs in attracting talented young researchers to academic careers. In the long term, one may fear a weakening of the science base, with a negative feedback to industry.

IPR science, start-ups from public science: Today, the use of IPR by public science plays a minor role for disseminating their research results and for producing spin-offs. A major reason may be the current IPR regulation, which does not foresee any special compensation to individual researchers out of incomes from inventions they made. Start-ups by public science researchers are also reported to be low. In this area, some policy initiatives have been established in order to raise awareness of this type of commercialisation of research results, and to reduce barriers to new firm formation by scientists.

Networking between industry and science: There is little evidence of well-established networks of enterprises and public science institutions in Ireland. Maintenance of such networks demands certain resources in enterprises which are often only available at large companies (such as separate R&D departments, and a high share of researchers). As such, large R&D intensive companies are absent in Ireland, along with industry-science networks. In HEIs, no specific networking activities with enterprises (such as membership of enterprise representatives in advisory boards, alumni, joint research labs, professorships to industry R&D managers, and researcher exchange programmes) are reported.

Involvement of SMEs in ISR: R&D in Ireland is carried out, to a large extent, by SMEs. R&D activities by SMEs have increased significantly over the past few years, promoted by several policy initiatives. Today, the SME sector performs rather well in terms of continuous R&D, patenting and innovation, when compared to EU standards. They present a growing potential for interaction with science. With respect to the HEIs, the TecNet, the Atlantic University Alliance and similar regional networks attempt to foster partnerships between SMEs and HEIs in innovation activities.

Science-based industries: High-tech industries are the main R&D performer in industry, and this sector showed the highest growth rate in R&D investment during the 1990s. However, the bulk of high-tech R&D activities is carried out by foreign-owned enterprises with rather loose ties to the domestic public science sector. The low level of ISR in the field of science-based industries is as a result of comparably low in-house R&D capacities in enterprises (as foreign-owned companies mainly carry out technology and further product development

tasks, rather than more fundamental R&D and new product development), and of a weak knowledge base in the high-tech sector in public science, compared to international standards. To foster linkages in this area is a major goal of Irish technology policy. Policies have been put in place to address those areas where public intervention is most needed, and to set up the capabilities at enterprises and HEIs for closer interaction.

B.5.6 Good Practice in Framework Conditions for ISR in Ireland

Amongst others, there are two examples of good practice in shaping policy-related framework conditions for ISR in Ireland. The first example refers to policy initiatives aiming at a promotion of start-up activities in HEIs, which are fairly low today. The second example is the National Development Plan 2000-2006 and other strategic technology policy initiatives introduced by the Irish government. They represent a successful way of how to increase R&D, innovation and industry-science links in an economy with an initially low level of R&D activities.

Third Level Business Incubation Programme

Aims and Objectives of the Programme

Internationally, the college campus has been identified as an ideal location for high-tech, start-up companies. Through the Third Level Business Incubation Programme, Enterprise Ireland aims to expand the base of high-tech companies operating on college campuses by providing funds to assist colleges to develop and expand incubation space facilities. The main objectives of the programme are

- to support the development and expansion of campus company activity
- to strengthen the role of the Third level Sector in supporting the development of high-tech companies in Ireland
- to encourage and support the commercialisation of R&D carried out in the Third level sector
- to recognise the important regional role which colleges can play.

Enterprise Ireland will provide grant support towards the capital costs associated with the development of a campus incubation centre, to a maximum of £ 1.3 million or 40 % of eligible capital costs, whichever is the lesser.

Internationally, the college campus has been identified as an ideal location for high-tech, start-up companies. Two new programmes have been put in place to facilitate the establishment of Incubation Space on the college campus, the *Third Level Business Incubation Programme*, and the *Regional Business Incubation Space Programme*.

Third Level Business Incubation Programme

This programme commenced in 1998, is aimed at the Universities and Institutes of Technology and is financed by Enterprise Ireland. It aims to expand the base of high-tech companies operating on college campuses by providing funds to assist the college to develop new incubation facilities or the expansion of existing operations. To date, three of seven universities have availed of the programme and are starting to develop the incubation units.

Grant support is available towards the capital costs associated with the development of a campus incubation centre, to a maximum of £ 1.3 million or 40 % of eligible capital costs, whichever is the lesser. Priority will be given to proposals offering a broad range of services and comprehensive solutions to the specialist problems faced by high technology start-ups and which catalyse significant new private sector support. Projects should lead to the expansion of the high tech sector in Ireland and result in enduring private sector support for campus company activity.

The main objectives of the programme are:

- to support the development and expansion of campus company activity
- to strengthen the role of the Third level Sector in supporting the development of high-tech companies in Ireland
- to encourage and support the commercialisation of R&D carried out in the Third level sector
- to recognise the important regional role which colleges can play.

Regional Business Incubation Space Programme

The National Development Plan 2000-2006 identifies balanced regional development as a key objective to be achieved over the period of the Plan.

The Operational Programmes for each region, BMW and Southern and Eastern, contain a sub-programme on Local Enterprise Development. The objectives include enhancing the quality and availability of employment within the Region and building research and technological development within the Region generally. The main elements are concerned with strengthening the regional innovation infrastructure by facilitating the provision of incubation and commercial R&D space for the development and establishment of high potential businesses, with a particular emphasis on the role of the Institutes of Technology. In particular, the Regions and sub-regions remote from the major urban Centres the Institutes of Technology are the main agents for delivering growth through innovation. The programme is administered by Enterprise Ireland through its Regional Innovation Infrastructure Measure. Funds will be available to Institutes of Technology to develop and expand incubation space and commercial research and development facilities.

The main objectives of the measure are:

- to support the development and expansion of campus company activity
- to encourage and support the commercialisation of R&D carried out in the Institutes of Technology

- to embed the Institutes of Technology as major supports for the development of high-tech companies in the Regions.

The programme will commence in early 2001 and support is available to all Institutes of Technology and equivalent 3rd level colleges in Ireland and it is expected that by 2006, all Institutes will have an Incubation Centre installed. Institutes can apply for assistance towards the development of new industrial incubation and R&D facilities or the expansion of existing operations. The measure will provide up to a maximum of Euro 2.5 million towards the costs associated with the development of a campus incubation and commercial R&D Centre with a maximum funding level up to 95 %. In all cases, it will be expected that the remainder of the costs will be raised by the applicant from business sources within the region.

Research, Technology and Innovation in the Irish National Development Plan 2000-2006

In 2000, the Irish Council for Science and Technology and Innovation (ICSTI) completed a Technology Foresight exercise and identified a wide range of actions aimed at advancing science and technological innovation, knowledge development and R&D in Ireland in future years in the interests of social and economic development. Key recommendations of the Council included: the need to create world-class research groups in information and communications technologies and in biotechnology, and the need to develop a national capability for innovation management. Research and Development has a critical role to play in developing the competitiveness and innovation capacity in the enterprise sector. Further measures are required to be developed to increase collaboration between industry and the HE system. As not all firms will be R&D performers, a "technology intelligence" network should be developed, to help firms define and access their technology needs from both domestic and overseas sources.

The *Technology Foresight Report* and further research by Forfás, identified the absence of a world-class research capability as a serious deficiency in the Irish research system. Technology-based industries increasingly expect public authorities to put such capabilities in place, to provide the fundamental science from which they will generate the next generation of products. R&D facilities that respond to the immediate and medium-term needs of industry are essential. A science and technology infrastructure that will develop and attract world-class researchers in niche areas, needs to be a policy priority. At present, expenditure on research and development in higher education and Government institutes amounts to 0.5 percent of GNP. There is considerable scope to increase this level of investment so that growth in 'public' R&D complements the required increases in business sector investment in R&D.

Employment and human resource development have received considerable funding under the new *National Development Plan 2000 - 2006 (NDP)*. The NDP considers people to be the country's most important asset and will invest almost Euro 51.5 billion to increase their employability and adaptability, encourage entrepreneurship and promote equal opportunity. The NDP attempts to balance concerns about the need to upgrade the skills of those in employment, while also addressing issues of social inclusion, gender mainstreaming and elimination of inequalities. The Irish Government has earmarked Euro 5.725 billion for Research, Technological Development and Innovation (RTDI) activities in the National Development Plan 2000-2006. The Science Foundation of Ireland (SFI, a sub-board of Forfás (The National Policy and Advisory Board for Enterprise, Trade, Science, Technology and Innovation)), is responsible for the management, allocation, disbursement and evaluation of expenditure. This newly formed Foundation reflects the Irish Government's decision to put research, Technological Development and Innovation at the heart of the future economic development policies. Furthermore, it is the Government's objective to establish Ireland as a centre for research excellence. Initially, specific preference will be given to the Biotechnology and Information & Communication Technology sectors. In summary, the key recommendations in relation to the promotion of science, technology and innovation are as follows:

- establish a Technology Foresight Fund under the National Development Plan 2000 - 2006;
- establish a 'technology intelligence' network to help non-R&D performing firms define and access their technology needs;
- promote the development of strategic collaborative partnerships between industry and public science institutions;
- provide more focused direct support for in-company R&D to encourage first-time R&D performers, to help smaller firms achieve a critical mass in R&D investment, and to help firms progress up the R&D capability ladder to become world-class R&D performers;
- to realise national goals with respect to science and technology, the following targets should be adopted and achieved:
- expenditure on R&D in manufacturing to increase from 1.2 percent of sales at present to exceed the OECD average of 2.4 percent by 2010;
- expenditure on R&D in Government and higher education institutes to increase from 0.5 percent of GNP at present to 1 percent by 2005.

A new EU-supported investment programme should complement the National Development Plan in the field of Research, Technological Development and Innovation (RTDI) by focussing on the following four areas:

- (i) RTDI for Industry e.g. support for R&D, innovation training and the collection and dissemination of technology intelligence in firms
- (ii) RTDI Collaboration involving industry, third-level colleges and public research institutes at home and abroad
- (iii) RTDI Infrastructure including public investment in key technologies, skills and research facilities to strengthen the national research capability and the ability of colleges and institutes to collaborate with industry

(iv) Natural Resource based-RTI for the development and improved competitiveness of the natural resource sectors.

Within this wider comparative framework, available data would suggest that Ireland should aim to achieve a level of spending on R&D equivalent to 2.5 % of GDP. This would mean additional public investment of the order of 254 million Euro per year. Future public sector R&D expenditure profiles, including both increases and decreases, should be developed on a sector-by-sector basis as an intrinsic part in achieving the development objectives for each sector and the prioritisation of resources for this purpose.

In order to implement the national strategy as set out under the 'Science and Technology' Budget', the various agencies (e.g. HEA, Enterprise Ireland, and SFADCO), have a portfolio of specific programmes to target focused investments into collaborative research, development of spin-off enterprises, setting up of company in-house R&D infra-structure and facilities, technology transfer and training of personnel.

B.6 Italy²¹

B.6.1 Knowledge Production Structures in Italy

Between 1990 and 1998, a negative rate of growth in R&D expenditure can be recorded in Italy. The 1998 value of R&D expenditure is equal to 1.02 % of GDP, ranking Italy on the bottom line together with Spain, Portugal and Greece, in Europe. Compared with the EU, it can be said that in the last decade, Italy started with a low value for R&D expenditure in relation to GDP (1.3 %) and ended the decade with a further increase of this gap. In 1998, R&D expenditure as a percentage of GDP, had fallen to about 1 %.

Table B.6.1: R&D Expenditures in Italy 1998 by Financing and Performing Sectors (in million €)

<i>Performing Sector</i>	<i>Financed by</i>			<i>Total</i>		
	<i>Enterprises</i>	<i>State*</i>	<i>Abroad</i>	<i>million €</i>	<i>%</i>	<i>% of GDP</i>
Enterprise Sector	4,579	776	477	5,833	54	0.55
State*	59	2,211	44	2,313	21	0.22
Universities	129	2,564	23	2,717	25	0.25
Total (million €)	4,767	5,551	545	10,863		
Total (%)	44	51	5		100	1.02

* including private non-profit institutions

Source: OECD (2000), calculations by the authors

In 1998 (as in previous years), 54 % of R&D in Italy was carried out by the business enterprise while the remaining 46 % was carried out by the public sector (universities 25 % and public research institutions 21 %). In 1998, 13,3 % of R&D activity in the business sector was financed by the public administration through incentives, contributions and procurements (in 1995, it was 16.5 %). The quota of financing coming from abroad was 8 %. In industry, the Italian business enterprises have financed less than 4.8 % of the 2,717 million € for R&D carried out at universities. Overall, the Italian business enterprises contribute 44 % of the total national intramural R&D investments and this means that in Italy (compared to the OECD countries), the research activity is strongly supported by the public sector. A survey carried out by ISTAT reveals that in 1998, apart from carrying out research activity directly, enterprises designated 18 % (1,051 million €) of the expenditure for the intramural research, to extramural research.

R&D financing in public science is, by and large, based on general, institutional funding (see Table B.6.2). It is estimated that in HEIs, about 90 % of the total R&D expenditures are financed via the general university fund, provided by the central government. No detailed

²¹ This chapter is based on the national report on ISR in Italy (see ASTER 2001). Compared to other countries, the information concerning ISR-related topics is scarce, and there are almost no statistics on the level and structure of interactions between enterprises and public science institutions for the different channels analysed. Therefore, discussion in some sections of this chapter is less detailed than for other country sections.

data on the relation between institutional and competition based project financing, is available for the PSREs sector but institutional funding is the major source for R&D too.

Table B.6.2: Financing Structure of R&D in HEIs and PSREs in Italy 1995 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (GUF)	~90	n.a.
Project Financing and other financing sources	~10	n.a.
National Government	> 90	n.a.
Regional Governments	< 5	n.a.
Other Sources (enterprises, internal financing, abroad)	6	4

Source: OECD (2000), own survey and calculations by the authors

In Italy, the manufacturing sector covers a central role in the production of wealth and employment. If the added value production and employment are taken into account, the most important sectors in the field of manufacturing are traditional sectors such as textile, agro-industry and mechanical. 13 % of the employees are employed in the textile and clothing sector, which counts for 10 % of the value-added. Although the importance of textile has decreased in terms of both the numbers of enterprises and employment levels, it is still a very competitive sector and maintains the leadership in the international market, due to strong specialisation. Within the enterprise sector, R&D expenditure is concentrated therefore, on technology sectors outside the narrow high-tech sectors. The major part of R&D takes place (more than 50 % of all R&D activities) in sectors which are technology-driven but not in exclusively high-tech sectors. The weight of furniture (NACE 36), textile and leather (NACE 17-19) is quite high in Italy which leads to the high share of these sectors in the category of manufacturing sectors.

Table B.6.3: R&D Expenditures in the Italian Enterprise Sector by Sectors 1995

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.2)	34	0.19
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	41	0.22
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	12	0.07
IT-Services (NACE 64, 72, 73)	9	0.05
Other Services (NACE 50 to 99, excl. IT-Services)	4	0.02

Source: OECD (2000), calculations by the authors

SMEs represent a huge proportion of Italian enterprises - enterprises with less than 50 employees represent 99 % of the total. Thus, the Italian system is characterised by a twofold system. On the one hand, there is a small number of big industries operating in the small scale intensive sector with high intensity of R&D, and on the other, there is the SME system, operating in traditional sectors as subcontractor to big enterprises. From a structural point of view, R&D carried out by business enterprises is, therefore, mainly concentrated in the segment of large firms where approximately 80 % of the expenditure for R&D is in fact, supported by companies with at least 500 employees, while business enterprise with less than 100 employees, contribute to R&D expenditure for only 4 % of the total. The R&D

expenditure is therefore, quite concentrated in a handful of enterprises in Italy: the first 30 business enterprises absorb 53 % of the R&D expenditure, the first 50 enterprises 63 %, and the first 100 enterprises, 75 % of the total.

Table B.6.4: R&D Expenditures in the Italian Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	4
Medium-sized Enterprises (100 to 499 employees)	16
Medium-sized to Large Enterprises (500 to 999 employees)	15
Large Enterprises (1,000 to 9,999 employees)	~15
Very Large Enterprises (10,000 employees and more)	~50

Source: OECD (2000), own calculations

This high concentration of R&D performers in Italy is reflected in the results of the recent CIS II innovation survey. According to an input measure such as innovation expenditure or share of innovative enterprises, it can be seen in the following table that the share of small and innovative enterprises in Italy, is above the European average, whereas the share of small enterprises measured with R&D related items, lies below the average. This exhibits a very clear-cut picture in Italy. Industrial innovative processes consists of the purchase and use of embodied technologies (machinery etc.) while the other components, such as R&D activity, play a relatively minor role within the small and medium enterprise sector. Small enterprises have a high propensity to innovate by acquiring machinery and plants against the greater propensity of large firms to internally generate new technologies. This is hardly surprising since R&D is an innovative source which requires a minimum threshold and does not capture the innovative effort typical of small firms. But when a much more comprehensive indicator, such as total innovation expenditure, is considered, it emerges that innovative small firms are not substantially disadvantaged.

Table B.6.5: Relative Innovation and R&D Performance of SMEs in Italy

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.07	1.04	n.a.	n.a.
Innovation Expenditures as a Share of Turnover*	1.32	1.31	n.a.	n.a.
Share of Turnover due to Innovative Products*	1.15	1.12	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	0.29	0.37	n.a.	n.a.
Share of Enterprises with Medium R&D Intensity**	0.88	0.66	n.a.	n.a.
Share of Enterprises Engaged Continuously in R&D**	0.71	0.91	n.a.	n.a.
Share of Enterprises Having Applied for a Patent**	0.96	0.96	n.a.	n.a.

* Figures show the relation of Italian SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Italian enterprises to all EU enterprises: $(\frac{SME_{x_{ITj}}}{SME_{x_{Ej}}}) / (\frac{x_{ITj}}{x_{Ej}})$, x being the variable considered, IT being Italy, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Italy to SMEs in the weighted mean of all EU countries (except Greece): $\frac{SME_{x_{ITj}}}{SME_{x_{Ej}}}$, x being the variable considered, IT being Italy, j being the sector considered (i.e. manufacturing and services),

and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, own calculations

Currently, there are 71 universities in Italy employing about 57,000 personnel. 57 universities are public and 14 are private. In addition, 3 polytechnics, 3 post graduate courses and 10 ISEF exist, which results in a total of 87 institutions. Out of the R&D personnel in the university sector, 25 % are ordinary and extraordinary professors, 28 % are associated professors, 35 % are researchers and assistants, and 12 % can be subsumed under the category of 'Others'.

After years of neglect, university research, both fundamental and applied, has undergone a complete renewal in Italy:

- New procedures have been introduced to evaluate and select research projects of national significance which are wholly computerised and will be the responsibility of a Committee of Guarantors, appointed by the Ministry, with the direct involvement of the national and international scientific community (anonymous referees and objective assessments and financing criteria);
- Progressive increase in the funds made available by the State for research projects.

The vast majority of Italian scientific universities are of public nature. The private ones are mainly involved in socio-economic issues, such as Bocconi and Cattolica universities in Milan (the former is focused on economic and business administration degrees, the latter on human sciences, economic and management topics). In the few cases where private universities deal with scientific topics, they behave very similarly to the public ones and they operate within the framework of co-operation agreements with the public system. This is the reason why it is not really relevant to distinguish between public and private universities - each university regulates their relations with industries, as each is free to define their internal norms and procedures.

Taking into account the distribution of research personnel in science in Italy, the majority are strongly oriented towards social sciences and humanities. Nearly 40 % of R&D personnel are employed in these fields which is rather high within this context compared to other countries. Only 18 % and 16 % of R&D personnel are employed in the fields of natural science and engineering, respectively. With regard to ISR, the public research sector does not exhibit a strong orientation towards these sectors, which is especially relevant to R&D and innovation activities at enterprises. Compared with the HEIs, the PSREs are more strongly oriented towards industry-relevant fields of science.

Table B.6.6: R&D Personnel in the Italian Public Science Sector (HEIs, PSREs) by Fields of Science (in %)

<i>Sector</i>	<i>HEIs (1995/96)</i>	<i>PSREs (1994)</i>	<i>Total</i>
Natural Sciences	18	~70	~64
Engineering	16		
Medical Sciences	22		

Agricultural Sciences	5		
Social Sciences	18	~30	~36
Humanities	21		

Source: Isrds-CNR, own calculations

The distribution of R&D expenditure among the different research activities is quite stable. In 1997, basic research absorbed 22.2 % of the total, 43.7 % was destined for applied research, while experimental development absorbed the remaining 34.1 %. Basic research is mainly concentrated in the Public agencies of research (CNR, INFN, etc.) and in universities. In business enterprises, such activity is much more limited, not exceeding 3 % of their R&D expenditure. Experimental development is, on the contrary, strongly evident (with a quota of 55.1 % of their R&D expenditure). Business enterprises invested approximately 2.9 billion € in experimental development in 1997, and 3.3 billion € in 1999 (estimate).

Related to the R&D quota, the Italian expenditure for basic research was equal to 0.24 % of GDP in 1997 (in 1993, the value was 0.26 % of GDP) with an incidence of enterprises equal to 0.01 %. Compared with France, USA or Japan, basic research in Italy shows worrying structural weaknesses. Basic research in Italy is undersized and practically non-existent in the enterprise sector.

In Italy, a large number of organisations are spread all over the country and act as intermediaries between the industrial and the science sector. However, the majority of them have a spread-out regional dimension and collaborate with firms on a local scale and with non-homogeneous approaches.

On a national level, institutions with this role are indeed, very few. Amongst them, there are two main public centres working in the field of research and technology transfer, namely:

- National Research Council (CNR)
- National Body for Energy, Environment and New Technologies (ENEA)

For CNR, its main role is to carry out - through its own different branch offices and institutions - advanced, fundamental and applied research and to implement and promote research activities in collaboration with university research and with other public and private actors. Nearly 7,500 researchers are employed in CNR. The recent reform of the Italian public research system has included CNR and the Decree n. 015446 regulates the setting and functioning of CNR's institutes, which defines the new autonomy in defining contents and objectives of research activity.

The institutes are entitled to carry out research, technology transfer and training activity, namely basic and applied research carried out with reference to the institutes specific interests, and in collaboration with other public or private research centres.

The new organisation of CNR foresees the realisation of plans on a three-year-basis, with an annual update, defining the directions, the objectives, the priorities and resources on the basis

of the new National Research Programme and the European Union Programmes. The plan and the updates will have then to be approved by the Italian Ministry of University and Scientific and Technological Research.

It is also interesting to note that the reformation also includes new legislation for the employment and training of new researchers and technologists, foreseeing the possibility of having 3-year-contracts renewable only once, and after a positive evaluation based on international parameters. Indefinite employment contracts are possible but only thorough open tenders and for candidates with a research post-graduate diploma or having already worked for CNR with a 3-year-contract.

Table B.6.7: Main Characteristics of Major Institutions in the Italian Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities	~ 53	57 public and 14 private universities	education and research	mainly basic research	low
Polytechnics and other HEIs	~ 1	6 polytechnics and post-graduate courses	education	applied research	low
CNR	~ 14	several independent research institutes	advanced, fundamental research; research, training; management of national research programmes	basic and applied research, technical and scientific support to public administration	medium to high, highly varying among institutes
ENEA	~ 8	large research centre with 11 branch offices	applied research	support innovation processes; technology transfer	links with industries, associations and service centres
INFN	~ 4	40 research Units and laboratories	applied research on the physical properties of atomic, molecular and condensed matter systems	applied research	links with industries and universities
others	~ 20	several government agencies and departmental institutes	research, R&D related public services	divergent	divergent, rather low

Source: Isrds-CNR, compiled by the authors

ENEA is one of the largest Italian scientific and technological state-owned institutions (with about 4,000 employees) with a specific mission of technology transfer and dissemination of information to companies. It is a wide-spread organisation at national level thanks to its 11 branch offices and several specialised laboratories and service centres, which are mostly oriented towards specific industrial areas such as ceramic, textile, new materials, chemical, environment, etc. However, started in the 1980's, ENEA has been working in the field of

technology transfer and innovation promotion for many years. It has been directly engaged in technology transfer to industrial systems and the territory, as a reaction to the need to change objectives after the national referendum which endorsed the end of nuclear research and nuclear energy production.

ENEA has strong links with a large number of institutions, active both at local and sector levels such as industries, associations, Chambers of Commerce and services centres. Along with other organisations in NorthEast Italy, it is also has a leading role as a member of the Innovation Relay Centre IRENE, which is connected with 52 European centres and is the National Focal Point and National Awareness Partner of the EC Impact programme. Thus, the involvement of this institution in technology transfer activity and ISR promotion is evident.

The huge variety and number of organisations and actors, acting as intermediaries between industry and science, represents a valuable resource in the national system. This is true even if there is a risk that efforts and results may be kept within individual relationships but would be better exploited if systematised and spread to a wider audience.

For this reason, a major effort is actually carried out by some Italian regions to create regional technology transfer and research networks involving all interested actors (companies, technology centres, public administrations, universities, etc.). The aim is to build a common methodology and system and to create common tools which allow the exchange and sharing of information (a strong example is Emilia Romagna).

B.6.2 The Level of ISR in Italy

Contract research between science institutions and industry is very low and quite below the European average. Thus, the overwhelming share of the university funding is public. The predominance of the public sector in the funding of higher education R&D is correlated with a modest involvement with the business enterprise sector. Only 3.8 % of HERD is financed by industry. Thus, according to OECD data, the level of interaction between science and the business sector is very low and enterprise funded R&D in universities is of minor relevance. However, the results of the CIS-II show an even worse result. According to this survey, only 2.5 % of innovative enterprises in the manufacturing sector co-operate with universities, and 1.3 % of innovative manufacturing enterprises co-operate with PSREs. It can be concluded that the links between science and the industry sector in terms of contract research, as well as co-operation within the innovation process, have a low intensity.

Concerning the different information sources, Italy is below the EU average as well. At the EU level, 5 % of innovative manufacturing firm use the university sector as an important information source, whilst the share is 1.7 % in Italy. Survey research by ISTAT and CNR shed some light on the sources of innovation within the industry sector. The results confirm that innovation is primarily based on influences from inside the firm or group driven by

feedback from clients, conferences and trade fairs, while information from universities and research and consulting centres plays a very marginal role.

Research mobility from science to industry is, according to general assessments, very low in Italy although some rationalisation of laws in 1999 have tried to increase the effectiveness of co-operation and stimulate the recruitment of graduates by SMEs. This is a fiscal incentive for the employment of graduates in the industry sector. Italian SMEs employ quite unqualified personnel and they do not typically employ people with university degrees or doctoral degrees. They face difficulties in acquiring and using new technologies, in moving into technologically more advanced sectors, in participating in R&D projects or investing in R&D themselves.

The Law no 196 focuses on the employment of professionals with Laurea or doctoral degrees, in research activities by SMEs. It allows for a contribution of 20,000 Euro per year for a maximum of two years, for each new employee with a doctoral degree obtained in Italy or abroad, and a contribution of about 8,000 Euro per year for a maximum of two years, for each new employee with a Laurea degree. The maximum contribution granted to each firm cannot exceed about 30,000 Euro. The new employees must be employed on full time contracts lasting for at least two years, and their salary should not be lower than the average salary of people with the same professional qualification. The funds made available in 1998 amounted to about 2.84 million Euro. In the first year of enforcement of Law 196, MURST has received 137 requests for doctoral degree holders and 246 for Laurea graduates.

Law N.449/97 has the same objective as Law no. 196. It aims to encourage the employment of people with Laurea or doctoral degrees by SMEs but the incentive takes the form of a tax credit of 7,750 Euro per each new employee, up to a total of 60 million Lire (31,000 Euro) for each beneficiary firm. In the first year of enforcement of Law 449, firms have made 368 requests to MURST for employees with a doctoral or Laurea degree. Altogether, Laws 196 and 449 can allow Italian SMEs to employ more than 600 highly qualified personnel with a modest financial effort.

Law N. 449 introduced an additional measure which allows firms to apply to universities or other public research institutions to second researchers as technical personnel to the firm for a period that cannot exceed four years. The individual keeps his/her employment relationship with the university or research institution, while the firm is asked to provide additional compensation as an incentive.

The above law allows firms to use the fiscal incentive to pay for R&D projects carried out on their behalf by public research laboratories. This scheme has the objective of fostering co-operation between industry and public research institutions in a more effective way than the one envisaged by Law 46/1982, which established a directory of public laboratories available to provide R&D services, but which is rather unsuccessful.

Up until now, some obstacles have affected the application of this mechanism, such as: the difficulties in identifying individual competencies within public research agencies and universities to be made available to firms; the appropriate regulatory framework to be adopted; only a modest part of the research carried out in public research institutions may have direct industrial application; and scarce interest in many 'public' researchers and industrial business initiatives.

Table B.6.8: Indicators and Assessments of ISR in Italy at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % of HERD	3.8
	R&D financing by industry for PSREs in % of GOVERD	3.0
	R&D financing by industry for HEI/PSREs in % of BERD	3.2
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	low
	Significance of R&D consulting with firms by PSRE resear.	low
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	2.5
	Innovative manuf. enterprises co-operating with PSREs in %	1.3
	Innovative service enterprises co-operating with HEIs in %	n.a.
	Innovative service enterprises co-operating with PSREs in %	n.a.
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	1.7
	PSREs used as inform. source by innov. manuf. enterpr. in %	1.6
	HEIs used as inform. source by innov. service enterpr. in %	n.a.
	PSREs used as inform. source by innov. service enterpr. in %	n.a.
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in %	low
	Share of researchers at PSREs moving to industry p.a. in %	low
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	low
Vocational Training (Source: national statistics, assessments)	Income from vocational training in HEIs in % of R&D exp.	low
	Number of vocational training participants in HEIs per 1,000 R&D employees at HEI	low
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in NSEM	low
	Patent Applications by PSREs per 1,000 employees in NSEM	low
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	low
	Royalties in % of total R&D expenditures at PSREs	low
Start-ups from Science (Source: national statistics, assessments)	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	low
	Number of technology-based start-ups at PSREs per 1,000 R&D personnel	medium
Informal contacts and personal networks (Source: national statistics, assessments)	significance of networks between industry and HEIs	low
	significance of networks between industry and PSRE	low

Sources: Eurostat, OECD, own surveys

The role of vocational training is minor in Italy as well. According to expert interviews, teaching by firm employees at universities, and vocational training programmes for industry measured as income as a percentage of R&D expenditure, do not play significant roles.

Patent application by Italian firms is extremely low and patent application in science is even lower. A study carried out by the EU underlining the relationship between high-tech patents and the number of inhabitants per million, exhibited a quota of 4.2 in Italy, which is "definitely inferior" to that of most EU countries. For Finland the quota is 69.9 and for

Germany 23.9²². Universities are hardly engaged in any patent activities, while there is some patenting at technically oriented PSREs.

During the last few years, Italy has been showing an increasing awareness regarding the need to increase the knowledge and information available on resources, competencies and technical-scientific organisations operating at the national and regional level. Following successful EU experiences (such as CORDIS and more recently ERGO), the efforts 'to map' the technical and scientific competencies and to diffuse information have multiplied also at national and regional level.

As far as the specific field of information provision is concerned, at national level the Institute for Research and Scientific Documentation (ISRDS), was the result of a strategic project developed by CNR (the National Research Council), aimed to support collaboration between the scientific research and the industrial worlds. Under this project, the creation of the Technology Transfer DataBase (BDTT) was developed and includes about 9,000 informative forms on scientific research projects. This activity has involved the whole national scientific community by sending a questionnaire to about 15,000 researchers working for universities and research bodies, requesting to make public the results obtained, the eventual possible future developments, the licences achieved, and the companies or economic sectors to be involved. In order to optimise the practical use of BDTT, all collected forms have been classified under the scientific and economic codes (application sectors). At the moment, the database is available online at the address <http://bdti.ipzs.it/bdti/bdti>.

As far as the regional level is concerned, one of the most successful experiences is Emilia-Romagna VERNE Network, which represents a unique experience in the national context. VERNE (the Virtual Emilia Romagna Network for the European Research) was born by the joint efforts of the Universities of Bologna, Ferrara and Modena, the Emilia Romagna Regional Government, the Industrial Association of Bologna Province, ASTER, Irene Innovation Centre (ENEA-CNR) and the Regional Entrepreneurial Forum. VERNE has the objective of providing to the industrial world, a better visibility of the research competencies available within the universities, favouring the development of joint research projects, in particular, promoting the participation of regional enterprises, labs and universities, to the European Union Framework Programme for Research and Technological Development.

With this aim in mind, VERNE created a database - following the CORDIS example - by collecting information on research projects carried out by the three universities belonging to its network, as well as on research and technology transfer projects implemented by public and private bodies and funded by the Emilia Romagna Regional Government. By the end of 1999, 1,000 research projects were present on the database www.aster.it/verne.

Internet diffusion at all levels has allowed the discovery on the web, of a huge amount of information on research activities and on competencies and tools available in the different

22 Linee Guida del Piano Nazionale della Ricerca, March 2000.

organisations. On the web sites of universities, CNR institutes, ENEA centres and private labs, more and more information is available, despite, very often, in an unstructured way and with some updating problems.

Within this framework, the objective of creating a single database or a single information system which houses information on the different organisations, is a difficult goal to achieve. The direction pursued is to develop some interfaces for the search of information allowing simultaneously access to the different information sources through "knowledge management" systems.

B.6.3 The Policy-related Framework Conditions for ISR in Italy

A debate on the regulations related to intellectual property rights is currently going on in Italy in the framework of the attention dedicated to research and development and specifically, ISR related issues. At the highest level, there is also the intention by the national Government to set up a specific Patent Agency in the forthcoming period. As for intellectual property rights protection related to research results coming from universities and public research bodies, no specific regulation exists at the national level, and general national and international norms must be applied. As such, each university and research body is free to regulate the attribution of the intellectual property right and other details related to this issue, by an internal regulation. Therefore, each body carries out its own 'patent policy' and decides autonomously if and when to register a new patent and how to exploit it. These regulations refer to inventions or any other innovation that can become a potential patent, and when a researcher or professor uses the equipment and financial resources belonging to the University in order to carry out their research. They usually contain details on principles relating to scope and procedures, role of the researcher, composition, competencies and functioning of the internal Patent Commission, patent related expenses, economic exploitation, sharing of profits between subject(s) owing the paternity of the patent object, and the university patent fund.

Concerning regulations related to joint R&D projects and contract research, no specific regulations govern relations between research organisations and enterprises but ad hoc contracts and agreements exist which are set-up according to the situation (subjects involved, type of activity, etc.). In other words, each research organisation (university, research centre, etc.) has developed its own set of 'contract forms' and the current reform of universities and public research centres is confirming this autonomy. In general terms, the reform process that interested the national research system, assigning more autonomy to research organisations, has also created the legal framework for the elaboration of specific contractual forms.

The year 1999 witnessed the approval of Law no. 297 whose main aim is to promote ISR by supporting scientific and technological research, by diffusing technologies and by encouraging the mobility of researchers. The activities financed by the this law range from the creation of spin-offs to employment of graduates, post graduates or research students, in firms of various dimensions. An important role is also given to mobility with regard to

researchers. Through this law, research centres, universities and enterprises are encouraged to work together to promote and apply the country's technological development.

The Official Journal n. 201 dated 27th August 1999, publishes the Legislative Decree no. 297 of the 27th July 1999 called: "Reorganisation of the Discipline and simplification of Procedures for the support of Scientific and Technological Research, for the diffusion of Technologies and for the mobility of Researchers". With such a measure, the Ministry of University and of Scientific and Technological Research has concluded the reform of the National system of Research.

In fact, the reorganisation and simplification of the instruments of intervention in support of Industrial Research (Law no. 46/82, no. 488/92, and others) was one of the main aims of the proxy process. The final objective of this proxy was to allow the System of National Research to give a more efficient response to the needs of development and modernisation of the national industrial reality and, as a consequence, of the Country.

In effect, the complex and stratified regulations concerning support to Scientific and Technological Research which began in 1968 with Law no. 1089, and proceeded with subsequent Laws, (no. 46/82 and no. 488/92 in particular), often led to duplications and useless overlapping. The time had come for a profound re-organisation which also addressed the need for simplification.

The approved legislative decree includes in its objectives the creation of a more favourable context for investments in research. This would involve industrial subjects of any dimension, though the processes of research and development should involve in particular, and more than before, the world of SMEs, their being the heart of the Production System.

Among the activities which are able to receive funding according to the new law are the well-known forms of intervention (independent projects, and projects submitted on the base of calls for proposals), including those which support employment and mobility in the field of research, which saw an experimental start in 1998 and proved to be, in general terms, very successful. New and important forms of funding are also included and, for instance, specific interventions with the aim of building new technology-based enterprises (business start up, spin off, etc.). This could also include funding for risk capital.

The subjects who can have access to these interventions are identified in a clear and simple way and efforts have been also made to facilitate the concrete possibility for University and Public Research Organisations to work and co-operate with enterprises in presenting research projects. In fact, the restraints, which previously forced enterprises and public research bodies to create complex consortia, have been eliminated - it will now be possible to present projects jointly without having to create any particular association. The law makes it possible for enterprises and university/research bodies to present joint projects, as long as the enterprise is prepared to give a financial contribution of 51 % (30 % for activities to be carried out in regions lagging behind).

The rationalisation of procedures enabling easier access to funds is also related to the fact that all interventions refer to the same fund and are subject to the same forms of management. Moreover, in order to avoid the repetition of interventions with the inevitable dissipation of resources, a new concrete activity carried out jointly with the Ministry of Industry is in the pipeline, and aims to provide users with a service similar to a unique help desk.

This Decree has been effective since the beginning of year 2001. Its adoption determines the final abolition of the previous laws, and provisions that are now still in force and effective.

Table B.6.9: Major Public Promotion Programmes in the Field of ISR in Italy

<i>Name of Programme (responsible authorities)</i>	<i>Public Funding p.a. (million €)</i>	<i>Main Approach</i>	<i>Type(s) of ISR Mainly Addressed</i>
Special applied research fund (MURST)	n.a.	grants for industrial research and/or pre-competitive development projects	vocational training, R&D co-operation, technology transfer
Employment in the field of research (MURST)	18.6	support for temporary placement of graduates in research projects, temporary secondment of public science researchers and technicians, contribution to the social charges of graduates who replace the personnel seconded	personnel mobility, recruitment of graduates
Support for the promotion of scientific culture	n.a.	support for activities which aim to promote scientific and technological culture ("cultural week on science and technology")	awareness building
Autonomous research projects in the regions lagging behind	154.9	grants for industrial research and/or pre-competitive development projects in Objective 1, 2 and 5b areas (94-99)	collaborative Research
Research centres in the regions lagging behind	187	support for the establishment of new research centres and the restructuring, enlargement, de-localisation of existing centres in underdeveloped areas	contract research, strengthening the research base
Measures aimed at sustaining innovation	122	tax incentives for industrial research and development	contract research, absorption capacities of SMEs
Research assignments to public research laboratories. Employment of researchers by SMEs (MURST)	n.a.	encouraging SMEs to employ graduates and to give contract research to PSREs through tax credits	contract research, personnel mobility
The reorganisation of the regulation and the simplification of the procedures: the Fund for Research Support	n.a.	reorganisation of the regulation and simplification of the procedures in the field of scientific and technological research, technology diffusion, mobility of researchers (institutional, organisational, financial, fiscal, budgetary)	personnel mobility, start-ups, legislation
Reorganisation and new establishment of PSREs (MURST)	n.a.	decrees that provide the public research bodies with new rules, establishing of new PSREs	institutional setting for ISR, expansion of research base
Large research projects	5.16 (total budget)	grants for large industrial research and/or pre-competitive development projects	expanding the research base at industry
Reordering of the promotion bodies and establishment of Sviluppo Italia SpA	n.a.	Sviluppo Italia is the national development agency, created in 1999 in order to enable Italy to promote its activities and to ensure that the states full potential is known to the international marketplace. Its mission focuses on three areas: regional promotion, investment attraction, development of	awareness

Community Support Framework Objective 2000- 2006 (PIA)		sectors with a high degree of technology	
	n.a.	stimulating enterprises to present a single multi-annual programme of development to obtain grants from different sources; new programme management model (single point of reference), enterprises can get grants for a number of purposes through a single application (acquisition of equipment, setting-up of networks, purchase of services and consulting, joint infrastructures), PIA represents a priority tool for the improvement of the environment for entrepreneurial activities and simplifies bureaucracy	networking, consulting
Agreement Sviluppo Italia (MURST)		support to professors, researchers, students who are interested in developing and marketing the results of their own research activities (free consulting services for the project and start-up phase), experimental programme involving the universities Federico II (Napoli), Sannio (Benevento), Lecce and Catania	start-ups
	n.a.		

Source: Trend Chart project, own surveys and calculations by the authors

As a result of the little significance of ISR in Italy at the end of the 1990s, major innovation actors are now showing an increasing awareness regarding the fundamental importance of the relations between industry and the research world. Given the low level of R&D, Italy has recognised that particular effort would be necessary in order to prepare the economy for the knowledge based economy, i.e. the growing importance of generating new knowledge and transferring it rapidly into new products, services and processes. In order to increase its resources, competencies and technical-scientific potential on the national and regional level, a seven-year National Programme of Research was announced in May 2000. This programme foresees major increases in expenditure on R&D in the period 2000-2006, both by government and industry. Table B.6.10 reports the main quantitative objectives of the programme with respect to R&D financing by the state and industry.

Table B.6.10: The Italian National Programme of Research: Main Quantitative Objectives on R&D Investment

Year	Public (in bio. €)		Private (in bio. €)		Total			Financing Share in Total	
	amount	increase to previous year	amount	increase to previous year	amount in million €	increase in %	in % of GDP	public in %	private in %
2000	6.71	0.00	5.16	0.00	11.88	0.0	1.03	0.57	0.44
2001	8.78	2.07	5.42	0.26	14.20	19.6	1.23	0.62	0.39
2002	9.81	1.03	5.80	0.38	15.62	31.5	1.35	0.63	0.37
2003	10.85	1.03	6.38	0.58	17.23	45.0	1.49	0.63	0.37
2004	11.36	0.52	7.28	0.89	18.64	56.9	1.62	0.61	0.39
2005	11.36	0.00	8.66	1.38	20.02	68.5	1.74	0.57	0.43
2006	10.85	-0.52	10.74	2.08	21.58	81.7	1.87	0.50	0.50

Source: Guidelines of the National Programme of Research, May 2000

R&D expenditure as a percentage of GDP should continually increase until 2006 to 1.87 %, i.e. the EU average. In this year, the state and the private enterprise sector should contribute the same share to total R&D financing. In 2001 to 2003, the government plans to enlarge their R&D appropriations by rather enormous amounts, while industry is expected to increase R&D investment dramatically from 2004 onwards. If Italy meets these ambitious goals, it would show a similar take-off as that of Finland in the 1980s and Ireland in the 1990s. In this case, framework conditions for ISR in knowledge production structures will change significantly and will then provide a much more favourable knowledge market environment for co-operation and knowledge interaction between enterprises and public science institutions, than is the case today.

In the coming years, there will be further major changes to policy-related framework conditions in Italy due to a regionalisation process that has been going on for some years now. The process implies, amongst others, the delegation of functions and administrative tasks regarding interventions in favour of industry, from central government to regional governments and local bodies, including innovation and technology transfer programmes.

B.6.4 ISR in Italy: A Summary Assessment

In Italy, the debate concerning ISR is strictly linked to the ongoing change of the national research system and is presented in the "Guidelines of the National Research Programme". The discussion lead to the identification of the clear need for a guiding role, specialising in systematic monitoring of national development conditions within the Human, Technology and Organisation areas.

As for universities, in common with almost all other countries, both public and private universities exist in Italy, but they differ greatly in terms of autonomy, funding mechanisms, etc. However, the most important thing to be underlined for public universities is the fact that they are now in the middle of evolution determined by the recent overall reorganisation of the national education and training system. Within this framework, between 1996-1999, a consistent and general innovation process of the Italian university system has been activated.

Where public research centres - CNR and ENEA - are concerned, these two, together with others, belong to the national science research system (including, amongst others, another major body, namely ASI Agenzia Spaziale Italiana - Italian Spatial Agency) and are undergoing a reform process too. On the basis of the Legislative Decree n. 204 of 5 June 1998, *ad hoc* legislative decrees were issued at the end of January 1999 for CNR and ENEA, including provisions to increase their operational and financial autonomy.

This situation greatly affects all ISR related issues. The various reforms are all directed towards strengthening ISR, putting in place new simplified procedures, new important financial and non-financial supporting measures, and more focus on this issue being considered as a central one for enhancing social and economic growth and the modernisation of the country. At the same time however, this very moment is a 'bridging' one, between the

old and new situation, and therefore, it is still premature to elaborate data and make assessment on the efficacy of the new tools.

In the past, Italian State support for innovation in firms has mainly been financial, in the form of incentives and facilitation, and to a minor extent, towards network oriented policy. This policy has not always been effective however, due to the overlapping of a number of initiatives which have been applied without any overall strategic plan. These shortcomings have been compounded by irregularity of the financing.

An important review and rationalisation activity of the complex and stratified legislation supporting the scientific and technological research has been carried out with the Legislative Decree no. 297 of 27th July 1999.

Scientific and technological research support started in 1968 with law n. 1089 and continued with further laws, in particular laws 46/82 and 488/92. The new law no. 297 overcomes the duplication and overlaps which, although difficult to understand, do occur, particularly by those actors less equipped from an organisational point of view, such as SMEs. Law no. 297 can be considered as a true, unified, single reference foreseeing a wide and organic panorama of activities to be financed and providing a clear and simplified identification, both of the beneficiaries and of the possible facilitating tools. For the latter, interventions also aimed at setting up new economic initiatives with a high technological content are now foreseen, both supporting the spin-offs of the research public network and favouring the commitment of venture capital.

Furthermore, an idea, which is not exclusively formal, with the Italian Ministry of Industry, Trade and Small Enterprises is foreseen with the aim of providing final users with a 'one stop shop' presenting their needs and requests, enabling them also to avoid overlaps of activities and dispersion of resources.

Finally, regarding the evaluation of interventions, the Ministry is now obliged to activate overall evaluation procedures - besides the daily monitoring - on the real impact of investments, with the support of the Guidance Committee for Research Appraisal (CIVR) also.

B.6.5 Good Practice in Framework Conditions for ISR in Italy

The Italian government attempts to promote ISR through different mechanisms. One major approach is to foster regional networks and ISR on a regional base. In the following, three recent examples of such initiatives are presented:

- The promotion of ISR by the regional government of Emilia Romagna via the establishment of ASTER as an intermediary agency aiming to foster regional co-operation.

- The STARTECH programme, aiming towards fostering structural changes in high-technology areas in the Mezzogiorno, laying special emphasis on industry-science collaboration as a means of technology development and industrial modernisation.
- The new SPINNER programme in the region of Emilia Romagna, having its main focus on training of new high-tech entrepreneurship and towards promoting the technology transfer from university laboratories and research centres to the entrepreneurial system and local bodies.

ISR Promotion by Regional Government: Emilia Romagna Region and ASTER

A good practice at regional level is represented by the experience of Emilia Romagna region with the Technological Development Agency ASTER. A specific commitment of the regional government to support and promote ISR in Emilia Romagna region has been recently confirmed, following the new competencies acquired in the framework of the decentralisation process which recently occurred in Italy.

Law no. 59 of 1997, followed by Legislative Decree no. 112 of 1998, delegated to regions, all functions regarding interventions in favour of industry, including innovation and technology transfer programmes. The Regional Law no. 3 of 1999 foresees the promotion of the development of research and innovation initiatives, a technology transfer network, joint initiatives involving public research bodies and single or associated companies, the commitment of local firms in the field of research and innovation, and the involvement of human resources of universities and research bodies.

Emilia Romagna research and productive system in numbers

The following scientific and technical resources operate within Emilia Romagna region:

- 6000 researchers and professors
- CNR National Council for Science and Research (800 Researchers and Technicians)
- ENEA National Body for Energy and the Environment (400 Employees)
- 5 Universities with 130,000 students (Bologna University being the oldest in Europe)

The regional entrepreneurial tissue is thus composed:

- Over 400.000 enterprises
- over 130,000 micro enterprises
- 3,000 co-operatives
- 97 % with less than 20 employees (average. 5.2 per enterprise)

Within this legal framework, the regional government focuses its attention on the fact that the regional economy must be based on knowledge and technological innovation, and thus, on initiatives directed towards the co-operation of universities, research centres, enterprises, financial markets, considering them strategic elements and drivers of regional competitiveness. The organisation entitled to promote and facilitate the above mentioned co-operation and the support of joint initiatives is ASTER, which must be seen as the agency stimulating industrial research, innovation and technology transfer in Emilia Romagna region.

ASTER shareholders

ERVET (Policies for enterprises)	41%
C.N.R. (National Research Council)	20%
ENEA (National Body for Energy and the Environment)	10%
Bologna University	10%
Modena & Reggio Emilia University	5%
Ferrara University	5%
Unioncamere Emilia Romagna	5%
Entrepreneurial associations	3%
Other service centres of the ERVET System	1%

A specific agreement has been signed by ASTER shareholders in order to formalise the main aims and related actions which ASTER will undertake:

1. Creation and animation of a regional technology transfer network by carrying out the following

- Monitoring research and innovation in the region, and those developed in the region, through the creation and management of research databases which support already existing databases on national and international levels.
- Supporting universities and research centres in activities of analysis and project management concerning scientific, technological and industrial issues, for the development and promotion of a culture of innovation.
- Diffusion of information concerning research and technology. Co-ordination between the system of regional research and enterprises.

- Services of information and technical assistance for the exploitation of research and the protection of industrial property.
 - Activities supporting the application of new technologies through the creation of valuation sites in enterprises, the constitution of task forces and the realisation of specific projects.
 - Information, specific services and support concerning the participation in projects, programmes and funding opportunities, technological transfer and innovation, promoted by regional, national, European and international authorities.
 - Promotion, diffusion and technical assistance regarding opportunities to receive private venture capital or funding in co-operation with others working in the field.
 - Promotion of projects which concentrate on training human resources for technology transfer and support to the mobility of researchers, in particular, towards enterprises.
 - Study and experimentation of methods and systems of rating for enterprises which invest on innovation.
2. Promotion of research and technology transfer projects and of contracts of strategic interest for Emilia Romagna Region, support to universities and research bodies working on European and national projects, co-operation on both management procedures and the realisation of technology transfer.
3. Undertaking actions to exploit research results. This also through the creation of enterprises and of autonomous high- tech activities, with particular reference to research spin off and to new technology based firms.

STARTECH

STARTECH is a programme promoted by Sviluppo Italia (the public Agency recently created after the reform and restructuring of some public agencies devoted mainly to the promotion of southern Italy) aimed at:

- new high-tech enterprises and
- improving industrial research,
- creating developing territorial systems of high-innovative enterprises.

Another important objective of the programme is to sustain the spreading of innovation tools in the South of Italy (more well known as "Mezzogiorno").

The programme focuses on the following aspects:

- Scaling down the distance between industry and research system
- Supporting the development of high knowledge and technology based firms
- Improving the quality of some areas in order to attract new high-tech investment at both national and international level

In terms of actions, the STARTECH programme aims to:

- promote research initiatives towards the production of new technologies (patents), spin off and knowledge based firms.
- support new entrepreneurial project in the most developed scientific-technological areas as indicated in the National Programme for Research (ITC, robotics, macro-systems, energy, bio-technologies, new technologies).

All activities are implemented through collaboration between universities, big enterprises, research centres and venture capitalist. Moreover, the territorial system of Sviluppo Italia will be engaged (BIC, CISI, regional associations).

LA RICERCA CREA IMPRESA ("Research creates enterprise")

"LA RICERCA CREA IMPRESA" is a pilot action promoted by IG (the public agency devoted to the creation of new enterprises mainly in the South of Italy now included in Sviluppo Italia) and INFN, in order to sustain the creation of high-tech enterprises in the Mezzogiorno regions through the creation of research spin-offs.

These enterprises will be able to compete on the market exploiting the competitive advantage rising from the link with the research centre of origin.

This action is co-financed by EU and Italian funds, namely: Support Community Framework Italy Objective 1 - 1994-1999, Operative Programme "Industry, craft and services to enterprises" - European Social Fund Measure 1.4 "Training for new youth entrepreneurship" Operative Programme of the Ministry of University, Scientific and Technological Research - Research Development and high Training - EFRD/ESF.

Beneficiaries of this programme are: young researchers, scholarship holders, graduated and post-graduate interested in developing products and application-oriented services for INFN, exploiting knowledge and skills learnt at University or obtained in the field of scientific and technological research.

This action can be an opportunity also for the realisation of research spin-off even in the complementary fields of physics.

Some services are offered free of charge, in fact during the conceiving and the planning of the new initiative beneficiaries are supported through:

- Stimulation and guidance activities towards entrepreneurship
- Information about possible entrepreneurial opportunities
- Information about laws and facilities for the creation of new enterprises
- Support to the development of entrepreneurial ideas
- Evaluation of the proposed idea
- Training on business planning: the product and the market, financial plan, public relations capabilities
- Individual assistance for the definition of the new enterprise project.

LA TUA RICERCA PER LA TUA IMPRESA ("YOUR RESEARCH FOR YOUR ENTERPRISE")

The Ministry of the University and Scientific Research and Sviluppo Italia in collaboration with four Universities situated in the Southern Italy are promoting an experimental activity for the creation of high-tech enterprises through research spin-off.

Beneficiaries are professors, researchers, scholarship holders, graduated and post-graduate interested in developing products and applied services for the improvement of the research.

In order to sustain the planning and the inception phase of each initiative, this action foresees the opportunity to get free services such as:

- Information about facilities for the creation of new enterprises
- Support to the development of entrepreneurial ideas
- Assistance in the definition of the new enterprise project
- Scientific tutorship and continuous assistance
- Free entry to laboratories and equipment use.

SPINNER Programme - Emilia Romagna Region

The SPINNER Programme is an initiative promoted by the Emilia Romagna Regional Government in the framework of the Global Grant of the European Social Fund, Objective 3, Operative Regional Programme Emilia Romagna, aimed towards implementing two specific actions:

- D3 - Development and strengthening of entrepreneurship with a specific focus on new employment clusters;
- D4 - Enhancement of human resources in the research and technological fields.

The programme is managed by the SPINNER Consortium (Services for the Promotion of Innovation and Research), created by ASTER, Sviluppo Italia and Fondazione ALMA MATER through which the Region contributes in the development of strongly innovation-oriented local systems.

In particular, SPINNER aims to support the training of new high-tech entrepreneurship and to promote the technology transfer from university laboratories and research centres to the entrepreneurial system and local bodies.

Thus the SPINNER Programme is particularly addressed to those operating in specific and technological research fields who will have access to free consulting, training services and financial contribution through grants and scholarship. The aim is to develop their entrepreneurial abilities and to enhance their know-how in the innovation dissemination processes.

Finally, SPINNER will test the following two pilot intervention models:

1. First, to face the problem of the generational change in regional firms through the creation of an integrated system of specialised services and competencies;
2. Second, to define a methodology which favours the emergence of Northern and Central Italian SMEs from the black economy.

B.7 Sweden²³

B.7.1 Knowledge Production Structures in Sweden

Sweden showed a R&D ratio (R&D as a percentage of GDP) of 3.7 % in 1997, which is the highest amongst all OECD countries. While the R&D ratio has declined in the early 1990s due to a serious recession, R&D expenditure has strongly increased again since 1993. Compared to the pre-recession stage at the end of the 1980s, the R&D ratio grew by about 1 percentage point until the end of the 1990s. This increase was largely the result of a significant expansion of R&D expenditure in the private business enterprise sector. This sector is by far the dominant group with respect to financing and performing R&D in Sweden. The Swedish business enterprise sector performs 75 % (or 2.77 % of GDP) of all R&D expenditure (see Table B.7.1). Given this exceptionally strong R&D orientation and potential of the enterprise sector, the share of HEIs (universities) of total R&D expenditure, is only 22 %, although the level of R&D spending in relation to GDP (0.80 %) is amongst the highest in the world.

Table B.7.1: R&D Expenditures in Sweden 1997 by Financing and Performing Sectors (in million €)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total</i>	
	<i>Enterprises</i>	<i>State*</i>	<i>Abroad</i>		<i>%</i>	<i>% of GDP</i>
Enterprise Sector	4,936	423	184	5,543	75	2.77
PSREs*	9	251	7	267	4	0.13
HEIs	72	1,460	63	1,595	22	0.80
Total (million €)	5,017	2,134	254	7,270		
Total (%)	68	29	3		100	3.70

* Including the very small private non-profit institutions sector.

Source: OECD (2000), calculations by the authors

R&D in the business enterprise sector is mostly financed by internal sources (90 %). The state finances about 8 % of enterprise R&D expenditure. This public funding comes solely from military agency funds and goes to defence enterprises, in particular, sectors such as transport equipment, precision instruments and machinery. Only a mere 2.5 % of BERD is financed from sources abroad. At the same time, Swedish enterprises, primarily about 20 large multinationals, finance a significant amount of R&D from their foreign branches, amounting to 36 % of their total R&D budget in 1997. A large fraction of the foreign share of R&D expenditure by Swedish multinationals is financed by their own sources in the foreign affiliates however.

The main financing source of the HEIs is public funding, which accounts for about 75 % of the total budget of HEIs. The remaining 25 % come from enterprises, non-profit organisations, research foundations, the EU, and other public and private actors. The public funds may be divided into two major categories. The first one (GUF), is basic financing and

23 This chapter is based on the national report on ISRs in Sweden (Norgren 2001).

accounts for 51 % of total research expenditure in HEIs. The second one is mainly project orientated funding on a competition basis, and accounts for 49 %. In the case of the small PSRE sector, the pattern is quite different. Basic funding is about 25 %, a much lower rate, while project oriented financing accounts for 75 %. The main financing source is the national government.

Table B.7.2: Financing Structure of R&D in HEIs and PSREs in Sweden 1997/98 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (GUF)	51	~ 25
Project Financing and other financing sources	49	~ 75
National Government	74	94
Other Sources (enterprises, internal financing, abroad)	26	6

Source: OECD (2000), statistics Sweden, calculations by the authors

As mentioned above, the business enterprise sector is the major player in the Swedish innovation system with respect to R&D expenditure. Within the business sector, the distribution of R&D expenditure is very uneven. As in other countries too, the overwhelming bulk of R&D (over 80 %) expenditure is concentrated in the manufacturing sector. A more detailed dis-aggregation (see table B.7.3) shows that the narrower high-tech-sector²⁴ accounts for 37 % of total R&D expenditure. Somewhat more conventional but also strong, technology-driven sectors (for example chemistry, and machinery) account for 37 % of R&D expenditure too. Low-tech sectors have only a tiny share of R&D (8 %). R&D in the service sector is concentrated, to an overwhelmingly extent, in IT-services.

Table B.7.3: R&D Expenditures in the Swedish Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	37	1.02
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	37	1.03
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	8	0.23
IT-Services (NACE 64, 72, 73)	15	0.40
Other Services (NACE 50 to 99, excl. IT-Services)	3	0.08

Source: OECD (2000), calculations by the authors

R&D in manufacturing is concentrated in very large enterprises (10,000 employees and more). Their share is about 60 % (see table B.7.4). In fact, the ten largest manufacturing groups alone account for more than 50 %. These are multinational conglomerates with headquarters and home base in Sweden, but with an international, if not global, focus on production facilities, in a huge range of countries. In the main, they are in high-tech sectors such as information technologies, pharmaceuticals, transport and engineering. As recent

24 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

studies show, their R&D performance is increasing abroad. However, the major part of their R&D activities are still conducted in Sweden (about 60 %), at least up to the end of the 1990s.

Table B.7.4: R&D Expenditures in the Swedish Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	3
Medium-sized Enterprises (100 to 499 employees)	13
Medium-sized to Large Enterprises (500 to 999 employees)	11
Large Enterprises (1,000 to 9,999 employees)	~13
Very Large Enterprises (10,000 employees and more)	~60

Source: OECD (2000), calculations by the authors

Small enterprises have only a tiny share (3 %) of R&D expenditures. The other three size classes given in table B.7.4 (medium-sized enterprises, medium sized large and large enterprises) account for very similar shares (13, 11 and 13 %).

Despite the small significance of SMEs (and especially small firms) for the R&D statistics in Sweden, they may be of great importance for ISR and the overall strength of the innovation system. Since they represent the vast majority of all firms, their absorption capacity for new knowledge generated in the HEIs and PSREs sector strongly influences the level of ISR.

Table B.7.5: Relative Innovation and R&D Performance of SMEs in Sweden

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	0.93	1.01	0.98	1.24
Innovation Expenditures as a Share of Turnover*	0.55	0.61	0.27	1.91
Share of Turnover due to Innovative Products*	0.79	1.07	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	1.22	1.78	0.60	1.83
Share of Enterprises with Medium R&D Intensity**	1.62	1.22	0.44	2.51
Share of Enterprises Engaged Continuously in R&D**	1.43	1.24	1.16	1.73
Share of Enterprises Having Applied for a Patent**	1.43	1.34	1.40	0.43

* Figures show the relation of Swedish SMEs' performance to the performance of SMEs in the EU average, normalised by the respective relation of all Swedish enterprises to all EU enterprises: $(\frac{SME_{xSj}}{SME_{xEj}}) / (\frac{x_{Sj}}{x_{Ej}})$, x being the variable considered, S being Sweden, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in Sweden to SMEs in the weighted mean of all EU countries (except Greece): $\frac{SME_{xSj}}{SME_{xEj}}$, x being the variable considered, S being Sweden, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, calculations by the authors

Information on the performance of SMEs with respect to various aspects of the innovation process can be found in CIS-2. Table B.7.5 shows some performance indicators in the field of innovation (in the narrow sense) and in the field of R&D. Very small firms in the manufacturing sector perform quite well (in comparison with the EU average) on R&D but

seem to be comparatively weak with respect to Innovation. Small firms are one exception (innovation expenditure as a share of turnover) out of all the indicators above the EU average. It can be deduced that Swedish SMEs perform comparatively well, especially in R&D. The comparative performance of very small enterprises in the service sector is below the EU average (with the exception of continuous R&D and patent application). On the contrary, small service enterprises are doing very well. Only with respect to patent applications are they below the EU average.

As in other countries, the Swedish public science sector compounds a set of different institutions, each having a different mission, structure etc. In total, R&D expenditure of the HEIs sector amounts to 1.5 billion Euro (1997/98). The number of R&D person-years is 18200. In total, there are (at the end of the 1990's) 65 different institutions which belong to the HEIs. The major bulk of these R&D expenditures (as well as R&D personnel) is to be found in six multidisciplinary universities, three technical universities and four other higher education organisations. They account for 1.4 billion Euro, which is 96 % of total R&D expenditure of the HEIs sector. Among them, Lund University has the highest level of R&D expenditure and person-years. Uppsala University, Göteborg University, Karolinska Institute, the Swedish University of Agricultural Sciences and the Royal Institute of Technology are universities which have both high R&D expenditures and a high percentage of R&D person-years. R&D expenditures for small and medium-sized university colleges were almost SEK 500 million, and R&D person-years, 900.

Table B.7.6: R&D expenditures for Swedish HEIs in 1997/98

<i>Type of institution</i>	<i>Number of institutions</i>	<i>million Euro</i>	<i>in % of total</i>
Universities (incl. Univ. colleges) with postgraduate studies)	13	1,427.1	95.8
Small and medium-sized university colleges	23	51.9	3.5
Colleges of Arts	7	1.8	0.1
Colleges of Health Sciences	21	3.7	0.2
Swedish Institute of Space Physics	1	6.0	0.4
Total	65	1,490.4	100.0

Source: Statistics Sweden, R&D statistics, calculations by the authors

Table B.7.7 provides information on the distribution of R & D personnel (full-time equivalent) in the HEI sector. Engineering dominates R&D in the Swedish higher education sector with slightly more than one third of total R&D personnel in 1997/98. Corresponding shares for medical and natural sciences are 20 percent and 18 percent, respectively. Humanities, with 7 %, is at the bottom.

Research areas have a different focus between small and medium-sized university colleges, and universities and university colleges with postgraduate studies. The social sciences and humanities have a significantly stronger position in small and medium-sized university colleges than in the large ones. Research in medical sciences and the natural sciences however, was carried out largely in universities and university colleges with postgraduate studies. Engineering and technology are well represented in both categories.

Table B.7.7: R&D Personnel (full-time equivalent) **in the Swedish Public Science Sector** (HEIs & PSREs) **by Fields of Science 1997** (in %)

<i>Sector</i>	<i>HEIs</i>	<i>PSREs*</i>	<i>Total*</i>
Natural Sciences	18	19	18
Engineering (incl. Agricultural Sciences)	36	70	41
Medical Sciences	20	4	18
Social Sciences	17	7	15
Humanities	9	0	8

Source: Statistics Sweden, own calculations

At PSREs, the field of engineering accounts for 70 % of the total R&D personnel, followed by natural sciences. Other science fields play only a minor role.

There are 7 public research laboratories. Additionally, there are about 30 small semi-public research institutes with a pool of more than 2,000 qualified scientists. They maintain contacts with thousands of companies and they play an important role in the Swedish technology transfer structure by developing new technology and disseminating knowledge to industry. Technology transfer occurs in the form of developing and tailoring new technology to suit companies specific needs, providing information and advice, training users, making sure that suppliers and contractors modify their products, overseeing pilot installations etc.

Table B.7.8: Main Characteristics of Major Institutions in the Swedish Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities	~ 82	7 multi-disciplinary universities; 3 technical universities, 3 private (small) universities	basic and applied research; higher education; co-operation with surrounding society and information	traditionally more orientated towards basic research; now growing orientation towards applied research	high
University Colleges	~ 3	23 small and medium sized university colleges	education	low but growing	high
Other HEIs	~ 1	7 Colleges of Arts; 21 Health Sciences	education	low research activities	low
Public Research Laboratories	~ 14	7 laboratories	very different objectives	applied research	high

Source: Statistics Sweden, survey and calculations by the authors

The labs and institutes have ties with companies, universities and other institutes. Most of the work is in the form of applied research carried out in close co-operation with industry. Several institutes also perform long-term research and knowledge development. Around two thirds of the semi-public research institutes' finances, come from enterprises. State bodies

such as, for example, NUTEK/VINNOVA, provide the remaining one third. The institutes cover a wide range of research and technology fields which are of potential use in a huge range of industries both in the high-tech sector as well as in the more traditional industrial sectors.

B.7.2 The Level of ISR in Sweden

The level of ISR in Sweden is described by a set of indicators and assessments (based mainly on expert information) for the various channels in which ISR take place. The results are given in table B.7.10. Also, it is indicated in which channels Sweden is above or below the respective EU average. As in other countries too, Sweden has its strength and weaknesses depending on the type of ISR channel.

Contract research: Information on the level of contract research can be obtained from national research funding statistics. R&D financing by industry for HEIs (in % of HERD) and for PSREs (in % of GOVERD) tends to be rather low and below the EU average. Only 1.5 % of BERD is used for financing R&D in HEIs and PSREs. This is not very surprising, given the huge BERD, in contrast to the comparatively low share of total HEI/PSREs budgets. Funding by enterprises is distributed very unevenly among economic sectors. Most funding comes from pharmaceuticals, an industrial (sub)sector with traditionally strong linkages with university research. This sub-sector alone accounts for 34 % of all R&D-related industry funding in HEIs (and 58 % of all payments of the manufacturing sector). Private R&D enterprises follow in second place with a share of 22 % (or 52 % in respect of payments to the service sector).

Interestingly, the results of the CIS2 show exactly the opposite pattern. The share of manufacturing firms in co-operation with HEIs and PSREs in innovation projects, is quite high and well above the EU average. The results for service sector firms are mixed. Co-operation with HEIs is above the EU average while co-operation with PSREs is below it. One possible explanation for these opposite results between R&D financing and co-operation in innovation projects may be the fact that in CIS2 there are no monetary weights (each firm is counted by one) whereas using R&D statistics, the monetary weights are included the calculation. Indeed, a study of NUTEK and Statistics Sweden shows that the share of enterprises that regarded collaboration with HEIs as very important to their innovative activities, decreases with size (the opposite holds true for PSREs). In respect to the use of HEIs and PSREs as an information source for the innovation process, Swedish firms are below the EU average.

Due to the international orientation of the large Swedish enterprises and their increasing R&D conducted out abroad, it can be expected that they co-operate extensively with foreign research institutions. Their demand for external know-how is not restricted to their homeland but they are looking for co-operation with research teams at the respective research frontiers, independent to their location.

Mobility: The mobility of researchers (% of researchers who moved to the business enterprise sector) in Sweden is in general, high, and above the EU average. This holds true for both HEIs as well as PSREs researchers, whereas the latter do have an almost fourfold mobility rate over university researchers. Between 1994 and 1995, 4 % of all researchers in HEIs moved to the private enterprise sector, at PSREs this ratio was 15 %. Also, the mobility in the other direction (i.e. higher education graduates moving from industry to HEIs/PSREs) is likely to be above the EU average. However, if compared with the former type of mobility (i.e. from HEI/PSREs to industry), the mobility ratio is rather low: only 0.6 % of the total higher educated workforce in the Swedish private enterprise sector, moved to HEIs or PSREs, the universities being the more important sector of destination.

Vocational and further training: Data on joint training activities is currently not available in Sweden. The experts interviewed assessed that it is quite low. They tend to think that it ought to be increased. Currently, there are no specific policy instruments towards stimulating vocational training. In addition, the current curricula's do not favour this channel of ISR in Sweden.

Table B.7.10: Indicators and Assessments of ISR in Sweden at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % of HERD	4.5
	R&D financing by industry for PSREs in % of GOVERD	2.9
	R&D financing by industry for HEI/PSREs in % of BERD	1.5
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	n.a.
	Significance of R&D consulting with firms by PSRE research.	n.a.
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	26.1
	Innovative manuf. enterprises co-operating with PSREs in %	16.3
	Innovative service enterprises co-operating with HEIs in %	12.0
	Innovative service enterprises co-operating with PSREs in %	5.8
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	4.5
	PSREs used as inform. source by innov. manuf. enterpr. in %	n.a.
	HEIs used as inform. source by innov. service enterpr. in %	4.7
	PSREs used as inform. source by innov. service enterpr. in %	n.a.
Mobility of Researchers (Source: national study 1994/95)	Share of researchers in HEIs moving to industry p.a. in %	~ 4
	Share of researchers at PSREs moving to industry p.a. in %	~ 15
	Share of HE graduates at industry moving to HEI/PSREs p.a. in %	0.6
Vocational Training	Income from vocational training in HEIs in % of R&D exp.	n.a.
	Number of vocational training participants in HEIs per 1,000 R&D employees at HEI	n.a.
Patent Applications at Science	Patent Applications by HEIs per 1,000 employees in NSEM	n.a.
	Patent Applications by PSREs per 1,000 employees in NSEM	n.a.
Royalty Income by Science	Royalties in % of total R&D expenditures in HEIs	n.a.
	Royalties in % of total R&D expenditures at PSREs	n.a.
Start-ups from Science	Number of technology-based start-ups in HEIs per 1,000 R&D personnel	n.a.
	Number of technology-based start-ups at PSREs per 1,000 R&D personnel	n.a.
Informal contacts and personal networks	significance of networks between industry and HEIs	high
	significance of networks between industry and PSREs	n.a.

* values above the EU average are indicated in **bold** letters

Source: OECD, Eurostat, national statistics, calculations by the authors

Patent applications: There is no systematic information available on patenting by researchers in public science, and the same holds true for royalties. However, there is some evidence in a comparative (although not representative) study by Aaltonen (1998) that patent activities by university researchers are, at least partially, a channel used for knowledge and technology transfer in the fields of natural sciences, engineering and medicine. 12 % of Swedish scholars reported having used patenting and/or licensing as a mode for technology transfer to industry. This is considerably lower than most of the other channels (contract research, consulting, and teaching) and somewhat lower than the level patenting and licensing is used by scholars in Finland and Ireland. Nevertheless, there seems to be significant patent activity at Swedish HEIs, as one would expect, given the specific IPR regulation that allows individual HEI researchers to commercialise their inventions/patents for their own benefit (see B.7.3). Concerning patenting and licensing at PSREs, no information is available.

Research start-ups: Information on start-ups from HEIs and PSREs is currently not available. According to an estimate by NUTEK in the early 1990s, about 2 to 3 % of all high-tech start-ups originated in universities. The above mentioned study by Aaltonen (1998), suggests that Swedish scholars in the fields of natural sciences, engineering and medicine, use start-ups as a technology transfer mechanism to a similar extent as their colleagues in Finland, where the number of start-ups of new enterprises by university researchers, is rather high.

Informal contacts: Exact data on informal contacts is not available. A common opinion is that informal contacts with HEIs are very frequent, at least among large companies.

Incentives & Barriers to ISR according to National Experts: The identification of the principal barriers and incentives for ISR in Sweden was carried out by expert interviews. The results are discussed briefly in the following:

The most important incentives to ISR in Sweden in science for promoting ISR are the following:

- The rights of university researchers to their own research findings (see B.7.3). Researchers can, by themselves or together with enterprises, commercialise their findings (patents and licenses) and generate private earnings. However, some experts are of the opinion that research findings do not become commercial because of a researcher's lack of interest or lack of knowledge of the possibility of such applications. Their argument is that universities could do better and that the IPR should be transferred to universities.
- The fact that the amount of public funding to university research is too small in relation to the needs of universities, means that it has to be supplemented by other funding sources e.g. contract research with business enterprises. This shortage of funding can be a very powerful 'incentive' to co-operate in joint projects with industry or contract research for industry.
- The amendment to the university law (Higher Education Act) of the so-called third mission is also an incentive for university researchers to collaborate with industry. The

intention is that university researchers shall commercialise research findings and collaborate with industry. As it is in the law as a mission, the attitudes and behaviour of university researchers ought to be influenced.

- The most important incentive for researchers at PSREs is that ISR activities are an explicit objective of these institutes. Other incentives include the evaluation criteria and awareness measures that are used (special awards etc). Special promotion programmes are of low relevance to ISR.

The most important barriers in Sweden in science according to experts' assessment are the following:

- The different objectives of university research and industrial R&D, different cultures and the qualification and career system in universities are (as in other countries too) all major barriers to ISR. Collaboration with industry is not a high valued qualification for a researcher wanting to create a university career. Other important barriers are: different time-schedules, lack of knowledge of industry research issues, abilities, and industrial demand. Many experts also regard the lack of incentives and fear of losing scientific independence, as major obstacles to ISR.

In industry, experts mentioned the following incentives and barriers:

- From the point of view of industry, it is essential to distinguish between large firms and SMEs when discussing incentives and barriers to ISR. In general, large firms do not find it difficult to collaborate with university researchers. They have collaborated for a long time and learned how to handle their university relations. In addition, they have both the financial as well as the personal resources (employment of graduated R&D staff).
- The situation is quite different for SMEs (with the possible exception of high-tech SMEs). Most of them have no experience in co-operation with universities. There are many barriers to such collaborations but the most important one is that they lack an in-house R&D competence (i.e. lack of qualified personnel). SMEs in general, also do not know the potential gains of university collaboration. Some other barriers are also notable. These include the lack of information about, and interest in, university research, and the uncertain outcomes of joint R&D. All these are especially relevant to SMEs.

In summary, Sweden has particular strengths in ISR channels concerning the co-operation between HEIs and PSREs, and innovative enterprises, during innovation projects, and concerning the mobility of researchers (in both directions). Due to data constraints, for some channels (i.e. vocational training, start-ups, patents, and informal contacts), no statement on their significance can be made. However, there is no evidence that the situation in Sweden is fundamentally different from other countries with a high R&D intensity and a well developed research infrastructure.

B.7.3 The Policy-related Framework Conditions for ISR in Sweden

Cultural attitudes and general framework: As the system of an innovative approach has gained some acceptance in Sweden (actually, Swedish researchers have been at the forefront of the development of this theoretical concept), the importance of framework conditions, different institutions and their interaction is widely acknowledged. During the 1990's, a hot debate emerged about the governing principles of research funding (free academic research versus mission orientated). The results of two public commissioned studies lead to a re-organisation of the supporting and financing structures of the Swedish innovation system. In summary, it can be stated that the general framework in Sweden is highly favourable for encouraging ISR. In addition, a recent trend is the regionalisation of technology and (to some extent) research policy. Due to this regional approach, potential suppliers of new knowledge may more easily match its demand (especially in the case of SMEs).

Legislation: The main legal regulations that have possible impacts on ISR are summarised in table B.7.11. As in most other countries, three different areas of legal regulation are of particular importance for possible encouraging or hindering ISR. All three areas are in the science side of ISR:

- Intellectual property rights: the general rule is that the right to exploit inventions developed by employees, belongs to the respective employer, with an exception for university researchers (researchers at PSREs do not gain this exception). The principal reasons behind this exception are (i) to guarantee scientific freedom, and (ii) to stimulate the output of publicly funded research in terms of patents by giving incentives to commercialise their research in the market place. Although this exception came into debate in the 1990's, it is still in force. University researchers appreciate the teacher's exception since the possibility of personal earnings of research findings is a powerful incentive for researchers to commercialise their research results. If a university researcher develops an invention in a project funded by third parties, e.g. companies, the right to the invention may be owned by the contracting partner. Stipulations in this regard are part of the contractual arrangement.
- Universities and Contract Research: Much of the present debate in Sweden concerns the relation between the academic community and industry, as well as the importance of developing improved mechanisms for the exploitation of public research within universities. In fact, in the Government bill on research of 1996/97, one of six overall goals for research (the development component was not mentioned) was explicitly the co-operation with industry and thereby, university research should contribute to *"the highest possible output from the joint national efforts within research and development"*. During the 1990's several laws were implemented. Universities have been given, by law, a third mission, namely that they should co-operate with the surrounding society. In 1998, it was became law that the ability to collaborate with society and inform externally of research and development work, was a qualification criterion for employment. Other laws regulate

the charging principles, sideline activities of researchers and the possibility for enterprises to purchase education from universities.

- PSREs and contract research: compared to university researchers, the situation is different for researchers in public and semi-public research institutes (PSREs). For many of them, their objectives are to transfer technology to enterprises by collaboration or contract research. Around 60 percent of the budgets of the semi-public industrial research institutes come from business enterprises. In most cases, researchers at the research institutes are not civil servants, as in the case of university researchers. Compared to researchers in enterprises, their employment conditions do not differ in any substantial way.

Table B.7.11: Overview of main legal regulations that influence ISR

Name of regulation	Year of implementation	Content
<i>Intellectual property rights</i>		
Law on the right to inventions of employees	1945:345	Teachers exception
<i>Contract research/education</i>		
Higher Education Act	1996	The third mission of HEI
Higher Education Act	1998:1003	§ 15 employment criteria
Regulation on charging external clients	1999:431	Contract research and charging principles
Higher Education Act	1992	Ch. 3 § 7 side-line activities
Regulation on Commissioned Education	1997: 845	Possibilities for enterprises to purchase education
<i>Researchers mobility</i>		
Law on the right to leave of absence	1997:1293	§ 3 The right to leave of absence
Regulation on leave of absence	1984:111	§ 10b Temporal leave of absence

Source: own compilation by the authors

- Researchers mobility: There are few legal regulations that are likely to influence the mobility of researchers in Sweden. There are no particular conditions of employment for university researchers that restricts them from taking appointments in companies. Furthermore, earning opportunities are much more favourable in companies compared to universities. However, these differences in earning opportunities hamper the mobility of a company researcher to a university. What really restricts the mobility of a university researcher is that research outside universities has not been considered a qualification in the career system of a university researcher.
- Temporary mobility is supported by legislation. According to a law on leave of absence (1997:1293 §3), university employees have the right to be on leave for up to 6 months in order to carry out business activities. A condition is, that these activities do not compete with the activities of the employer, and that the leave does not create substantial inconvenience to the activities of the employer. University employers also have the possibility to give the employees leave of absence if particular reasons exist, and if it can be done without inconvenience for the employer (Regulation on leave of absence 1984:111 §10b).

- The universities may finance so-called 'contact researchers'. This means that researchers employed at the university for a certain period, can work full or part time at a company. Government money can be used for almost half of the salary. Other ways of promoting temporary mobility and collaboration are visiting professors and industry postgraduate students. A visiting professor means that an individual with a professor's competence, but employed outside the university, e.g. in a company, can work at the university on a part time basis. In the same way, industry employees can take part in postgraduate studies at a university during his or hers employment. The financing is shared between the company and the university most of the time.

The Institutional setting in Sweden has changed recently due to the merger of: the Swedish Transport and Communication Research Board (KFB), the R&D unit of the Swedish Board for Industrial and Technical Development (NUTEK), and a section from the Council for Work Life Research (RALF) into VINNOVA ("The Swedish agency for innovation systems", since January 1st, 2001). VINNOVA's main roles are: (i) financing research, development and demonstration activities that meet the needs of business and the public sector; (ii) fostering co-operation between universities, industrial research institutes and business; (iii) promoting the diffusion of information and knowledge, especially to SMEs; (iv) stimulating increased Swedish participation in the EU's general R&D programmes; (v) evaluation and developing Technological Foresight process; and (vi) developing the role of research institutes in innovation systems. Thus, VINNOVA tries to bring together all important actors of the national innovation system.

University Research Funding: For some years now, there have been a few foundations that fund university research. Government has some influence in the activities of these foundations but they are not public agencies in a legal or practical sense. The Swedish Foundation for Strategic Research is a very important funding source in key areas, such as bio-sciences, information technology, microelectronics, manufacturing, and production technology. The Swedish Foundation for Strategic Environmental Research has a corresponding mission in the environmental area. The Knowledge Foundation aims to boost Sweden's international competitiveness and increase employment by supporting the exchange of knowledge and competence between universities, institutes and industry, and by funding research at new universities and university colleges.

Promotion programs: The Swedish technology policy is characterised by a diversified range of programmes, some of which target ISR explicitly. Table B.7.12 provides an overview of the most important public promotion programmes in the field of ISR. Some main features of these measures are characterised below.

- Funding of business enterprise research: Public funding of research carried out in enterprises is an exception. Swedish joint research and technology programmes are mainly aimed towards increasing the competence level of research within universities, in areas of future interest to enterprises. Thus, EU projects represent a new source of funding for Swedish companies. Increased efforts are being made to increase involvement

with industry in the form of co-funding or actual work in co-operation with universities and institutes.

- Financial support for joint R&D projects: The mission of the government agency NUTEK/VINNOVA is to promote university research of relevance to industry and within areas of strategic importance for Sweden. The main tool used by NUTEK/VINNOVA is R&D programmes that are organised as joint efforts between industry and universities. These R&D programmes aim to increase the competence level and industrial relevance of university research. A large part of these joint programmes are found within the fields of material sciences, IT (in the broad sense), and biomedicine. The programmes and their projects are carried out at universities with participation from enterprises. The programmes and projects are partly funded by NUTEK/VINNOVA and partly by participating enterprises. On a yearly basis, the funding amounts to around 40 million Euro (Competence Centres are not included)
- In 1995, a new kind of R&D programme the so-called Competence Centres, was introduced for promoting the industrial relevance of university research and collaboration. The Competence Centres are joint ventures between universities and enterprises (and sometimes, research institutes). The Centre programme has a planned life-span of 5 to 10 years and its aim was to "achieve a stronger industrial impact and enhanced concentration of resources by creating multidisciplinary academic research environments in which industrial companies participate actively and persistently in order to derive long-term benefits". Currently, there are 28 centres at 8 universities, and they organise and carry out integrated research collaboration between universities and enterprises, and develop research at universities by industry participation. In total, 220 enterprises and research groups from 130 departments at 8 universities are participating. Around 20 percent of the enterprises are SMEs (less than 250 employees). The Competence Centre programme can be regarded as an example of good practice and is described in more detail in chapter B.7.6. The funding of NUTEK/VINNOVA is around 18 million Euro annually.
- Technology Transfer for SMEs (TUFF): The programme aims to give SMEs access to technology expertise in Sweden as well as abroad. It consists of different parts. By funding the formation of local company networks, participating companies should be enabled to develop enough strength to become a customer of qualified technology services. At the same time, support is given to develop a transparent supply system of technology services by offering training in technology brokering to selected organisations. The programme is trying to find new ways to increase SMEs capacity as technology buyers but also, to create a system of technology provision that is steered by demand. The programme will develop a larger and better functioning market of technology services in Sweden. The funding amounts to 2.5 to 3.5 million Euro per year by VINNOVA.
- AIS (Active industrial collaboration): AIS is the further development and broadening of an older, more focused program (VAMP). The principal objectives of AIS are: (i) promoting clustering and co-operation for innovation; (ii) financing; (iii) co-operation

between universities (including university colleges) and enterprises; and (iv) enhancing the absorption capacities of SMEs. A typical AIS-project involves one or two research institutes, one or two university or university college research departments, and 6-15 enterprises. These actors are to collaborate actively during a period of three years with an overall budget of 0.7 to 0.9 million Euro, of which NUTEK finances 0.3 million Euro only to research institutes and universities. The contributions of the enterprises are only in the form of the cost of their own labour. Technology/knowledge transfer is an integrated part of the project. The four focus areas of AIS are IT, life sciences, manufacturing and processing and sustainable development.

Table B.7.12: Major Public Promotion Programmes in the Field of ISR in Sweden

Name of Programme (responsible authorities)	Public Funding (million € 1999)	Main Approach	Type(s) of ISR Mainly Addressed
Joint R&D programmes (VINNOVA)	40	Establishing joint R&D between HEIs and business aimed at increasing industrial relevance of HEIs research	Research collaboration between HEIs and business
Competence Centre Programme (VINNOVA)	18	Establishing large scale research consortia between HEIs/PSREs and business enterprises	Research collaboration between HEIs, PSREs, business enterprises
New Graduate School (The Knowledge Foundation and the Swedish Foundation for Strategic Research)	~ 26	Education of graduation in scientific fields with strategic importance	University-industry collaboration in education
New liaison function with the new Universities and Univ. Colleges for co-operation with SMEs (NUTEK, VINNOVA and the Knowledge Foundation)	~ 2.8	Increasing the interaction between universities and industry focusing on a regional level	Mobility of researchers; technology transfer
Technology Transfer for SMEs, TUFF (VINNOVA)	2.5 to 3.5	Enhancing absorption capacities of SMEs, facilitating the trade between SMEs and HEIs/PSREs	Technology Transfer; co- operation in the innovation process
AIS - active industrial collaboration (VINNOVA)	11 (for the whole programs: about 30 projects)	Establishing consortium of research institutes (typically one or two); university institutes (one or two) and business enterprises (6-15); Focussed on IT, life sciences, manufacturing and processing, sustainable development	Research collaboration between HEIs, PSREs, business enterprises
The regional technology program ("SME consortia") (NUTEK)	~ 4 (per year)	Establishing networks between universities, research centres, local actors, SMEs, and partly large enterprises	Co-operation between firms and HEIs/PSREs in the innovation process
Technopole (NUTEK)	1 - 1.5	Commercialisation of research results gained at universities	Creating and supporting spin-offs
Technology Bridge Foundation;	Interests of 110 million Euro	Commercial exploitation of university research	Co-operation between industry and academia
CapTec (NUTEK)	n.a.	"Meeting place" between NTBFs and investors	Supporting spin- offs and NTBFs
Provision of management	n.a.	Providing management assistance	Creation of spin-

support for NTBFs (various
technology and science parks)

offs

Source: Trend Chart project, own surveys and calculations by the authors

- As in other countries too, high-tech spin-offs have attracted a lot of interest by economic and technology policy during the last few years. Hence, a variety of programmes have been designed and established to stimulate high-tech or research oriented spin-offs. In the following, the most important programmes are briefly discussed:
- The Technopole programme is a demand-led initiative from NUTEK aiming towards fostering the process of commercialising research results through stimulating the foundation of new technology based firms (NTBFs) and fostering the growth of NTBFs. In 1998, 24 Technopoles received funding. Technopoles may be units of universities or part of a science park structure. The Technopoles are centres that promote a business-like and supportive environment for start-ups. They are also targeted towards stimulating growth in small technology-based enterprises based on commercialisation of research findings. They supply technology-related services (R&D projects, patent services, technological consulting and search for R&D partners), market-related services (market analysis, search for business partners, marketing assistance and contact with other firms), finance-related services (EU schemes contact with financiers and financing of projects), software (seminars, training and education, general consulting and law consulting) and founder-specific services (offices, internet access, reception desk etc). Public funding is around 1 to 1.5 million Euro per year
- The interest in the creation of new technology-based firms has also resulted in action being taken in most university regions and new instruments have been created. The new instruments aim, not only to stimulate the creation of NTBFs, but also to develop the provision of management support activities. Examples include the Business Development Programmes for Technology-based Growth Firms, organised by the Centre for Innovation and Entrepreneurship in Linköping, and the Centre for Entrepreneurship in Uppsala. Around the universities and Science Parks in Sweden, various initiatives have also been launched to give technology start-ups access to resources in incubator units. Good examples may be found in Gothenburg (Chalmers), Linköping, Lund and Uppsala. In the last two years, 'green houses' for student start-ups have been created in many of the new universities and university colleges.
- Since 1994/1995, the commercial exploitation of university research and inventions have also been the focus for other new initiatives. The formation of actors such as the Technology Bridge Foundations and the University Holding Companies, as well as the Patent & Exploitation Offices, are concrete manifestations of the political system's belief in the commercial potential of R&D and academic research. These are described in more detail below:
- In 1995, seven Technology Bridge Foundations located in major university cities became operational. Together they received capital of about 110 million euros, the return on

which, they may use to increase commercial benefit from university research and to encourage co-operation between industry and academia. The overall objectives are (i) to facilitate patenting, licensing and commercialisation of knowledge and research results from the universities, (ii) to facilitate firms and single innovators to search for knowledge in the universities, (iii) to develop common research between firms and universities and finally, (iv) to stimulate co-operation between SMEs in joint projects. The Technology Bridge Foundations were established with money from the Swedish wage-earners funds.

- In 1994-95 eleven University Holding Companies were formed in Sweden. Their mission is to form project enterprises in order to exploit research from the universities and to develop services for such exploitation. They are themselves owned by the universities and are expected to become minority owners in firms created jointly with researchers and industrial actors for the exploitation of university research. In total, they have received around 7 million Euro of public money.
- During the 1990s, some new actors were created in order to help to bring together independent inventors and researchers interested in market exploitation. One example is SIC, a foundation created in 1994, and commencing operations in 1995. It was designed to support innovation among inventors and small firms. Its capital amounts to about 56 million euro, which it focuses on inventions/inventors in the very early stages of the development process (pre-seed or seed stage). NUTEK also provides seed-money to inventors e.g. university researchers. Apart from NUTEK and SIC, there is another state-owned actor, the Swedish Industry Fund, which provides conditional loans for development projects in industry, as well as new equity through its venture capital branch. A relatively new pension fund controlled by the government - The sixth AP Fund - has been formed with the objective of engaging in venture capital via established actors in the field.
- One initiative of special interest for the NTBFs population is NUTEK's CapTec programme, which provides an annual meeting-place for young, innovative firms and investors. It has been run now for five years and is planned to continue. At the same time, new Financing Forums are being set up with the same purpose but with other organisers, one of which is CONNECT Sweden, whose activities were initiated in 1998 by the Royal Swedish Academy of Engineering Sciences (IVA).
- New Graduate Schools: This type of initiative is in accordance with the prevailing view that universities must work closer with industry. The main goal is to increase the number of graduates with PhDs, and the examination rate in sciences of strategic importance to Swedish industry, with an industry related and/or across disciplines and/or international angle. They aim towards stimulating university-industry collaboration as well as collaboration between different universities. The graduate school programs in general, have funds specifically assigned to the development of new graduate courses, which may sometimes be problem-oriented and/or across disciplines. An aim of the initiators, i.e. the Swedish Foundation for Strategic Research and the Knowledge Foundation, is also to

increase the number of PhD holders employed in the private sector. The graduate schools are found in scientific areas which are believed to be of strategic importance. Initiators can submit an application that is evaluated over several steps. It is important to find in it, the goals described above. Once the application is approved, the first evaluation is carried out after 3 years, and is repeated again after 4 years. The Knowledge Foundation demands that industry is involved in the application, that they contribute substantially to the funding, that graduate students have one supervisor from industry or an industrial research institute and one from the university, and that the graduate student is only funded by the Knowledge Foundation for 4 years.

- A new liaison function with new universities/university colleges for co-operation with SMEs. The overall aim of this programme is to increase the interaction between the new universities and university colleges and industry (especially SMEs) and to give the new universities an important role in regional development, primarily in their own regions. The measure is run by NUTEK under a special Government mission, in a joint effort with the Knowledge Foundation.
- Educational programmes: Recognising the role of new and small firms for economic development, new educational programmes which focus on entrepreneurship and innovation management, have been established. These programmes address both the undergraduate and graduate levels. The creation of Centres of Entrepreneurship in Linköping and Uppsala or the International Business School in Jonköping, are good examples of an on-going trend. In order to create a more general entrepreneurial culture in Swedish society, measures have been taken to introduce entrepreneurship as a special subject as early as in primary school. One example is the growing interest from industry to be part of the Youth Enterprise movement, which has gradually increased its coverage in the upper secondary schools in Sweden.
- Awareness programmes: Information about science and research findings is an important part of the new third mission of the universities, i.e. the universities' interaction with the surrounding society. Universities and university colleges are trying new ways to fulfil this task with the assistance of public authorities. The activity "Light year 1997", co-ordinated by the Royal Swedish Academy of Engineering Sciences, was a national project carried out in co-operation with about thirty organisations. The aim was to make better use of people's ideas, creative power and capacity for innovation. The primary objective was to promote broader use of the range of ideas for improving and developing society that are to be found all over the country. This was done in a process, which involved industry, public administration and private citizens through numerous initiatives.

The Swedish Intermediary structures with relevance for ISR are characterised by a broad variety of distinct institutions with various missions, objectives and measures:

- An important part of the intermediary structure between universities and business in Sweden is the semi-public Industrial Research Institutes. The first semi-public industrial research institutes were founded in the 1940s, and today, they number about thirty. Over

recent years there has been a shift in orientation, with the oldest being oriented towards industrial sectors and the youngest being oriented towards technology areas. The government, through different agencies and Ministries, funds the smaller part (around 40 percent) of their R&D activities. Most of the remaining funding comes from member enterprises and from contract research. Thus, these institutions can be regarded as examples of Private Public Partnerships. The motives for government involvement are threefold: (i) to finance activities (long-term research and support to SMEs) that is beneficial for the society, (ii) to stimulate knowledge diffusion, and (iii) to develop a well functioning technological infrastructure. The goals of restructuring at the end of the 1990s were to strengthen the research directly targeted to industrial needs, to increase the number of researchers in industry (i.e. increase mobility), to generally strengthen the function as a bridging organisation between the higher education system and industry, and to intensify technology transfer, especially to SMEs.

- Today, there are around 20 science and technology parks in Sweden. There are no purely private business parks. The majority of the parks are connected to universities or university colleges. The parks are organised in the SwedePark Association. Around the universities and science parks, different initiatives have been introduced to give technology start-ups access to resources. Good examples are found in Gothenburg, Linköping and Lund. In the last two years 'green houses' for student start-ups have been created in many of the new universities and university colleges.
- Within the SME technology transfer programme TUFF (see above), consulting networks for SMEs are promoted. The infrastructure for technological services should be adapted so as to respond better to the needs of SMEs. Existing technology providers should be better co-ordinated in relation to their clients. The Swedish Innovation Relay Centres, which are consortia networks of institutes, industrial liaison offices, and technology parks, played an important role in establishing such a co-ordinated infrastructure, and their actions have consequently become fully integrated into this national effort..
- Another NUTEK initiative in the middle of the 1990s, was the regional technology development programme. During the period 1995-2000, the programme generated 21 enterprise consortia, including 200 SMEs. The aim of the programme was to upgrade the technological competence and capacity of participating enterprises so that they could create new links with both private and public research organisations. The programme promotes the development capabilities of SMEs in prioritised regions through co-operation between participating SMEs. In this co-operation, knowledge from large firms, research institutes, universities and university colleges are used. The idea is to improve the possibilities of SMEs towards technology development and to build up their competence by collaboration in consortia. Public funding is a maximum of 37.5 % in each consortium and the rest comes from consortia participators. NUTEK co-ordinates the programme.

- In 1998, the Government commissioned NUTEK to increase the capacity of universities to collaborate with local SMEs. The aim of the programme was to support universities to build up contacts with a large proportion of the local SMEs. The programme will renew and broaden the opportunities in SMEs to exploit the knowledge generated at the nearest university, by different collaborative means.
- The TIPPS centres (Technology Input in Products, Processes and Systems) aim to help SMEs with their need for technological problem solving. Such centres have been built up at ten of the smaller university colleges. Each centre has its own speciality and provides smaller enterprises with technical services, co-operation or consultation in connection to the work within the University College. The TIPPS centres are linked through the Sefström network association, in order to offer the customer the best possible solution, even if it means putting the customer in contact with a centre other than the one originally contacted.

Assessments of Public Promotion Programmes by National Experts: About 15 national experts were contacted and requested for an assessment of the significance and effectiveness of the programmes enhancing ISR in Sweden. Some findings from the responses are outlined below:

- In general, the significance and effectiveness of the various joint programmes for promoting ISR are regarded among the interviewed experts, as being high. Especially the Competence Centres Programme by NUTEK are mentioned most often by the experts as a successful example of a public programme promoting joint R&D. Thus, it can be regarded as example for good practice with respect to stimulating ISR.
- According to the interviewed experts, public programmes primarily aiming towards increasing the mobility of researchers are not that developed in Sweden. However, the mobility of researchers is, in some joint R&D programmes, an objective of a lower order, e.g. the graduate research schools. Many of the experts suggested that programmes explicitly aimed towards enhancing mobility should be developed and introduced.
- Public promotion programmes for high-tech spin-offs from science are regarded as highly significant and effective by several experts, while some others acknowledge their importance but question their effectiveness. Many of the experts are of the opinion that there is a shortage of seed money, i.e. funding in early stages in the commercialisation of innovations.
- The opinions are divided among experts whether or not the programmes (and organisations) for licensing, are significant and effective. They all agree on the importance of designing new instruments for promoting the commercialisation of research findings.
- Training or educational programmes which try to promote the commercialisation of research findings (e.g. entrepreneurship courses etc.) have started to emerge in some

universities only recently. According to the experts, it is still too early to assess the significance and effectiveness of these programs.

- The extent and significance of graduate education programmes is rather weak according to experts. However, the "graduate research schools" are regarded as effective in promoting ISR and it can be expected that these schools will be significant in the near future.
- Awareness programmes are a rather new activity in Sweden. The size of such programmes is generally small. Experts agree that awareness programmes are important in relation to ISR but differ in opinion (if they hold one) on the effectiveness of existing programmes.
- The semi-public industrial research institutes for co-operative research are, according to the experts, one important intermediary between science and business enterprises. A common expert opinion about these institutes is that they are too small and too few, in relation to their objectives and to what is needed to improve the Swedish innovation system further.
- During the 1990s, activities aiming towards linking researchers from universities with business enterprises in Sweden increased significantly. The range of tools and instruments promoting ISR has expanded so much that voices are being raised for co-ordination and better transparency of the system.

B.7.4 ISR in the Field of Human Capital in Sweden

The annual number of graduates in the academic year of 98/99 was about 36,500 persons, of which 91 % had three or more years of HEI training. The corresponding number of postgraduates (doctors and licentiates) was about 3,000. The majority of graduates, 46 %, were to be found in social sciences (including education and legal sciences). With 21 % in engineering (including agricultural sciences), this took the second position, followed by medicine & health care (19 %). The share of natural sciences was 5 %.

At the end the 1990s, about 70,000 graduates were unemployed. The distribution of these unemployed graduates does not correspond fully to the respective distribution of graduates, indicating that the labour market for some scientific fields, is somewhat in trouble. This holds true for the natural sciences and for the humanities. In those fields, the percentage of unemployed graduates is higher, as would be expected if there were an even distribution (i.e. the same share unemployed as there are graduates). The opposite holds true for engineering and (to a lesser extent) for medicine.

Table B.7.10: Higher Education by Disciplines in Sweden 1998 (in %)

<i>Field of Study</i>	<i>Registered Students*</i>	<i>Graduates</i>	<i>Unemployed Graduates</i>	<i>Gainfully Employed</i>
Natural Sciences	n.a.	5	10	6
Engineering (incl. Agricultural Sciences)	n.a.	21	11	17
Medicine & Health Care	n.a.	19	14	19

Social Sciences (incl. Education)	n.a.	46	48	52
Humanities and others	n.a.	9	14	6
Total number (1,000)	310.0	36.5	69.6	507.1

* Distributing registered students by fields is complicated because many students are registered in more than one field or at more than one level within one field.

Source: Statistics Sweden, own calculations

At the end of the 1990s, a total of 507,000 employees had a graduate qualification (share of total employees: about 13 %²⁵). Most of them (52 %), have their degrees in social sciences (including education), followed by medicine (19 %) and engineering (17 %).

Information on the employment of graduates and postgraduates is available for the year 1995²⁶. In this year, the number of employees in Sweden was 3,842,488, out of which 498,977 had at least 3 years or more of higher education (including 29,102 postgraduates). These higher educated people were distributed over scientific fields as follows: natural & engineering sciences: 18.3 %; medical & health related sciences: 12.3 %; social sciences/humanities and others: 69.4 %.

Sectors with a large share of graduates and postgraduates out of total employment in 1995 were, in particular, business service sectors (18 %), public service sector (22 %), R&D institutes (50 %) and the higher education institutions (63 %). The corresponding shares in the manufacturing sector were by far lower (6 %).

The distribution of the higher educated employees over scientific fields and sectors shows that the manufacturing industry employed almost one third of all higher educated engineers and natural scientists. The graduates of medical and health related sciences were primarily found in the public sector (health care). The public sector also employed most of the other higher educated employees.

Intersectoral mobility (and especially the mobility between HEIs/PSREs to economic sectors) can be interpreted as another important channel of ISR. Each person moving from one occupation to another brings not only formal (i.e. codified) knowledge with her/him, but also (and very importantly) tacit knowledge (i.e. not codified knowledge). A study carried out in 1998²⁷, showed that internal flows were most important, i.e. the mobility of higher education employees within a sector. This is especially true for the mobility of HEI employees. The overall mobility rate from HEIs and PSREs was high, i.e. almost 25 percent of the employees in 1994 had moved out within a year. Among the total number of higher educated employees in HEIs in 1994, 4 % moved to industry, while at PSREs, almost 15 % moved to industry.

25 This share was calculated using employment data from 1995 assuming that this share was relatively constant between 1995 and 1998.

26 Formal competencies in the innovation systems of the Nordic countries: an analysis based on register data. 1998.

27 Formal competencies in the innovation systems of the Nordic countries: an analysis based on register data. 1998.

According to the assessments by national experts the level of mobility between science and industry can be summarised as follows:

- The mobility of researchers and graduates from universities to industry seems to be working rather well according to many of the experts. There are no employment regulations that hamper mobility. Some experts say that mobility is working too well in the sense that too many university researchers move to enterprises, especially in research fields of great importance to industry. Examples can be given of whole research teams moving from science to business enterprises. A consequence is that university research in certain fields risks being impoverished. To the extent that such mobility occurs, it can be interpreted in shortage terms, i.e. too few researchers are being trained in 'hot' scientific fields. Regarding the mobility of graduates, the picture is almost the same. As in other European countries too, enterprises complain of a shortage of graduates (especially engineers and IT experts).
- The mobility of researchers from business enterprises to universities is not that extensive and among some experts regard this limited flow as a problem. According to them, it would be desirable for much more enterprise researchers move to universities. The most important barrier for the mobility between industry and university is the significant difference in earning options. The salary of a university researcher is much smaller compared to a researcher in the business enterprise sector.
- Mobility in terms of temporary employment is also regarded among experts as being too low in Sweden. This is explained by the fact that, in general, it is not a step up in an academic research career to work in business R&D. However, a common opinion among experts is that there is much to be done in order to promote temporary mobility between science and industry.

B.7.5 ISR in Sweden: A Summary Assessment by Type of Interaction

Contract and collaborative research: The level of R&D expenditure in public science institutions financed by industry is below the EU average, although its volume compared to GDP is rather high by international comparison, given the overall high level of R&D expenditure in Sweden. Therefore, ISR performance measured by this indicator should not be regarded as a weak point in the Swedish innovation system. For example, the results of CIS2 show that the co-operation linkages of Swedish business enterprises with HEIs and PSREs are very strong, and that a high percentage of innovative firms co-operate with public science institutions in the course of innovation projects. Moreover, some sectors, especially pharmaceuticals, are heavily involved in financing HEIs and PSREs. In general, the Swedish industry structure is quite favourable for ISR through contract and collaborative research. The Swedish industry is characterised by a strong high-tech sector with a group of multi-nationals which have an international, if not global, focus. These enterprises have tight linkages with Swedish HEIs and PSREs but they are also engaged continuously in R&D abroad. Swedish SMEs are also comparatively strong in R&D activities.

Personnel mobility: Mobility rates of researchers (both from HEIs and PSREs) are comparatively high in Sweden. Due to the structural features of the Swedish industry, the demand for highly skilled personnel is constantly high. The outflow of researchers from HEIs is so high, that some experts hold the opinion that in science, there may be a scarcity of skilled researchers in some fields in the future. The main reason for this migration from HEIs to industry is the difference in earning options. Although the mobility from industry to HEIs is higher in Sweden than the EU average, it is not very significant. Attracting qualified personnel from the business enterprise sector seems to be very difficult for universities.

Training and education: There is only limited information on the extent of co-operation between enterprises and universities concerning training and education. Some measures have been taken to increase the amount of training by experts from enterprises in HEIs and special courses for entrepreneurship have been developed. However, it is too early to make a final assessment of these programmes.

IPR: The Swedish IPR regulation in HEIs, gives the IPR to the individual researcher. There is however, no data available on what extent individual researchers file patents for their inventions. Some experts indicate that the typical university researcher lacks the management capacity to exploit their results efficiently in the market place.

Start-ups: No quantitative information is available on start-ups from public science institutions. However, some programmes have been implemented recently which try to encourage and support the formation of spin-offs. Nevertheless, it is too early to evaluate their effectiveness.

Involvement of SMEs in ISR: The R&D landscape in Sweden is dominated by a group of large multi-nationals. Small firms (> 100 employees) have only a tiny share of R&D (3 %) expenditure. Nevertheless, according to CIS2 data, these small firms have a comparatively high R&D intensity. Thus, their absorptive capacity can be assessed as quite high. During the last few years, special programmes have been implemented to encourage SMEs to use the potentials of HEIs and PSREs.

Networking between industry and science: Although there is no 'real' data available, the high mobility between HEIs/PSREs researchers indicates a high degree of networking between science and industry in Sweden. The success of the Competence Centre Programme shows that networks between science and industry are strong (assuming that these formal networks are built on the basis of former contacts). In addition, some measures concerning networks have been implemented on a regional basis.

Science-based industries: The importance of high-tech industries for R&D in Sweden is high. Most Swedish multi-nationals (for example, in telecommunications, pharmaceuticals, transport and engineering) can be associated with this high-tech base. Their engagement with domestic HEIs/PSREs is quite strong but additionally, they perform a significant part of their R&D activities abroad. The attractiveness of Sweden as a location for foreign based R&D

intensive enterprises seems limited as is indicated by the low share of foreign financing of R&D.

B.7.6 Good Practice in Framework Conditions for ISR in Sweden

In the following pages, some examples of good practice in ISR in Sweden are described in some detail. They refer to those areas of policy-related framework conditions that are reported to be positively influential on ISR and provide interesting approaches which are not common in other countries and thus, are potential candidates for learning by comparison:

- The NUTEK/VINNOVA Competence Centre Programme represents a public promotion programme that focuses on networking and long-term co-operation between industry and science based on providing joint research infrastructure and funding in thematic fields of research.
- The Chalmers School of Entrepreneurship is an example of incorporating entrepreneurs into university curricula, raising awareness among students of start-ups, and supporting graduates in their start-up activities.
- The Third Mission of Universities provides an example for institutional changes with respect to raising awareness of, and increasing incentives for, ISR.
- The Materials Science Department at the University of Technology at Chalmers shows the way a long term oriented mutual collaboration with a large corporation (Volvo) is established and maintained.

Competence Centre Programme

The Swedish Competence Centre Programme is an effort to build bridges between science and industry in Sweden by creating excellent academic research environments in which industrial companies participate actively and persistently in order to derive long-term benefits.

The basic idea underlying the Competence Centre concept is that active involvement from industry in academic research brings about mutual benefits. Active collaboration between research groups and companies in joint R&D projects is seen as the most effective way of achieving good agreement between academic research and industrial needs and an effective transfer of knowledge and technology. The complex needs and problems of industry offer new and exciting challenges to the universities. This translates into a demand for active participation by all the industrial partners in research collaboration and not only a commitment to pay in cash. From 1998 to 2000, the budget for the competence centre programme was about 53 million euros, i.e. around 1 percent of Swedish R&D expenses. NUTEK/VINNOVA, participating universities and enterprises are each contributing one third of that amount. Each centre is closely connected to the activities, long-term priorities and plans of a host university. The university has the responsibility for the centre administration and contributes to their financing by providing a base organisation and other resources.

The programme started in 1995 after an initiative by NUTEK. At present it comprises 28 Competence Centres at 8 universities and about 220 participating industrial companies. The programme is run as a joint venture between NUTEK (now: VINNOVA) and the Swedish National Energy Administration, STEM, which is the governmental financing partner in five energy-related Competence Centres. NUTEK/VINNOVA and STEM intend to contribute to the Centres for up to 10 years.

The Competence Centres are specialised in specific research fields within the following areas: (i) Energy, Transport, and Environmental Technology (8 Centres), (ii) Production and Process Technology (7 Centres), (iii) Biotechnology and Biomedical Technology (5 Centres), and (iv) Information Technology (8 Centres)

From the very beginning, Swedish industry has shown a great interest in the Competence Centres and played an active role in their build-up. Many enterprises, especially the large international groups based in Sweden, are engaged in several centres. About 20 % of the industrial partners are small and medium-sized firms, here defined as companies with less than 250 employees and not belonging to large groups.

A first round of evaluations was carried out in 1997-98 by an international team of experts on this kind of university-industry collaborative effort, focussing on reviewing the introductory efforts to develop Competence Centres.

A second round of evaluations is currently underway. This time, the evaluation teams are constituted of the same experts as in the first evaluation, as well as 2-3 scientific experts in the field of the Centre.

The Centres are reviewed with respect to their development as Competence Centres (their Added Values), their technical and scientific achievements as well as the industrial relevance and benefits.

The first report of the second round of evaluations included statements such as:

"We were impressed by how many times during the visits we were told by the scientific subject experts from their respective technical areas that the intellectual calibre of the work performed to date was world class or first class."

"The involvement of industrial personnel in the Competence Centres Programme, from both large corporations and SMEs (small and medium enterprises), is phenomenal and exemplary. It ranges from project participation all the way to serving on the Boards in strategic roles."

The concept of the Swedish Competence Centre Programme has served as a basis for the development of an initiative of similar kind in Austria, called the K+ Competence Centre Programme.

Chalmers School of Entrepreneurship: Training the Entrepreneurs of the Future

Chalmers University of Technology was founded in 1829 and has a long history of collaboration with industry. Over the last twenty-five years, Chalmers has also gained a reputation for its track record of producing 10 to 15 spin-off firms per year. One estimate in the early 1990s suggested that the university's spin-off companies contributed about 100 million Euro to the local economy each year. However, of the network of over 200 Chalmers spin-off companies that still exist, only around 40 are substantial businesses that have been built up to more than just a few staff. Some 8 % of the university's income comes from industry-funded research.

Chalmers University of Technology is quite unique in assuming that the researcher/inventor and the entrepreneur are not the same person. Whereas most other universities rely on having entrepreneurial researchers with a drive to exploit, Chalmers focuses on finding the right entrepreneur for each new technology product or service. As part of this matching exercise, Chalmers School of Entrepreneurship fits well into this broader scheme to encourage commercial exploitation of university research.

Chalmers School of Entrepreneurship aims to 'teach' entrepreneurial skills to final year Masters students. The course has been heavily oversubscribed since the outset, and has had to be designed to accept only the strongest, most driven students selected according to the results of external psychometric testing, and extensive interviews with the School's board. The School had 12 students in its first year, and has added another three students to its intake in each subsequent year. The students are grouped into teams of three, and matched with a new technology and its university inventor. The students then undergo a year of intense real-time, live case study, in which they must develop an appropriate strategy for the new technology to be developed into a start-up firm by the end of the training. Teaching is done as modular workshops that are relevant to the position of the business to date. Groups meet their other peers to discuss successes and assess their strategies for 'their' businesses; although the students are actively discouraged from having any ownership stake in the company until they have completed their course. The School has had a good rate of success with the course and has only this year had to build in an element to discuss failure in a positive way.

Another feature of good practice in Chalmers is the facility for start-up firms to be helped at each step of the process. The School of Entrepreneurship only captures a small number of the technologies available for development/exploitation. In general though, the process of commercialisation is as follows. Once a researcher has an invention, he/she can approach Chalmers Innovation (Chalmers Foundation owned unit) to discuss whether this idea should be patented or developed as a spin-off company. If patenting is the chosen route, Chalmers Innovation has links with a group called Research Patents-West (partly owned by Chalmers Foundation and Göteborg University). Research Patents-West will assess the invention to determine the return from patenting, and should it go ahead, will direct the inventor toward a specific patent attorney.

If it is decided that a start-up company should be formed, Chalmers Innovation has links with Chalmers Invest. This organisation, owned by the Chalmers Foundation, has 30 million SEK at its disposal for early, equity investment in start-up companies (although the maximum investment per company is 1 million SEK). Chalmers accept that it would be better if other actors were available to provide funds at this early stage, and that its lone role at this stage may be a weakness. However, this early stage investment is only for a very short period (generally, one year), in which time the firm must develop a business plan to attract venture capital. If firms fail at this stage, the funding from Chalmers Invest is not repaid to the Foundation. This therefore encourages Chalmers Invest to back only those companies that will succeed.

Firms are encouraged to approach external venture capitalists for funding. However, the majority of firms from this system approach a firm called Innovationskapital, a venture capital company which participates in newly-established, high-tech companies. This private finance concern aims to build growth in the early years of these firms, which can then be returned from the sale of its shares in the firm at a later date.

Throughout this process, Chalmers Innovation provides low cost services and equipment to the start-up companies. It also provides advice and training throughout the build up of the firm. However, Chalmers Innovation only envisages firms being situated in their premises for a maximum of five years. They believe that at the end of this period, potentially successful businesses will survive on their own. The companies are encouraged to seek new premises outside the university. This is contrary to the popularly conceived model of spin-offs re-locating to a university science park (however, see following pages). The University of Chalmers does not see the science park as being the most appropriate location for spin-off companies since high rents are prohibitive and are intended to be affordable only by those large national/multinational companies based there.

Source: Howells et al. (2000)

Third Mission of Universities

The beginning of the 1990s brought with it a escalation of the debate on how society could profit from the research carried out by universities and university colleges. In 1996, the debate was depicted in the Higher Education Act, through its amendment that: *"The Higher Education Institutions shall also [besides providing education and performing research and development] co-operate with the surrounding society and inform about their activities"*. This may be a good example of a measure that would enhance the attitudes of university researcher towards ISR. However, there remains a question mark. Currently there is no central and systematic evaluation of the third mission of universities. Although it is discussed, for the moment it remains uncertain if and when such evaluations may be introduced.

Chalmers, VOLVO and Materials Science: Long Term Oriented Mutual Collaboration

Chalmers University of Technology has a long history of collaboration with industry. It also has a well-established science park, Chalmers' Science Park, situated adjacent to the university campus. One measure of the success of Chalmers Science Park is that it already has a number of companies vying to be situated on the, as yet unbuilt, extension to the facility. However, the majority of the facilities based at the science park, are the research units of large national and multinational firms like Volvo (see below), Ericsson and SKF. Chalmers has a range of schemes to facilitate industry collaboration as well as the exploitation and commercialisation mechanisms. These include: continuing professional development programmes; technology support schemes for SMEs; high-tech firm collaboration mechanisms; and university firm spin-offs programmes.

Volvo needed a flexible and skilled workforce that had specific competencies that were relevant to Volvo's technology requirements and approached Chalmers to provide this training. These specific competencies were in the fields of: aerodynamics, sheet forming, automated assembly, noise reduction, tribology, combustion, exhaust catalysis, corrosion control and use of light alloys.

As an initial way to tap into this expertise, Volvo agreed to invest in equipment, personnel and laboratory space that would allow Volvo staff, together with Chalmers academics, to work jointly on the study of surface technology and develop training courses for work into this field. Such work particularly focused on tribology and mechanical and corrosive wear. Laboratory space was taken at Chalmers' Science Park, microscopes and other laboratory equipment was purchased, together with the hiring of Chalmers' graduates to man the operation. A number of staff work for Volvo and Chalmers on a 50:50 basis.

The co-operation has benefited both parties, aside from just the specific collaboration. For the university, the collaboration has generally allowed:

- staff to use equipment bought by Volvo to work on other research projects which Volvo is not involved in;
- feedback by Volvo on the quality of its graduates;
- Volvo personnel to work with university staff and students; and
- use of direct examples from Volvo of modern engineering design problems and issues as teaching tools.

For Volvo, it has allowed the firm to:

- to obtain preferential access to the university's research base more generally;
- use of other specialist equipment and instruments housed in Chalmers; and
- to use the university as a 'listening post' for wider developments in science and technology related to Volvo's activities.

Source: Howells et al. (2000)

B.8 United Kingdom²⁸

B.8.1 Knowledge Production Structures in the UK

The UK's gross expenditure on R&D (GERD) was 23.1 billion Euro in 1997, equivalent to 1.83 percent of GDP. Compared to international standards, the UK is placed below the OECD average and just above the EU average. During the 1990s, total R&D expenditure in the UK decreased significantly. The enterprise sector is the dominant group of actors in the UK R&D system, performing 66 percent of all R&D expenditure (Table B.8.1). Business enterprises are also the main funding source of R&D in the UK. R&D at enterprises is mainly financed by internal sources, although a considerable portion of business enterprise R&D stems from abroad.

Table B.8.1: R&D Expenditures in the UK 1997 by Financing and Performing Sectors (in million Euro)

<i>Performing Sector</i>	<i>Financed by</i>			<i>million Euro</i>	<i>Total %</i>	<i>% of GDP</i>
	<i>Enterprises</i>	<i>State*</i>	<i>Abroad</i>			
Enterprise Sector	10,701	1,574	2,833	15,108	66	1.20
PSRE*	431	2,885	137	3,453	15	0.27
HEI	324	3,818	388	4,346	19	0.36
Total (million Euro)	11,455	8,277	3,359	23,090		1.83
Total (%)	50	36	14		100	

* including non-profit private institutions

Source: OECD (2000), own calculations

Research in HEIs is funded basically by the government through what is known as the dual support system. First, there are so-called Higher Education Funding Councils, that are separate bodies for England, Scotland, Wales and Northern Ireland, with funds derived from Ministries responsible for education, provide general funding, used mainly for academic salaries and research infrastructure. Second, Research Councils provide funds funding for projects (including salaries of contract researchers), research training and research centres on a competitive peer-reviewed basis. The funds are derived from the Office of Science and Technology in the Department of Trade and Industry. The other principal funding source for research is the charitable, non-profit sector, notably the Wellcome Trust which is the largest single founder of medical research. Furthermore, industry and the EU provide further funding for R&D in HEIs (nearly 20 percent of total R&D expenditures in HEIs in 1997). The PSRE sector is of significant size in the UK, performing 15 percent of all R&D. It consists of research institutes belonging to Research Councils, and of departmental bodies, which are responsible to their respective central government department.

28 This section is based on the following information sources: Rigby (2001), Howells et al. (1998), Cunningham (1998), Lissenburgh and Harding (2000), OECD - BSTS, MSTI, ANBERD, Eurostat - CIS2

A major characteristic of the UK public science sector is the low share of basic financing and a corresponding high share of R&D money allocated on a competitive basis. In 1997, funding by Higher Education Funding Councils amounts only to 36 % of total R&D expenditures in HEIs (Table B.8.2). At PSREs, basic financing by the government was much higher at the beginning of the 1990s, but was shifted more and more towards project and programme financing allocated on a competitive basis.

Table B.8.2: Financing Structure of R&D in HEIs and PSREs in the UK 1997 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing	36	~25
Project Financing and other financing sources	64	~75

Source: OECD (2000), own calculations

Within the enterprise sector, R&D is rather strongly concentrated on the high-tech sectors²⁹ which have especially strong linkages to the science sector. In 1997, the high-tech sector performed about 37 percent of BERD, while the medium to high technology sectors (machinery, motor vehicles, chemicals etc.) accounted for only 30 percent (Table B.8.3). R&D in the service sector is concentrated on IT services, whose share is 14 percent of total BERD. The share of R&D in IT-services in GDP is 0.18 percent, which is remarkably high with respect to OECD standards.

Table B.8.3: R&D Expenditures in the UK Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in R&D Expenditures (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	37	0.46
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	30	0.38
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	17	0.21
IT-Services (NACE 64, 72, 73)	14	0.18
Other Services (NACE 50 to 99, excl. IT-Services)	2	0.02

Source: OECD (2000), own calculations

The main business R&D performers in the UK are heavily concentrated in pharmaceutical companies. The three top performers of R&D belong to this high-tech business sector. Two of these firms have merged to form GlaxoSmithKline, now the world's largest pharmaceutical company. These three firms account for 26 % of the total of all UK business R&D, and the top 20 companies account for 67 %. Nearly a third of all business R&D is carried out in large enterprises with more than 1,000 employees (Table B.8.4). The chemicals and pharmaceuticals sector's share in BERD is about 30 %, the electrical machinery and telecommunication equipment sector's share is 13 %, while that of the aerospace industry is 10 %.

29 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

Table B.8.4: R&D Expenditures in the UK Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 100 employees)	6
Medium-scaled Enterprises (100 to 399 employees)	15
Medium-scaled to large Enterprises (400 to 999 employees)	16
Large Enterprises (1,000 to 9,999 employees)	53
Very Large Enterprises (10,000 employees and more)	10

Source: SET (2000), own calculations

Although SMEs only account for about 20 % of total BERD in the UK, they represent nevertheless, the vast majority of enterprises in the UK. Their behaviour concerning contact and co-operation with science determines the absolute level of ISR. The level of ISR by SMEs strongly depends on their absorptive capacity and their involvement in innovation activities. According to various indicators on these variables provided by the CIS2, the UK SME sector shows a divergent performance (Table B.8.5)³⁰. In the manufacturing sector, very small enterprises show above average values for nearly all indicators, while absorptive capacity in SMEs in the service sector, seem to be rather low compared to EU standards.

Table B.8.5: Relative Innovation and R&D Performance of SMEs in the UK

	<i>Manufacturing</i>		<i>Services</i>	
	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>	<i>Very small enterprises (< 50 employees)</i>	<i>Small enterprises (50-249 employees)</i>
Share of Innovative Enterprises*	1.09	0.88	1.09	0.76
Innovation Expenditures as a Share of Turnover*	1.53	1.45	1.63	0.79
Share of Turnover due to Innovative Products*	1.29	1.36	n.a.	n.a.
Share of Enterprises with High R&D Intensity**	1.49	0.52	0.99	0.97
Share of Enterprises with Medium R&D Intensity**	1.05	1.00	0.62	0.46
Share of Enterprises Engaged Continuously in R&D**	1.12	0.86	0.88	0.83
Share of Enterprises Having Applied for a Patent**	0.71	0.74	0.31	0.08

* Figures show the relation of SMEs' performance in the UK to the performance of SMEs in the EU average, normalised by the respective relation of all UK enterprises to all EU enterprises: $(SME_{xUKj}/SME_{xEUj})/(x_{UKj}/x_{EUj})$, x being the variable considered, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. The EU average is the mean weighted by the number of enterprises of all EU countries (except Greece): Values above 1 show that SMEs are more innovative than in the EU average.

** Figures show the relation of SMEs in the UK to SMEs in the weighted mean of all EU countries (except Greece): SME_{xUKj}/SME_{xEUj} , x being the variable considered, j being the sector considered (i.e. manufacturing and services), and SME indicating that the variable is measured for SMEs only. Values above 1 show that SMEs are more R&D and patenting oriented than in the EU average.

Source: Eurostat-CIS2, own calculations

In 1997, foreign-owned enterprises had a share in total business enterprise R&D expenditure of 40 percent, which is significantly above the EU average. These figures may change

30 In order to compare innovation performance as reported in the CIS2 among EU countries, one has to take into account national variations in the way innovation was defined (see Leppälähti 2000). Therefore, innovation performance indicators for SMEs are calculated with respect to the national average and the EU average, respectively, and these ratios are compared in order to position innovation activities by SMEs in the UK. With respect to R&D and patent indicators, there seem to be

however, in short intervals due to international mergers and acquisitions. Nevertheless, the UK business enterprise R&D sector is highly internationally linked, and funding of R&D by companies from abroad plays a higher role than in many other countries. Foreign-owned enterprises seem to behave rather similarly to UK owned firms concerning ISR with HEIs and PSREs in the UK. About 20 percent of HEIs' research incomes from enterprises stems from foreign-owned enterprises (Howells et al. 1998, 24ff).

Research in science in the UK is strongly oriented towards the natural sciences and engineering, with higher concentration in PSREs than in HEIs. For PSREs, nearly more than three quarters of all R&D personnel are occupied in the natural sciences and engineering, which may be regarded as especially relevant to both R&D and innovation activities. For PSREs and HEIs combined, about half of all R&D personnel in the UK science sector work in these fields (Table B.8.6).

Table B.8.6: R&D Personnel in the UK Public Research Sector (HEIs & PSREs) by Fields of Science 1998/99 (estimates, in %)

<i>Fields of Science</i>	<i>HEIs</i>	<i>PSREs*</i>	<i>Total*</i>
Natural Sciences	23	13	20
Engineering (incl. Agricultural Sciences)	16	63	31
Medical Sciences	25	13	21
Social Sciences	21	2	15
Humanities	11	2	8
Others, no assignment possible	4	8	5

* rough estimates

Source: DTI, SET statistics, HESA, FDS records (2000), own calculations

The following institutions shape the research scene in public science in the UK (see Table B.8.7):

- Universities are the main performers of basic research in the UK. Although principally funded by government, they are independent institutions with charitable status. Their employees are not civil servants. In August 2000, there were 114 university institutions in the UK, including the former polytechnics which were given the status of universities in 1992 and are often referred to as 'new' universities. Universities are funded for research via the dual support system. The Higher Education Funding Councils in each of the four UK countries provide general funding, mainly for curiosity-driven research. The allocation of funds follows the results of a Research Assessment Exercise (RAE) which takes the form of disciplinary panel-based reviews of publications and other data and occurs every four to five years. This quality-related basic funding amounted to 1,162 million Euro in 1998/99 for the total HEI sector, supplemented by funds for the supervision of research students (103 million Euro). Research project funding is provided by six Research Councils specialised in different fields of science/technology. They offer research funds to both HEIs and PSREs. HEIs received about 1,090 million Euro in

less serious definition biases, thus one can directly compare SME performance on a national level with SME performance on

1998/99 from this funding source. The university sector is characterised by high heterogeneity: the five largest institutions by research income receive 25 % of all research income, and the top fifteen receive about half of this income. The bottom 50 % of institutions account for under 10 % of research funding.

Table B.8.7: Main Characteristics of Major Institutions in the UK Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D*</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities (including former polytechnics)	59	114 institutions	education and research	basic and applied research	high for a small number of top-level institutions
Higher Education and Further Education Colleges	included in Universities, but < 1	several hundred institutions	education	low research orientation	high in education and training
Research Council Institutes	12	about 70 - 80 research establishments	strategic research in key technologies, provision of research facilities	basic and applied research	medium to low
DERA	19	17 research establishments	long-term oriented top-level research	defence research and related areas	high
Departmental Research Bodies	10	84 institutes	providing public research services	R&D services to the government	low

* %, based on R&D expenditures, estimates for 1998/99

Source: SET Statistics 2000, calculations by the authors

Higher Education Colleges and Further Education Colleges: There are several hundred such colleges in the UK offering higher education courses and study programmes. They also receive financing by the Higher Education Funding Councils but their research efforts are low.

Research Council Institutes (RCI): There are currently six research councils, three of which operate civil research centres of their own. Furthermore, there are research centres operated by the Council for the Central Laboratory. Although civil R&D spending at government laboratories has declined, it remains substantial. It is now disbursed primarily on a competitive basis. The total R&D personnel at RCIs was 11,110 in 1998/99.

- The Biotechnology and Biological Sciences Research Council (BBSRC) sponsors eight strategic research institutes (mainly via the Competitive Strategic Grant scheme), operates six structural biology centres, and funds a number of other research centres in biotechnology. The total R&D personnel assigned to BBSRC was about 3,250 in 1998/99.
- The Medical Research Council (MRC) has over 40 rather small research establishments with a total of 2,900 R&D personnel in 1998/99.

- The Natural Environment Research Council (NERC) operates several research centres in the fields of ecology, hydrology and oceanography. In 1998/99, nearly 2,700 researchers were employed in NERC research centres.
- The Council for the Central Laboratory of the Research Councils provides large research facilities in the field of laser technology, pulsed neutron and muon source, space observatory, synchrotron radiation, but also provides R&D services in engineering and information technology at two research centres. Their R&D personnel is about 1,700.

The Defence, Evaluation Research Agency (DERA) operates 17 research establishments in the field of defence research, i.e. various fields of engineering and space sciences. The total R&D personnel is more than 11,000. In 2001, it is planned to privatise DERA. DERA plays an important role in technology transfer to industry, in any one year it co-operates with over 2000 companies. DERA is involved in three science parks located close to DERA research centres.

Departmental Research Bodies: They are responsible to central government departments either as an executive agency or as part of the department. They comprised a total of 6,200 R&D personnel in 1998/99. Due to budget cuts and privatisation, the number of R&D personnel in this type of PSREs has fallen. For example, the number of researchers employed by the Department of Environment, Transport and the Regions has fallen to 15 % of the number in the predecessor Ministries (DoE and DoT) because of the privatisation of the Building Research Establishment and the Transport and Road Research Laboratory. However, the scientists who continue to work in these establishments are still primarily engaged in providing services to government, in some cases in pursuit of an ISR mission.

B.8.2 The Level of ISR in the UK

The level of ISR in the UK is described by a set of indicators and assessments on the significance of various interaction channels. Table B.8.8 lists the indicators used and the main results. It also indicates those areas where ISR in the UK may be regarded as above average with respect to EU standards. There is however, no uniform pattern of ISR, rather interactions between industry and science differ largely by the type of interaction and by the type of actor involved in industry and science.

Contract research by science institutions for industry and collaborative research carried out jointly by industry and science, are revealed by financial flows from industry to science. In the UK, comparably high shares of R&D expenditures in HEIs and PSREs are financed by industry. For HEIs, the level of industrial and public corporation funding increased both in real terms and as a proportion of the total funding for research activities carried out. In 1997, about 7 % of total R&D expenditure was financed by the business enterprise sector. Nevertheless, the proportion of the orientation towards industry varies between the different subject areas of the HEIs. Disciplines such as "Mechanical, Aero and Production Engineering", "Other Technologies", "Pharmacy", "Business and Management Studies", "Mineral, Metallurgy and Materials Engineering", as well as "General Engineering" show extremely high shares of industrial funding in total R&D expenditure, up to 20 % and more.

The distribution of industrial income across universities is highly skewed. In fact, the top ten universities in terms of industrial income account for 43 % of total industrial research income. The share of R&D expenditure financed by industry is, for PSREs, even higher (about 12 %). In HEIs, just 59 % of the funding that is linked to industrial research collaboration is commissioned directly by industry, while a quarter (27 %) comes from research collaboration with industry supported by EU-programmes. A further 9 % and 5 % respectively, is associated with UK collaborative research programmes such as LINK, and with programmes undertaken in the context of regional collaborative arrangements. The high level and growing importance of collaborative research between enterprises and universities is also revealed by bibliometric studies (Katz and Hicks 1998).

Science is used as a co-operation partner for industry in a significant number of innovation projects. While manufacturing firms collaborate with HEIs more than the EU average, the share of co-operation with PSREs is relatively small. Collaboration of service enterprises with science show upside-down patterns - co-operation with PSREs are much more likely and occur more than the EU-average, while co-operations with HEIs occur less. It must be appreciated however, that these figures are highly determined by the behaviour of SMEs, while large enterprises, who are responsible for the vast majority of industrial R&D funding in HEIs and PSREs, may behave very differently.

PSREs are more likely than the average to be used as an information source of innovation by service enterprises, whereas it seems, science plays a less important role in information collection for manufacturing enterprises. The science base is the least important source of technological knowledge for innovation by comparison with other sources. Even among novel innovators, only 31 % state that public science was a source for new product developments. The majority of novel innovators collect their information commercially.

There is no representative data on the mobility of researchers between industry and science in the UK. Based on expert assessments, it may be assumed that the mobility of researchers from HEIs to industry is rather high, given the significant wage difference and the absence of major legal barriers. This may be slightly different with respect to PSREs where a significant number of researchers are civil servants, and pension arrangements may hamper mobility. Mutual personnel mobility between industry and science is strongly encouraged by several public promotion programmes (see below).

There is a high income from vocational training (continuing education and training) for enterprises in HEIs, amounting to 97 million Euro in 1996/97 and 128 million Euro in 1995/96. This is about 2.5 % of the total R&D budget in HEIs in the UK. Nearly two thirds of the revenue was received from SMEs, employing less than 500 employees. Vocational training activities are often short courses directed towards industrial needs. Notable examples included an industry-led specific training programme provided by Cardiff University on semiconductors as part of a Korean company's inward investment in Wales. A general trend in this type of training is towards accreditation up to the point where units are accumulated towards a higher qualification. Distance learning is widely available for MBAs but also

across a broad range of more industry-specific subjects. In to the wide range of vocational training, the number of vocational training participants at HEIs per 1,000 employees at HEI, is considerably high.

In addition to the ISR mentioned above, there are more direct ways of knowledge transfer. Knowledge may also be commercialised more directly by HEIs if they are able to secure the intellectual property rights arising from their work and exploit them. In the UK, the number of patent applications by HEIs and PSREs is rather high. A survey by PREST shows that the top-performing HEIs with respect to income from industry (i.e. representing 79 % of all industry money going to HEIs) filed about 600 patents in 1996/97, with a significant rate of growth (Howells et al. 1998). On projection to the whole HEI sector in the UK, this figure suggests a patent propensity of about 15 UK patent applications per 1,000 R&D personnel in natural sciences, engineering and medicine in 1997. For the PSRE sector, no data is available but patent propensity might be somewhat lower. Nevertheless, there is a considerable potential for commercialisation of knowledge produced by the UK public science sector. It can be taken into the market by means of licensing or spin-off companies that are (at least in part) owned by individual academics from HEIs.

The licensing of the intellectual property generated within universities is a relatively small area of ISR but there was an increase in the number of licenses from 139 in 1995-1996 to 177 in the year 1996-1997, according to the survey mentioned above. Overall, income from royalties appears to be increasing but the overall level is low, with an annual total of 17 to 19 million Euro in the period 1995 to 1997 in HEIs. This is less than 0.5 % of all R&D expenditures in HEIs and about 5 % of all research income from industry, i.e. licensing activities remain of limited importance within the current industry-science relationship in the UK. In comparison to other EU countries, the UK shows above average shares of royalty of total R&D expenditure.

The UK has a growing number of spin-off businesses that have been set up by universities to commercialise a particular research potential. In 1998, around half of the universities had set up wholly, or partially, owned companies, to exploit research results (Howells et al. 1998). A total of 223 such holding companies were identified. The majority of these firms are working in the biotechnology, life sciences and medicine, with engineering in second place. HEIs and, to a lesser extent, PSREs, have been closely linked with the emergence and development of science parks in the UK. Some of them are closely linked to universities and aim, amongst others things, to capture more satisfactorily, IPR leaking out of the university; attracting companies who may then become customers for the universities' research; and providing facilities for start-ups by graduates and former university staff (incubators). However, there are also science parks with few or no ties with universities. The number of firms in UK science parks was 1,414 in 1997 and has increased since 1991 by 40 %. Case studies suggest that about one in six of these firms are HEI start-ups. Some universities run research field specific incubators, such as the University of Manchester. At PSREs, spin-off activities seem to be lower, although some institutions, such as DERA, have recently proposed changes to contractual relationships with their employees to ease start-up activities by researchers.

Table B.8.8: Indicators and Assessments of ISR in the UK at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % (1999)	7.2
	R&D financing by industry for PSREs in % (1999)	11.9
	R&D financing by industry for HEIs/PSREs in % of BERD (1999)	5.0
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	high
	Significance of R&D consulting with firms by PSRE resear.	low
Co-operation in Innovation Projects (Source: CIS2)	Innovative manuf. enterprises co-operating with HEIs in %	11.3
	Innovative manuf. enterprises co-operating with PSREs in %	4.5
	Innovative service enterprises co-operating with HEIs in %	2.9
	Innovative service enterprises co-operating with PSREs in %	21.9
Science as an Information Source for Industrial Innovation (Source: CIS2)	HEIs used as inform. source by innov. manuf. enterpr. in %	3.9
	PSREs used as inform. source by innov. manuf. enterpr. in %	1.9
	HEIs used as inform. source by innov. service enterpr. in %	3.7
	PSREs used as inform. source by innov. service enterpr. in %	6.9
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in % (1997-1999, NSE only)	high
	Share of researchers at PSREs moving to industry p.a. in % (1997-1999, NSE only)	medium
	Share of HE graduates at industry moving to HEIs/PSREs p.a. in %	low
Vocational Training (Source: national statistics, assessments)	Income from vocational training in HEIs in % of R&D exp.	2.5
	Number of vocational training participants in HEIs per 1,000 employees in HEIs	high
Patent Applications at Science (Source: national statistics, assessments)	Patent Applications by HEIs per 1,000 employees in natural sciences, engineering and medicine (1997)	~ 15
	Patent Applications by PSREs per 1,000 employees in natural sciences, engineering and medicine (1997)	medium
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs	0.5
	Royalties in % of total R&D expenditures at PSREs	high
Start-ups from Science (Source: national statistics, assessments)	Number of R&D-oriented business start-ups in HEIs per 1,000 R&D personnel (1999)	high
	Number of R&D-oriented business start-ups at PSREs per 1,000 R&D personnel (1999)	medium
Informal contacts and personal networks (Source: national statistics, assessments)	significance of informal contacts and personal networks between industry and HEIs	high
	significance of informal contacts and personal networks between industry and PSREs	high

* values above the EU average are indicated in **bold** letters

Sources: Eurostat, OECD (2000), Howells et al. (1998), calculations by the authors

Networking and informal contacts between industry and science have a long history in the UK. HEIs and industry are entering into a new and wider set of research and training links, based on partnerships with deeper but less formal relations. On a regional basis, enterprises are very involved in HEIs' activities, including advisory boards and co-operation in teaching programmes. An example of long-term oriented networking is joint R&D establishments. These joint establishments were set up to allow researchers working in basic and applied research to work on common problems and thereby to share tacit knowledge and develop novel techniques. Overseas multi-nationals who have established laboratories in, or close to, UK universities, for example also favour this format, the Hitachi Research Laboratory at Cambridge University.

In the pharmaceuticals area, some of the larger firms are very strongly involved with large numbers of universities from the United Kingdom and abroad. Glaxo Wellcome (pre-merger)

had a number of links which it terms "strategic partnerships" with universities around the world. There are currently four major joint developments in which the company is linking with specialist academic expertise in the UK and Wales. As the firm has historic ties to the UK, the relationship with the UK is strong. Another example is the Centres of Expertise which have been established during the last few years in Wales.

In summary, ISR in the UK have continued to grow during the 1990s and have reached a high level compared to EU standards. ISR in the UK mainly rely on the four major channels: First, research grant and contract income has become absolutely and relatively more important over time. Industry income is increasingly used as a financing source for R&D in HEIs and PSREs. However, major success in obtaining such income is concentrated on a few public science institutions. Second, HEIs and PSREs attempt to commercialise their research results via patenting, licences, establishing of companies owned by public science institutions, and fostering start-up activities by their researchers (such as on-campus incubators). Third, vocational training and co-operation in the context of teaching is a type of ISR which increases in importance. Fourth, long-term oriented networks of top-level public research institutions and large, R&D intensive enterprises have evolved and are a major element in ISR in the UK, including joint research establishments.

B.8.3 The Policy-related Framework Conditions for ISR in the UK

Cultural Attitudes: In the UK, there is a long tradition of industry-science interaction, and public science is generally expected to contribute to industrial innovation. In many HEIs and PSREs, technology transfer to industry is perceived as a major mission of the institution. However, there are also some disincentives. In HEIs, there has been consistent criticism that the incentive schemes for universities and for individual academics do not sufficiently reward or motivate them for taking part in ISR activities. A focus of such criticism is the Research Assessment Exercise (RAE), which is used to allocate the bulk of block funding for HEIs' research by Funding Councils. Individual appointments and promotions are heavily influenced by the RAE and reflect traditional academic values. The RAE does not reward engaging in ISR activities. In an attempt to counterbalance this influence, a "third leg" of funding (i.e. in addition to teaching and research) has been announced in the form of the "Higher Education Reach Out to Business and the Community" (HEROBAC, see below).

Legislation: In the United Kingdom, the legal frameworks in which the production, use and transfer of knowledge takes place have not exerted as profound an influence upon ISR as have policy initiatives and promotion programmes. Nevertheless, through laws and procedures relating to patents and employment contracts of employees, governments exert some effect upon ISR.

In the field of IPR regulation, up until 1985 a public body known as the National Research and Development Corporation (NRDC) had a monopoly in the exploitation of publicly funded research in the HE sector. This was ended by the then Conservative government with the intention that universities should take ownership of intellectual property generated as an

incentive to engage in commercialisation (a similar logic to the US Bayh-Dole changes). The NRDC itself was restructured under the new name of the British Technology Group (BTG). During the 1980s, the universities were required to commercialise their IPR through the BTG. After 1992, the BTG became a public company (quoted on the Stock Exchange) and universities were free to decide whether and how to use IPR. During the period when universities had their IPR commercialised by the BTG, the universities were nevertheless entitled to royalties from their work, and the BTG provided funds for the commercialisation of university research. Since the mid-1980s, many HEIs started to set up specialised intellectual property management and administrative centres, commonly known as technology licensing offices. These were set up within, or parallel to, existing industrial liaison offices. Today, these offices support university researchers in making use of IPR.

The distribution of royalties to staff is carried out through different arrangements at different institutions. Taking the University of Newcastle as an example, IPR regulations in HEIs may look as follows: The university is the owner of a patent, revenues are shared between the university and the inventor(s). After subtracting legal costs, the first £ 5,000 of IP income goes to the inventor(s), the next £ 200,000 of IP income is split - 50 % goes to the inventor(s), 25 % to the department(s) of the inventor(s), and 25 % to the university. In the case of IP exploitation via a university-owned start-up company, the inventor(s) can take equity in the company, the inventor(s) involvement being subject to the university's company directorship policy.

At PSREs, until the year 2000, the presence of incentives for researchers to commercialise IP was simply dependent upon whether the scientist worked for a government department or for a non-departmental public body (NDPB, i.e. research council institutes) (Baker 1999). This 'accident of birth' led to a situation in which those scientists who were employed in NDPBs were subject to incentive schemes, whereas those who were employed by government departments were bound by the civil service management code which forbade the use of incentives. Amongst NDPBs, a wide variety of incentives schemes have prevailed. Table B.8.9 shows the incentive schemes for researchers at research centres operated by BBSRC and MRC.

Table B.8.9: Incentive Schemes at BBSRC and MRC in 2000

<i>Biotechnology and Biological Sciences Research Council (BBSRC)</i>		<i>Medical Research Council (MRC)</i>	
Income from IPR	Proportion of receipts paid to inventor(s)	Income from IPR	Proportion of receipts paid to inventor(s)
First £ 1,000 (gross)	100 %	£ 500 to 1,400	100 %
£ 1,000 to 50,000 (gross)	20 %	£ 1,400 to 80,000	33.3 %
£ 5,000 to 500,000 (net)	10 %	£ 80,000 to 600,000	25 %
£ 500,000 to 1 million (net)	5 %	£ 600,000 to 1.5 million	20 %
Over £ 1 million (net)	2.5 %	£ 1.5 million to 15 million	15 %
		Over £ 15 million	10 %

Source: OST (2000)

Employment Contractual Contexts: In HEIs, no specific employment regulations, which may impede ISR activities, apply. At PSREs however, for scientists bound by the civil service management code, no incentive schemes for commercialising research results were available until the government revised the code in 2000. This considerably hampered ISR activity in departmental research bodies such as DERA. At DERA, changes to the way in which staff are employed have also been proposed. In the future, scientists who wish to commercialise their ideas will be deemed "DERA Entrepreneurs". DERA Entrepreneurs will work along side DERA in the commercialisation of their own ideas with DERA intending to take a share in the proceeds of their work. Such employment practices are new and untested and it will take time for their effects to become evident.

Institutional Setting: The institutional setting in HEIs in the UK is characterised - when compared to other EU countries - by a high degree of organisational independence of universities, indicated by no specific working contract regulations for university researchers, a high proportion of private universities and colleges, and the absence of a basic funding via General University Funds provided by the central government. However, funding for basic research and teaching is provided by Funding Councils and based on the results of the RAE which pays strong attention on scientific performance and undervalues ISR activities. For a longer period of time, HEIs face increasing financial stringency, thus, the attempt to generate further funding from whatever source, including government, charities, industry and overseas, has been strong.

A recent development in this area are the increasing number of HEIs which form consortia to identify, co-ordinate and deliver research and training services to industry. Often, these consortia are regional and may be targeted on specific services (e.g. technology specific, task specific) or clients, such as SMEs. Such alliances occur both between HEIs, and also between a HEI and a Further Education Institution.

At PSREs, two types of establishments have to be distinguished - departmental bodies and NDPBs, the latter offering a more favourable environment for ISR. The largest PSRE in the UK, DERA, has traditionally strong ties to firms engaged in the defence industry, but also to a large number of firms acting in the civil economy. DERA follows a decentralised approach of technology transfer, using various channels of interaction with industry, such as licensing new technologies, establishing joint companies (e.g. recently with Ford Motor), forming new companies, and carrying out contract research. DERA most commonly interacts with the Engineering Industries Directorate within the DTI, e.g. under the Civil Aircraft Research and Demonstration programme (CARAD)

Promotion Programmes: In the UK, the policy context is of fundamental importance for ISR. A whole range of relevant institutions - governments, their agencies, industrial sectors, higher education institutions and intermediaries - have all contributed to the development of a large number of initiatives intended to further the development of networks of collaboration. The government's White Papers on Science and Technology stress the need for the creation of industry-academic links. In the field of education, the creation of a new system of foundation

degrees and a 'university for industry' have also indicated a desire to make the educational system involved in a closer relationship with industry. Following the White Papers, a variety of new key policy initiatives and programmes associated with developing and increasing the level of ISR was implemented, and already long-established programmes have been prolonged. Today, the following policy support mechanisms exist (see Table B.8.10).

- The goals of the Foresight Programme are to develop visions of the future technology development and to build bridges between business, science and government. It is managed by the Office of Science and Technology (OST). The programme has operated through ten sectoral and three thematic panels with varying degrees of academic and industry representation. One follow-up measure was a dedicated scheme, the Foresight Challenge competition, allowing consortia of business and the science base to apply for matching funds for projects addressing Foresight priorities. Foresight (and LINK) activities are regarded as being the most effective government mechanisms in the promotion of ISR.
- The LINK programme aims to support collaborative projects between HEIs and industry which address Foresight priorities. LINK stimulates interdisciplinary research in areas such as sensors, medical engineering, advanced food science, new communication systems, future vehicles, surface engineering and catalysis. All new programmes address priorities identified under the Foresight Programme. SMEs are particularly encouraged to get involved.
- Faraday Partnerships were initially (1992) proposed as a means of bridging academia and SMEs in the UK, inspired by Germany's network of Fraunhofer Institutes. In 1997, four pilot Faraday Partnerships started to operate, three of them involving partnerships between universities and independent R&D organisations. Their main goal is to promote more effective links between research and commercialisation in certain fields of technology (packaging technology, multimedia, mechatronics, and sensors). The DTI/EPSRC have announced the establishment four new Partnerships in each of the financial years commencing 2000-01, so that by 2003 there will be a national network of 20 Partnerships in total.
- The Joint Research Equipment Initiative (JREI) supports the provision of equipment in Foresight areas. The Funding Councils co-fund with external sponsors, equipment costing above 300,000 Euro, and the Research Councils cover amounts below that figure. One aim of this initiative is to promote partnership between HEIs and external sponsors of research, including industry and commerce. After two *ad hoc* competitions it is intended that the JREI should become an annual feature.
- The University Challenge Fund gives winning universities or consortia of universities, support to set up local 'seed' funds. These are to support the early stages of commercialisation of academic research. Each fund is managed by a board, normally with venture capital expertise present. The funds may finance further research in support of commercialisation, the cost of patenting, building prototypes, market research and the

preparation of business plans to attract next stage capital. The fund was initially supported by the DTI, the Wellcome Trust and the Gatsby Charitable Foundation. It is envisaged that a typical seed fund will have a size of around 3-6 million Euro.

- The University for Industry (Ufi) scheme aims to deliver education to adults, through home PCs and in the workplace. Some 600,000 individuals are expected to take part annually in its learning programmes by 2002 and 2.5 million to use the university's information services. It works in partnership with a number of organisations including colleges, Training and Enterprise Councils and libraries. The Ufi is acting as intermediary, broker and conduit to place students with the relevant teaching programmes.
- The Higher Education Reach-Out to Business and the Community (HEROBAC) scheme aims towards developing the capability of HEIs to respond to the needs of business, by enabling HEIs to put into practice organisational and structural arrangements to achieve their strategic aims in this area. The HEROBAC Fund is intended to initiate a permanent third stream of funding, complementing the Higher Education Funding Council for England's existing grant for teaching and research, to reward and encourage HEIs to enhance their interaction with business. The mechanisms whereby these links may be developed could include the establishment of centres of expertise, training and development for staff, staff exchange programmes, and one-stop-shops in HEIs so that businesses have easy access to advice and expertise. The HEROBAC scheme has however, now come to an end and while there are a number of operational projects, all major future Third-Leg funding through government will be channelled through the Higher Education Innovation Fund, which was announced by the government's White Paper on Science and Technology in 2000.
- The Teaching Company Scheme (TCS), dating back to 1975, is regarded as a cornerstone of the development of ISR in the UK. The scheme operates through partnerships between firms and academic institutions. Partnerships employ a graduate student (termed an associate) originally with a science or engineering background although schemes now include social science graduates, who spends 90 % of their time working in a company on specific projects. The balance of their time is spent in the higher education institution where they undergo training. Programmes have ranged in size from a single associate employed over a two-year period to a group of 14 associates employed over a period of three years, on contracts which have been renewed. Around 2,000 PCT partnerships have been created since the scheme's foundation in 1975. Companies provide up to 60 % of the cost of the programmes and at least 50 % of the cost of renewed projects. SMEs pay less towards the cost of the programmes than larger firms, usually 30 %. Plans are currently being made to increase the number of schemes through a doubling of the budget allocated to the TCS. The government intends to increase the number of active partnerships from around 703 (in April 2000) to 1000 by the end of 2001. The government is on record as stating that TCS is its premier technology transfer scheme.

- The Collaborative Awards in Science & Engineering (CASE) scheme offers several collaborative awards. Within the "CASE for new academics" scheme, the student receives a grant from a research council and also a supplementary contribution from an industrial partner. The doctoral research addresses an industrial or commercial problem, and supervision is provided jointly by academic and company representatives. CASE has now also been introduced for new academic staff as a means of broadening their experience. Other schemes operating, which educate graduates through links with industry, include engineering doctorates, postgraduate training partnerships, research masters, and the *Total Technology Scheme*. The array of initiatives also includes the integrated graduate development scheme, the creation of research council fellowships, and the running of graduate schools for graduates in the second or third year of their doctoral degrees who wish to know more about industrial and commercial careers.

Table B.8.10: Major Public Promotion Programmes in the Field of ISR in the UK

<i>Name of Programme</i>	<i>Public Funding (million Euro in 1999 or estimates)</i>	<i>Year of Introduction</i>	<i>Main Approach</i>	<i>Type(s) of Interaction Mainly Addressed</i>
Foresight Programme	~ 29	1993	building up of networks and consortia, strategic vision of technology development	networking, collaborative research
LINK	~ 35	1995	funding for collaborative research projects which shall act as demonstration projects	collaborative research
Faraday Partnerships	~ 6	1999	establishing intermediary infrastructure for technology transfer in certain fields of technology	collaborative research, start-ups, personnel mobility, training & education
University Challenge Fund	~ 94	1999	support to universities or consortia of universities to set up local "seed" funds supporting early stage commercialisation	start-ups, IPR, prototypes
Teaching Company Scheme (TCS)	~ 36	1975	subsidies to enterprises for employing highly qualified graduates on specific projects	personnel mobility
Science Enterprise Challenge	~ 13	1999	establishing "centres of enterprise" at up to 8 universities	training & education, technology transfer
Higher Education Reach-Out to Business and the Community (HEROBAC)	~ 31	1998	funding for the establishment of centres of expertise in HEIs, ISR-oriented training for HEI staff, "one stop shops" for business partners.	contract research, networking, personnel mobility
Joint Research Equipment Initiative (JREI)	~ 55	1996	funding of equipment in areas of high quality research grants to students for carrying out doctoral research	contract research, collaborative research
Collaborative Awards in Science & Engineering (CASE)	n.a.	n.a.	addressing industrial problems and jointly supervised by HEIs and firms	training & education
University for Industry (Ufi)	~ 131	1999	support to HEIs for activities in the education of adults,	training & education

especially concerning new
technologies

* The remaining share is performed in other institutions.

Source: EU Trend Chart Project, own survey and compiled by the authors

- The Science Enterprise Challenge provides funds for up to eight centres of excellence at universities to teach the state of the art in entrepreneurial and business skills to graduates and undergraduates. They are expected to increase scientific entrepreneurialism and incorporate the teaching of enterprise into the science and engineering curricula.
- There are several other policy support mechanisms which provide financial or infrastructural support for various types of ISR. The *Biotechnology Exploitation Platform Challenge* encourages syndicates of universities, companies and intermediaries to work together and build portfolios of intellectual property. The *Regional Competitiveness Development Fund* attempts to establish regional networks between industry and science. Further measures in the field of mobility, training and education concern, amongst others, the Colleges and Businesses in Partnership (CBS), postgraduate training partnerships, the Shell Technology Enterprise Programme, the Biotechnology Young Entrepreneurs Scheme, enterprise fellowships, industrial secondments, senior research fellows and many more. In the field of joint research, one should also mention the Space Technology Research Programme, the Industrial Programme Support Scheme, several DERA related programmes, the Biotechnology Mentoring and Incubator Challenge, and the Realising Our Potential Awards scheme.

Intermediary Structure: The number of intermediaries in the area of industry science links has grown significantly over recent years. Many of these intermediaries have a regional or local character and are intended to work closely with TECs, LECs, Chambers of Commerce, Business Links, new and existing national and regional development agencies, former development corporations, RTCs and local authorities. In the UK, the pharmaceutical and biotechnology industries have strong intermediary organisations whose impact on industry science relations has increased significantly within the last three years. There are two particular organisations - the Association of the British Pharmaceutical Industry (ABPI) and the BioIndustry Association (BIA). The BIA in particular, is concerned with support for SMEs which have been adversely affected by the decision of larger pharmaceutical firms to base their manufacturing processes outside the UK to reduce costs. The class of Intermediaries also includes such organisations as AIRTO (Association of Independent Research and Technology Organisations) which offer management expertise to projects initiated by government, such as Faraday, which also run their own technology transfer activities that involve academic industry links. The Research and Development Society is another organisation providing opportunities for interaction between academics and industrial organisations, as is Techman - the Technology Management Network.

In order to encourage patenting, the UK Patent Office has undertaken to reduce charges for patenting or, in some cases, to reduce them altogether. To increase general awareness of

patents and new technologies, a new database based on the work of the Association of University Research and Innovation Links (AURIL) will be set up on the Patent Office Web site. In response to the recommendation of the Creative Industries Taskforce, the Patent Office will create an intellectual property portal on the Internet, beginning operations by the end of 2000.

In the UK, a relatively large infrastructure of intermediary organisations has developed in response to successive initiatives. These may be part of the main players in ISR, or may exist independently, with a mandate for regional development being a common mission. A current issue of discussion is whether excessive emphasis on specialised transfer agencies will monopolise knowledge flows and act as barrier to creation of a positive knowledge culture diffused throughout the industry-science nexus, i.e. if there is a risk in consigning ISR to peripheral units away from the core.

In summary, framework conditions for ISR in the UK are strongly shaped by public promotion programmes addressing several types of market failures on the knowledge market via specific programmes. Within the huge variety of policy measures, each type of interaction between industry and science is supported. There is however, also the feeling that the present range and mix of policies is too extensive and therefore, too complicated, and that a rationalisation might allow better targeting of initiatives. Other framework conditions such as legislation, institutional settings and intermediaries seem to drive ISR to a lesser extent, despite the use of IPR by public science institutions is heavily affected by the different forms of regulation prevailing in HEIs, non-departmental public bodies and departmental bodies.

Despite the absence in the UK of some of the legal barriers to ISR which are characteristic in other countries, it may be concluded that framework conditions are increasingly favourable to the collaboration of industry and science. A change of culture is occurring in response to shifting incentives and there is a growing alignment between framework conditions and industry-science interaction. Overall, ISR in the UK is driven by a long standing tradition of interaction and a rather strong orientation of the public science system towards industry needs, i.e. favourable cultural attitudes towards ISR.

B.8.4 ISR in the Field of Human Capital in the UK

The production of human capital in the United Kingdom has been strongly influenced over many years by the need to ensure that graduates receive both the theoretical and the practical knowledge required by industry and the professions. The trend in post- and undergraduate training goes towards close industry involvement. Students are engaged with industry through work and project placement and the establishment of mechanisms for the industrial sponsorship for masters and PhD students. Industry is also becoming more involved in the development of curricula for under- and postgraduate courses. A majority of institutions has master courses specifically designed to meet the needs of industry. In total, of the masters courses that received support in their design and implementation, the largest share were in

business, management and accountancy fields, followed by engineering, and health and life science courses.

Industrial links to undergraduate teaching take a wide variety of forms. On a general level, advisory committees to faculties with courses of vocational relevance typically contain industrial representatives. Active involvement by industry in courses includes provision of visiting speakers (and occasionally lecture series), the validation of courses, membership of examination boards, carrying out of student projects in collaboration with firms, and sponsorship of student prizes. Also widespread is a trend towards seeking to develop students' transferable skills relevant to the industrial environment, including for example, computer literacy and working in teams. Training for entrepreneurial skills is supported by the Enterprise in Higher Education initiative. The establishment of mechanisms for sponsorship of undergraduate courses is lower than for postgraduate courses but it is still a high figure and is likely to continue to grow. In terms of the sponsorship profile regarding the design and implementation of courses, the pattern is very similar to that for masters courses.

Sandwich courses, in which the student typically spends a year working for a company during their course, are increasingly popular with many more organisations seeking placements for their students in industry. Schools were also moving into the area, increasing competition for places. However, certain parts of the country were cited as being difficult in which to arrange student placements, with London identified as an area of particular difficulty. There is a proposal to establish a database of companies and students in the capital, supported by eight HEIs, in order to provide a matching agency for placements. Sandwich courses were seen as a good lead into a job for students, as a means of forging links with industry for staff and as a selling point for courses. The rising numbers of part-time students creates a new need that may be addressed by the creation of the university for industry.

Shell, in conjunction with DTI, has established a technology enterprise programme in which 1,500 students have been placed in enterprises around the UK. During an eight-week placement - what is effectively a mini-sandwich course - each student has tried to devise a solution to a pressing problem faced by the host business.

The government's Life Long Learning Green Paper "The Learning Age" set out a range of proposals on the further development of educational provision to meet the needs of industry. Attention was given in the paper to: learning in the workplace, support for smaller firms which do not have a good reputation for training their workforces, and the establishment of sound and agreed targets for skills and knowledge, by setting up a National Skills Taskforce with a new Skills Unit in the Department for Education and Employment.

In the last two years, the government has taken steps to align educational provision in the UK further towards the needs of industry through the creation of a new degree format, the Foundation Degree. The prototype Foundation degrees announced reflect the growth of the new service economy with the number of degrees in the new media and technologies numbering 16 while the number of degrees developed in the areas of health, supporting public

services and tourism is also 16. The number of engineering and chemical industry related courses is low with only three indicated within the first group of around 40 prototype courses. Foundation degrees are not, as yet, significant for industry-science relations, as the number of courses operating currently is small. However, if the number of degrees increases and industry sees advantages from them, their relative importance within the educational sector could change.

As a result, income from continuing education and training from the UK industry in HEIs is considerably high, with about 130 million Euro in 1995/96 and nearly 100 million Euro in 1996/97. Universities and colleges are major suppliers of vocational and further training for the UK industry. Activities by HEIs in this field are certainly encouraged by the incentive to receive additional income, especially at the side of private HEIs. There is no information on whether a strong orientation on mostly short time, practical training activities by university staff is crowding out other activities, especially concerning research.

In relation to postgraduate education, a number of policy mechanisms have been introduced in the UK and are supported by government funding in order to improve links and collaboration with industry. The two most important initiatives in the UK in terms of numbers, durability and perceived effectiveness, have been the Teaching Company Scheme (TCS) and the Co-operative Awards in Science and Engineering (CASE), both of which are regarded as being highly successful. They are described in B.8.3.

In the area of personnel mobility of trained academic and industrial staff, there are no legal or contractual barriers that either prevent or facilitate movement. However, barriers to movement between the academic and industrial sectors do exist through salary differentials and pension arrangements. These barriers are perceived as major restrictions on staff movement between academic institutions and industry. The most important mechanisms for movement are through personal contacts which often give rise to research collaborations. The provision of a sabbatical year is also thought to be a useful means of promoting the exchange of staff. The Research Assessment Exercise may act as a significant barrier to greater movement of senior university staff to industry because of a lack of an academic publication track record.

In the area of engineering science, professional bodies have played a significant role in the ISR relationship. The Engineering Council and the Royal Academy of Engineering are two of the most active professional bodies in industry-science relations. The Engineering Council plays a major role in the certification of professional staff and promotion of engineering expertise. Its members and affiliates include a number of the foremost professional bodies in the UK. The Royal Academy of Engineering (RAEng) works collaboratively with the Council but undertakes a number of its own activities. These currently include the following four main themes: (1) to ensure that the supply of trained graduates meets the needs of industry; (2) to promote exchange between industry and science in the process of curriculum development; (3) to ensure that academic researchers are aware of developments faced by the profession itself; and (4) to convey the findings of the latest engineering research directly to

the profession in the workplace. The third objective is met through a number of personnel mobility schemes set up by the RAEng or in which it is active as an international participant. The fourth objective is met through a relatively new initiative, the Partnership for Profitable Product Improvement, which is jointly funded with the Department of Trade and Industry.

In respect of personnel mobility, it is the RAEng's Visiting Professor Scheme that shall ensure that the needs of industry are understood by engineering students and researchers. This scheme allows senior engineers from industry to spend time in a university. The RAEng has also been active in seeking greater recognition of the value of practical contributions of academics.

Despite the strong orientation of R&D in the HEI sector on natural sciences, engineering and medicine (see B.8.1), the majority of graduates are in the social sciences and humanities (Table. B.8.11), reflecting the high weight of business colleges etc. in the higher education system in the UK, which are important institutions in the field of education but rarely carry out R&D. Unemployment was rather low among graduates in the UK at the end of the 1990s.

Table B.8.11: Higher Education by Disciplines in the UK 1998/99 (in %)

<i>Field of Study</i>	<i>Students</i>	<i>Study Beginners</i>	<i>Graduates (domiciled qualifiers)</i>	<i>Unemployed Graduates (= unknown destination)</i>	<i>Gainfully Employed (1998/99)</i>
Natural Sciences	15	20	20	21	18
Engineering (incl. Agric.)	10	11	9	10	10
Medicine	13	13	10	4	13
Social Sciences	30	29	36	33	38
Humanities	13	16	18	23	16
Others	19	11	8	9	7
Total number (1,000)	1,626	332.0	227.5	11.6	158.5

Source: HESA (2000), own calculations

B.8.5 ISR in the UK: A Summary Assessment by Type of Interaction

Contract and collaborative research: Commissioning R&D projects to be undertaken within the context of publicly funded science and collaborating in joint R&D activities is a major type of interaction in the UK system of ISR. Enterprises spend 5 % of their total R&D budget to HEIs and PSREs, and both HEIs and PSREs receive a significant amount of R&D funding from industry. The main motivation in public science for ISR in contract and collaborative research is the access to industrial funding. As basic financing by the government is relatively low, industry money is an important source for strengthening R&D activities in many fields of research. In some research areas and at some institutions, collaboration with industry can also be seen as a strategic institutional policy objective. Furthermore, collaboration with industry provides an outlet for research results. Those incentives to establish contract and collaboration research also have relevance for establishing consultancy links. While research grants and contract income from industry are becoming absolutely and

relatively more important over time, major success in obtaining such income is concentrated within relatively few institutions.

On the other hand, there are some barriers impeding IRS in the field of contract and collaborative research. Differences in the research objectives between industry and science could be a problem, as well as that the work needed by industry might be of little interest for academic researchers. The Research Assessment Exercise (RAE) is viewed as a major barrier in this respect - RAE performance determines the allocation of basic funding to departments in HEIs but solely focuses on scientific performance indicators. Strong ISR activities may weaken a department's RAE result, and therefore ISR activities may receive a lower level of priority.

Personnel mobility: Mobility from HEIs to industry is assessed to be high, mainly due to significant salary differences. Furthermore, a large number of policy initiatives attempt to stimulate this type of interaction, such as the Teaching Company Scheme, introduced as early as 1975. The RAE may act as a significant barrier to the greater movement of senior university staff to industry too, because of a lack of an academic publication track record.

Training and education: In the context of teaching and training, ISR are at a high level and still increasing. It should be stressed that industry regards the supply of trained people as its first priority, even from research collaboration. Postgraduate activity is dominated by policy-led initiatives, notably the TCS and CASE. But industry is also becoming more involved in the design and implementation of lower level courses. As this type of teaching must directly respond to industries' needs, course content is the most important factor of the success whereby industry itself counts as an important initiator and 'shaper' of new course work. The second, most important success factor, is the development and maintenance of close links between the HEI and its industrial clients. The most common barrier is the lack of willingness or ability on the part of industry to pay an economic rate for provision. SMEs are facing particular problems. They are often not able to release staff for training even for short periods. Despite the high level of vocational training activities, there is often a lack of priority for this type of activity in HEIs. Education in HEIs often involves student placements at enterprises.

IPR in science: Commercialisation of public science research results by licensing of technology has received central attention in research and innovation policy in the UK. The level of IPR use has increased and may be assessed as high today. Many universities have established holding companies for exploiting a HEI's IPR portfolio. There is an extensive infrastructure in HEIs aimed towards supporting researchers in commercialisation activities. The most common problem associated with the commercialisation of research results is the lack of capital or seed corn development funds. Problems of finance, encompassing marketing and development capabilities are further major barriers, as well as finding the right partner or licensee. In addition, the fear of possible disclosure of results in publications and confidential requirements inhibits the development of ISR in this field.

Start-ups from science: The UK followed an 'infrastructure based approach' to foster spin-off business from public science. Starting in the early 1970s, a large number of science parks located at, or nearby, universities or large PSREs have been established, forming an incubator for start-ups. Many universities have also founded companies to exploit research results arising from a specific stream of research. In 1998, at least 223 such companies existed. No exact figures on the number of enterprises created by former HEI researchers are available but anecdotal evidence suggest that start-up activities from public science is high in the UK.

Networking between industry and science: Networks between industry and science have a long history in the UK. In particular, HEI-industry partnerships have evolved, including enterprises' participation in advisory boards, teaching and training programmes, R&D establishments, and Centres of Excellence. As a result, formal and informal links are widened and deepened between both types of organisations at all levels, and not just centred on a few research staff from both sides.

Involvement of SMEs in ISR: The UK SME sector seems to be less innovative and R&D oriented than in other EU countries. ISR are strongly shaped by large enterprises in high-tech areas such as biotechnology, aerospace and telecommunication. There have been rather few policy initiatives to increase SME involvement in contract and collaborative research so far. New initiatives such as LINK and the Faraday Partnerships address more directly the barriers to ISR at SMEs. In the field of training and education however, SME involvement is high. For example, 66 % of all HEI income from continuing education and training comes from SMEs. Policy measures such as TCS show a share of SMEs in all participating enterprises of 90 %.

Science-based industries: The UK industry shows a high share in high-tech industries, especially in pharmaceuticals and aircraft. These industries intensively use the excellent science base in the UK in the respective fields of research to strengthen their competitiveness. Furthermore, this science base attracts international companies for example, in the agricultural business (Aventis, Monsanto and Agrevo). As a consequence, the share of foreign firms in business enterprise R&D expenditure in the UK is comparably high.

B.8.6 Good Practice in Framework Conditions for ISR in the UK

In the following pages, five examples of good practice in the UK in the area of framework conditions favourable to ISR are presented and listed below:

- LINK and Foresight: Policy initiatives to strengthen research collaboration, these are examples for promotion programmes aimed towards joint research efforts in strategic research and technology areas.
- The programme "University for Industry" and so-called "Company Universities" represent innovative measures in order to improve the organisational basis for ISR.

- There are several public programmes aiming towards the promotion of co-operation in education. The Teaching Company Scheme is one of the most prominent examples of how to promote interaction between industry and science in the field of education and mobility, but there are many other programmes addressing specific market failures in this area.
- Local, regional and national HEI consortia build networks between HEIs and intermediaries in order to offer a targeted set of services and thus making the HEIs' knowledge and competence better available to enterprises
- Individual universities follow divergent strategies in exploiting the knowledge produced in HEIs. Two examples from the Manchester University and the University of Newcastle-upon-Tyne show successful approaches to the commercialisation of research results.

LINK and Foresight: Policy Initiatives to Strengthen Research Collaboration

LINK

The basic objective of the LINK initiative is to improve the competitiveness of UK industry and to improve the welfare of people's lives through the support of programmes of pre-competitive science and technology. More specifically, LINK's mission is to "offer a well-established framework for collaboration between public and private sectors in support of science and technology (S&T) in areas of strategic importance to the national economy. LINK aims to enhance the competitiveness of UK industry, and quality of life, through support for managed programmes of pre-competitive S&T in market or technology sectors, and by encouraging industry to invest in further work leading to commercially successful products, processes, systems and services."

Currently, 56 LINK programmes are sponsored by various government departments and Research Councils in a wide range of technology sectors. Each programme supports a number of collaborative research projects, which each last between two and three years. The government funds up to 50% of eligible costs of a LINK project, with the balance coming from industry. As LINK's programmes focus on a particular technology or market area, the initiative became a good "vehicle" by which the government could implement some of the recommendations coming out of the Foresight initiative (see below). Since March 1995, the government has announced 19 new LINK programmes which are responsive to priorities identified under the Foresight initiative. These programmes will support projects costing up to £ 169 million over the next few years.

The UK Research Councils have all participated in schemes that have sought to encourage industry-academic research links and exploitation activities. They have all been closely associated with the LINK and Foresight initiatives and have established packages which provide adjuncts to such schemes. Thus, the Medical Research Council (MRC) runs an Open-LINK scheme which funds high-quality collaborative projects that meet the LINK criteria, but which do not fit into any particular LINK programme. The Natural Environment Research Council (NERC) operates a pump-priming programme, Connect A, for short research projects, workshops or seminars with industrial relevance. A larger scheme, Connect B, offers grants of up to £200,000 for innovative partnerships with 50% funding from industry. The EPSRC also runs several initiatives in which contributions from industry are required as evidence of commitment and interest.

Foresight

The Foresight Programme (originally Technology Foresight Programme) was announced in the White Paper on Science, Engineering and Technology (1993) "Realising Our Potential", and began in 1994 with the dual aims of forging a new working partnership between science and industry and informing decisions on the balance and direction of publicly funded science and technology. Foresight is managed by the Office of Science and Technology. At the core of the Programme are 16 panels (initially 15) with varying degrees of academic representation in their membership, along with representatives from industry and government. The first phase of the Programme culminated in the publication of sectoral reports by each panel. These reports aimed to identify the likely social, economic and market trends in each sector over the next 10 to 20 years, and the developments in science, engineering, technology and infrastructure required to address these future needs. The conclusions were based upon widespread consultation. Since the publication of the reports, there has been extensive dissemination of the findings and numerous events have been held. Most of those events have aimed to promote the development of academic-industrial networks to support the exploitation of opportunities revealed by the Programme. The most recent phase of Foresight has concentrated on stimulating wider and deeper engagement of business, beyond the R&D function, towards marketing, finance and business planning. Currently, consultation is in progress about the format for a new cycle of Foresight, which is scheduled to report in November 2000.

Among the follow-up measures to Foresight was a dedicated scheme, the Foresight Challenge competition. This was launched at the end of 1995 with the explicit aim of increasing interaction between industry and academia. Consortia of business and the science base were able to apply for matching funds for projects addressing Foresight priorities. In the first round, following a large number of applications, awards were made to 24 projects costing a total of £ 92 million, of which £ 62 million came from industry and £ 30 million from the OST. The second round of the initiative, renamed Foresight LINK Awards, has £ 10 million of government funding available. The SHEFC and HEFCW also provided funding for research projects reflecting Foresight priorities, awarding £ 7.5 million and £1 million respectively to support a total of 25 projects.

Source: Howells et al. (1998, 73f)

The University for Industry and Company Universities

University for Industry (Ufi)

In April 1998, the UK government outlined the new University for Industry (Ufi) and promised £ 15 million funding for its launch in 2000. Some 600,000 individuals are expected to take part annually in its learning programmes by 2002 and 2.5 million to use the university's information services. In the long term, the Ufi will be privately funded, with the proportion of public sector support declining over time. Users will be charged, mainly through individual learning accounts. A central aim of the university will be to act as an education broker and deliverer, facilitating access to education and training provision, whilst also stimulating new demand and developing innovative products and services. The Ufi will have four priorities:

1. Improvement of basic literacy and numeracy. The university has been set a target of training an additional 200,000 people a year in basic skills to level two of the national qualifications framework within five years.
2. Meeting the skills needs of SMEs. The university is being asked to deliver services to 100,000 start-up businesses and 50,000 established companies within five years.
3. Information and communication training for the workplace. The Ufi will be required to ensure that an additional 200,000 people enter into this kind of training within five years.
4. Specialist training provision for automotive components; multimedia; environmental technology and services; and distributive and retail trades.

"Company Universities"

There are a number of "company universities", such as the *Unipart University*, which have emerged in the UK over the last few years and which have followed successful American models, including Motorola University and Ford University. These company universities have sought to provide in-house higher, further and vocational training to their staff. The creation of such universities has allowed companies to develop a more systematic approach to the education and training of their staff. As with the Ufi, their critics regard them as not being proper universities. For company universities, the designation of the title "university" has almost been an internal marketing tool to emphasise the firm's commitment to high-quality education. It has also been used, however, to denote a trend away from company support of very specific vocational training, often aimed at shopfloor workers, towards much wider professional and business qualifications which upgrade the skills of employees who are already graduates and postgraduates. This move indicates a shift in philosophy to encompass the concept of lifelong learning and education to enable the workforce to be more flexible and "rounded".

A more ambitious development is the *British Aerospace Virtual University*. This is being established with an annual budget of £ 200 million to provide the company, its customers and suppliers with both a major education and training facility, and a focal point for contact with universities for technology transfer. Its three faculties are for engineering and manufacturing technology, "learning" (covering a wide range from lifetime education to masters and doctoral training), and an international business school. The academic input will be provided by selected leading universities.

In this sense, both the Ufi and company universities represent "virtual" universities by acting as intermediaries, brokers and conduits which place students with the relevant teaching programmes in what might be termed "linked workplace learning". Central to the Ufi concept is the inclusion of other universities and colleges in delivering directly many of its courses. This brokerage and conduit role is also central to the success of the Ufi, acting as it does as "gatekeeper" to the process of lifelong learning for many people who have had little or no direct contact with traditional universities.

Source: Howells et al. (1998, 75ff)

Promotion of Co-operation in Education

Teaching Company Scheme (TCS)

The Teaching Company Scheme was founded in 1975 and has been regarded as one of the greatest successes of UK HEI-industry links. The TCS was initiated by the DTI and aims to develop active partnerships between HEIs and industry in the field of education. The scheme sets up partnerships between firms and HEIs through the formation of teaching company programmes. Firms take on graduates, known as TCS associates, to work full time on specific projects jointly supervised by the HEI and the company.

Projects are intended to be closely linked to the interests of the firm and should be aimed at achieving a substantial and comprehensive change in the firm, for example in management and production techniques. Partnerships are exclusively between HEIs and firms within the region as the associates must travel regularly between the two organisations. The scheme has five formal objectives, namely to:

- raise the level of industrial performance by effective use of academic resources;
- improve manufacturing and industrial methods by the effective use of advanced technology;
- train able graduates for careers in industry;
- develop and retrain existing company and academic staff;
- provide academic staff with broad and direct experience of industry, to benefit research and enhance the relevance of teaching.

A typical programme lasts for two years. The graduates have a science and engineering background and are recruited jointly by the partners. The associates spend 90% of their time working in the company on specific projects and are paid at industrial rates. The remaining 10% of their time is spent within the HEI undergoing training. Until 1981, the TCS was financed totally out of public funds, but since then firms have provided up to one-third of the cost of new programmes and at least 50% of the cost of renewed programmes. The programmes range in size from one associate over two years to 14 associates in a three-year programme which is then renewed. A quinquennial review during 1996 found that 70 % of associates are offered employment in participating companies at the completion of a TCS programme. Well over 2,000 TCS partnerships have been created since it was first established.

One example of the new TCS centres is that of Cardiff University, the University of Glamorgan and North East Wales Institute who are partners in the TCS centre in Wales (one of 40 programmes in the Principality). An SME participating in the scheme for the first time only needs to pay 30 % of the direct costs (compared to a larger firm, which normally pays 60 % of costs). Although it is still too early to provide an adequate assessment of TCS Centres, early evidence indicates that it has been successful in making HEIs more aware of the education and teaching needs of SMEs.

CASE

The Co-operative Awards in Science and Engineering (CASE) scheme is used to fund research students, who are jointly supervised by academics and external sponsors who may come from industry or from public sector bodies. The CASE scheme is largely financed by the UK Research Councils, with some industrial finance for the student and the academic department. The awards aim to encourage industrially relevant research projects by PhD students in HEIs. Standard awards are allocated to HEIs, typically by a quota allocation to a department.

In 1994, the CASE programme was extended to cover Industrial CASE. This extension was set up under a three-year trial period. Industrial CASE operates in exactly the same way as CASE, except that the Research Councils allocate the awards to industrial companies to support projects in HEIs which they select. Thus with Industrial CASE, studentships are allocated directly to firms so that they can take the initiative in defining the research project and selecting the academic partner. Under a 1996 review of the pilot scheme, the Industrial CASE programme received strong support. Aside from the normal Industrial CASE mechanism, a small number of awards under a continuing pilot scheme are made available to SMEs through regional technology centres regional technology centres. This initiative also appears to have worked well and has extended the reach of the scheme to firms who would not normally have participated in CASE.

Other postgraduate schemes

The UK Research Councils also run a range of bespoke schemes often linked with wider government programmes (other bodies run similar schemes, e.g. the Royal Society of Edinburgh). Schemes run by the EPSRC are presented here as one example. The EPSRC manages a number of postgraduate schemes linked in with the TCS and CASE:

- 1) *Engineering doctorate*: Most notable perhaps is the engineering doctorate, which is a four-year award designed to develop innovative thinking, whilst tackling industrial problems. It aims to develop not only engineering skills, but also a wider repertoire of research, business and management expertise essential to successful innovation in industry. Five centres based in HEIs operate the scheme and 75 new awards are allocated each year. Some 200 companies are currently participating in sponsoring research projects within the centres.
- 2) *Postgraduate Training Partnerships*: This scheme is jointly funded with the DTI and offers the opportunity for doctoral students to undertake industrially relevant postgraduate training in industrial research organisations, again in partnership with selected HEIs. In 1996, three new partnerships were established and support for the initial five centres was extended for a further three years. From 1997, 65 studentships were to be available annually through the eight designated centres.
- 3) *Research masters*: In 1995, a four-year pilot scheme was established to provide students with a range of skills of value to research careers within industry and elsewhere. A total of 160 studentships have been made available each year since 1995 through 16 courses.
- 4) *Total Technology*: This scheme's objective is to provide young engineers with a thorough training in research, development, design, planning, production and maintenance activities. It also seeks to broaden their skills base by making them more effective "hands-on" engineers. A total of 46 CASE studentships are channelled to four designated centres each year through this scheme.
- 5) *Integrated Graduate Development Scheme (IGDS)*: The IGDS aims to promote and develop industrially oriented postgraduate training for students employed in industry. The scheme involves a series of short intensive modules designed to extend graduates' technical and managerial abilities, especially in terms of attuning them to the needs of their firm. For the individual, the scheme can lead to a part-time MSc. Funding is provided on a pump-priming basis to establish the course, with the intention that the programmes will become fully funded by industry. Up to the end of 1997, the EPSRC has funded 45 IGDS programmes across the UK, involving more than 300 firms. The EPSRC is currently seeking to extend the scheme through distance learning and innovative teaching methods.
- 6) *Fellowships*: In 1997, the EPSRC instituted 25 new advanced fellowships, seven new industrial fellowships and three new senior fellowships, and the funding for one fellowship under the Daphne Jackson Trust (to support career-break returnees) each year.
- 7) *Graduate schools*: Graduate schools are one-week courses set up by EPSRC to broaden the skills training of postgraduate engineers and in particular to help prepare them for employment. Around 1,000 students pass through these graduate schools each year.

Source: Howells et al. (1998, 84ff)

Local, Regional and National HEI Consortia

Higher Education Support for Industry in the North (HESIN)

HEIs in the UK are not only combining to act as pressure groups according to age, status and so on, they are also increasingly combining to form regional interest groups. These often have a strong industrial collaboration dimension, as can be seen in an increasing number of local, regional and national groupings of HEIs. One of the longest running is Higher Education Support for Industry in the North (HESIN) which was established in the Northern Region of England to support wider frameworks for HEI-industry links in the region. More recently in 1996, HESIN set up the Knowledge House, an initiative to provide local industry with a single point of contact to the universities. The scheme is specifically targeted at SMEs who otherwise would not consider contacting or searching for university-based expertise and it is partially funded by ERDF money. In Yorkshire and Humberside, the Yorkshire and Humber Universities Association was founded as a collaborative venture between the region's nine universities and seeks to encourage regional development. In particular the association is seeking to develop a more co-ordinated and targeted business agenda for the region.

HESIN was formed in 1983 as a local industry-academic consortium. HESIN's constituent bodies were five HEIs in the Northern region: the University of Newcastle upon Tyne, the University of Durham, the former polytechnics of Newcastle, Sunderland and Teesside together with the Northern regional office of The Open University. HESIN has set up several training schemes in collaboration with industry. The two most notable are a former EU-funded COMETT project and an integrated graduate scheme.

NEPTUNE was a COMETT-initiated university training enterprise which co-ordinated individual submissions from HEIs in the Northern region. It comprises a partnership between the six HESIN members, the Regional Technology Centre (RTC North), the Northern Development Company and three private sector organisations. Although HESIN has been very successful in stimulating collaboration in training and another new areas of technology transfer (such as the Knowledge House; see below), the universities remain fiercely independent and still pursue very different exploitation strategies.

Knowledge House

More recently in 1996, HESIN set up the Knowledge House to provide an interface connecting the universities and industry in the North East. Its task is to encourage local SMEs to take advantage of the combined resources located within the six North Eastern universities. The Knowledge House functions as a centrally co-ordinated enquiry and response service providing local industry with a single point of contact for advice, guidance and support on a range of technology and management-related issues. RTC North acts as the central co-ordinator of the Knowledge House, with additional managers based at each of the universities. The central aims of the Knowledge House in terms of providing research services to local firms are to:

- provide a rapid and confidential response services;
- offer a free initial search and diagnosis package;
- "source" local assistance wherever possible (i.e. to the nearest available university);
- arrange initial introduction between the firm's staff and the university personnel; and
- monitor the progress of the delivery of the service once specified.

Contact by firms can be made either through the Central Co-ordinator at RTC North or to individual Knowledge house managers which operate at each of the six universities. Where necessary, assistance is provided by defining the exact nature of the enquiry; often an important issue for SMEs who are not used to using external research or technical assistance. This service is provided free of charge by the Knowledge House team. The enquiry is then confidentially circulated throughout the Knowledge House network and sources of assistance and expertise are then identified. In order to achieve a high and even standard of service, once a proposal and a contract is agreed the progress of the project is then closely monitored by the Knowledge House team.

The Knowledge House has been received several accolades in the UK. It also has been commended and promoted in the UK National Inquiry into Higher Education. Its initial enquiry and revenue targets have been exceeded and crucially SME repeat business has been achieved. Second round ERDF funding has also been secured. However, staff associated with the Knowledge House recognise that have the desired "reach" to SMEs substantial public support (subsidy) is required to get "first-time" (i.e. who have never used a university for research or technical services before) small firms to use the scheme.

The Sussex Academic Corridor

In a more local scheme in Sussex, the local HEIs have received funding from local authorities and industry to establish the "Sussex Academic Corridor" and the Sussex Innovation Centre to lead a more entrepreneurial and property-led scheme to

support HEI spin-outs and high-technology companies in the local economy. The Sussex Academic Corridor involves the collaboration and support of Brighton College of Technology, the University of Brighton and the University of Sussex, together with Brighton Borough Council, East Sussex County Council, Lewes District Council and Sussex TEC. The aim is to help contribute to the economic regeneration and development of an area running along Lewes Road from Brighton to Falmer. The vision is for the HE sector in Brighton to become an engine of local and regional growth, both through its own development along the Corridor and through the co-location of advanced, competitive, high value-added enterprises across a range of industrial, technological, professional, commercial and cultural activities. One mechanism the initiative seeks to use is that of providing technological and research support to existing or newly locating businesses in the area. Another is that of spinning out commercial activities from the partner academic institutions. In addition, the Sussex Innovation Centre (see below) will provide a key resource centre for innovative activity in the Brighton area.

The Sussex Innovation Centre

The Sussex Innovation Centre is a 20,000 square foot business campus located adjacent to the University of Sussex's campus at Falmer near Brighton. It represents a public-private partnership between the University of Brighton, the University of Sussex and Brighton College of Technology. The Centre has received funding from Brighton Council and East Sussex County Council and is sponsored by Seaboard plc. It is subdivided into units, ranging from 145 square feet to 1,500 square feet. The units are available as offices, laboratories, or a mix of both on rental terms of up to five years. Tenants have access to a group of external advisers and consultants on various issues, including finance, marketing, and intellectual property protection.

RCID: Sector Targeting through Institutional Networking

In 1996 three universities in the North East of the UK, University of Northumbria, University of Sunderland and the University of Newcastle upon Tyne, established the Regional Centre for Innovation in Engineering Design (RCID) together with 10 SMEs in the region. The new centre was established with the support of the national government's office in the North East, ERDF funding, the Tyneside Training & Enterprise Council (TEC), the collaborating companies and the University of Newcastle. The mission of RCID is "to create a collaborative research and development environment in which SMEs can develop methods and processes to enhance product development and improve their business performance."

RCID seeks to provide the following range of services to locally-based firms:

- generic research and development programmes;
- high calibre team of design engineers;
- access point for SMEs to the regions' innovation and design capability;
- support for supply chain development activities; facility for identifying best practice in the product design process; and,
- technology transfer activities.

Even over its short history RCID has helped over 300 businesses in the region and has helped attract inward investment. RCID has also become a strategic model for technological development in the North East region more generally and this has been recognised through its commendation into the UK National Inquiry into Higher Education. It should be acknowledged though that although RCID is a novel mechanism for Europe, exhibiting much of what best practice should be about, it appears to have remarkable similarities to a mechanism described as operating in Canada some twenty years ago, namely the University-Industry Research Centres. However, the RCID appears to have a broader approach, especially on a sectoral level, than most of the UIRCs outlined in Anderson(1986).

System Level Integration Institute (SLI)

Another more specific example is the System Level Integration institute in Livingston (SLI), supported by a coalition of HEIs and agencies in the local region. Scottish Enterprise, together with the Universities of Glasgow, Edinburgh, Heriot-Watt and Strathclyde, established SLI in 1997 which specialises in the science of combining increasing numbers of hardware and software functions within ever-reducing dimensions on a computer chip.

The institute forms part of two other facets comprising Project Alba, supported by Scottish Enterprise. This project represents a major investment by Cadence Design Systems, the world's leading supplier of semiconductor design technology and services, in Livingstone, West Lothian. The last facet is the establishment of an independent design complex based on SLI. This will be the focus of a friendly environment to facilitate the trading of intellectual property, thus speeding up time-to-market in an industry where product life can be extremely brief.

The institute is based at the new design complex in Livingstone, where it will provide a focus for teaching and research and will work closely with the companies based there. The new institute aims to develop MSc courses and professional development modules relating to system-level design.

Source: Howells et al. (1998, 92ff), Howells et al. (2001, 71ff)

University Strategies toward Exploiting Knowledge

University of Manchester: VUMAN

Vuman Limited was set up in 1981 by the University of Manchester to act as the university's technology development and exploitation company and has had a chequered history. Vuman is responsible for the protection of IPRs, licensing and the transfer of technology, including the establishment and management of spin-off companies. The University of Manchester is the UK's fourth largest university in terms of research output and not unexpectedly Vuman has grown over time and is now a parent "umbrella" company for some 20 spin-out firms; with about £ 10 million worth of assets under its control amongst companies whose total worth is £ 20 million. Vuman also works with Campus Ventures and the Manchester Biosciences Incubator (MBI). Campus Ventures was set up in 1995 to attract monies from local industry to help establish new high technology enterprises, some created from within the university and some which have emerged from the local economy. Some 24 companies have been supported so far. The MBI was established in 1997 to provide an incubator unit for new bioscience companies.

Interest in Vuman is not so much in terms of its commercialisation and new formation rate but rather in its experience and role in corporate parenting and in the decision framework over disposing of university controlled companies. Although from the outset, Vuman did not want to be a long term holding company, it had no clear strategy of when and how to dispose of assets that would meet the following criteria:

- benefit the university;
- benefit the long term prospects of the spin-off company and its employees; and
- aid the long term growth prospects local and/or national economy.

Through a slow process of evolution and trial-and-error, Vuman has settled on four strategies regarding exiting strategy:

1. *Retain*: Vuman has realised that in some instances that some university-owned will never be disposed of, or at least not for a very long time. This is essentially because such companies would find it very difficult to stand alone because of their very closely integrated with parts of the University and/or because of their heavy reliance on University staff or facilities. Examples include Manchester Informatics Limited which acts as a focus for the commercial activities of the department of Computer Science and Flow Science which depends on using the facilities of the University's Goldstein Laboratories.
2. *External Investment/Partial Disposal*: In relation to this option, a financial institution (usually a venture capital company) invest substantial funds into a university company, whilst the University retains a (sometimes substantial) share in what effectively becomes an independent company from the University. Examples here include Kestra Limited, an industrial inspection company that grew out of the Medical Biophysics Wolfson Image Analysis Group and where the University still retains a 25 % stake, after a £ 1.25 million was received from external investment. In the case of Semantic Technologies Limited only £ 0.25 million funding was required and the University retains a 37% stake.
3. *Trade Sale*: This is where a company is sold to a larger firm already well established in a particular business. Thus Predictive Control Limited was recently sold to Siebe plc a major UK-owned international engineering controls and filters company. Reasons for trade sales centre on a set of related factors: needing access to a large-scale marketing and/or financial base; where high growth rates may also need financial muscle to continue such growth targets; and in sectors which make it difficult for small firms to compete effectively on their own.
4. *Management Buy-Outs (MBOs)*: Under this option, the management of the firm, sometimes strengthened by additional management expertise and often supported by external financiers, seeks to purchase the whole of the business from Vuman. Thus Vuman Lasers Limited, a medical laser company was brought by its management team under Dr. Andy Charlton. The context for this option is that Vuman often responds to approaches relating to MBOs and the management team is confident of its independent future. Gaining external backing both in terms of finance and management expertise, is important in allowing the MBO option to go ahead.

Although Vuman is trying to develop a more systematic method for deciding alternative exiting routes for the university companies it accepts that it has to allow certain flexibility in the decision-making based on the individual circumstances, whilst selecting the "right time" for disinvestment still remains problematic.

University of Newcastle upon Tyne

The exploitation and commercialisation aspects of the University of Newcastle upon Tyne are co-ordinated by its Technology Transfer Office (TTO) which operates within the University's Research Services Unit. As for the UK as a whole, ownership of any intellectual property generated by university staff vests with the employing organisation.

Unlike most North American universities, universities within the UK have only recently tried to formalise and codify their intellectual property exploitation policies. The University of Newcastle upon Tyne case is an example of good practice via its more stringent focusing on three aspects of its exploitation strategy, namely:

1. through more effective scanning of intellectual property that the university's researchers are generating;
2. its more formal incentive structure to encourage the production and development of inventions and technical developments; and
3. its decision-making procedures about whether the intellectual property is worth defending and, if so, how it should be defended.

Scanning: Although the university had been increasing its commercialisation of research output this had largely been done on a reactive or "word-of-mouth" basis. The university's officers had largely waited for academics to announce that they had something valuable to exploit commercially. Although this generally did yield the key IP output of the university, an audit of several departments highlighted the fact that there was still valuable research output that had commercial worth which was simply not being disclosed. This IP was therefore not being exploited by the university; or left to the industrial partner to surreptitiously exploit the IP, even though the university may have had equal or even greater rights to the IP. To counter this loss of IP potential, technology audits were put in place across the university as well as formal annual reviews at departmental or faculty levels. However this was shown to cause resentment amongst academics who felt that they were constantly being monitored and not allowed to get on with the research. Over time a more informal approach has been made by the TTO by contacting senior academic staff and meeting individual staff or project team members. Although in terms of contact the approach is informal, just as much attention is paid to ensuring that a full "sweep" of the university is made and better relationships can be engendered with the staff. As a bonus, potential areas of future IP conflict can be dealt with and monitored through this scanning process. An "education" programme has also been instituted to make academic staff more aware of IP management issues and to improve their understanding of industry needs and concerns. Nonetheless, IP scanning and identification remains a time consuming process and it has been realised that more effort needs to be made for IP identification at the outset of a project at the project planning stage.

Incentive Structures: Although the university formally has all rights over any IP generated by academic staff this provides little incentive for academics to consider the exploitation and commercial benefits of the research they undertake. University of Newcastle upon Tyne had for many years considered whether and how academics should benefit from the IP they generated on an ad hoc basis. Although in some ways this was necessary because of the wide range of different IPR circumstances to each case it led to an opaque system that caused resentment. As a result a more formal structure was introduced that has been fine tuned over the years. In the case of exploitation by licensing or assignment, the revenue is shared between university and inventor(s) in the following way: After legal costs, the first £ 5,000 of intellectual property (IP) income goes to the inventor(s). The next £ 200,000 of IP income is split the following way: 50 % to the inventor(s); 25 % to the department(s) of the inventor(s); and 25% to the university. In the case of exploitation via start-up enterprises, the inventor(s) can take equity in the company while the inventor(s) involvement is subject to the university's company directorship policy.

Screening and Selection for IP Protection: The improved scanning process outlined above, although successful led to the creation of a new problem in that more IP cases were now being generated which the university had to review for exploitation and defending. Where the university has the rights over the invention, or has been granted them, decisions have then have to be made over the costs and benefits of protection. Different valuation approaches are used in relation to intellectual property including sunk cost valuations, direct financial return accounting and models providing for a wider recognition of indirect benefits associated with proceeding with protection. The university still realises, though, that IP exploitation benefits may not be obvious and that schemes are being rejected which should have been allowed to go ahead. With a potential protection gap (from idea/results through to launch of a commercial product and service) period ranging from 1 year through to 15 years, the university has to consider the appropriate mechanisms to decide about defending, how long "protection gap" will be and how much it will cost. There are various sources of money to fund the idea to product gap. If the decision is to exploit the invention via IPR, the University of Newcastle upon Tyne itself only has a very small patent protection budget (£ 40,000 p.a.) and therefore the TTO usually allows only a 12 month "window" from patenting something for it to then find a royalty income or licensing deal with a company which will then secure the funding of protecting the invention for the rest of its life.

It may be that if the technology is really ahead of its time and that the innovation may still not be properly developed after its 18th year, the university has increasingly sought to take out a trademark which may have a life of anything between 50 to 70 years. This secures the protection of the technology in terms of a wider envelope and creates a "brand awareness" for the technology. For inventions which the university decides it wants to commercialise itself it has its own venture capital company Newcastle University Ventures Limited (NuVentures Limited) which can seek to support the new venture on a medium to long term basis.

Source: Howells et al. (2001, 74ff)

B.9 USA³¹

B.9.1 Knowledge Production Structures in the USA

The USA has been the leading R&D performer of the world economy since World War II. Although some smaller economies and Japan have passed the USA in R&D intensity (total R&D expenditure as a percentage of GDP) in the 1990s, the US economy is still among the most intensive R&D performing economies, with R&D expenditure of 2.59 % of GDP. The enterprise sector is the dominating group of actors in the US R&D system, performing 75 % of all R&D expenditure. In science, there is a large university sector accounting for 14 % of total R&D expenditure, and a somewhat smaller state-owned sector of PSREs. Compared to most other countries, the USA also shows a private non-profit sector with a significant R&D performance (Table B.9.1).

Table B.9.1: R&D Expenditures in the USA 1998 by Financing and Performing Sectors (in million €)*

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total %</i>	<i>% of GDP</i>
	<i>Enterprises</i>	<i>State</i>	<i>private non-profit**</i>			
Enterprise Sector	158,276	26,528	0	184,804	75	1.95
PSREs*	0	19,365	0	26,733	8	0.20
HEIs	2,046	24,970	7,357	34,373	14	0.36
Private non-profit	1,134	4,399	1,836	7,369	3	0.08
Total (million €)	161,455	75,262	9,193	245,910		
Total (%)	66	30	4		100	2.59

* US statistics do not report any R&D funding from abroad. R&D funding by foreign enterprises for their US affiliates is contained in the total sum of R&D financing by the enterprise sector.

** including own R&D funding by HEIs

Source: NSF (2000), calculations by the authors

R&D in enterprises is mainly financed by internal sources of the enterprise sector. Public funding of industry R&D, which was a much more important financing source until the 1980s, has declined considerably and now in 1998, accounted for only 14 % of total business R&D, although this is still above the average in international comparison. In 1990, this figure was 26 % however. Public funding is mainly provided via direct research programmes. About 10 % of public R&D funding for industry R&D is distributed via Federal Funded Research and Development Centers (FFRDCs) run by industry.

R&D at the institutions in public science³² is financed mainly by federal sources (about 60 % in HEIs and 90 % at PSREs). State and local governments as well as industry and private

31 This chapter is a literature-based summary on ISR in the USA, drawing mainly on the following sources: NSF (2000), Nelson (2001), Adams et al. (2001), Thursby et al. (2001), Hall et al. (2001), Santoro and Gopalakrishnan (2001), Carlsson and Fridh (2000), Siegel et al. (1999), Hane (1999), Feller (1999), Etzkowitz (1999), Mowery et al. (1999), Lerner (1999), Smith (1999), Abramson et al. (1997), Mowery and Rosenberg (1993).

32 In this chapter, the private university and college sector in the USA, which is of significant size, is treated as part of "public science" as private research universities follow the same principal mission as public research universities do, i.e. carrying out academic research and providing higher education as a joint production.

non-profit organisations play a minor role in R&D financing in public science. In HEIs, nearly one fifth of all R&D expenditure stems from internal sources (Table B.9.2). Within the very heterogeneous HE sector, institutional (general purpose) funding of R&D is rather rare, and most R&D is performed on a project or programme basis, while the allocation of these funds is generally based on competition. This holds true for most of direct R&D financing by the Federal Departments as well as by the National Science Foundation (NSF) which provides financing for fundamental research.

Table B.9.2: Financing Structure of R&D in HEIs and PSREs in the USA 1995 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (general purpose grants, own institutional funds)	< 20	~ 75
Project Financing and other competition based financing sources	> 80	~ 25
National Government	60	90
Regional Governments	8	0
Other Sources (enterprises, internal financing, abroad)	32	10

Source: NSF (2000), Abramson et al. (1997), estimations by the authors

Within the enterprise sector, R&D expenditures are strongly concentrated in the high-tech sector, i.e. pharmaceuticals, microelectronics and computers, telecommunication equipment, aircraft and missiles, and instruments (Table B.9.3)³³. About 45 % of all R&D activities take place in these sectors which are characterised by a strong science relationship, short product cycles, high market dynamics, and sometimes extremely high R&D investments in order to be able to compete in the market. Technology sectors that are more strongly oriented towards cumulative technological changes, such as machinery, basic chemicals, and vehicles, show a significantly lower share of total business R&D (25 %). The information and communication services (software, telecommunication) account for 15 % of total BERD. With a share of R&D expenditure in this sector to total GDP of 0.28 %, this sector is a major R&D performer by international standards.

Table B.9.3: R&D Expenditures in the US Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in total BERD (in %)</i>	<i>R&D Expenditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	45	0.86
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	25	0.47
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	7	0.13
IC-Services (NACE 64, 72, 73)*	15	0.28
Other Services (NACE 50 to 99, excl. IT-Services)*	8	0.16

Source: OECD (2000), estimations and calculations by the authors

33 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

A major feature of the US R&D system that distinguishes it from nearly all other countries, is the very high share of military oriented research. Since the 1940s, the US research system (both in industry and science) has developed via large public funding for defence related R&D, and the defence related share of federal R&D in every year, was above 50 % (after more than 80 % in the 1950s and 1960s). About a quarter of total R&D expenditure in the USA is directed towards R&D in defence related fields. Consequently, the US Department of Defense is the main public R&D funding source (47 % of total federal obligations for R&D in 1999), and the NASA accounts for another 13 %. In 1998, 54 % of all government R&D budget appropriations were allocated to defence related objectives. Most of this defence related money is spent on development activities (more than 80 %). The second most important R&D financing source within the government is the Department of Health and Human Services (see Table B.9.4).

Table B.9.4: Obligations for R&D by the US Federal Government in 1999, by agencies

Agency	Total (million US\$)	Share in total obligations allocated to (in %)		
		basic research	intramural (govern. labs)	industry
Department of Defense	34,350	3	23	70
Department of Health & Human Services	14,821	54	21	6
National Aeronautics & Space Administration	9,201	23	25	51
Department of Energy	6,541	34	12	37
National Science Foundation	2,655	92	1	5
Department of Agriculture	1,426	43	70	1
Department of Commerce	1,036	4	67	23
Department of Transportation	768	7	38	40
Department of the Interior	638	10	89	3
Environmental Protection Agency	610	9	48	14
All other Agencies	1,288	16	50	9
All Federal Agencies	73,334	23	24	45

Source: NSF (2000), calculations by the authors

The overwhelming majority of business R&D is spent in large enterprises. Small enterprises (i.e. with less than 500 employees) account for 15 % of total business R&D while about 60 % of all business R&D is performed by very large enterprises, consisting of more than 10,000 employees (Table B.9.5). However, many small enterprises contributed much to the growth in business R&D in the 1980s, mainly in new technologies such as computer & software (Intel, Microsoft, Oracle, Cisco) and biotechnology (Amgen, Genentech). But, due to their rapid growth, they soon became large enterprises themselves.

Table B.9.5: R&D Expenditures in the US Enterprise Sector by Size Classes of Enterprises 1997

Sector	Share in %
Small Enterprises (< 500 employees)	15
Medium-sized Enterprises (500 to 999 employees)	3
Large Enterprises (1,000 to 9,999 employees)	22
Very Large Enterprises (10,000 employees and more)	60

Source: NSF (2000), calculations by the authors

The main business R&D performers in the USA are multi-national corporations in the car, computer and software, chemical and pharmaceutical, electronics, and aircraft industries (the latter two are heavily engaged in the military industry). Out of the top 100 R&D performers in 1997, 76 belong to the above mentioned industries, and some of them spend extraordinary large amounts of money on R&D compared to the R&D expenditure in science. For example, in 1997 only five companies (General Motors, Ford Motor, IBM, Lucent, and Hewlett-Packard) spent the same amount of money on R&D as the total spent by all of the c. 900 research universities in the USA. In general, the large corporations run their own R&D divisions, both at US and foreign locations. Most of them have established large, central R&D laboratories since the 1970s. Although many of them have been downsized during the 1990s, when large corporations increasingly attempted to shorten development periods for new products and shifted R&D activities away from fundamental research towards near-to-production development, these labs still maintain a manifold R&D network, both with other enterprises and with domestic and international science institutions. Since the 1980s, many firms started to develop external sources of R&D expertise. Out-contracting of R&D and external R&D linkages to foreign firms, SMEs, universities, and start-ups developed somewhat earlier than in all other countries.

Foreign-owned enterprises are of little significance in the US R&D system. They showed a share of 12 % (1996) in total business enterprise R&D expenditure in the USA. This share has increased however, since the 1980s until the early 1990s, from 9 to about 15 percent.

There are two special segments of R&D performing institutions, which may also be regarded as part of industry in a broader understanding. Firstly, there are five Federal Funded R&D Centers (FFRDCs) administered by industrial firms. Their R&D expenditures were about 2,4 billion US\$ in 1998, i.e. 1.4 % of total BERD. The largest industrial FFRDC are the Sandia National Laboratories, operated by Lockheed Martin (1997: 658 million US\$ federal obligations by the Department of Energy (DOE) for R&D) and targeted on "weaponise" nuclear weapons designs created at the DOE national laboratories at Los Alamos and Livermore (both university administered FFRDCs). Other large industry FFRDCs are the Oak Ridge National Laboratory (DOE-funded, energy research) and the NCI Frederick Cancer R&D Center (funded by the Department of Health and Human Services, and undertaking cancer research). Anecdotal evidence suggests that industry FFRDCs show a high performance in ISR, not only related to the administering enterprise, but to the much broader circle of enterprises.

Secondly, there is a rather large non-profit sector that performs R&D. It spent 6 billion US\$ on R&D in 1998, i.e. about 3 % of the total R&D expenditure in the USA. It is often referred to as the "fourth sector" and consists of a diverse population of privately held, non-academic organisations specialised in R&D activities. Most R&D enterprises are very small and less than 100 have a staff of more than 100, or an R&D budget of over 10 million US\$. The larger R&D enterprises concentrate in the health and medical sciences, biological and environmental sciences, and engineering and technology. There are also 13 FFRDCs administered by non-profit organisations, performing about 820 million US\$ on R&D in 1997, totally financed by

federal funds, mainly from the Department of Defense (DOD) and the DOE. The four largest non-profit FFRDCs are the Aerospace FFRDC (R&D expenditure in 1997: 215 million US\$, financed by DOD and DOE), the C3I (163 million US\$, DOD), the National Renewable Energy Laboratory (148 million US\$, DOE) and the Pacific Northwest National Laboratory (146 million US\$, DOE).

Research in science in the USA is strongly oriented towards natural sciences, engineering, and medical sciences. Nearly 90 % of all research activities in public science takes place in these fields. Research in the social sciences and humanities is of very minor importance. 69 % of all research activities in HEIs are regarded as basic research, while the PSREs are much more oriented towards applied research and development activities (Table B.9.6).

Table B.9.6: R&D Expenditures in the US Public Science Sector (HEIs & PSREs) by Fields of Science 1997
(in %)

<i>Sector</i>	<i>HEIs</i>	<i>PSREs*</i>	<i>Total</i>
Natural Sciences	38	40	39
Engineering	16	45	28
Medical Sciences	30	11	22
Agricultural Sciences	8	4	6
Social Sciences	6	0	4
Humanities	2	0	1
Basic Research	69	18	48
Applied Research	24	32	27
Development	7	50	25

* rough estimations for GOGO and GOCO for 1994

Source: NSF (2000), calculations by the authors

The US public science sector consists of different institutions each showing a particular organisational and financing structure, mission and research orientation, and orientation towards technology transfer and firm interaction. The following institutions may be distinguished:

- Universities and Colleges comprise a total of more than 3,600 colleges and universities (both publicly and privately funded ones), as well as nearly 7,000 vocational and technical institutions but in 1997, only 832 of them performed R&D. This small fraction of the total Higher Education Sector is commonly called "research universities". Amongst them, the largest 100 research universities account for 80 % of all academic R&D and constitute the heart of the US basic research sector. In the USA, the university sector is highly diverse and there is neither any kind of uniform institutional setting nor are there common regulations for all universities and colleges. Rather, the HEI sector is a heterogeneous, highly autonomous population of research colleges and universities established in a particular regional and local environment. In general, one may distinguish public and private HEIs, although this distinction is not fundamental. Although all HEIs receive federal funding and thus, must comply with common federal regulations, each institution has a distinct governing body, administration, accounting practices, and mission statement (Abramson et al. 1997, 92).

- With respect to technology transfer to industry, the so-called University-Industry Research Centres (UICRs, also called industry-university co-operative research centres - IUCRCs) have a clear mission on industry-oriented technology transfer. They are university affiliated but a considerable part of their budget (about one third) is financed by industry, often in the form of sponsorship. They perform both basic and applied research, i.e. they are much more application oriented than universities. In 1990, they spent a total of 2.5 billion US\$ on R&D expenditure which was about 15 % of the total R&D expenditure at US universities and colleges.
- There are 18 FFRDCs administered by universities established at the request of federal agencies with congressional authorisation. They are funded up to more than 70 % by federal government sources, mainly from the Department of Energy, NASA and the DOD. Many of these university FFRDCs are organised as government-owned, university-operated laboratories (GOCOs). The employees are not civil servants. Their main objective is to carry out certain types of research commissioned by the funding agencies using access to knowledge and competence also available at the administering universities. Because FFRDCs operate largely outside the government's personnel and contracting systems, they are free from many regulatory and administrative requirements.
- The FFRDC sector consists of university administered, industry administered and non-profit organisation administered FFRDCs. The university FFRDCs account for 65 % of all R&D expenditure at FFRDCs, while the 5 industry FFRDCs account for 25 %, and the 13 non-profit FFRDCs account for 10 %. The latter two are not considered part of the public science sector although they show similar features concerning financing, mission and regulatory framework conditions.
- The US PSRE sector consists of nearly 500 laboratory campuses, distributed over all Federal States, including 5 campuses abroad. These government-owned and government-operated research centres (GOGOs) are under the responsibility of Federal Departments. They carry out R&D relevant to the activities of these Departments. Their employees and managers are civil servants. Almost all Federal Departments operate GOGOs:
- The Department of Defense (DOD), collectively with the Departments of the Army, Navy and Air Force, operates more than 70 laboratories. They received DOD-funding of 7.8 million US\$ in 1997, i.e. 23 % of total R&D funding of DOD. During the 1990s, the DOD GOGOs were downsized considerably. The laboratories have strong ties to the military industry. The Defense Authorization Act of 1992 required the encouragement of technology transfer from DOD labs, including the establishment of an Office of Technology Transition and a diversification programme.
- The Department of Health & Human Services (HSS) spends about 3 million US\$ annually for intramural R&D at about 20 laboratories and institutes. 10 of them form the National Institutes of Health (NIH) laboratories. NIH is the main funding source for biotechnology research in the USA although most of the total R&D financing of about 14 million US\$

goes to universities and non-profit organisations. At NIH laboratories, clinical, medical and drug research is carried out.

- The National Aeronautics and Space Administration (NASA) is a main financing source for R&D in the field of space sciences and aviation. About half of its total R&D budget is used for financing R&D projects in industrial firms, and about 20 % goes to universities or a university administered FFRDCs (the Jet Propulsion Laboratory). NASA also operates 9 GOGOs, spending at total of 2.3 million US\$ on R&D on 1999, including the Johnson Space Center, the Kennedy Space Center, and the Goddard Space Flight Center. In the early 1990s, NASA extended its mission by introducing the commercialisation of technologies as a primary NASA objective.
- The Department of Energy (DOE) is financing three large defence related FFRDCs (Los Alamos, Livermore, and Sandia, the first two being administered by universities, the latter by Lockheed Martin) to which the largest part of its R&D budget is allocated. The DOE operates about 20 GOGOs in the field of energy research, although the majority of energy related R&D funding is also spent at DOE-financed FFRDCs.
- The Department of Agriculture operates, via the Agricultural Research Service (ARS) and the Forest Service, a total of more than 180 laboratory campuses. In 1999, they spent about 1.0 billion US\$ on basic and applied research in the fields of soil, water and air, plant and animal productivity, commodity conversion and delivery, human nutrition, systems integration, and forestry.
- The Department of Commerce is financing the National Institute of Standards and Technology (NIST) as well as several institutes of the National Oceanic and Atmosphere Administration. The NIST's primary objective is to develop and apply technology, measurements, and standards to promote economic growth, including research on, and implementation of, standards and testing methods, quality-outreach programmes, the Advanced Technology Program (ATP), and the Manufacturing Extension Partnership (MEP).
- The Environmental Protection Agency runs three national laboratories and two national centres at 10 different campuses. Its main objective in the field of R&D is to carry out applied science in the NSF risk assessment/risk management model, and to increase the role of the extramural science community in environmental research.
- Other Federal Departments and authorities (Dept. of the Interior, Dept. of Transportation, Dept. of Veterans Affairs, Dept. of Education, and National Science Foundation) operate other laboratories, numbering more than 100, most of them rather small.

In summary, knowledge production structures in the USA provide a favourable structural framework for extensive interaction between industry and science. Sectoral structures of R&D performance are concentrated in science-based industries such as biotechnology & pharmaceuticals, computer & software, and new information technologies. The federal

government is a main financing source of R&D in certain fields of research (weapons and space research, energy research, and health research) and contributes to extensive R&D resources both in industry and science in areas which raise the potential and demand for interaction between both sides. Business R&D is carried out in the main by very large corporations who dispose of huge research budgets and have sufficient absorptive capacities. In public science (including the private university sector), competition-based research financing, a tradition in outside financing, and the autonomy of the individual institutions, provide favourable structures for close interaction with industry.

Table B.9.7: Main Characteristics of Major Institutions in the US Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D*</i>	<i>Structure</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
Universities and Colleges	54	~ 840 R&D performing universities and colleges	research and education, "research universities": fundamental research	basic research	high among the top-performing
University-Industry Research Centres (UIRCs)	included in Universities and Colleges	more than 1,000 centres	technology transfer, both short-term to strategic oriented	basic and applied research, development	very high
Federal Funded R&D Centers (FFRDCs) in HEIs	11	18 laboratories	research in commission of Federal agencies	basic and applied research	divergent
Department of Defense (DOD) Labs	16	73 laboratories	military research	technology development	medium
Department of Health & Human Services (NIH, FDA, CDCP)	6	19 laboratories	clinical research, medical research, drug research	basic and applied research	high
National Aeronautics and Space Administration (NASA) Labs	5	9 laboratories	aeronautics and space research, commercialisation of technologies	technology development, partly basic and applied research	medium
Department of Energy (DOE) Labs	2	22 laboratories	energy research	applied research, development	high
Department of Agriculture Labs (ARS, Forest Service)	2	185 laboratories	agricultural research	applied research	high at ARS
Department of Commerce Labs (NIST, NOAA)	2	38 laboratories	new technology development, measurement & standards	applied research	high at NIST
Environmental Protection Agency (EPA)	1	11 laboratories	risk assessment and risk management	applied research	high
Other Labs	2	> 100 laboratories	divergent	divergent	divergent

* estimates for 1998

Source: Abramson (1997), NSF (2000), calculations by the authors

B.9.2 The Level of ISR in the USA

The level of ISR in the USA is described by a set of indicators and assessments on the significance of various interaction channels. Table B.9.8 lists the indicators used and the main results. It also indicates those areas where ISR in the USA may be regarded as above average with respect to EU standards. There is however, only limited information on the type and intensity of interaction between industry and science, and the patterns and levels of knowledge and technology transfer vary considerably between economic sectors and research fields. As there is no consistent data on ISR in different economic sectors available, the following characterisation is restricted to some general trends on how industry and science interact in the US innovation system. Interactions between industry and science are discussed for the higher education institutions (HEIs, i.e. research universities and FFRDCs administered by universities) and public sector research establishments (PSREs, i.e. government-owned and operated laboratories - GOGOs).

R&D funding by industry for HEIs amounts to 6 % of total R&D expenditure in research universities (including R&D at university FFRDCs, 7.2 % excluding FFRDCs). While there was a significant increase in industry-sponsored R&D in HEIs in the 1980s, the industry finance share remained more or less constant during the 1990s. However, the industry share varies considerably between fields of science and institutions. Among the top 100 research universities, 16 have industry R&D funding shares of 10 % and more. Industry money for university R&D is provided either via contracts or grants. Contracts usually specify particular deliverables whereas grants are generally more open-ended. At the top-level research universities, the vast majority of industry-funded R&D is distributed via grants. Research grants often include other contractual agreements, such as favourable consideration of the enterprise in licensing negotiations, royalty-free exclusive rights, or visiting fellows from industry.

R&D funding by industry can also involve other types of co-operation. University-Industry Research Centres (UIRC)s are a major forum for carrying out collaborative research. They represent university-affiliated research centres or institutes that mainly conduct applied research and development which is partly funded by industry. In the early 1990s, their total number exceeded 1,000 at more than 200 different HEIs. Some of them were founded in the 19th Century but the vast majority were established only in the 1980s (see Cohen et al. 1994). It is estimated that more than half of all industry support for academic R&D was channelled through UIRCs in 1990. In addition to direct funding, industry support also includes equipment and internship opportunities for students. Many of the UIRCs established in the 1980s received start-up support (seed money) by the NSF via its IUCRC programme (see B.9.3). UIRCs cover almost all fields of basic science, applied science and engineering. Although the majority of UIRCs are engaged in fields of research associated with high-tech industries (pharmaceuticals, computers, electronic equipment, and software), there is also a large proportion of UIRCs that focus on medium and low tech industries (e.g. food products, metals, mining, lumber and wood, rubber and plastics, and paper).

Apart from UIRCs, there are also other, less formalised forms of research collaboration within research consortia, mostly involving multiple corporate sponsors, and often, also federal government funding agencies. Within industrial liaison programmes (ILPs), enterprises pay fees to HEIs to gain facilitated access to current research results. Dissemination mechanisms include, amongst others, working papers, research reports, workshops, lectures, and conferences. In the main, ILPs are focussed on narrowly defined research areas. In 1992, a total of 278 such programmes were identified at 35 leading research universities.

Another type of R&D collaboration between HEIs and enterprises is R&D related consulting activities by faculty members. It is estimated that more than 80 % of engineering faculties have been engaged in this kind of activity, devoting up to 10 to 15 % of their time to it. Academic consultants are generally paid hourly or daily fees.

There is no direct industry funding for PSREs in the USA. However, there is significant co-operation in R&D between PSREs and industry. The so-called Co-operative Research and Development Agreements (CRADAs) are today, the main mechanism for carrying out collaboration with industry in R&D, although various other contractual models were applied before the introduction of CRADAs in 1986. CRADAs provide authority for labs to contribute staff and equipment to a joint project with industry, and the participating enterprises can contribute staff, equipment and funds to this project at PSREs. The PSREs' contribution to a CRADA-based joint research project with an enterprise is generally funded by the labs' own R&D budget - following the technology transfer objective of the PSREs. PSREs are not allowed to transfer CRADA funds to the private sector partner. Furthermore, CRADAs allow the participating labs to protect from disclosure any IP relevant to the agreement with an enterprise, under the Freedom of Information Act. There are several thousand active CRADAs that have been negotiated between federal laboratories and private enterprises but no information is available on the amount of R&D performed under CRADAs. NASA does not use the CRADA system but remains under the Space Act with regard to its commercialisation activities. R&D consulting for industry is not common at PSREs as the scientists at federal labs are civil servants and are prohibited from working outside the government. Some consulting activities are reported from some PSREs but they do not involve extra compensation. PSREs are also engaged in technical assistance to enterprises, most often mediated by an intermediary within a state technical extension programme, or on the national level within programmes such as the manufacturing extension programme. R&D services are also provided as work that may be reimbursed, for others, which is mainly used by other governmental authorities but sometimes also by enterprises.

PSREs are involved in research collaboration with industry to very different degrees. At some institutions such as ARS, NIH, and NIST (and also some non-profit FFRDCs), technology transfer is the main objective of the institution, and co-operative R&D is very common. There are however, some institutions that, more or less exclusively, develop technology and knowledge for government use. Technology transfer from these labs tends to be a by-product of the principal objective. This is especially true for military service laboratories, including DOE weapons laboratories.

Researcher mobility from HEIs to industry is assessed to be high, although no recent aggregate data is available. In the early 1990s, it was estimated that about 2,000 PhD scientists and engineers moved from academia to industry annually, i.e. about 2 % of the total R&D staff in HEIs. In 1997, out of about 58,000 students who finished their PhD study that year, about 30 % moved to business. In the context of collaborative research projects, UIRCs and research consortia, temporary exchange of R&D personnel between industry and science, and vice versa, is very common. Researcher mobility is stimulated by the general employment and career system in the USA that encourages horizontal (i.e. inter-sectoral) mobility as a means of improving salaries and positions of employees. Compared to many other countries, salary differences between university and industry researchers are less pronounced.

Personnel mobility between PSREs and industry is low as a result of the mobility restricting civil servant status of scientists at government labs. There are some exchange programmes which foster temporary mobility between the two sectors but they are not significant in size. There is a natural reluctance on the part of both management (fear of losing their best staff) and scientists (fear that absence will hurt their career options at the PSRE) to engage in exchange programmes.

HEIs occupy a central role in vocational and further training for industry employees. Such activities are carried out either as a separate task, or as an activity within research collaboration, mobility programmes or knowledge exchange programmes (such as ILPs). Within the higher education sector, there are thousands of vocational and technical institutions that also offer vocational training. Accurate data on this type of interaction is not available however, and there has been a rather small amount of attention paid to this aspect of ISR in the USA so far.

The number of patent applications by HEIs, and patents awarded to HEIs, has risen strongly since 1980, i.e. the introduction of a new regulatory setting concerning IPR on R&D funded by the federal government (Bayh-Dole Act, see B.9.3). In 1985, the number of patent awarded to HEIs was about 600, while in 1998 it grew to 3,150. In the same period, the top 100 research universities increased their share in total patent awards to HEIs from 77 % to 89 %. Within the PSRE sector, the number of patent awarded had not grown since 1980 but fluctuated around an annual number of 1,000. Patent activity both in HEIs and PSREs are high by international standards. The number of granted patents per 1,000 researchers is about 35 in the case of HEIs and about 15 for PSREs.

Income from royalties in HEIs has increased greatly during the 1990s, from 221 million US\$ in 1990 to 698 million US\$ in 1997. University licensing revenues amounted to 2.3 % of all R&D expenditure in that year. However, at most HEIs, the expenditure for commercialising IPR clearly exceed the royalty income. In 1995, the six top-performing HEIs accounted for over 56 % of total royalties received by US HEIs. The largest proportion of royalties stem from "embryonic inventions" in the field of pharmaceuticals and biotechnology.

At PSREs, licensing is the traditional way of technology transfer to industry. There are about 1,000 licenses issued by the federal laboratories, most of them non-exclusive licenses. The DOE labs (including the university and industry administered FFRDCs) account for the vast majority of licenses but royalties are low. Significant income from licenses is only reported from the NIH. For all PSREs combined, royalty income was only about 25 million US\$ in 1995, i.e. equal to 0.1 to 0.2 % of the total R&D expenditure.

Start-ups data from HEIs and PSREs is not systematically collected in the USA. A survey by the Association of University Technology Managers (AUTM) on the number of newly created enterprises that were dependent upon licensing their HEI's technology for initiation, reports a total of about 350 such start-ups per year in the years 1997 and 1998 (see OECD 2000b). This figure clearly underestimated the total number of technology-based start-ups from US HEIs, as start-ups by researchers from HEIs who do not license a technology held by their institution, are not considered. Furthermore, the survey covered only 132 research universities. Since the mid-1990s, a growing number of universities have taken equity positions in companies engaged in the commercialisation of new technologies invented at the university. The HEIs' engagement in the venture capital business takes place either through portfolio investment of the university's endowment or through independent organisations established specifically for this purpose. Equity investment in start-ups allows HEIs to exploit IPR with the promise of a much larger financial return than could be earned from licensing alone but without substantial risks.

No data on start-up activities at PSREs is available but anecdotal evidence suggests that the level - compared to HEIs - is low. A rather high level of start-ups is reported from the three large DOE national laboratories (university or industry administered FFRDCs). At these labs, scientists are not civil servants.

The high and growing level of knowledge interaction between industry and science is also revealed by joint publication and collaborative patenting (see Hicks 2000). The number of collaborative papers grew from an annual figure of about 6,000 at the end of the 1980s, to nearly 9,000 at the end of the 1990s. In the field of joint patenting, the increase is considerably higher, although the absolute numbers (c. 230 patents co-assigned by public science institutions and enterprises in 1997) are still low.

Informal, personal contacts are regarded as the most important channel of technology transfer and information dissemination both by representatives of industry and public science. In HEIs, several mechanisms and instruments foster the establishment of personal networks among industry and science researchers: joint R&D infrastructure at universities (university-industry research centres); industrial liaison programmes; R&D consortia; and the high level of inter-sectoral personnel mobility. At PSREs, technical workshops and laboratory tours are a means of fostering a high level of personal contacts. Informal contacts are further enhanced by the science orientation of researchers in industry who participate in academic discussions, including attending scientific conferences.

Table B.9.8: Indicators and Assessments of ISR in the USA at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % (1998)	6.0
	R&D financing by industry for PSREs in %	n.a.
	R&D financing by industry for HEIs/PSREs in % of BERD (1998)	1.7
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	high
	Significance of R&D consulting with firms by PSRE resear.	high
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in % (1988-1993)	> 2
	Share of researchers at PSREs moving to industry p.a. in %	n.a., low to medium
	Share of HE graduates at industry moving to HEI/PSRE p.a. in %	n.a.
Vocational Training (Source: national statistics, assessments)	Income from vocational training for enterprises in HEIs	n.a., but rather high
	Number of vocational training participants in HEIs per 1,000 employees in HEIs	n.a., but rather high
Patent Applications at Science (Source: national statistics, assessments)	Patents Awarded to HEIs per 1,000 researchers (1998, natural sciences and engineering only)	~ 30
	Patents Awarded PSREs per 1,000 researchers (1998, natural sciences and engineering only)	~ 15
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs (1997)	2.3
	Royalties in % of total R&D expenditures at PSREs (1995)	0.15
Start-ups from Science (Source: AUTM, assessments)	Number of start-ups created via licenses from HEIs per 1,000 R&D personnel in HEIs (1997-1998)	> 3
	Number of R&D-oriented business start-ups at PSREs per 1,000 R&D personnel	n.a., but rather medium
Informal contacts and personal networks (Source: national statistics, assessments)	significance of informal contacts and personal networks between industry and HEIs	high
	significance of informal contacts and personal networks between industry and PSREs	heterogeneous, high at some institutions

* values above the EU average are indicated in **bold** letters

Sources: NSF (2000), OECD (2000), Abramson et al. (1997),

In summary, there is a high level of ISR in the USA, characterised by three main features. First, collaboration follows a networking infrastructure oriented approach that provides organisational and physical facilities for carrying out joint research and facilitates the flow of resources into opportunities that arise from turns and discontinuities across a less predictable horizon of innovation (Hane 1999). University-industry research centres and industry grants are perhaps the most typical outcome of this approach. Second, the top-level US research universities place increasing attention on the commercial relevance of their research, on spin-off commercialisation via patenting & licensing, and fostering the start-up of new enterprises. Market characteristics such as a well-developed venture capital market, a horizontal mobility oriented labour market, and an extensive supportive infrastructure for research commercialisation, supports these activities. Third, among the public science sector, research universities are the main actor in ISR, while PSREs show a less impressive record, although in recent years, many federal labs have extended their objectives towards technology transfer.

B.9.3 The Policy-related Framework Conditions for ISR in the USA

Cultural Attitudes: Co-operation between industry and science has a long tradition in the USA, and there was always a division of labour and a culture of co-operation between the two sectors. The federal government strongly stimulated ISR in order to utilise the whole intellectual potential of the USA for research in fields of public interest, such as weapons and space research (e.g. the Manhattan project in World War II), health research, and energy research. As early as the 1950s, there has been a high level of ISR as revealed by industry funding of R&D at universities. The tradition of research collaboration has been heavily pushed by national military research projects since World War II, along with the associated establishment of a large public research infrastructure, the strong increase in public funding for academic research, and a high portion of government financing in industry research in military related industrial sectors. Although military research has at times been a sensitive issue with universities, there is a common view that public science must contribute to industrial innovation and economic wealth. However, there is an ongoing discussion on the shape of this contribution, i.e. whether to put emphasis on commercialisation and co-operation in applied research and development, or whether to strengthen fundamental, non-oriented research and provide industry with new insights, rapid access to new technology paths, and well-trained highly qualified labour.

Legislation: During the 1970s, there was growing public concern regarding the international competitiveness of US industry. Amongst others, a lack of technology transfer from academic research to industrial application was identified. As a result, beginning in 1980, several laws came into force aimed towards promoting industry-science partnerships and fostering technology transfer and collaborative research. These laws aimed to establish an effective system of collaboration among public science and industry, which is viewed as a keystone for economic growth in US science and technology policy.

- The Patent and Trademark Laws Amendments Act of 1980 (Bayh-Dole Act) has permitted universities, small businesses, and non-profit organisations to hold exclusive patent rights to the results of research sponsored by the federal government. Based on this Act, IPR in HEIs belong to the institution. Inventors receive a certain share of incomes earned from IPR, differing from institution to institution. Furthermore, the Act has granted GGOs the authority to grant exclusive licenses to inventions that they patent, and to protect inventions from public dissemination under the Freedom of Information Act.
- The Economy Recovery Tax Act of 1980 has extended industrial R&D tax breaks to support research universities, with a break of 65 % of the amount eligible for the 25 % R&D tax credit. This legislation is regarded as having been a major stimulus for the growth in UIRCs through stimulating industry to invest in these centres.
- The Stevenson-Wydler Technology Innovation Act of 1980 and subsequent amendments, have been directed at engaging PSREs more extensively in technology transfer to industry as well as fostering co-operative research among PSREs and with HEIs and industry,

including the active dissemination of information about their activities and research. Under this Act, a Center for the Utilisation of Federal Technology (CUFT) was established at the NIST.

- The National Co-operative Research Act (NCRA) of 1984 has fostered the proliferation of industrial R&D consortia and research joint ventures (RCVs) by removing the threat of treble damages under US antitrust law. This is regarded as a major contribution to develop a co-operation culture in industrial R&D. The share of university partners in RCVs has increased since the introduction of NCRA. In 1993, NCRA was amended by the National Co-operative Research and Production Act (NCRPA).
- The Federal Technology Transfer Act of 1986 has enabled PSREs to step into Co-operative Research and Development Agreements (CRADAs) with other entities. Furthermore, the Act required that personnel evaluations of researchers PSREs have to include information about their technology transfer activities, and that PSREs have to pay inventors a minimum of 15 % of any royalties generated by the licensing of their inventions. The act also allows federal employees to participate in commercial development with private enterprises as long as there is no conflict of interest.
- The National Competitiveness Technology Transfer Act of 1989 further amended the Stevenson-Wydler Act to allow for the protection against disclosure of information, inventions, and innovations contained in CRADAs for a period of 5 years. It also established a technology transfer objective for the nuclear weapons laboratories.
- The Defense Authorization Act of 1992 required the Secretary of Defence to encourage technology transfer between DOD laboratories and other actors, including the private sector. This legislation created the Office of Technology Transition to monitor and encourage technology transfer from defence labs and the Federal Defense Laboratory Diversification Program, to encourage greater co-operation between DOD labs and private industry.
- Within the PSRE sector, researchers at GOGOs (government owned and government operated laboratories) are civil servants and thus, fall under the respective regulations. These regulations are sometimes viewed to have too little flexibility and burden interaction with industry through administrative requirements. For example, civil servants are not allowed to take up secondary work, and possibilities for leave of absence are complicated.

Several other regulations and policies encourage ISR in different ways:

- The liberal intellectual property regulation upholds the possibility of a patent for living organisms and stimulated research in agriculture and biotechnology. The permissive intellectual property system in microelectronics and biotechnology industries reduces the burden on young firms on litigation over innovations and stimulates start-ups.

- Furthermore, the US antitrust policy is said to have contributed to a high level of start-ups too, while at the same time, restriction research collaboration because antitrust considerations have been loosened.

Government procurement policy, above all in the military sector, aids new firms as contracts may be given to firms with only a short track record in serving the military so far.

Institutional Setting: In B.9.1, the main features of the different institutions in public science in the USA have been described. In general, the institutional setting in HEIs, despite the high diversity among the institutions, shows several common features which can be regarded as favourable for ISR. First, there is a high degree of organisational autonomy for each HEI, and every university is free to decide how to manage and organise interaction with industry. Many university administrations foster ISR by the way they treat appropriability of research results in joint projects, by the management of ISR related transaction costs, an ISR oriented human resource development, mobility schemes and regulations, and the provision of venture capital. Second, there is a long-standing tradition of university funding through outside funds on a competitive basis. The vast majority of academic research is sponsored directly via grants or contracts from federal agencies on a peer-review basis. Third, most assistant and full professors in HEIs are salaried for only nine months, the remaining time of the year they have to look for alternative sources of funding. In fields of research near to industry applications, there is a strong incentive to engage in consulting work for enterprises, which strengthens industry-science links.

Among research universities, since the 1980s, there has been a growing perception of using the commercial relevance of university research. Commercialisation activities have been stimulated by three factors (see Cohen et al. 1998): (1) a decline in federal funding per full-time academic researcher, which dropped by 9.4 % in real terms between 1979 and 1991; (2) the appearance of new science-based industries in biotechnology and microelectronics with a high commercialisation potential of new research findings; and (3) a change in the legal environment concerning intellectual property rights.

At PSREs, institutional settings seem to be less favourable for technology transfer due to some specific regulations and legal settings, such as the civil servant status of scientists, the restriction of disseminating information in fields of 'national security', and the provisions in the National Competitiveness Technology Transfer Act which requires enterprises carrying out CRADA-based joint research with PSREs to undertake further design, development and substantial manufacturing of products and processes embodying intellectual property, resulting from the CRADA in the USA. Furthermore, the CRADA negotiation process is sometimes bureaucratic and time consuming and might discourage enterprises from interaction with PSREs. A more flexible institutional form is the FFRDCs operated by universities, companies or non-profit organisations.

Promotion Programmes: There are a large number of public programmes designed to promote technology transfer and industry-science links through different measures, funded by both

federal and State sources. When summarising the diversity and variety of public promotion programmes in the field of ISR, the following basic types of ISR-related programmes may be distinguished (see also Coburn 1995):

- Research and technology development programmes: They provide technology specific support for R&D projects carried out by enterprises, partly in co-operation with public science institutions. Financial support is provided through grants. Such programmes are operated by federal authorities as well as by State and local authorities. For the federal programmes, the following should be mentioned:
- The Advanced Technology Program (ATP) is operated by NIST and attempts to bridge the gap between the research lab and the market place. ATP's early stage investment should accelerate the development of innovative technologies that promise significant commercial payoffs and widespread benefits for the nation. The ATP enters into partnership with companies of all sizes, universities and non-profits organisations, encouraging them to take on greater technical challenges with potentially large benefits that extend well beyond the innovators. For smaller, start-up firms, early support from the ATP can make the difference between success and failure. To date, more than half of the ATP awards have gone to SMEs or to joint ventures led by an SME. Large firms can work with the ATP, especially in joint ventures, to develop critical, high-risk technologies that would be difficult for any one company to justify because for example, the benefits spread across the industry as a whole. Out of more than 460 projects selected by the ATP since its inception, well over half of the projects include one or more universities as either subcontractors or joint-venture members. For many years, ATP focussed on specific programme areas (technologies) but in 1999, competition was up opened again to all fields of technology.
- The Manufacturing Extension Partnership (MEP) programme is operated by NIST and started in 1988. Its initial purpose was to foster technology transfer from NIST's research facilities and other federal laboratories. However, the programme quickly shifted to helping SMEs adopt less-advanced technologies, including training, management and networking. Under MEP, several Manufacturing Technology Centers (MTCs) have been established. They are locally oriented and provide, amongst others, services such as technology assessment, definition of technology changes needed at a SME, and support for implementing improvements. The majority of MTCs were funded by the Technology Reinvestment Project (TRP), which also provided grants to enterprises for technology deployment. TRP no longer exists. The MEP also operated the State Technology Extension Program (STEP) for those States without their own industrial extension programme, although today almost all States have their own programmes.
- The NSF Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programme stimulates technological innovation in the private sector, by strengthening the role of SMEs' concerns in meeting federal research and development needs, and increasing the commercial application of federally supported research results.

The primary objective of the SBIR/STTR programme is to increase the incentive and opportunity for SMEs to undertake cutting-edge, high risk, high quality scientific, engineering, or science/engineering education research that would have a high potential economic payoff if the research is successful. The STTR programme further expands the public-private partnership to include joint venture opportunities for SMEs and non-profit research institutions. NSF expects synergism in the proposed research. A team approach is required in which at least one research investigator is employed by the small business concern and at least one investigator is employed by the research institution. The proposed research for both SBIR and STTR must respond to the NSF programme interests.

- Technology development programmes are also operated by the DOD, such as the Manufacturing Science & Technology (MS&T) programme. It focuses on R&D in military applications and provides direct grants to all types of organisations. NASA operates an Aerospace Industry Technology Programme, and the EPA has an Environmental Technology Initiative. Other federal departments also run technology specific programmes some of them with significant volumes (E.g. Department of Transportation). Furthermore, most States offer their own technology extension programmes and other types of technology financing, including grants, low-cost loans, guarantees, and equity investment.
- Collaborative research infrastructure programmes are operated by the National Science Foundation (NSF) and provide support to universities for establishing research facilities for joint projects with industrial partners.
- The most prominent and significant programme is the Industry-University Co-operative Research Centers (IUCRCs) programme and related programmes. The programme started in 1973 and aimed towards facilitating industry access to university research results, engage industry in the definition of a research portfolio, and foster the use of a variety of technology transfer channels to the participating enterprises, including joint research, education, technology licensing and start-ups. The programme was a major stimulus to the rapid growth of UIRC's during the 1980s. An evaluation of the output of NSF-sponsored UIRC's in 1989-90 showed that they had a major impact on mobility (master and PhD students finding permanent employment with a participating enterprise) and contributed significantly to the patent activities of HEIs (20 % of all patents granted to HEIs in 1990).
- NSF Science and Technology Centers (STCs) programme supports innovation in the integrative conduct of research, education and knowledge transfer. Science and Technology Centers build intellectual and physical infrastructure within and between disciplines, weaving together knowledge creation, knowledge integration, and knowledge transfer. STCs conduct world-class research through partnerships with academic institutions, national laboratories, industrial organisations, and/or other public/private entities. Thus, new knowledge created is meaningfully linked to society. STCs enable

and foster excellent education, integrate research and education, and create bonds between learning and inquiry so that discovery and creativity support the learning process more fully.

- Other NSF programmes aiming towards establishing a collaborative infrastructure include the Engineering Research Centers (1985), Supercomputer Centers (1986, ended), the State-Industry-University Co-operative Research Centers (1990), and the Materials Research Science and Engineering Centers (1993 ended).
- Federal sponsorship for R&D in a specific field is often allocated through Research Consortia (or Government-Industry Consortia). They involve universities (or UICRs) with multiple corporate sponsors and federal government funding agencies. Well-known examples are the Biotechnology Process Engineering Center Consortium at MIT or the Computer Aided Design/Computer Aided Manufacturing Consortium at UCB. Some States also sponsor this type of long-term oriented research collaboration.
- Technical Assistance Programmes (TAPs) are designed to serve SMEs within a defined region by providing them with technical advice and problem-solving capabilities related to manufacturing issues. TAPs may either have a permanent staff or serve a broker function by putting SMEs in contact with experts. Most TAPs are associated with universities and are financed by the States. Similar activities concern the university-affiliated small business development centres in community colleges established by the US Small Business Association. The various technical and management centres established via the MEP programme also follow similar goals. However, all of these programmes rarely have strong alliances with teaching and fundamental research at universities and require heavy subsidies. Moreover, States provide equipment and facility access programmes in order to ease the accessibility of expensive and sophisticated research equipment and facilities, and associated staff expertise, to enterprises.

Another major mechanism regarding how the federal government indirectly fosters ISR, is the direct financing of R&D activities both at enterprises and public science institutions in certain fields of research and technology through Federal R&D obligations. In 1999, the US Federal Government spent a total of 73.3 billion US\$ on R&D. From this amount, 43 % went to industrial firms, another 2 % to industry administered FFRDCs, 19 % to HEIs, 5 % to university administered FFRDCs, and 6 % to non-profit organisations. The majority of this money was provided for research in defence-related areas (weapons, aerospace, new materials, electric equipment, and instruments) and for health research (biotechnology etc.). By providing such large R&D funds, the federal government supports a strong R&D base in certain fields of research and technology, both in industry and science, creating a precondition for strong ISR.

Table B.9.9: Selected Federal Promotion Programmes in the Field of ISR in the USA

<i>Name of Programme (responsible)</i>	<i>Public Funding (million)</i>	<i>Starting year</i>	<i>Main Approach</i>	<i>Type(s) of ISR Mainly Addressed</i>
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<i>authorities)</i>	<i>US\$)</i>			
ATP (NIST)	~ 100	1990	direct grants for R&D projects, special emphasis on joint projects involving industry and science, SME focus	research collaboration
MEP (NIST)	~ 90	1988	consulting for SMEs for technology upgrading, including training, management, networking; establishment of technology centres	technology transfer, training
SBIR/STTR (NSF)	n.a.	1990s	support for building research teams between SMEs and universities	personnel mobility, collaborative research
IUCRCs, STCs, and other Centres (NSF)	n.a.	1973	start-up financing for establishing research facilities for joint projects with industrial partners	collaborative research
GOALI (NSF)	n.a.	1998	support for faculty visits to industry, industry visits to university, support for collaborative research, post-doctoral student support for working at industry	personnel mobility, training & education, collaborative research
PFI (NSF)	6	2000	setting-up networks of enterprises, universities, and public authorities to stimulate innovation and the transformation of knowledge	networking
CRCD (NSF)	n.a.	1991	curricula development in emerging technology areas	training & education

Source: literature review, webpages of NSIT and NSF

Intermediary Structures: There are a large number of publicly supported intermediaries in the field of ISR including:

- Technology Transfer Offices (TTOs): In 2000, almost every research university had such an office. There was a significant increase in TTOs during the 1990s. Today, the major task of TTOs is to facilitate the diffusion of new technology invented at a HEI by providing technical and managerial support for patenting inventions, and by purchasing inventions, or licensing IPRs, to industry. This includes, amongst others, carrying out the search for inventions, encouraging faculty members to disclose their inventions, filing patents, negotiating royalty agreements, and monitoring those agreements. Furthermore, many TTOs are also engaged in administering industry-sponsored research and facilitating start-ups. TTOs differ largely in size and expertise. Some are rather small (2 to 4 professionals) and focus on certain fields of technology, while at some large research universities, TTOs have a staff of 20 and more. At most HEIs, the costs for running a TTO clearly exceeds the license revenues (see Nelson 2001, Siegel et al. 1999, Carlsson and Fridh 2000).
- Incubators and research parks: In 1997, there were more than 100 technology business incubators operating in the USA, about half of which were affiliated to research universities. In the middle of the 1990s, there were about 140 university-related research parks (sometime called science parks) in the USA, housing about 5,000 companies.
- Offices of Research and Technology Applications (ORTAs) at each federal laboratory: PSREs are required by the Stevenson-Wydler Technology Innovation Act of 1980 to establish an ORTA. These offices receive a set-aside equal to 0.5 % of each laboratory's

budget to fund technology transfer activities. Within the DOD labs, there is a central Office of Technology Transition.

- Manufacturing Technology Centres (MTCs) and other types of consulting oriented technology centres: There are more than 400 MTCs operating under the MEP programme and providing support to SMEs in technology development and adoption. Technology consulting centres were established by the States of local authorities throughout the USA, many of them are linked to universities and colleges.
- There are several on-line databases on government sponsored research projects, brought together on the Gov.Research_Center website (www.grc.ntis.gov), and maintained by the National Technical Information Service. It provides direct access to eight different databases, including the Federal Research in Progress (FEDRIP) which offers access to current government-sponsored research projects in the fields of the physical sciences, engineering, life sciences, and more.
- Despite these public initiatives in the field of intermediaries, there is a much higher number of private enterprises offering services related to ISR:
 - Technology brokers assist in marketing technologies developed by others and charge success fees to their clients. There are some larger brokers on the market such as RCT, BTG USA, or CTI.
 - Technology transfer consultants help enterprises, universities or federal labs to license their technologies and start-up new enterprises by offering training, management and technology consulting services. They are paid on an hourly basis. The American Consultants' League has over 40,000 members.
 - Law firms offer legal expertise in technology transfer related areas such as licensing agreements, research contracts, patenting etc.
 - Technology transfer conference organisers facilitate introductions between suppliers and buyers of technology, and help to initiate the process of technology transfer.
 - Private technology business incubators offer infrastructure and consulting to start-ups. There are about 500 such incubators outside the public sphere.
 - Technical and professional associations conduct activities designed to stimulate co-operative research in their respective business or technology field.
 - Venture capital firms are widespread in the USA and offer equity investment for technology start-ups and growing young firms. At the end of the 1990s, there were about 1,000 venture capital funds in the USA.

In summary, policy-related framework conditions for ISR in the USA provide a favourable environment. Strengthening ISR has been at the centre of US science and technology policy

for many decades, and since the late 1970s, special emphasis was laid on improving the legal and institutional setting, financing, and infrastructure for interaction between enterprises, universities and federal laboratories. Several laws have significantly improved the framework conditions for ISR. A large number of public promotion programmes provide financing for R&D and technology development, many which focus strongly on research collaboration and direct technology transfer from science, including training, consulting and personnel mobility. The large numbers of intermediaries contribute to a reduction in information asymmetries and transaction costs, although the efficiency of the extensive and costly supply of publicly financed services, is under discussion in the USA.

B.9.4 ISR in the USA: A Summary Assessment by Type of Interaction

Research collaboration between industry and science is highly common, and a number of top-level research universities receive major proportions of their R&D budgets from industry. Two types of research collaboration dominate. Firstly, joint R&D within long-term oriented infrastructures such as university-industry research centres, and secondly, research grants to universities, often associated with priority access of the donor to research results. Short-term oriented contract research is less significant. A considerable amount of technology transfer takes place via consulting and technical assistance by faculty members. Many co-operative research projects receive financial support through public promotion programmes and do not involve direct financial contribution by industry to university. As a consequence, the industry's share of total R&D financing at US research universities is relatively low compared to other countries. At PSREs, industry is not involved in direct R&D funding, although there is a significant amount of co-operation and technology transfer. At most federal labs, the CRADAs scheme is applied which does not involve direct financial contribution by enterprises.

Personnel mobility between research universities and industry is high in the USA and reflects some general features of the US labour market and career system. Mobility is supported by few regulatory impediments (researchers at universities are not civil servants, and employment contracts are negotiated individually) and comparably little salary differences between university and industry researchers. Furthermore, NSF programmes such as GOALI give financial support for researcher mobility. In PSREs, i.e. federal laboratories, the situation is different due to the civil servant status of the scientists working there. Mobility is reported to be lower at this type of institution.

Training and education: At US research universities, the combination of education and research has been carried much further than elsewhere. HEIs are heavily engaged in vocational training and further professional education. There is a close interaction between industry and science in graduate education, including lectures by firm employees, placements at enterprises, and joint supervision of master and PhD thesis. Many large enterprises offer fellowships to students and graduates, including an option to employ the student/graduate after completing their study. Furthermore, many enterprises finance professorships at

universities. On a local level, industry representatives contribute to curricular planning and decisions on strategic orientation of higher education programmes at universities and colleges.

IPR in science: Both in HEIs and PSREs, IPR belongs to the institution. Inventors receive a certain share of licensing incomes, and the regulation differs between each institution. The level of patent application is the highest among public science institutions in the world, partially due to the strong orientation of US academic research on fields of technology where patenting is highly common (life sciences, engineering, chemistry). Changes in IP regulation (Bayh-Dole Act of 1980) have strongly contributed to the increase in patent activities. In HEIs today, a significant amount of money is earned from royalties (2.3 % of total R&D budget) while PSREs' licensing income is still low. Commercialisation of research results via patenting and licensing is very common at US research universities, and almost every university operates a technology transfer or technology liaison offices responsible for IPR organisation and commercialisation.

The number of start-ups from universities is reported to be high in the USA, although no reliable and complete data is available. Start-ups are supported through infrastructure (incubators) and consulting programmes at the level of individual institutions. Many start-ups rely on licensing university technologies. Many universities provide venture capital to start-ups and operate separate venture capital firms. At PSREs, start-up activities seem to be less pronounced.

Networking between industry and science: Personal contacts and informal networks between industry and science are regarded as the keystone for successful technology transfers, both by industry and university representatives. There are a number of mechanisms to establish and maintain such contacts, ranging from institutional approaches (industry liaison programmes, and technology conferences) to individual approaches (e.g. technology consulting by faculty members).

Involvement of SMEs in ISR: There are several federal and State programmes supporting SMEs in the field of R&D, technology adoption, and innovation. Many programmes include training, management and networking elements. The States offer technology assistant programmes and technology consulting networks, many of which are affiliated with universities or involve university researchers. Nevertheless, the vast majority of SMEs in the USA - as in most other countries - are not involved in ISR.

Science-based industries: ISR in the USA are driven strongly by the rapid development of science-based industries. The USA is the world's leading market in biotechnology, computers, and software. The rapid growth of these industries, and their reliance upon new scientific knowledge, has significantly increased the demand for ISR. At the same time, the universities' opportunities to commercialise new knowledge in the fields mentioned have largely increased with the strong market growth.

B.9.5 Good Practice in Framework Conditions for ISR in the USA

Within the scope and resources of this benchmarking exercise, no analysis of good practice in policy-related framework conditions for ISR in the USA has been carried out. Therefore, a characterisation of good practice examples is not provided. Nevertheless, such examples do exist. According to literature (see Abramson et al. 1997), the following may be mentioned:

- University-Industry Research Centres (UIRC), including those established through the support of the Industry-University Co-operative Research Centers (IUCRC) Programme, providing a flexible infrastructure for joint R&D with industry.
- The management of technology transfer at large research universities, including specialised Technology Transfer Offices or Industry Liaison Offices that take over the professional management of spin-off commercialisation through patenting and licensing.
- In PSREs, the Co-operative Research and Development Agreements (CRADAs) may be regarded as providing an efficient way of organising joint R&D activities with industry, given the special situation at government-owned and government-operated laboratories.
- The Federally Funded Research and Development Centres (FFRDCs) represent a certain type of long-term public funding of thematically oriented research, both in HEIs and at companies, most often following a specific public objective in technology development, including military research.
- There is a large 'fourth-sector' within the US R&D system, i.e. private, non-academic R&D organisations. Some of them are highly significant both in size and in research output. They demonstrate ways on how to organise high-level basic research and efficient technology transfer outside public institutions.

B.10 Japan³⁴

B.10.1 Knowledge Production Structures in Japan

Japan has one of the highest R&D expenditure compared to GDP, in the world, its ratio of 2.91 % excelled only in Sweden. The business enterprise sector accounts for 72 % of the total R&D expenditure. The relation of BERD to GDP is 2.1 %, i.e. significantly above EU and OECD averages. In public science, the national and private universities, summarised as the higher education institutions (HEIs), have a share of total GERD of 14 %, while the government laboratories' (PSREs) share, is 9 %. R&D investment in HEIs is above the EU and OECD average, although there is some argument that these figures may be overestimated (see Ohtawa 1999). Compared to most other countries, Japan also shows a significant R&D performance in the private non-profit sector (Table B.10.1).

Table B.10.1: R&D Expenditures in Japan 1997 by Financing and Performing Sectors (in million €)*

<i>Performing Sector</i>	<i>Financed by</i>			<i>million €</i>	<i>Total %</i>	<i>% of GDP</i>
	<i>Enterprises</i>	<i>State</i>	<i>private non-profit*, abroad</i>			
Enterprise Sector	96,247	1,279	509	98,035	72	2.10
PSREs	113	11,902	6	12,022	9	0.26
HEIs	472	9,593	9,358	19,423	14	0.42
Private non-profit	3,841	1,963	791	6,595	5	0.14
Total (million €)	100,673	24,738	10,664	136,075		
Total (%)	74	18	8		100	2.91

* including own R&D funding by HEIs

Source: OECD (2000), calculations by the authors

R&D at enterprises is almost entirely financed by internal sources within the enterprise sector. Public funding of industry R&D is negligible and represents only 1.3 % of total BERD. R&D at PSREs is based on government financing, and external sources represent less than 1 % of total R&D funds. Research at universities is financed in equal parts by both the government (mainly via the Monbusho, i.e. the Ministry of Education, Science, Sports, and Culture) and internal university funds, mainly sponsored by study fees and donations. The private non-profit sector receives the bulk of R&D funds from the enterprise sector. This sector profits highly from an increasing trend among corporations to outsource parts of their R&D activities, and private R&D organisations are the main outsourcing partner (see Niwa 1999).

About 42 % of the research budget of HEIs is provided from the Monbusho's general university fund (i.e. standard research allowance, plus labour costs for university researchers),

34 This chapter is a literature-based summary on ISR in Japan, drawing mainly on the following sources: Hane (1999), Niwa (1999), Ohtawa (1999), Pechter and Kakinuma (1999), Negishi and San (1999), Hashimoto (1999), Odagiri (1999), Kneller (1999a,b), Yoshihara and Tamai (1999), Chien (1999), Ogura and Kotake (1999), Smith (1999), Yamamoto (1999), Zucker and Darby (2001), Odagiri and Goto (1993).

and about 48 %, by internal funding which is allocated to HEIs' researchers via both institutional and project based funding. About 10 % of HEIs' research expenditures are financed by other sources such as other public authorities, enterprises, and private non-profit organisations. Financing from abroad is negligible (see Table B.10.2). At PSREs, the vast majority of R&D is financed through general purpose grants by the public authorities responsible for the various national and public research institutions. While HEIs concentrate their research activities on basic and applied research, the PSREs focus on experimental development.

Table B.10.2: Financing Structure of R&D in HEIs and PSREs in Japan 1997 (in %, estimates)

<i>Public Financing Source</i>	<i>HEIs</i>	<i>PSREs</i>
Basic Financing (general purpose grants)	42	~ 95
Own university funds	48	0
Project Financing	10	~ 5
Basic Research	55	21
Applied Research	36	32
Experimental Development	9	47

Source: OECD (2000), calculations by the authors

Within the enterprise sector, R&D expenditure is highly concentrated in technology sectors outside of the high-tech sector (pharmaceuticals, microelectronics and computers, telecommunication equipment, aircraft and missiles, and instruments). About 45 % of all business R&D activity takes place in sectors where cumulative technological change prevails and science-links are a less important competitive factor than in the high-tech sector (e.g. machinery, electrical machinery, vehicles, and basic chemicals, see Table B.10.3)³⁵. The share of high-tech sectors in total BERD is 32 %. Nevertheless, its R&D activity is still highly significant, as the sector specific BERD to total GDP ratio indicates (0.73 %, which is clearly above the OECD average and not far below the respective US figure). Only a small R&D expenditure is reported from the information and communication service sector, but there appears to be a lack of data recording.

Table B.10.3: R&D Expenditures in the Japanese Enterprise Sector by Sectors 1997

<i>Sector</i>	<i>Share in total BERD (in %)</i>	<i>R&D Expen- ditures in % of GDP</i>
High-Tech Sectors (NACE 24.4, 30, 32.1, 32.2, 33, 35.3)	34	0.73
Other Technology Sectors (NACE 23, 24, 29 to 35 excl. high-tech sectors)	43	0.95
Other Manufacturing (NACE 01 to 45, excl. technology/high-tech sectors)	18	0.39
IC-Services (NACE 64, 72, 73)*	4	0.08
Other Services (NACE 50 to 99, excl. IT-Services)*	1	0.01

* to low values due to lack in data recording

Source: OECD (2000), estimations and calculations by the authors

35 High-tech sectors are (NACE-codes in parentheses): pharmaceuticals (24.4), office and computer machinery (30), electronic components (32.1), telecommunication equipment (32.2), instruments (33) and aerospace (35.3). Other technology sectors are refined petroleum products (23), chemicals (24) excl. pharmaceuticals, machinery (29), electrical machinery (31), radio and television equipment (32.3), motor vehicles (34) and other transport equipment (35) excl. aerospace.

Two major features of the Japanese R&D system, which clearly distinguish it from other countries, concern the absence of R&D performing foreign firms and the high share of very large enterprises in total BERD. The share of business R&D performed in affiliates of foreign-owned enterprises is about 1.5 % and corresponds to the generally low presence of foreign firms in Japan until the end of the 1990s. R&D in the enterprise sector and thus, the Japanese innovation system as a whole, is primarily performed by very large corporations. Their share of total BERD is at least 70 %, and of total GERD, is more than 50 %. Among the top performing corporations are NTT, Hitachi, NEC, Toshiba, Fujitsu, Mitsubishi Electric, Sony, and Toyota. The SME sector contributes to total BERD by only 6 % (SMEs up to 299 employees), and 16 % (SMEs up to 999 employees), respectively (Table B.10.4).

Table B.10.4: R&D Expenditures in the Japanese Enterprise Sector by Size Classes of Enterprises 1997

<i>Sector</i>	<i>Share in %</i>
Small Enterprises (< 300 employees)	6
Medium-sized Enterprises (300 to 999 employees)	10
Large Enterprises (1,000 to 9,999 employees)	~ 14
Very Large Enterprises (10,000 employees and more)	~ 70

Source: OECD (2000), calculations by the authors

R&D at large industrial corporations is mainly carried out at central laboratories and in development units at production sites. From their beginning, the central laboratories had strong linkages to production and marketing departments, strengthened by internal mobility (job rotation). Their major purpose was to support the rapid introduction of new technologies into production. Consequently, these central laboratories were strongly development oriented. Since the middle of the 1960s, more than 100 such labs have been established. In the 1980s, the central R&D laboratories of enterprises shifted their R&D efforts increasingly towards more fundamental research. As a result, nearly 40 % of all basic research in Japan is carried out at enterprises today, which is a much higher share than in any other OECD country. The expansion required the recruitment of many university researchers and tightened the personal linkages to HEIs. As a result, Japanese enterprises today, contribute significantly to new scientific knowledge in some fields of science such as engineering. In electrical engineering for example, in 1995, about 45 % of all articles in Japanese scientific journals were written, at least partially, by industry authors. In the mechanical engineering field, this share was 40 %. Most of these publications are written jointly by industry and public science researchers (see Pechter and Kakinuma 1999).

Research in science in Japan has a high share (with respect to OECD standards) in social sciences and humanities, which account for about a third of total research expenditure. The share of natural sciences is rather low, while about a quarter of all financial research resources are devoted to the engineering field (Table B.10.5). PSREs concentrate their research almost exclusively, on research in natural sciences, engineering medical sciences and agricultural sciences.

Table B.10.5: R&D Expenditures in the Japanese Public Science Sector (HEIs & PSREs) by Fields of Science 1997 (in %)

<i>Sector</i>	<i>HEIs</i>	<i>PSREs*</i>	<i>Total</i>
Natural Sciences	13		
Engineering	24	98	78
Medical Sciences	25		
Agricultural Sciences	4		
Social Sciences and Humanities	34	2	22

Source: OCED (2000), calculations by the authors

The Japanese public science sector consists of two main sectors, the universities, and the national and public research organisations. Within the university sector, three types of institutions should be distinguished. Table B.10.6 summarises some general features of the various institutions, mentioned below:

- The 99 National Universities are the main R&D performers in public science in Japan. Their employees are civil servants of the central government, and the Monbusho (Ministry of Education) provides basic financing for research through Standard Research Allowances. Until 1995, several restrictions on professors for carrying out consulting and joint R&D with industry existed, but they have been eased with the new Basic Law for Science and Technology. This law also authorised Ministries other than Monbusho to fund research at universities and eased industry funding. As a result, the number of joint projects, the income from industry, and the share of research funding via commissioned research have increased. Some large national universities run separate research laboratories as thematically focussed research institutes in areas near to industrial R&D.
- Some larger universities operate separate research institutes that are specialised on themes relevant to industrial innovation and maintain close ties to industry. A new development in the 1990s within the government-owned HEI sector, was the establishment of new national graduate schools. Their objective is to pursue interdisciplinary, advanced research and contribute to economic development. In 1990, the Japan Advanced Institute of Science and Technology was established, followed in 1991, by the Nara Institute of Advanced Science and Technology. They face a more flexible institutional research environment than national universities, and research is more strongly based on grants and endowments by industry.
- The Private Universities perform about one third of the total academic R&D. Private universities are not constrained however, by many of the regulations that guide national universities, e.g. their researchers are not civil servants. Thus, they are free to engage in creative partnerships with industry and test new forms of collaboration, including liaison offices and regional research networks. ISR at this type of institution often take place on a local basis, although the intensity of ISR concerning financial flows from industry is at the same (low) level as at national universities. ISR are highly concentrated on medicine and dentistry, and R&D projects with industry are often very small (1996: 12,500 US\$ per project).
- Local Public Universities and National Technical Colleges represent a very small segment of the R&D potential in public science in Japan, although they do represent the majority

amongst the c. 600 HEIs in Japan. Their major objective is to provide a higher education infrastructure for regional economies. They carry out some applied research and development but on a rather low level compared to the other two types of HEIs.

- The Japanese PSRE sector consists of several hundred national and public research institutions, and government affiliated agencies and R&D institutions. They have a long history which dates back to the end of the 19th century. Most are thematically focussed, and their initial task (until World War II) was to support industry in its effort to adopt new technologies and develop them further, and they played a major role in the innovation system. During World War II, much emphasis was laid on military-related research. In the post war period, the relevance of PSREs for industrial innovation gradually declined with the increase of in-house R&D capacity at enterprises. Today, they comprise a heterogeneous group of research institutes, carrying out all types of research. Their main objective is to foster technology development and diffusion in the sectors they are thematically specialised in, and to provide public services in the field of R&D, such as testing and standardisation. Concerning regulations on ISR, they face higher hurdles than HEIs, depending on the policies of the particular Ministry or agency they are affiliated to. Amongst the most important national research institutions are:
 - the Electric Research Institution,
 - the Industrial Research Institution (research on chemistry, engineering, ceramics),
 - the Institute of Physical and Chemical Research (Riken),
 - the research institutes of the Agency of Industry, Science and Technology, such as the National Research Institute for Metals

Table B.10.6: Main Characteristics of Major Institutions in the Japanese Public Science Sector (HEIs & PSREs)

<i>Institution</i>	<i>Share in Total Public R&D*</i>	<i>Main mission</i>	<i>Research Orientation</i>	<i>Level of Firm Interaction</i>
National Universities	~ 38	research and education	basic and applied research	low to medium but increasing, strongly based on informal contacts
Private Universities	~ 20	research and education	basic and applied research	low to medium, some interesting initiatives
Local Public Universities, National Technical Colleges	~ 3	education	applied research, but on a low level	low
National and Public Research Institutions	~ 39	R&D in fields of national interest, public R&D services	applied research, development	divergent, strong ties in some sectors

Source: Hane (1999), Ohtawa (1999), Niwa (1999), own survey and calculations by the authors

- The thematic orientation of the PSREs in Japan is characterised in Table B.10.7. Research is focussed on fields with a specific public interest such as energy (23 %), agriculture, food and fishing (18 %), and defence (14 %). There is also a significant fraction of the total R&D budget allocated to industrial development (engineering etc.) and aviation research with civil applications.

Table B.10.7: Socio-economic Objectives of R&D at Japanese PSREs in 1997

<i>Institution</i>	<i>Volume of R&D expenditures in bio. Yen</i>	<i>Share in total volume of R&D expenditures at PSREs</i>
Agriculture, forestry and fishing	229.7	18
Industrial development	195.2	15
Energy	296.1	23
Transport and telecommunications	42.7	3
Urban and rural planning	38.2	3
Prevention of pollution	26.2	2
Health	58.2	5
Social development and services	23.2	2
Advancement of knowledge	41.7	3
Civil space	156.6	12
Defence	175.4	14

Source: OECD (2000), calculations by the authors

Finally, some general features of the Japanese system of innovation should be stressed that are only partially reflected in the quantitative indicators on knowledge production structures:

- Industrial innovation in Japan was characterised for a long time by rapid technology diffusion based on purchasing technology developed in other countries, reverse engineering, copying and developing technologies further along a given trajectory. A major pre-condition for this technology strategy was a large number of well-trained engineers ready to learn and to adopt novelties. Universities met this demand at enterprises by orienting education strongly towards engineering fields, laying special emphasis on rather short-term and practical education. As highly qualified labour became an increasingly scarce resource, enterprises established close ties to university professors in order to gain access to new graduates.
- The readiness for rapid technology adoption became a general feature of Japanese society and served as a stimulating factor for technology development at enterprises
- In order to further develop technologies, Japanese enterprises have built up large in-house R&D capacities and expanded their R&D expenditures to the high volume it is today. From the beginning, R&D was closely connected with production, including in-house mobility of engineers between R&D and production. Thus, science links of enterprises' R&D departments and laboratories were rather loose and have focussed on personal contact by enterprise researchers with their former professors who served as technology consultants, often as an informal contact.

- Since the 1970s and 1980s, Japanese enterprises gradually changed their innovation strategies towards technology leadership in new technologies such as microelectronics, receiving support from the government's S&T policy. As basic research became more important, central R&D departments at enterprises shifted their research efforts towards more fundamental research and further developed their in-house research capacity. As a result, nearly 40 % of all basic research in Japan is carried out at enterprises today. Thus, enterprises' demand for scientific knowledge from public science is much lower, but demand for well-trained scientists is much higher.

B.10.2 The Level of ISR in Japan

Contract and collaborative research: Direct research funding by industry in HEIs is of little significance in Japan. According to official OECD figures, in 1997, only 2.4 % of the total research budget at universities came from the private enterprise sector through commissioned research, joint research and endowments. This figure may underestimate the real significance of industry funding for university research however, for two reasons. First, national data compiled by MITI and the University-Industry Council suggests that there has been a remarkable increase in commissioned research by industry since 1995, following a change in legislation with respect to consulting activities by university professors, and increasing efforts by the government to set up formal partnerships between industry and science (see B.10.3). Based on this national data, industry funding would amount to 4.7 %. While for a long time, industry support to university research was restricted to general endowments (donations) for research facilities, the share of directly commissioned research increased considerably in the second half of the 1990s and may now exceed 50 % of total industry funding to HEIs. Commissioned research is carried out under Joint Research Agreements and faces several restrictions (see B.10.3). This increase in industry funding corresponds however, with a general increase in R&D outsourcing by Japanese enterprises in the second half of the 1990s. Within this process, HEIs and PSREs play only a minor role, while the vast majority of external R&D funding by Japanese enterprises goes to private R&D institutions (49 %), other enterprises (27 %) and overseas (12 %) (see Niwa 1999).

Second, a large fraction of direct R&D collaboration between industry and science takes place outside formal contracts and agreements, but is based on personal networks and individual consulting by professors. Anecdotal evidence suggests that informal technology transfer is a widespread practice in ISR in Japan. This type of interaction typically does not include direct financial transfers from industry to HEIs. However, new research findings are often transferred to industrial partners (e.g. via patents or simply by forwarding research papers or inventions) in return for general laboratory support such as research equipment, materials, or visiting researchers from the enterprise (Hane 1999). Expert assessments suggest that the system of informal transfer works well and leads to appropriate interchanges between the two sectors. However, no quantifiable data on the actual significance is available.

A large fraction of the increase in industrial financial support for research in HEIs is allocated through university-industry centres. These centres have been established under the

government's Co-operative Research Centres Programme, started in 1987. This programme was strongly oriented to the NSF programme Industry-University Co-operative Research Centres. Since 1997, 49 such centres have been established at national universities. Private universities also made an effort to implement such a type of research facilities. In 1997, 22 university-industry research centres operated at private universities.

At private universities, R&D projects funded by industry are very common, although on a very small scale. In 1996, private universities reported about 15,000 such projects but the R&D income from these projects amounted to only 190 million US\$, i.e. 12,500 US\$ per project.

At PSREs, the industry financing share is even smaller than in HEIs and amounted only about 1 % in 1997. Nevertheless, for those PSREs with a thematic focus, industrial development and sector-specific R&D, ties to industry are strong, but are not reflected in financial flows. Instead, PSREs carry out joint R&D activities with industry whereby each partner finances its contribution from its own funds. Furthermore, some thematically oriented national laboratories have a clear objective to contribute to technology development and diffusion within the Japanese economy and actively provide their R&D findings to the enterprises in the respective sector. The national test and research institutes provide public R&D services such as testing and measuring to enterprises. There is however, no data available on the extent to which the PSRE sector interacts with industry or on the share of technology transfer activities at PSREs which form part of their total R&D activity.

Personnel Mobility: The Japanese labour market is characterised by a low level of horizontal mobility between sectors but a high level of vertical mobility within organisations. For many decades, highly qualified personnel were a scarce resource in Japan, and enterprises attempted to attract graduates by offering lifetime employment and favourable career options. Changing to a different company was frowned upon and most major companies had policies that discourage job-hopping, e.g. through recruiting new employees only on one day of the year, preventing the need to bid for recruits.

There is no data on the mobility of researchers between industry and science in Japan. The general data on mobility among high-qualified people suggests that the level of ISR-related mobility is very low. A survey in 1996 by the STA, showed that only 32 % of elderly scientists and engineers changed jobs at least once during their life, and this single mobility occurring later in life rather than early in their careers. Among those working at universities, 45 % had changed their employees, whilst among national laboratory researchers, this ratio was 38 %, and among industry employees, it was 25 %. When taking this into account, mobility by scientists and engineers primarily takes place either within the public science sector or industry, inter-sectoral mobility.

In contrast to most other countries, there seems to be a significant amount of temporary mobility from industry to public science based on visits of industry researchers to universities in order to participate in research projects. Anecdotal evidence suggests that this is a common

way to indirectly compensate university professors for informal technology transfer activity. Visiting industry researchers remain employed at their enterprise, and the enterprise typically provides additional funding. From the professors' point of view, they represent additional research capacities, while the enterprise profits from learning and access to new knowledge.

Training and Education: Since the 19th century, universities see their major contribution to national technology development as providing industry with a sufficient number of well-trained people. Universities oriented their teaching programmes strongly towards industry demand. As a result, engineering studies have a much higher weight in total university education than in most other countries, and the ratio of engineering to natural sciences students is about 5 to 1. Within engineering studies, less emphasis is laid on pure scientific education, reflected in a very low share of graduates continuing with a PhD study.

Co-operation in education mainly takes place through informal channels, i.e. personal contacts between professors and enterprises. As demand for graduates in engineering, and other fields of science highly relevant to industry research, tended to be higher than supply for a long time, enterprises attempted to establish close links with professors in order to achieve priority access to new graduates, and at the same time, to forward information on future qualification demand to the professors.

In the field of vocational training, there is evidence that HEIs are involved in such type of knowledge transfer. In exchange for technology advice, information on new findings, and even forwarding new inventions, enterprises provide university professors with additional resources, including temporary visits of industry research staff to the university to participate in research projects. As a result, new technological and methodical knowledge is forwarded to the industry researcher, which may be viewed as a type of vocational training. Furthermore, HEIs are involved in supervising technicians and researchers employed in companies carrying out graduate or post-graduate research, including writing a thesis. These 'students' remain employed at their enterprise, and the enterprise pays a research fee to the university. Another type of education-oriented interaction are the 'thesis doctorates' whereby enterprise researchers submit the results of research they have performed at their workplace for evaluation to a university, but they are not enrolled as PhD candidates. Generally, Japanese enterprises show a high willingness to invest into on-going qualification of their employees, mainly by employing internal measures of human capital development such as job rotation and internal training.

Patents and royalties: In 1996 (the latest year for which data is available), national universities had 448 inventions that were forwarded to Invention Review Committees. In relation to the number of researchers (full-time equivalent) in natural sciences, engineering and medical sciences, this is equal to 5 patent applications per 1,000 researchers. Private universities reported 124 patent applications in 1994, i.e. 3 per 1,000 researchers. Because procedures for applying for inventions to be patented are complicated at national universities (see B.10.3), many professors directly forward their inventions to companies they are in contact with. Patent applications are then made by the enterprise. The professor is mentioned as inventor in

the patent file, and they are typically compensated for their work by a donation or non-financial remuneration. It is estimated that the annual number of patent applications in Japan based on university invention may be 1,000, i.e. patent intensity would be 10 patent applications per 1,000 researchers. For PSREs, no data on patent activities is available.

Out of the total of 340,000 resident patent applications at the Japanese Patent Office, patent activity from public science institutions is negligible. This low level may be explained, firstly, by the above mentioned orientation of ISR towards informal channels and long-term oriented personal relations that shift the focus of commercialising new research findings towards rapid dissemination to companies in exchange for general grants and other (non-financial) types of research collaboration, while costs and the trouble of applying and administering patents are avoided. Secondly, there is an unfavourable legal setting and a lack of patent-related support in HEIs, producing little incentives to patent inventions (see B.10.3). Thirdly, as mentioned above, many university inventions are forwarded to companies without claiming IPRs by the university researcher. A study in the field of genetic engineering (Kellner 1999b) has shown that out of 874 patent applications that were filed annually (in average) at the Japanese Patent Office within the period 1987 to 1997, 40 % (i.e. 350) listed a Japanese university faculty member as an inventor. This suggests that the contribution of university research to patenting in Japan is highly significant, although unaccounted for in any normal statistic.

As a consequence of the patent regime, income from licensing patents is very low at Japanese HEIs. In 1994, it was estimated to have been less than 300.000 US\$ (Hane 1999), and there is no evidence that a huge increase has taken place since then. Compared to the total R&D budget, royalties are far below 0.01 % of total R&D expenditure.

Start-ups: No data is available on the number of technology-oriented start-ups by researchers from HEIs or PSREs, but various expert assessments suggest that this is a rarely used way of commercialising research results in Japan. A low level of science-based start-ups would coincide with a general underdeveloped entrepreneurial sector in Japan. There is only a small amount of venture capital available, and the JASDAQ (an over-the-counter market comparable to the New York NASDAQ) provides rather high entry barriers for young technology-based firms, as it demands a positive profit record from a firm, which is often difficult to achieve by enterprises in new fields of technology in their first years of operation. The traditional finance market (banks) is conservative and reluctant to invest in small high-risk projects. In HEIs and PSREs, there are no special promotion programmes for start-up activities. Furthermore, the civil servant status of researchers provides little incentives for engaging in a new venture compared to lifetime occupation in public science. Several universities operate, or are involved in, science and research parks that also provide incubator functions for start-ups, but they seems to have little effect upon start-up activities. In the field of biotechnology for example, until 1995, only one start-up from public science was observed.

Networking, informal contacts: Informal technology transfer based on personal contacts between university professors and researchers at enterprises (who are most often, their former

students) are reported to be the most important channel of interaction between industry and public science in Japan, although very difficult to quantify. Japanese professors are frequently collaborating with industry by giving advice in joint technology committees, at conferences and workshops, by allowing company researchers to work in their university laboratories, by mediating between companies, national laboratories and other organisations, or by diffusing information through former students (Odagiri 1999). Scientists who are well known or whose research is of interest to industry often talk to enterprises about their research, and corporate researchers working in university laboratories communicate research results back to their enterprise. Sometimes, informal methods of interaction go as far as forwarding inventions made by university professors (or his/her team) directly to enterprises instead of applying for a patent and negotiating a license. In such cases, remuneration is provided by the enterprise via endowments for laboratory instruments and materials or by offering additional research capacity through temporary visits by industry researchers.

Table B.10.8: Indicators and Assessments of ISR in Japan at the End of the 1990s

<i>Type of ISR</i>	<i>Indicator</i>	<i>Value*</i>
Contract and Collaborative Research (Source: OECD-BSTS)	R&D financing by industry for HEIs in % (1997)	2.4 - 4.7
	R&D financing by industry for PSREs in % (1997)	0.9
	R&D financing by industry for HEIs/PSREs in % of BERD (1997)	0.6
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI research.	high
	Significance of R&D consulting with firms by PSRE resear.	high
Mobility of Researchers (Source: national statistics, assessments)	Share of researchers in HEIs moving to industry p.a. in %	n.a., but low
	Share of researchers at PSREs moving to industry p.a. in %	n.a., but low
	Share of HE graduates at industry moving to HEI/PSRE p.a. in %	n.a., but rather high
Vocational Training (Source: national statistics, assessments)	Income from vocational training for enterprises in HEIs	n.a., but rather low
	Number of vocational training participants in HEIs per 1,000 employees in HEIs	n.a., but rather high
Patent Applications at Science (Source: national statistics, assessments)	Patents Awarded to HEIs per 1,000 researchers (1996, natural sciences and engineering only)	~ 5
	Patents Awarded PSREs per 1,000 researchers	n.a., but rather low
Royalty Income by Science (Source: national statistics, assessments)	Royalties in % of total R&D expenditures in HEIs (1994)	< 0.01
	Royalties in % of total R&D expenditures at PSREs (1995)	n.a., but low
Start-ups from Science (Source: assessments)	Number of start-ups created via licenses from HEIs per 1,000 R&D personnel in HEIs (1997-1998)	n.a., but low
	Number of R&D-oriented business start-ups at PSREs per 1,000 R&D personnel (1999)	n.a., but low
Informal contacts and personal networks (Source: national statistics, assessments)	significance of informal contacts and personal networks between industry and HEIs	high
	significance of informal contacts and personal networks between industry and PSREs	medium

* values above the EU average are indicated in **bold** letters

Sources: OECD, Hane (1999), Hashimoto (1999), Odagiri (1999), Kneller (1999a), Yoshihara and Tamai (1999), Niwa (1999)

The significance of informal networks as a means of knowledge and technology transfer, is regarded as a strength of the Japanese ISR-system. Such networks, nested in well-defined channels of resource flows, support a rapid vertical movement of a technology to the market, with public science contributing by offering technology advice along defined technology trajectories to speed up development. Moreover, such networks meet industry needs in short-term oriented co-operation, producing innovations on the time horizons.

Informal networking and interaction between industry and science in Japan seem to be effective. At least, there is no significant difference in the use of university knowledge by enterprises in science-based industries such as biotechnology. 60 % of Japanese corporate biotechnology patents cite university research results, while in the USA, this percentage is about the same.

B.10.3 The Policy-related Framework Conditions for ISR in Japan

Cultural attitudes: The attitudes in public science with respect to their relation with industry have undergone some changes in the 20th century. Until World War II, collaboration was close and was further mobilised during wartime. In this time, science was viewed as a major contributor to the national goal of catching up technologically and becoming more independent of technology imports. Immediately after war, ISR diminished as a result of the elimination of military research. In the 1950s, both industry and the government attempted to re-built industry-science relations. But there was increasing reluctance among universities to get engaged in direct collaboration with industry again. The arguments for shrinking away co-operation with industry were related to moral considerations (anti-war position of the Japan Science Council) and fears of crowding out basic research and education. Since the 1960s, there has been a hesitant relationship between industry and universities, and university researchers largely refrain from direct interaction with industry. There is however, a strong tradition of establishing and maintaining personal relationships in Japan. In the field of ISR, relationships between professors and their former students (who often moved to industry research) form the backbone of interaction.

Legislation: The following regulations are most often mentioned in the context of affecting ISR in Japan:

- Civil servants law: Researchers in public science in Japan are civil servants of the government. Until 1995/97, a large number of regulations restricted their activities in ISR. For instance, professors were not allowed to establish a new business or become directors or employees of private enterprises as long as they retained a professorship. This regulation was relaxed in 1997. Full-time employees in public science have been highly prescribed with regard to direct consultation with industry. In 1995, changes were made but academic researchers remain constrained.
- IPRs in public science: IPRs of inventions made at national universities belong to the individual inventors, except the following: (a) inventions under special funding from the

government for projects on practical applications, including commissioned research by joint research with industry (both types may cover up to 50 % of total research project funding at national universities); and (b) inventions under a project that utilises special research facilities of the government (such as nuclear power research facilities). In both cases, the invention belongs to the government and is labelled a "national invention". In order to determine whether an invention is a "national" one, a system of university-based Invention Review Committees was established, to which patent applications are submitted. Most members of these committees are university professors. Committees operate without staff funding and typically do not have the services of legal advisors. Also, they do not provide for public participation and are not under a prescribed timetable for review. Many of them meet only once a year. Therefore, this system makes it difficult for an industrial partner to know in advance, how rights may be allocated for an invention, and when. A common method used by Japanese enterprises in collaboration with HEIs is therefore, to provide a formally untied grant or endowment with an informal understanding that the benefits of research would accrue to the donor. In practice, most of the patent rights have been returned by the committees back to the individual researchers (in 1996, 85 %). Inventions arising out of research funded by enterprise donations do not face the delay and uncertainties associated with the review process. At PSREs, IPRs belong to the government. At private universities, IP regulation varies by institution. Some follow a system such that inventions belong to the university, and some adhere to the principle that IPRs remain with the inventor.

- Technology Transfer Law of 1998: This new law authorised the formation of Technology Licensing Offices (TLOs) at national universities. TLOs may be part of the university administration, legally independent private corporations or publicly chartered corporations. This law establishes a greater stake for universities in the successful use of their research results. The new law also provides for cost-shared support for up to the first five years through subsidies and loans, establishes grants to encourage university-industry co-operation at these offices, and liberates TLOs from fees in the maintenance of "national innovations". However, the use of TLOs by professors is not affected, i.e. it is entirely voluntary. Furthermore, the law provides financial assistance to SMEs in commercialising university-based inventions. Other IPRs related regulations are not affected by the law.
- Science and Technology Basic Law of 1995: This law called for the promotion of overall science and technology and of ISR in particular. It has substantially lessened the restrictions on the ability of national university professors to consult with industry. Furthermore, Ministries other than Monbusho were allowed to fund university research.
- Taxation: Until recently, donations by enterprises to universities were treated merely as charitable gifts and could automatically be deducted from taxable income. In practice, technology transfer activities by professors in HEIs are most often remunerated through donations. In contrast, corporate support for commissioned or joint research has been

subject to scrutiny by Japanese tax authorities who can challenge deducting specific expenditure in support of such research.

Institutional Setting: Institutional settings at national universities and PSREs seem to impede ISR through several mechanisms (see Keller 1999a, Yoshihara and Tamai 1999, Hashimoto 1999, Odagiri 1999), including:

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- Formal technology transfer procedures set out in a number of official "notifications" by Monbusho, and internal rules that individual universities have enacted. These notifications regulate, amongst others, Joint Research Agreements (JRAs), which are a major mechanism for formal research collaboration. There are some regulations in this respect which may be viewed as impediments to their use, including: the start of JRAs must coincide with the start of the Japanese fiscal year (April 1st); corporate funds must be disbursed on an annual basis through the Monbusho; funds for one year may not be rolled over to the next year; and IPRs on inventions made in JRA based projects belong to the government, although mechanisms to transfer IPRs to the enterprise do exist.
- There are no institutional incentives for researchers to engage in ISR such as evaluation or compensation. However, the practice of industry donations to professors has evolved as an effective remuneration mechanism on an individual basis. Informal technology consulting activities and forwarding of inventions are often compensated with untargeted financial donations, and their use by professors is much more flexible than funding through JRAs. However, donations to individual professors by industry exceeding 5 million Yen per year (45,000 Euro) must be approved by the Ministry of Finance, and professors are often unwilling to go through this approval procedure. As a result, technology transfer activities are kept to a small scale. This is reinforced by the common practice at enterprises whereby donations above 1 million Yen (9,000 Euro) need approval by executive boards.

- Universities have not developed formal structures to co-ordinate ISR, with respect to both collaborative and commissioned research, and the commercialisation of research results. There is no clear path for initiating a formal relationship. Only few universities run technology transfer offices or similar institutions but they are viewed to be ineffective.
- Private universities are generally free to set their own technology transfer policies. At PSREs, the institutional setting is in general, unfavourable to ISR concerning regulation on researchers' activities with enterprises, regulation on commissioned and joint research, and concerning IPRs and start-ups.

S&T Policy: Strengthening the science orientation of large industrial companies is a major objective of the Ministry for International Trade and Industry (MITI). The government's S&T policy is puts special emphasis on bringing together national industry and national universities. After World War II, such initiatives started in the 1960s with formal Research Associations (RAs) between industry and science in the 1960s and were continued, amongst others, with the Joint Research Programme and Co-operative Research Centres Programme.

Public Promotion Programmes: During the 1980s and 1990s, the Japanese government introduced a number of new programmes aiming towards supporting interaction and co-operation between industry and science. The implementation of these programmes was part of a shift in the national S&T policy orientation. Perceiving the growing importance of the autonomous production of knowledge for the future technology performance, more emphasis was laid on research in future technologies, including a strengthening of the links between industry and basic research in science. In this respect, the existing pattern of interactions, with its focus on informal contacts, should be further developed towards direct interaction in joint research projects. The following programmes may be mentioned in this context (see Hane 1999, Odagiri 1999):

- Joint Research Programme: The Programme for Joint Research with the Private Sector began at national universities in 1982 and is administered by Monbusho. Its aim is to increase the number of direct research co-operation between university professors and enterprises. The projects are small (about 25,000 US\$) in most cases and are oriented to rather short-term industry needs. They are often based upon existing informal contacts between professors and enterprises. In 1996, about 2,000 projects received support and there a clear growth trend has been noted.
- University-Industry Research Co-operation Committees: This programme, initially started as early as 1933, attempts to establish long-term oriented partnerships between industry and science, including financial support for joint R&D activities. The groups are composed of the leading industrial enterprises and prominent academics. A total of about 170 committees have been established since then, of which are about 50 are in operation today.
- Innovative Industrial Technology R&D Promotion Programme: This MITI programme gives support to enterprises for R&D projects in specific priority research themes,

including: materials processing technology, biotechnology, electronics and information technology, medical and welfare equipment technology, human life engineering technology, and resources technology. In the first round of the programme, out of c. 3,000 proposals, 109 received funding. Projects may involve contributions from public science but this is not necessary.

- Core Research for Evolutionary Science and Technology (CREST): This programme addresses somewhat longer-term research themes than the MITI programme (brain functions, genetic programming, immune mechanisms, quantum effects, and single molecule atomic reactions). It should encourage Japan's basic research by invigorating the potential of universities, national laboratories and other research institutions with the clear aim of building up a tangible foundation for the future direction of Japan's science and technology. Initially, R&D funding was provided for universities mainly but in 1997, it was opened up to enterprises and consortia of industry and science. A similar programme is PRESTO (Precursory Research for Embryonic Science and Technology programme). It is aimed towards providing open pastures prepared by respected senior scientists for individual young researchers to develop their emerging ability, by supporting and stimulating their embryonic research for three-year periods.
- Co-operative Research Centres Programme: This Monbusho programme was modelled on the NSF programme "Industry-University Co-operative Research Centres" programme in the USA. By 1997, 49 such centres had been established. Until 1995, the centres were hampered by a lack of authority to accept funds directly from industry for commissioned research, but the Science and Technology Basic Law of 1995 changed this situation in favour of contract research for industry. Before this date, industry research was limited to funding for equipment, personnel, endowing grants, and other general contributions.
- Venture Business Laboratories Programme: In contrast to the Co-operative Research Centres Programme, this programme focuses on the establishment of thematically oriented laboratories at universities that provide space for joint research projects with industry and contribute to the commercialisation of new results out of fundamental, scientific research. The initial budget to establish these labs was about 200 million Euro. The themes concern for example, advanced electronic materials, high functionality nanostructure materials, knowledge-base multimedia, and photonic materials. By the end of 1997, 24 such laboratories were established at national universities.
- Research for the Future Programme: This programme is administered by the Japanese Society for the Promotion of Science (JSPS), a main financing source for research projects in HEIs. The programme provides large-scale competitive grants to groups of university researchers for application-oriented research. Funding is provided for a five-year period. In 1997, about 180 million Euro was budgeted for a total of 204 projects under this programme. There are also several other research funding programmes by sector oriented ministries such as MITI, Ministry of Health and Welfare (basic research in human science) and Ministry of Agriculture, Forestry and Fisheries (agricultural science). Also,

local governments offer programmes for collaborative research in a regional context and on a small scale.

- **Exploratory Research for Advanced Technology Programme (ERATO):** This programme, administered by the Japan Science and Technology Corporation (JST), a subsidiary of the Science and Technology Agency (STA), gives significant financial support (about 20 million Euro) to scientists from universities, public labs or industry, that get research directors to establish a new research team for a five-year period of time. Directors are free to choose researchers, locations and themes of research activities. After the five-year period, all researchers within the team have to move on to another activity i.e. mobility is a main issue of this programme. The directors typically do not work full-time in the team but maintain their original positions in HEIs, PSREs or enterprises. Selection of directors is based on a survey among researchers, including hundreds of interviews with young researchers. In each programme round, a shortlist of possible directors is then produced, and they are invited to write proposals. Finally, four directors are selected. ERATO is regarded as a highly effective programme, bringing together researchers from science, industry and from abroad (see B.10.5). The programme **INCORP** (International Co-operative Research Project) is an international version of the ERATO programme, which is conducting 5-year, 50-50 co-sponsored, twined, joint-research projects involving two key individuals, their institutions and the funding organisations, located in both Japan and abroad. With this programme, JST is aiming to establish cross-border scientific adventures.

Table B.10.9: Selected Public Promotion Programmes in the Field of ISR in Japan

Name of Programme (responsible authorities)	Administering Agency	Starting Year	Main Approach	Type(s) of ISR Mainly Addressed
Programme for Joint Research with the Private Sector	Ministry of Education	1982	Providing funding for joint research projects involving professors at national universities and enterprises	Collaborative research, technology transfer
University-Industry Research Co-operation Committees	Japanese Society for the Promotion of Science	1933	Support for joint research carried out between industry and universities on a long term base	Collaborative research, networking
Innovative Industrial Technology R&D Promotion Programme	Ministry of International Trade and Industry	1995	Funding for research projects in priority research themes that are oriented on industry needs, competition based approach	Strengthening company research, contract research
Co-operative Research Centres Programme	Ministry of Education	1987	Funding for establishing laboratories for joint research with industry at national universities, funding for joint projects	Collaborative research, mobility, training
Research for the Future Programme	Japanese Society for the Promotion of Science	1994	Funding for application-oriented research at universities in strategic fields of science and technology	Enlarging the ISR relevant research base in HEIs
Venture Business Laboratory Programme	Ministry of Education	1996	Funding for establishing laboratories for joint research with industry, each lab has a focus on a specific key	Strengthening research in key technologies, collaborative

Exploratory Research for Advanced Technology Programme (ERATO), INCORP	Japan Science and Technology Corporation	1981	technology Funding for interdisciplinary research for 5 years (involving researchers from science and industry), including separate research facilities	research Technology transfer, mobility
Core Research for Evolutionary Science and Technology (CREST), PRESTO	Science and Technology Agency, Japan Science and Technology Corporation	1995	Funding research in long-term oriented strategic themes, focus on basic research	Strengthening research in future technologies, collaborative research
Network-Structured Centre of Excellence. Regional Research Link	Japan Science and Technology Corporation	1999	Establishing regional research networks centred around a regional R&D centre (Center of Excellence)	Collaborative research, networking

Source: Hane (1999), Odagiri (1999), compiled by the authors

- Network-Structured Centre of Excellence: This new JST-operated programme aims towards promoting joint research on a regional level by bringing together various institutions and organisations within a region, such as companies, public labs, national labs and universities. A main approach is to establish new infrastructures and institutions in a region that should facilitate research and knowledge exchange. A Central Research Facility may serve as a common gathering point where joint R&D can take place. A Joint Research Promotion Committee and a Research Exchange Promotion Council may manage these activities. Funding is provided for establishing and running this new infrastructure for five years with about 3 million Euro per year and region. There are also other regional activities in the field of ISR, such as the Regional Research Link programme, particularly targeted to national laboratories and linking them with regional research institutions.

Intermediaries: Compared to other countries, the intermediary infrastructure in Japan is less extensive. The following institutions serve as intermediaries in the field of knowledge and technology transfer in Japan:

- There are several public agencies engaged in various co-ordinating and stimulating activities in the field of ISR. The Japan Society for the Promotion of Science (JSPS) is one of the oldest, founded in 1932 and affiliated to the Ministry of Education. It serves as a founding body for strategically oriented and joint research projects and manages the patenting of government-owned inventions. The Japan Science Council (JSC) was formed in 1948 as an organisation of scientists who provided advice to the government on matters involving science and technology. The Council represents quite strongly, the university point of view, and had a major impact on the slowdown of direct industry-university relations after World War II (declaring an anti-military position with respect to scientific research orientation in the 1960s, and implying an anti-industry orientation too), as well as on the re-emergence of university-industry co-operation since the late 1970s. The Council for Science and Technology is an advisory board of the government. The Science and Technology Agency is a government body responsible for, amongst others,

the administration of some industry-science related programmes, and the operation of some national research institutes. The Japan Science and Technology Corporation (JST) was founded at the end of the 1990s and is responsible for licensing government-owned patents (i.e. less than 100 patents per year).

- Science and Technology Parks: In 1998, 31 such parks existed. They serve, amongst others, as incubators for the public science institutions located close to the park, but this function is of little significance. The main objective of the parks is to stimulate regional technology development by providing supportive infrastructure and fostering networking, co-operation and knowledge exchange among firms and between industry and science, mostly on an informal basis.
- Technology Licensing Offices: Private universities started in the 1990s to establish technology transfer offices and special laboratory facilities for carrying out co-operative research with enterprise. In 1998, national universities were authorised to establish TLOs. Some of the large national universities have founded such TLOs, mostly as independent companies owned by the national university. The main purpose of TLOs is to manage IPRs belonging to the professors at their universities (or university IPRs in the case of private universities). At national universities, their efficiency is largely hampered by the fact that professors are not forced to forward their patents to the TLO in order to commercialise it. TLOs have the possibility to make use of special Monbusho funds for covering patent application costs. There is also a five-year limited Monbusho contribution of about one third of the basic costs of TLOs.
- Industrial and Professional Associations serve as intermediaries to bring together university professors and enterprises on an informal, personal basis by offering occasions for meetings.
- Databases of Science and Technology: Among the several databases on research activities, the ReaD (Directory Database on Research and Development Activities: www.read.jst.go.jp) provides information on all major public and private institutions carrying out R&D in Japan, including universities and colleges, national institutes, government-affiliated R&D organisations, municipal institutes, and R&D labs of private corporations. ReaD is operated by JST and covers nearly 40,000 research projects, more than 1,600 institutions and about 25,000 individual researchers. There are also databases for certain disciplines or fields of technology operated by JST.

B.10.4 ISR in Japan: A Summary Assessment by Type of Interaction

Contract and collaborative research: There is a rather low level of direct research co-operation between industry and public science in Japan on a formal basis. Concerning commissioned research by industry, several regulations apply that reduce the attractiveness of this channel of interaction. There was a strong increase in contract research in the second half of the 1990s however, but this was partly due to a shift from general industry donations to commissioned research agreements demanded by the government. Formal collaborative research is rare,

although several promotion programmes are run by the government, including a university-industry co-operative research centre programme which attempts to stimulate this type of interaction. Given the high-tech orientation of the Japanese enterprise sector and the likely high demand for scientific knowledge in industrial innovation, the following factors may explain this pattern:

- First, regulation at public HEIs and PSREs provide little incentives for formal research co-operation due to inflexibility, bureaucracy and uncertainty on ownership of IPRs. Therefore, enterprises tend to rely more on general donations to a university professor, and define the research carried out by donation funds on an informal basis.
- Second, Japanese enterprises have built up large in-house R&D capacities, including basic and strategically oriented research, reducing the demand for acquiring knowledge from public science. However, enterprises rely heavily on interaction with HEIs in order to recruit well-trained personnel for their central R&D laboratories.
- Third, there is a significant private enterprise R&D sector, offering technical support, specialised applied research and other R&D services to enterprises. External R&D funding by large enterprises is increasingly allocated to these private R&D companies.

Personnel mobility: There is generally a low level of inter-sectoral labour mobility in Japan, and mobility of researchers between public science and enterprises follows this pattern. In public science, the civil servant status imposes researchers with serious mobility restrictions, e.g. leave of absence, part-time working for other institutions and secondary occupations are almost impossible. However, there seems to be a rather high level of temporary mobility of researchers from industry to science, taking place within informal contacts and personal networks.

Training and education: Co-operation in training mainly takes place on an informal basis, relying on personal relations between university professors and their former students. An interesting type of "indirect vocational training" is temporary visits by industry researchers at universities in order to participate in research projects. Other types of co-operation concern graduate or post-graduate research carried out by technicians and researchers employed in enterprises ("commissioned researchers") and evaluation of research results achieved by industry researchers for PhD.

At Japanese HEIs, there is a longstanding tradition of contributing to industrial innovation through the supply of well-trained graduates, and HEIs therefore, put special emphasis on engineering fields and rather short-term, practically oriented studies.

IPRs in science: The number of patent applications by university researchers is low as a result of a complicated and bureaucratic regulatory framework at national universities and PSREs, and a lack of financial and administrative support (the latter was improved by a new law on technology transfer in 1998). Nevertheless, public science in Japan does contribute to technology development through inventions, but typically without claiming IPRs by the

public science institutions. In fields such as biotechnology, up to 40 % of all industry patent applications, lists a Japanese university faculty members as an inventor. Professors are willing to forward inventions to enterprises within personal networks in exchange for general donations. This system is viewed as effective. However, it strongly favours large enterprises, while SMEs have insufficient access to this informal way of distributing university inventions. Therefore, within the new law on technology transfer of 1998, special support to SMEs is provided in order to make use of university-based inventions.

Start-ups from science: There are hardly any start-ups by public science researchers due to the specific incentive and regulatory system. Civil servants are not allowed to hold a management position in a company, i.e. to create a new venture, they must resign from their position at a national university or PSRE. There is no supportive infrastructure for science-based start-ups despite some science parks located close to universities. Financing for technology-based start-ups is rather difficult as there is only a small venture capital market, and even venture capital firms refrain from investing in high-risk projects.

Networking between industry and science: The Japanese ISR-system is characterised by a predominance of this type of interaction. While standard quantitative indicators on ISR in Japan show a low volume (e.g. industry funding, collaborative research, start-ups, use of IPRs, and formal co-operation in vocational training), there seems to be a high volume of new knowledge being transferred through personal contacts and informal interaction. However, it is impossible to quantify the intensity of technology transfer based on informal, personal networks, and industry-science collaboration produces less visible results than in other countries. Assessments by national experts from both industry and science suggest that informal technology transfer is effective, at least from the point of view of large enterprises. However, in some industries where rapid gaining of IPRs is a major competitive factor, a stronger focus on formal interactions and a clear regulation on ownership of IP is demanded (Smith 1999). Furthermore, allocation of science inventions does not follow market mechanisms, i.e. they may not be allocated to those enterprises who may obtain the largest profit out of them.

Involvement of SMEs in ISR: There is no information available on the involvement of SMEs in ISR, but anecdotal evidence suggests that it is mainly the large enterprises that use public science as a partner in innovation. The predominance of the informal system of technology transfer strongly supports such an assessment. SMEs are less attractive to university professors to build up long-term oriented networks as they do not provide a large demand for their graduates, only rarely demand technology consulting, may be unwilling to allow their researchers temporary visits to universities, and have less funds available for donations. At the same time, the complicated regulation on formal research collaboration may represent a serious barrier for SMEs to enter into partnerships with public science. Furthermore, the vast majority of SMEs do not carry out R&D and thus, lack absorptive capacity, and there are only few policy measures to specifically support SMEs in making use of science for their innovation activities. Finally, many technology-oriented SMEs are nested in innovation

networks with large enterprises, and technology transfer mainly takes place along supplier chains.

Science-based industries: A significant share of R&D in the Japanese enterprise sector is carried out in industries commonly regarded as science-based industries (especially microelectronics, information and communication technologies, and pharmaceuticals), and high export ratios reflect the international competitiveness of these industries. Their technology performance seems to be less based on the direct transfer of new scientific findings from science to industry than in the science-based industries of other countries. At least two factors may be responsible for this phenomenon. First, Japanese high-tech firms have focussed their innovation efforts on market oriented incremental innovations and adjusted inventions made elsewhere to the specific market needs, including low cost production in order to reduce prices and thus, raise diffusion of new technologies and products. For this strategy, interaction with suppliers and internal R&D on improving production processes and product characteristics are more important than integrating basic science results. Second, Japanese high-tech enterprises have built up large in-house capacities in fundamental research as part of their activities at central R&D laboratories. As these laboratories typically have strong direct ties to development and production activities at production facilities, they allow for a more rapid transfer of new findings into new products and a better consideration of marketing and production demands in new product development, than an external interaction with science would allow. This - highly generalised - behaviour of Japanese high-tech industries has however, weaknesses in some new fields of technology such as biotechnology, where direct transfer of basic research results achieved at universities to commercialisation is a major competitive factor. Here, the lack of formal interactions, in personnel mobility from science to industry, in start-ups from science, and in clear ownership rights of inventions made at universities, are considered ISR based barriers for the development of this industry in Japan (see Kneller 1999). The Japanese government has started several initiatives to gear basic and applied research in HEIs and PSREs more directly towards the need of science-based industries, including programmes such as ERATO, CREST and PRESTO.

B.10.5 Good Practice in Framework Conditions for ISR in Japan

Within the scope and resources of this benchmarking exercise, no analysis of good practice in policy-related framework conditions for ISR in Japan has been carried out. Based on literature (see Odagiri 1999), we have selected one public promotion programme that is often mentioned as a good practice, the ERATO programme, to be particularly worthy as a good practice example. The main features of this programme are characterised in the following.

Exploratory Research for Advanced Technology (ERATO)

The Exploratory Research for Advanced Technology (ERATO) programme was initiated in 1981 "for the purpose of fostering the creation of advanced science and technology while stimulating future interdisciplinary scientific activities and searching for better systems by which to carry out basic research". It is administered by the Japan Science and Technology Corporation (JST), an organisation fully controlled and supported by STA. A unique characteristic of ERATO is that JST selects its project directors from a wide variety of researchers based on its own survey, interviews hundreds of young researchers and asks them to offer names of potential research leaders. Based on this survey, JST makes a list of about 15 candidates for the directorship, asks them to write proposals, and selects four from among them as directors. Each director is given research funds of around \$ 20 million Euro for a period of five years, and a free hand (but with JST's advice) in choosing researchers and locations for the project. The project is non-renewable - a finite research period which is a unique feature in Japan, requiring the researchers (who typically number between 15 and 20 per project) to seek new jobs after the five-year period because, except for directors, all the research positions are full-time. This is quite unusual in Japan, where lifetime employment is supposedly the norm.

JST uses a scheme of surveys for intensively tapping the opinions of the young generation at universities and industry, as well as personal contacts and databanks, to identify individuals who stand out as being strongly supported by young researchers. Having personal charisma and imagination is as important as being a good scientist. Still, each director must have deep insight into the problems that must be dealt with, and has the overall responsibility for executing and managing their project. In measuring the 'soft' quality of leadership, the ability to stimulate is more important than being very directive. Based on these reviews, JST chooses the young candidates, and the project directors are then selected by the Research and Development Council of JST, comprising both scientists and industrialists from public and private sectors, and are recommended to its president.

Directors can maintain positions elsewhere, i.e. at universities, national laboratories, and industry. Researchers' backgrounds are diverse. Many of them are company researchers on leave. But they participate as individuals and not as representatives of their companies. Two or more people from the same company rarely join a single project. Others may be post-doctoral students, researchers at various laboratories or universities, or foreigners. Therefore, although the aim of ERATO is to promote basic and interdisciplinary research and ISR itself, the diversity of researchers in a project ensures that such collaboration actually takes place in various ways.

Projects: The project themes evolve from the visions of the Directors with the help of JST so as to attract both academic and industrial participation in each project. The fields of research are broad and concern many unexplored and pre-competitive regions of science and technology. Themes that are fashionable or trendy are eliminated, in preference of those that are emerging and challenging. Since the research motifs provide only starting points, without goal-oriented restrictions, a broad spectrum of disciplines are invited to participate in any project. In these projects 'science' and 'technology' are not differentiated. One feature of the ERATO program is that each Director has a supporting project office to take care of administrative details. Each project team comprises between 15 and 20 scientists usually grouped into 3 sub-teams. Including the supporting staff, most projects involve about 25 persons. Interestingly, over time ERATO has evolved from a strictly domestic program to an international, borderless one. This first took the form of one research group being located abroad, but has been extended to a case in which the project Director is located outside Japan.

In an effort to tap the creative spirit and ideas of youth, teams usually comprise young Ph.D. type scientists and engineers in their early thirties coming from a heterogeneous mixture of world-wide academic, government, private and individual sectors. Thus, the ERATO program also serves as a good place for young scientists to gain the experience and discipline necessary to become future professional leaders. ERATO also functions as a learning ground for individuals who can later stimulate and refresh creative basic-research atmospheres alongside the short-term technological goals of private industry.

Administration: All projects are funded at around 1.7 billion Yen (averaging on the order of 20 million Euro) for a five-year project lifetime. JST administers and fully funds the ERATO programme. Members of project teams are employed by JST on an annual contract, renewable for between two and five years. All new research motifs and orientations are publicly announced in early summer of each year. Each year, 4 new projects for a five-year period are granted, resulting in a total of 20 projects at each point in time.

In order to maintain independence and flexibility, JST has no research facilities of its own. Thus, research is carried out in co-operation with research parks as well as various academic, industrial and other institutions in rented laboratories, sometimes at several convenient locations. Uniquely, the laboratories and project offices are established near to the selected directors and their principle colleagues in the projects, rather than having them move to pre-established locations. ERATO laboratories

are rented from, and located within, established research institutes owned either by a private company, university or a non-profit public organisation.

All results from a project are the common property of JST and the members of the project team. Any patent right resulting from a project is shared by JST (50 %) and the members (50 %), in an agreed manner, who are directly responsible for the invention for which the patent has been granted. The portions of the patent right belonging to members can be transferred to their home institutions upon the termination of the project.

Post-Project Phase: As it is crucially important that research results are brought to their best possible maturity, JST is continuously organising interested academic circles and companies in diverse fields so that they can develop the results from basic research that are likely to lead to innovative technologies.

Evaluation: After 19 years of activity, the ERATO programme has proved to be more successful than had been expected and has come to be highly rated both in Japan and abroad. JST judges the "success" of ERATO projects not only on the successful development of research themes within a project, but also whether the projects produce "clues" for the next generation of research. JST believes that the eventual evaluations of the ERATO projects are ultimately done by society, including industry and future endeavours. Intensive efforts are put into organising symposia both inside and outside of Japan, as well as producing special seminar publications and media reports to the general public. The time conceived to actually detect the response of society is about 10 years.

Among the 995 past and present researchers, 167 are from 30 countries outside of Japan and 421 are from industry. The researchers from industry are paid by JST and are asked to take a leave of absence from their companies, so that their research is independent of the companies' interests. Most of them return to their companies on completion of the research projects.

The results of ERATO projects are impressive. By August 1996, they had produced 1,107 patents (925 in Japan and 182 overseas) and 5,672 papers and presentations (3,335 in Japan and 2,337 overseas) (Kusunoki 1998). Through a questionnaire study, Kusunoki (1993) found that their researchers made more publications and presentations, particularly abroad, than those in a comparable MITI laboratory, and argued that "the dynamic network organization could enable researchers to make full use of external outside professionals, as well as to communicate more frequently with outside professionals. In this sense, the findings in this analysis emphasize the effectiveness and the possibility of dynamic network organization like ERATO more than expected" (Kusunoki 1993, 56).

The success of the ERATO programme has led to the launching of three new programmes: ICORP (International Co-operative Research Project) in 1989, PRESTO (Precursory Research for Embryonic Science and Technology) in 1991 and CREST (Core Research for Evolutionary Science and Technology) in 1995.

Source: Odagiri (1999, 258f); www.jst.go.jp/erato (May 2001)

C. ISR in Comparison: Good Practice in Shaping Framework Conditions

This chapter contains the main results of the comparative study of the national reports on ISR which attempts to apply an "intelligent benchmarking approach" (see A.1). The information on the respective "national models of ISR" is used to carry out two types of benchmarking analyses and is presented in three sub-headings:

- (i) To carry out the first type of benchmarking analysis, we systematically compare the national models of ISR in order to identify critical success factors for effective interaction between enterprises and public science institutions. The focus of this analysis is to assess the role of different policy-related framework conditions for fostering ISR. Our attempt is not to analyse in depth some 'best performer' but rather to look in each country for those framework conditions which effectively foster ISR under the prevailing features of the its national innovation system. Learning from good practice thus may also include countries with an overall weak performance in ISR but with some good practice examples. Chapter C.1 presents the findings on this part of the exercise.
- (ii) Secondly, we investigate in greater detail the role of policy-related framework conditions in several channels of ISR regarded as particularly relevant to strengthen the interaction between industry and science. On the one hand, these areas concern particular types of knowledge exchange and transmission of public science R&D results to enterprises, such as the commercialisation of new research findings via intellectual property rights or via the creation of new enterprises, collaborative research between enterprises and public science institutions, and the interaction in the field of human capital (researcher mobility, co-operation in training & education). On the other hand, they refer to certain types of actors (SMEs, transfer oriented PSREs) and to certain industries with special ties to science (such as biotechnology and pharmaceuticals, information and communication technologies, new materials). For these areas, we attempt to identify good practice in policy-related framework conditions (i.e. legislation, promotion programmes, institutional settings, intermediary structures) which shape - given the characteristics of knowledge production structures - the performance of ISR in a positive way. The results on this part of the benchmarking exercise are presented in C.2.
- (iii) In the final part of this chapter (C.3) we conclude the main findings of this project and derive recommendations on how to use the results achieved in order to improve policy-related framework conditions for industry-science relations.

C.1 Benchmarking National Models of ISR

In chapter B, for each of the EU member states participating in this benchmarking project, as well as for the USA and Japan as 'third countries', we presented a summary of the way industry and science interact with each other, including the framework conditions guiding this interaction. In this chapter we attempt to summarise the main findings by drawing on the "national model of ISR" for each country analysed.

In order to characterise national differences in the various elements of the national ISR models, major aspects of these elements are compared on a systematic level. The performance of ISR may be characterised by a mix of quantitative indicators and qualitative assessments for the various channels of interaction, in order to exchange knowledge between enterprises and public science institutions (Table C.1.1). In the area of knowledge production structures (industry structure, structure of public science, knowledge market characteristics), several quantitative indicators are available (Table C.1.2). A comparative characterisation of the different policy-related framework conditions at work is considerably more difficult for the following reasons. Firstly, there are hardly any quantitative indicators available. Secondly, the overall national policy framework - i.e. the significant differences in public administration, law, and policy institutions - matters to a much greater extent than in the case of structural (i.e. market related) framework conditions. In the case of the latter, national structures compete with each other due to market internationalisation and the internationalisation of science, making an international comparison of these structures meaningful. This is clearly different to the case of policy-related framework conditions which act under very different national settings, making a simple comparison of individual aspects of national framework conditions largely meaningless without taking into account the overall setting. Nevertheless, we make an attempt to compare the overall setting in policy-related framework conditions and compile different national approaches with respect to the following four areas:

- (i) public promotion programmes and Science & Technology (S&T) policy,
- (ii) institutional settings in public science,
- (iii) legislation in the field of ISR,
- (iv) intermediary structure design to foster ISR.

Tables C.1.3 (for the first two aspects mentioned) and C.1.4 (for the latter ones) present the results of this attempt.

Finally, for each of the ten countries considered we outline a "national model of ISR" containing the main features of industry-science relations, i.e. the performance of ISR by type of interaction and type of actor, the role of knowledge production structures, and the role of policy-related framework conditions. These "national models" are of course simplistic and strongly reduce the complexity and diversity of ISR in each country. They serve, however, to highlight the main factors driving knowledge interaction between industry and science. By

using a common structure and notation, comparison of different national approaches and structures is made possible and this is considered a prerequisite for learning from different practices.

C.1.1 Comparison of National Performances of ISR

There are considerable differences in the performance of industry-science relations among the countries analysed. Table C.1.1 indicates that some countries show above average levels of ISR performance on most of the indicators applied, while other countries report values below average for nearly all types of interactions considered.

Among the countries with high ISR performance are Belgium, Finland, Germany, Sweden, the UK and the USA, while Austria, Ireland and Japan report lower levels of ISR. However, these findings should be interpreted with some degree of caution due to the following three reasons:

- First, although the indicators have been selected carefully, definitions, measurements and reference years may vary. Furthermore, for several indicators, only expert assessments are available which may be biased or suffer from a lack in information.
- Second, the indicators represent national average values, i.e. they comprise very different actors both in industry and science with very different roles in ISR. In industry, ISR performance may differ by the size of enterprises, sector and market orientation or location, while in science, different institutional affiliation, disciplinary orientation or size of research collectives will determine the level of ISR activities. Unfortunately, only scattered information exists on the actual ISR performance of these different groups of actors in the countries analysed. The empirical information available suggests that there are very considerable differences within one country, while similar groups of actors tend to show similar ISR behaviour across countries. Thus, as countries show different industry and public science structures, differences in national ISR performance may be attributed to these structural differences.
- Third, theoretical reasoning (see A.2.1) shows that it may be misleading to simply associate a higher level of ISR with better industry-science interaction in an innovation system. Industry's demand for scientific knowledge, and thus the enterprises' demand for interaction with public science institutions, depends heavily upon the specialisation of enterprises and sectors on certain types of products, markets and associated stages of product life cycles. Despite the increasing trend towards knowledge based economies (see OECD 1999a), there is still an overwhelming majority of enterprises who derive their competitive advantage from: close market contacts; client-oriented (incremental) innovations; rapid adoption of new technologies previously introduced by other enterprises; flexible production and marketing strategies in niche markets; or the acquisition of input factors (labour, capital, initial products) at favourable prices in factor and good markets. Only a small portion of enterprises gain competitive advantage and

high profitability from directly exploiting the commercial potentials of R&D results and new scientific findings. Therefore, a strong orientation of enterprises' innovation activities towards scientific linkages and sources may overemphasise the pure technology aspect of innovation and distract attention from demand trends, client needs and the activities of competitors (see Beise 2001). Furthermore, ISR are only one of many possibilities for enterprises to acquire new technology knowledge, and a low level of ISR may be associated with an intense use of alternative sources such as technology databases, co-operation with private R&D enterprises, international technology co-operation, or intra-industry R&D co-operation.

Considering countries performances in ISR, (Table C.1.1) shows that ***there is no single country which may be taken as a benchmark***. High levels of interaction for some are associated with rather low levels in others. This points to important aspects which should be considered when looking at aggregate levels of ISR in any one country:

- First, different channels for knowledge and technology transfer suit different types of knowledge to be exchanged. As industries demand different types of knowledge which is a result of the prevailing innovation strategies, market demands and types of technological changes (e.g. embryonic inventions versus cumulative technology development, radical product innovations versus permanent process innovations), differences in industry structures cause different patterns of ISR. This is especially true for the commercialisation of new research results through patenting & licensing, and start-ups. These may be appropriate channels for new break-through technologies such as microelectronics, biotechnology and genetic engineering where basic research results may lead to totally new products and short time processing.
- Second, some modes of exchanging knowledge and technology between industry and science are substitutive, i.e. if industry strongly relies on one type of ISR, the level of interaction in other types will be low. For example, if enterprises follow a human capital oriented strategy of knowledge acquisition, such as recruiting young top-level scientists, continuous training for their in-house R&D staff (including temporary visits to scientific institutions) and a high intra-industry mobility of researchers, there will be less demand for direct co-operative research with science.
- Third, ISR is only one option for enterprises to acquire new scientific knowledge. Alternative strategies include, for instance, investment in in-house research capacities covering all types of research activities needed for the development of new products and technologies; collaborative research with other enterprises (such as sectoral research networks and consortia); or the use of private R&D enterprises that offer specialised R&D services for specific industries. Hence, a low level of ISR in a specific country may be caused by a well-developed supply of alternative modes of knowledge production and exchange.

Bearing these in mind, the level of interaction between industry and science for various types of interaction may be characterised as follows:

In the field of contract and collaborative research, Belgium and Germany (with respect to HEIs), Finland and Ireland (with respect to PSREs) and the UK (with respect to enterprises) report the highest interaction intensity with respect to the share of public R&D expenditures financed by industry, and the share in total industry R&D funds, which is used for contract and collaborative research in public science institutions. Among public science sector institutions, there is considerable variation in the level of contract and collaborative research in each country. High levels of financial flows from industry to science for carrying out R&D are reported for technically oriented universities and for specialised PSREs ("contract research institutes"). The low level of financial flow reported for the USA is associated firstly, with specific regulation in PSREs (joint research is carried on a contractual basis with no direct financial flows from industry to laboratories), and secondly, with the growing importance of industrial co-operative research organisations, which may contribute to a higher share of basic R&D carried out in the enterprise sector itself.

However, formal research co-operation is only one way for enterprises to acquire expertise available in public science. In some countries, other channels of exchanging new scientific knowledge have evolved. For example, faculty consulting with industry is a commonly used method by university researchers in many countries, to supply enterprises with specific technological and methodical knowledge which they have accumulated. There are different modes of remunerating researchers for these services but typically there are no, or only small, direct flows to the university. In Japan, for example, the low level of industry funding of research in public science may be partially explained by the high significance of consulting activities by faculty members. Consulting as an important channel of ISR is also reported in Austria, Germany, the UK and the USA.

The level of financial flows from industry to science is strongly affected by the behaviour of large enterprises as they have the largest R&D funds available. Concerning co-operation in industrial innovation projects, it is the behaviour of SMEs which determines the level of interaction, measured by the respective indicators in Table C.1.1. Here, Finland shows the highest level of interaction but high intensity of co-operation is also reported by Sweden, Belgium, the UK and Germany (However, no information is available for the USA and Japan).

A similar picture can be observed in the case of using science as an information source in innovation projects. Compared to EU standards, innovative enterprises in Belgium, Finland, Germany and Ireland rely rather strongly on new research results achieved in public science. Two striking facts in this respect are the significantly lower relevance of science as an information source for innovation projects in the service sector, and the considerably lower share of enterprises using science as an information source compared to the use of science as a co-operation partner in innovation. Both facts show that most innovations in the enterprise sector are not science driven. Rather, interaction with other market actors (clients,

competitors, suppliers) as well as in-house R&D, provide the main sources for innovation. This is especially true for the service sector in which direct interaction with clients is expected.

Table C.1.1: Indicators and Assessments of ISR in Selected EU Countries, the USA and Japan at the End of 1990s (shaded fields: values significantly above EU average)

Type of ISR	Indicator	Austria	Belgium	Finland	Germany	Ireland	Italy	Sweden	UK	USA	Japan
Contract and Collaborative Research (1998)	R&D financing by industry for HEIs in % of HERD	2.0	10.6	4.2	9.7	6.4	3.8	4.5	7.2	6.0	2.4
	R&D financing by industry for PSREs in % of GOVERD	2.0	2.1	14.0	2.0	15.4	3.0	2.9	11.9	n.a.	0.9
	R&D financing by industry for HEIs/PSREs in % of BERD	1.7	4.9	3.9	2.9	3.4	3.2	1.5	5.0	1.7	0.6
Faculty Consulting with Industry	Significance of R&D consulting with firms by HEI researchers	high	low	low	high	low	low	n.a.	high	high	high
	Significance of R&D consulting with firms by PSRE researchers	low	low	low	low	low	low	n.a.	low	high	high
Co-operation in Innovation Projects (1996)	Innovative manuf. enterprises that co-operate with HEIs (%)	12.6	13.4	47.3	10.4	13.8	2.5	26.1	11.3	n.a.	n.a.
	Innovative manuf. enterprises that co-operate with PSREs (%)	7.1	8.5	38.0	13.6	6.3	1.3	16.3	4.5	n.a.	n.a.
	Innovative service enterprises that co-operate with HEIs (%)	5.8	15.3	19.2	7.2	3.6	n.a.	12.0	2.9	n.a.	n.a.
	Innovative service enterprises that co-operate with PSREs (%)	2.5	6.0	13.8	3.0	2.5	n.a.	5.8	21.9	n.a.	n.a.
Science as an Information Source for Industrial Innovation (1996)	Innov. man. ent. that use HEIs as inform. source in innov. (%)	4.7	6.7	6.9	6.7	5.0	1.7	4.5	3.9	n.a.	n.a.
	Innov. man. ent. that use PSREs as inf. source in innov. (%)	1.1	4.8	5.3	2.9	7.4	1.6	n.a.	1.9	n.a.	n.a.
	Innov. serv. ent. that use HEIs as inform. source in innov. (%)	0.6	2.0	2.7	5.6	5.8	n.a.	4.7	3.7	n.a.	n.a.
	Innov. serv. ent. that use PSREs as inf. source in innov. (%)	0.7	2.7	0.6	2.7	2.1	n.a.	n.a.	6.9	n.a.	n.a.
Mobility of Researchers	Researchers in HEIs moving to industry p.a. in %	medium	~ 3	~ 3.5	~ 5	low	low	~ 4	high	> 2	low
	Researchers at PSREs moving to industry p.a. in %	medium	~ 5	~ 4	~ 3	low	low	~ 15	medium	medium	low
	HE graduates at industry moving to HEIs/PSREs p.a. in %	low	0.4	0.4	medium	low	low	0.6	low	medium	high
Training and Education	Income from vocational training in HEIs in % of R&D exp.	low	high	9	low	medium	low	n.a.	2.5	high	low
	Vocational training particip. in HEIs per R&D empl. in HEIs	low	high	16	low	medium	low	n.a.	high	high	high
	Share of students carrying out practices at enterprises during their study (placements, master thesis, PhD programmes) in %	medium	high	high	high	low	low	n.a.	high	high	high
Patent Applications by Public Science	Patent Applications by HEIs (and individual HEI researchers) per 1,000 employees in NSEM* in HEIs	low	high	high	19	low	low	n.a.	~ 15	> 35	5 - 10
	Patent Applications by PSREs (and individual PSRE researchers) per 1,000 employees in NSEM* at PSREs	medium	~ 15	~ 12	20	low	low	n.a.	medium	> 15	low
Royalty Incomes by Public Science	Royalties in % of total R&D expenditures in HEIs	low	low	low	low	low	low	n.a.	~ 0.5	2.3	< 0.01
	Royalties in % of total R&D expenditures at PSREs	low	low	~ 0.3	~ 0.7	low	low	n.a.	medium	0.15	low
Start-ups from Public Science	Technology-based start-ups in HEIs per 1,000 R&D personnel	~ 4	< 1	2 - 3	3 - 4	low	low	n.a.	high	> 3	low
	Technology-based start-ups at PSREs per 1,000 R&D personnel	~ 1	~ 3	~ 1	2 - 3	low	medium	n.a.	medium	medium	low
Informal contacts, personal networks	Significance of networks between industry and HEIs	medium	low	high	high	low	low	high	high	high	high
	Significance of networks between industry and PSREs	high	high	high	medium	low	low	n.a.	high	high	high

* Natural sciences, engineering (including agricultural sciences) and medicine

Figures refer to the latest year available, which is normally 1997, 1998 or 1999. In the case of missing data, assessments by national experts are given.

Sources: OECD, EU, various national sources, calculations by the authors

In the field of R&D personnel mobility, quantitative measures are available for Belgium, Finland, Germany, Sweden and the USA only. The reported level of mobility from science to industry is rather high in these countries (as well as in the UK) with a benchmark of about 5 % of the R&D personnel working in public science and moving into industry, per year. As far as data is available, the majority of this mobility seems to take place among young scientists who often face temporary employment contracts or work on temporary research projects. In all these countries, mobility is stimulated heavily by significant differences in earning and career options. Consequently, the level of mobility in the opposite direction is lower. In addition to permanent changes in occupation, researcher mobility from science to industry also includes temporary movement by senior researchers to industry, mutual exchange of researchers, and temporary visits of industry researchers to science. In Japan, the latter is reported to be an important channel of interaction. In countries with a low level of personnel mobility (Austria, Ireland, Italy, Japan), senior researchers and professors in public science are most often employed as civil servants, and the respective regulations may hinder mobility. However, other countries with similar employment regulations (e.g. Finland, Germany) report high levels of mobility.

Presumably, the most important channel of mobility between science and industry is the recruitment of graduates. An analysis of this channel was outside the scope of this study. Empirical evidence from enterprises suggests however, that the supply of well-trained graduates is one of the most important contributions of public science to industrial innovation. In some countries, such as Japan or Ireland, ISR rests heavily on this type of interaction.

Industry-science co-operation in vocational training and graduates education so far has received little attention with respect to systematically collecting data on this area of interaction. Thus, only expert assessments on the level of ISR in this area are available. In Finland, Belgium, the UK and the USA, there seems to be high interaction in vocational training for enterprise employees offered by HEIs. In Japan, HEIs are indirectly involved in vocational training of enterprises' researchers in the course of temporary visits of these researchers to universities. The level of further professional training activities by HEIs is affected however, by the supply of similar services by private companies. In Finland and the UK, HEIs (i.e. education colleges in the case of the UK) take a significant role in the further education system while in countries such as Germany or the USA, other public education institutions or private enterprises dominate the market.

Co-operation between HEIs and enterprises in the field of graduate education are common in many countries with the organisation, type and level of interaction, varying by field of study. In some countries, such as Belgium, Finland, Sweden and the UK, there are institutionalised types of joint graduate education (mostly including the writing of master or doctoral thesis in enterprises) while in countries such as Austria, Germany and the USA, such interactions take place on an individual basis.

In the last two decades or so, dissemination via disclosures of patents has received growing attention too, especially in the fields of natural sciences (chemistry, biotechnology), some

areas of medical research, and engineering. While patenting limits the direct spillovers from new research results by restricting the use of the new technology to the owner of the intellectual property, it makes the new knowledge more systematically available (via the common structure of patent specification) and allows public science institutions to gain income from their intellectual property. Patent activities in public science are currently highest in the USA following the 1980 Patent and Trademark Amendments Act, with more than 35 patent awards by HEIs per 1,000 R&D personnel in natural sciences, engineering and medicine, per year. High levels are also reported in Germany (about 20 patent applications), the UK, Belgium and Finland.

Despite the increase in the number of patents, royalties from IPRs are still only a minor source of financing in public science. Even at institutions which are highly specialised in applied research in fields where patenting is very common and carry out a high quality of research, royalties rarely exceed 1 % of total R&D expenditures and mostly stem from a few patents. The highest level of royalties is achieved by US universities, amounting to 2.3 % of their total R&D budget. Comparably high royalty incomes are also reported by public science institutions in the UK (concerning HEIs) and Germany (concerning PSREs). In almost all countries considered, there is an on-going discussion on the role patenting and licensing should play in commercialisation strategies of public science's research results. There is no doubt that in some fields, such as pharmaceuticals, biotechnology and new materials, patenting is an appropriate way for transferring new findings to commercial use. However, in many other fields, claiming IPR by public science may make technology transfer more costly and time consuming, and may restrict the spreading out of publicly financed research results to the economy (see Nelson 2001).

The creation of new enterprises by public science researchers is another way of directly commercialising new research results. Start-up activities have received a lot of attention in the last few years but international comparisons of the level of start-up activities from public science are hampered by a lack of data and divergent national definitions of start-ups (see OECD 2000b). A high level of start-up activities is reported in Austria, Finland, Germany, the UK and the USA, with a benchmark of about 4 % of public science researchers creating a new (technology-based) firm per year. Start-up activities seem to be fostered both by favourable market environments (high rate of growth in the respective markets, availability of venture capital) and by supportive and awareness measures at the level of public science institutions. There is some evidence that start-ups are concentrated in some emerging fields of technology. However, there was no evaluation so far of the significance of public science based start-ups in the total new firm formation in these fields of technology.

One of the most preferred ways of exchanging knowledge between industry and science which was mentioned by representatives from both disciplines, are personal contacts and informal networks. They particularly allow for the exchange of tacit knowledge and provide a trusting environment for co-operation and discussion. Such networking on an informal, personal level seems to be a common type of ISR in most of the countries analysed. It allows rapid access to new research results and increases appropriateness by controlling access to

these networks. In Japan, personal contact between university professors and researchers in enterprises is reported to be the most important method of technology transfer. For example, many professors are involved in stable, long-term oriented personal networks with industry, maintained, amongst other methods, through the recruitment of graduates by the firms involved in the network. Within these networks, industry demand for specific R&D activities is communicated to universities, and professors often directly distribute new findings to the enterprises without claiming IPR (but receiving some indirect remuneration in the form of research equipment and visiting research personnel from industry). Therefore, this type of interaction seems to substitute for a number of other channels and reduces the need for enterprises to enter into formal collaborations.

C.1.2 Comparison of Knowledge Production Structures

In our conceptual model of ISR (see A.2), knowledge production structures are assumed to determine the potential for industry-science relations in each national innovation system. They cover various aspects of R&D orientation, sector and enterprise structure, the structure and scientific performance of the public science sector, and market characteristics. Indicators of these variables are summarised in Table C.1.2. In order to ease the comparison of the main factors driving structural characteristics relevant to ISR potential, Figure C.1.1 shows the deviation of national values from the EU average for some indicators regarded as especially relevant.

First of all, knowledge production structures clearly differ among the countries considered in our benchmarking exercise, reflecting different specialisations and paths of development in the national economies. In general, Finland, Sweden and the USA show highly favourable knowledge production structures with respect to ISR, i.e. a high level of R&D expenditure, a strong high-tech orientation of the enterprise sector, a high share of large enterprises (which are expected to have high absorptive capacities for knowledge interaction with science), a strong R&D orientation among SMEs, and a competition-oriented public science sector with a strong orientation on innovation relevant fields of research (i.e. natural sciences and engineering) and a high quality of research output. Other countries with relatively favourable knowledge production structures are Germany and Japan, while the features of the national innovation systems in Belgium and Ireland are less favourable for ISR. Unfavourable knowledge production structures with respect to the potential for ISR can be observed in Austria and Italy.

A high level of R&D expenditure - when compared to the level of GDP - is reported in Finland, Germany, Sweden, the USA and Japan. There are however, major differences in the sectors performing this high level of R&D. Finland, Germany and Japan show above average R&D intensity for the business enterprise sector, and for both the HEIs and PSREs, while in Sweden, public R&D is mainly performed in the HEI sector. In the USA, R&D expenditure in HEIs and PSREs with respect to GDP are lower than the OECD and EU average. Conversely, Austria and Belgium invest a relatively high amount of R&D in HEIs while the overall level of R&D expenditure is rather low.

ISR may not only be stimulated by the level of R&D expenditure in the enterprise and public science sectors but also by the change in R&D expenditure, as such changes may signal actors to change their behaviour. During the 1990s, countries with both low and high levels of R&D expenditure increased their R&D investments (Finland, Sweden and Japan were among the countries with high R&D intensity, while Austria and Ireland were among those with low intensity).

Concerning enterprise structure, size and ownership of enterprises may affect their behaviour with regard to ISR. Empirical evidence suggests that large enterprises have the necessary in-house capacities to effectively interact with science (e.g. separate R&D departments, university-trained employees, experience in external co-operation, available time and financial resources for establishing and maintaining external links). In countries such as Finland, Germany, Italy, Sweden, the USA and Japan, the majority of business enterprise R&D is performed in very large enterprises (with more than 10,000 employees) which in almost all cases, shows high knowledge absorption capacities.

A large share of foreign-owned enterprises in BERD - as depicted in Austria and Ireland - may be a factor which restricts ISR as the national affiliates of multinational enterprises may not carry out the type of research which relies strongly on new scientific knowledge, i.e. strategic research and research on completely new products, materials and technologies. However, empirical studies have shown that foreign-owned affiliates behave very similarly to the domestic-owned enterprises of the same sector and size class (see Reger et al. 1998). Furthermore, foreign-owned enterprises may have R&D funds available from their parent company.

Although small and medium-sized enterprises (SMEs) have a rather limited significance on the overall level of R&D expenditure in a national economy (which is mainly driven by the large enterprise segment), they do represent the vast majority of enterprises in each country. Their behaviour concerning contacts in, and co-operation with, science therefore, determines the absolute level of ISR. The level of engagement in ISR by SMEs strongly depends on their absorptive capacities and their involvement in innovation activities. A large proportion of SMEs with continuous R&D performance and patent activities are reported in Austria, Belgium, Finland, Sweden and, to a lesser extent but currently increasing strongly, Ireland (No data is available for the USA and Japan).

The high-tech orientation of the business enterprise sector is commonly regarded as a major prerequisite for effective ISR. High-tech sectors such as pharmaceuticals and biotechnology, information and communication technologies, new materials, aerospace, and optical and precise instruments, are regarded as sectors in early stages of product cycle developments. Therefore, fundamental innovations, the application of new scientific findings, and high R&D investments are characteristic for those sectors, including a strong relation to science. Consequently, high-tech sectors are sometimes called 'science-based industries'. A large proportion of high-tech sectors in total BERD (i.e. exceeding a one third share) are reported in Finland, Ireland, Italy, Sweden, the UK and the USA.

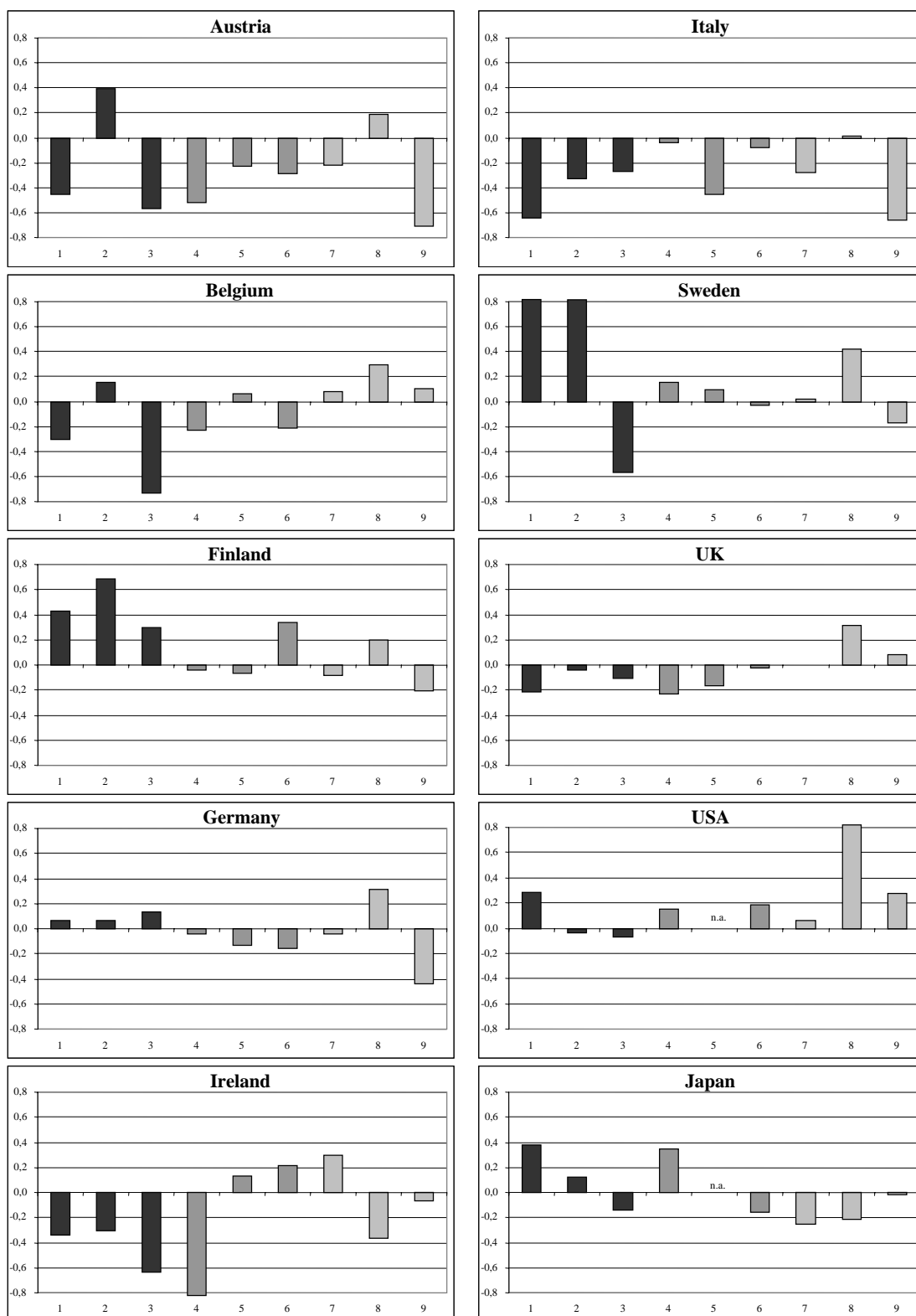
Table C.1.2: Indicators of Knowledge Production Structures in Selected EU Countries, USA and Japan at the End of 1990s (shaded fields: values significantly above EU average)

Variable	Indicator	Austria	Belgium	Finland	Germany	Ireland	Italy	Sweden	UK	USA	Japan
R&D Expenditures	BERD in % of GDP	0.83	1.06	2.18	1.63	1.01	0.55	2.77	1.20	1.95	2.10
	HERD in % of GDP	0.52	0.43	0.63	0.40	0.26	0.25	0.80	0.36	0.36	0.42
	GOVERD (incl. non-profit private) in % of GDP	0.13	0.08	0.39	0.34	0.11	0.22	0.13	0.27	0.28	0.26
	Change in GERD as % of GDP 1988-1998 (in %-points)	+0.28	-0.01	+1.14	-0.57	+0.58	-0.20	+0.86	-0.32	-0.04	+0.22
Size Structure and	Share of enterprises > 10,000 employees in BERD in %	~ 25	~ 40	~ 50	~ 50	0	~ 50	~ 60	~ 40	~ 60	~ 70
Ownership of Firms	Share of BERD carried out by domestic enterprises in %	~ 40	~ 70	88	83	25	77	84	60	88	99
R&D Activities by Innovative SMEs	Share of continuously R&D performing small manufacturing enterprises (20-50 employees) (1996)	24	33	29	27	35	17	34	26	n.a.	n.a.
	Share of continuously R&D performing medium-sized manufacturing enterprises (50-249 employees) (1996)	53	58	59	44	52	38	52	36	n.a.	n.a.
Patent Activities by Innovative SMEs	Share of small manuf. ent. having applied a patent (1996)	21	19	21	17	17	14	22	11	n.a.	n.a.
	Share of me.-siz. man. ent. having applied a patent (1996)	39	18	43	32	28	27	36	21	n.a.	n.a.
High-Tech Orientation	Share of BERD performed in high-tech in %	36	30	51	32	46	34	37	37	45	32
	Share of BERD performed in medium- to high-tech in %	35	41	15	54	21	41	37	30	25	46
	Share of BERD performed in IT-services, private R&D in %	7	7	9	3	11	9	15	10	15	4
	Number of high-tech patents per 1 million of population (1998)	9	16	70	24	1	4	42	15	20	9
	Triade patents per 1 million of econom. act. population (1998)	79	86	295	177	31	29	381	89	171	223
	Share of enterprises in total basic research performance in %	~ 10	n.a.	n.a.	~ 14	~ 25	7	n.a.	~ 20	25	38
Disciplinary Orientation of Science	Share of natural sciences in total HERD in %	29	~ 30	29	29	44	~ 20	18	31	30	13
	Share of engineering in total HERD in %	11	~ 25	18	20	22	~ 17	~ 34	20	19	24
	Share of NSE in total R&D personnel at PSRE in %	42	~ 90	76	70	~ 75	~ 55	89	~ 75	~ 85	98
Excellence of Science	Impact factor of scientific publications in natural sciences (citations per publication) (1995-99)	4.4	4.7	4.6	4.9	3.5	4.0	5.1	5.4	6.7	3.7
	Impact factor of scientific publications in engineering (citations per publication) (1995-99)	1.8	1.9	1.7	1.8	1.3	1.7	1.9	1.6	2.0	1.4
Financing of R&D	Share of HERD financed outside GUF in %	17	65	47	33	55	~ 20	49	64	> 80	58
	Direct government funding of BERD in % of GDP	0.81	0.47	1.37	1.47	0.54	0.73	2.11	1.39	2.81	0.29
	Venture capital investment in % of GDP (1999)	0.4	2.4	1.7	1.3	1.1	1.4	4.9	8.0	high	low
Market Dynamics in New Technologies	Turnover at ICT markets in % of GDP (2000)	5.9	5.8	6.4	5.7	5.4	5.5	8.3	7.4	8.7	6.6
	Diffusion of internet in % of population (1999)	10.4	13.8	32.2	19.4	12.0	8.7	41.4	21.3	39.8	14.5
	Share of new products in turnover in % (manuf. only, 1996)	31.3	13.9	24.6	44.9	32.2	27.1	30.8	23.2	n.a.	n.a.
	Mobile telephone users in % of population (1999)	51.4	31.5	65.1	28.6	45.6	52.8	58.3	46.3	31.2	44.9

If no year is given, data refer to the latest year available for each country, which is either 1997, 1998 or 1999.

Source: OECD, EU, ICT, EITO, EVCA, ISI-NSIOD, calculations by the authors

Figure C.1.1: Comparison of Major Indicators of Knowledge Production Structures in Selected EU countries, the USA and Japan at the End of the 1990s



R&D Orientation

- 1: BERD in % of GDP
- 2: HERD in % of GDP
- 3: GOVERD in % of GDP

Enterprise Sector Structure

- 4: Share of very large enterprises in BERD in %
- 5: Share of continuously R&D performing SMEs in %
- 6: Share of BERD performed in high-tech in %

Public Science Sector Structure

- 7: Share of natural sciences and engineering (NSE) in HERD in %
- 8: Impact Factor of scientific publications in NSE
- 9: Share of HERD financed outside the general university funds in %

(All values represent the deviation from the EU average)

Sources: see Table C.1.2

However, these shares in R&D expenditure are not always associated with an obvious high-tech orientation in the field of patents as an output indicator for R&D investment. Here, Ireland, Italy and the UK show rather weak performances - given their high incidence of high-tech companies - while Germany and Japan show a strong high-tech orientation with respect to patents (but not so much with respect to industry structure).

In science, there are less distinct variations in structural characteristics with respect to disciplinary structure and scientific research performance. Concerning disciplinary structures, the proportion of natural sciences (chemistry, biology, mathematics, informatics, physical and environmental sciences) and engineering (including agricultural sciences) may be taken as an indicator for the share of public R&D performed in potentially industry relevant fields. In almost all countries, the share of the above two groups of scientific disciplines in total HERD is between 40 and 50 %, higher shares being reported by Belgium and Ireland. Concerning the PSRE sector, all countries except Austria and Italy show an explicit orientation towards natural sciences and engineering.

With respect to ISR, the quality of the research carried out in public science is highly relevant too. A broad indicator for covering this aspect is the so-called 'impact factor' of scientific publications, which measures the number of scientific citations received by a paper in the field of natural sciences and engineering. Here again, national differences are small, and on an aggregate level there seems to be a rather high quality of research available in each country considered. In comparison, the USA public science system seems to perform best, while Ireland and Japan report impact factors significantly below the average. However, variation among sub-disciplines is considerable and each national public science system shows a distinct specialisation in some fields of technology with top-level international research.

A third aspect of public science structures is the type of R&D financing in HEIs with respect to the degree of competitive orientation. Here, very different national approaches may be observed. In the USA, Belgium, the UK, Japan, Ireland and Sweden, more than 50 % of R&D funds are provided on a competitive basis, while in Austria, Italy and Germany, this share is rather low, and between 67 and 83 % of HERD is provided via the general university fund. Competitive R&D financing in public science - even in cases where it is solely from public sources - may stimulate the general outward orientation of public science and increase its ability to acquire industry money too.

In modern innovation theory, industrial innovation is depicted as an interactive system of technology driven factors, market driven factors, and behavioural and organisational characteristics of the innovating firm (see Kline and Rosenberg 1985, Rothwell 1991). Of course, market characteristics and market forces play a prominent role for ISR in the course of innovation activities too. Among others, the dynamics in new technologies, the internationalisation of a national innovation system, the financing of R&D and innovation, the market for highly qualified labour, and the "lead market potential" of national economies, may either stimulate or hinder the development of effective ISR (see Beise 2001). Relying on a few, rough indicators of these general market characteristics, Finland, Sweden, the UK and

the USA seem to provide favourable market conditions for strong ISR, i.e. market dynamics provide incentives to enterprises for engaging in science-related innovation activities. Again, behind the aggregate indicators there are huge differences between individual markets.

It must also be borne in mind that cultural and social attitudes which shape the actors perception and outlook on innovation, co-operation, and the role of science in society, are make up another important feature of national innovation systems and is likely to affect the potential for ISR. Alas, cultural attitudes are difficult to measure and there is no systematic information available on the relevance of such attitudes in shaping ISR, or on national differences in such attitudes.

C.1.3 Comparison of Policy-related Framework Conditions

One of the main purposes of this benchmarking exercise is to evaluate the role of policy-related framework conditions for industry-science interactions. In this chapter, we attempt to systematically compare important aspects of these framework conditions, and distinguish four broad categories. Table C.1.3 presents characteristics of ISR-related *public promotion programmes* and other types of policy measures, including the overall layout of science & technology (S&T) policy, as well as the role of *legislation* and legal settings of ISR. Table C.1.4 summarises characteristics of ISR-relevant *institutional settings in public science institutions* as well as assessments on the relevance and structure of public and private *intermediaries* which attempt to foster industry-science relations.

In every country, there are considerable efforts by policy makers to foster knowledge and technology transfer between industry and science, and to stimulate and direct the R&D efforts of enterprises with respect to technology policy objectives. The level of intervention is revealed, for example, in government funding for private business enterprise R&D. The government share in total BERD is especially high in the USA, Italy, the UK, Austria and Germany and includes, with exception of Austria, significant R&D funding for the weapons and space industry. In each of the EU countries analysed, a significant volume of money is spent on directly strengthening ISR, amounting to 0.1 ‰ (Italy) to 0.9 ‰ (Finland) of GDP. Compared to the total R&D financing of the state sector, the financing for ISR-related programmes is between 2 % (Italy) and 11 % (Finland, Ireland), although it must be noted that only a portion of ISR-related public financial promotion is associated with R&D activities.

One major indirect measure which supports ISR is the strengthening of enterprises R&D activities through public funding of R&D projects or providing tax allowances for R&D expenditure. All of the EU countries considered in the analysis provide direct financial support for business R&D. Although no direct stimulus to use scientific knowledge is provided by these measures, a strengthening of research activities increases the demand for researchers, increases the absorptive capacities of enterprises, enlarges the financial fund available for contract research to science, and may produce future demand for co-operation with scientific institutions. Financing of industry R&D as part of stimulating ISR is a major

issue in Austria, Finland, Germany, Ireland, Italy, the UK and the USA, and has gained increasing attention in recent years. In the case of Sweden however, direct public R&D support to enterprises is restricted to the field of defence-related R&D. In Japan, public financing of company R&D plays a negligible role. Instead, innovation policy puts more emphasis on providing favourable market conditions for R&D, including the areas of education policy, foreign trade and home market protection policy, policies related to financial markets, and sectoral policies.

Among the direct policy measures to foster ISR, the following measures are well-established practices in almost all countries:

- Specific financial support for collaborative research, mostly provided within thematic programmes or for special groups of enterprises (SMEs, enterprises in less developed regions), is the recipient of the largest portion of public money for ISR promotion and is still gaining in importance in most countries. This type of supportive measure is based on the assumption that direct collaboration between industry and science researchers is the most effective way to transfer knowledge and exchange competence. Public financing reduces barriers to entry for such collaborations, such as uncertainty of outcome, information asymmetries, and the problem of individually appropriating the results of joint research efforts. The EU framework programmes for research and technology development also follow this line of ISR promotion and represent major additional funding for collaborative research.
- Specific financial and informative support to SMEs for ISR activities is often particularly targeted towards those SMEs not yet engaged in R&D activities or co-operation with public science. Support is directed towards improving innovation management capabilities, enlarging R&D and innovation financing, and direct grants for stepping into collaborative research relationships, contract research, personnel mobility, training and consulting services. In Austria, Ireland and Italy - as a result of the dominating SME structure of the enterprise sector - most ISR-related measures are especially targeted towards SMEs but are not specifically limited to them.
- Researcher mobility from science to industry is fostered by various measures, including subsidies to enterprises (typically small enterprises) for covering labour costs when employing young researchers. Other measures aim towards building up partnerships in graduate education, such as scholarships for PhD students for carrying out a PhD at an enterprise or related to a research problem defined jointly with an enterprise. Some countries operate exchange programmes for mutual visits and temporary placements, although the volumes are low and their effect upon the overall pattern of personnel mobility between industry and science is minor (such as Austria, Belgium, Germany, Ireland, Italy). In the UK however, the teaching company scheme is regarded as a major measure in this field. In some countries like Finland, Sweden and the USA, researcher mobility is fostered indirectly through the establishment of long-term oriented joint

research facilities bringing researcher from industry and science together and thus stimulating mutual mobility.

Table C.1.3: Characteristics of ISR-Related Promotion Programmes, S&T Policies, and Legislation in Selected European Countries, USA and Japan at the end of 1990s

		<i>Austria</i>	<i>Belgium</i>	<i>Finland</i>	<i>Germany</i>	<i>Ireland</i>	<i>Italy</i>	<i>Sweden</i>	<i>UK</i>	<i>USA</i>	<i>Japan</i>
Overall	Share of government funding in BERD in %	9.8	4.4	6.3	8.0	5.3	13.3	7.6	11.6	14.4	1.3
Financial	Volume of ISR promotion progr. in % of GDP (rough estimates)	~ 0.3	~ 0.2	~0.9	~0.4	~ 0.3	~ 0.1	~ 0.4	~ 0.3	~ 0.5	n.a.
Support	Expend. for dir. ISR prom. progr. in % of government R&D financ.	~ 5	~ 5	~11	~ 4	~ 11	~ 2	~ 4	~ 5	~ 5	n.a.
Public	R&D financing for enterprises ("indirect ISR promotion")	■ ■ =	■ =	■ ■ =	■ ■ =	■ ■ >	■ >	■ =	□ =	■ ■ =	■ =
Promotion	Tax allowances to enterprises for ISR activities	■ =	□ =	□ =	□ =	□ =	■ >	□ =	■ =	■ ■ =	■ ■ =
Program-	Specific financial support for collaborative/contract research	■ =	■ ■ >	■ ■ >	■ ■ >	■ ■ >	■ =	■ ■ >	■ ■ >	■ ■ =	■ ■ =
mes	Specific support to SMEs for ISR activities	□ =	■ ■ >	■ ■ >	■ ■ >	■ ■ >	□ =	■ ■ >	■ =	■ ■ =	■ =
	Support for joint R&D facilities	■ ■ >	□ =	■ =	■ =	■ >	□ =	■ ■ >	■ ■ >	■ ■ =	■ ■ >
	Technology focus of ISR promotion (Centres of Expertise etc.)	■ ■ =	■ =	■ ■ >	■ ■ >	□ =	□ =	■ ■ >	■ ■ >	■ ■ =	■ ■ >
	Support for researcher mobility	■ =	■ ■ =	■ ■ =	■ =	■ =	■ ■ >	■ =	■ ■ =	□ =	□ =
	Support for (under)graduates training at enterprises	□ =	■ ■ =	■ ■ >	□ =	■ =	□ =	■ ■ =	■ ■ >	□ =	□ =
	Promotion of employees training in HEIs	□ =	□ =	■ =	□ =	□ =	□ =	□ =	■ >	□ =	□ =
	Promotion of co-operation in curricula/education planning	□ =	□ =	■ ■ >	□ =	□ =	□ =	■ >	□ =	□ =	□ =
	Raising transfer capacities in public science institutions	■ >	■ >	■ ■ >	■ ■ >	■ =	■ >	■ =	■ ■ >	■ =	■ ■ >
	Support to public science researchers for IPR activities	■ >	■ =	■ ■ >	■ >	□ =	□ =	■ =	■ ■ >	□ =	■ ■ =
	Start-up promotion in HEIs/PSREs	■ ■ >	■ ■ >	■ ■ >	■ ■ >	■ >	■ ■ >	■ ■ >	■ ■ >	■ =	■ =
	Promotion of networking initiatives	■ ■ >	□ =	■ ■ >	■ ■ >	■ >	■ =	■ ■ >	■ ■ >	■ ■ >	■ ■ =
	Awareness measures both in industry and science	□ =	□ =	□ =	■ ■ >	□ =	■ =	■ ■ >	■ ■ >	□ =	□ =
	Regional approaches to ISR promotion	■ ■ =	■ ■ =	■ ■ >	■ ■ >	□ =	■ ■ >	■ ■ >	■ >	■ =	■ ■ =
S&T Policy	Long-term strategy to strengthen R&D and ISR	■ >	□ =	■ ■ =	■ >	■ ■ >	■ >	■ =	■ ■ >	■ ■ =	■ =
	Bringing together ISR responsib., centr. co-ordinat. of ISR policies	□ =	□ =	■ ■ =	□ >	■ ■ =	■ ■ >	■ ■ >	■ >	□ =	■ =
	Strategic vision of S&T policy	■ =	□ =	■ ■ >	■ >	■ >	□ =	■ >	■ >	■ ■ =	■ ■ =
Legislation	Regulation of contract and collaborative research	+ =	~ =	~ =	~ =	~ =	~ =	+ >	~ =	+ =	- =
	Researcher mobility: civil servants law	- =	- =	- =	- >	~ =	- =	~ =	~ =	~ =	~ =
	Researcher mobility: flexibility (salaries, leave of absence)	- >	~ =	- =	- >	~ =	- =	+ >	~ =	+ =	- =
	Regulation in HEIs concerning co-operation in graduates education	~ =	- =	+ =	~ =	~ =	~ =	~ =	~ =	+ =	~ =
	Regulation in HEIs concerning training/further educ. for employees	~ =	~ =	~ =	~ =	~ =	~ =	+ =	~ =	+ =	~ =
	Intellectual property regulations in HEIs concerning patenting	+ =	- >	+ =	+ >	- >	~ >	+ =	~ =	+ =	- =
	Intellectual property regulations in HEIs concerning royalties	~ =	+ >	~ =	~ >	+ =	~ >	~ =	+ =	+ =	- =
	Intellectual property regulations in PSREs concerning patenting	+ =	+ =	+ =	+ =	~ >	~ >	+ =	- >	~ =	~ =
	Intellectual property regulations in PSREs concerning royalties	+ =	+ =	+ =	+ =	+ =	~ >	+ =	~ >	~ =	+ =
	Regulation on start-ups from public science conc. indiv. researchers	~ =	~ =	~ =	~ =	~ =	~ =	~ =	~ =	+ =	~ =
	Regulation on start-ups from public science conc. investm. by HEIs	~ =	- =	~ =	~ =	~ =	~ =	~ =	+ =	~ =	~ =

Note: ■ ■: high relevance; ■: important; □: less important/missing; >: currently gaining public attention; =: no major current change public attention; +: positive impact; ~: neutral impact; -: negative impact

Source: national reports

Table C.1.4: Characteristics of ISR-Related Institutional Settings in Public Science and Intermediary Structures in Selected European Countries, USA and Japan at the end of the 1990s

		<i>Austria</i>	<i>Belgium</i>	<i>Finland</i>	<i>Germany</i>	<i>Ireland</i>	<i>Italy</i>	<i>Sweden</i>	<i>UK</i>	<i>USA</i>	<i>Japan</i>
Institutional Structure at Public Science	Universities (incl. technical univ., univ. of arts, univ. of theology, other specialised univ.)	76	82	59	52	61	53	82	58	64	58
	(share in total R&D in public science in %, partly estimates)										
	Polytechnics and HE colleges	~ 1	~ 2	~ 1	2	5	~ 1	4	~ 1	-	3
	Primarily transfer-oriented PSREs	11	10	18	~ 7	~ 12	~ 22	14	19	24	
	Large research centres with strategic mission		-	-	16	-		-			
	PSREs specialised on basic research	8	3	22	~ 11	-	~ 24	-	12	5	39
	Departmental PSREs, others	4	3		12	~ 22		-	10	7	
Institutional Setting at Public Science	Competition-based R&D financing in HEIs	□	■ ■	■	■	■ ■	□	■	■ ■	■ ■	□
	Competition-based R&D financing at PSREs	■ ■	■ ■	■ ■	■	■	■	■ ■	□	□	□
	Third mission of universities	□	□	■ ■	■	■	□	■ ■	■ ■	■ ■	□
	Technology transfer as part of evaluation in HEIs	□	□	□	□	□	□	□	□	■	□
	Relevance of private HEIs	□	□	□	□	□	□	□	■	■ ■	■
	Incentives for ISR activities at the level of individual researchers	■	■	□	■	■	□	■	■	■ ■	□
	Thematically specialised PSREs with transfer mission	■	■ ■	■ ■	■ ■	□	■	■ ■	■	■	□
	Industry representatives in advisory boards etc. of PSREs	■ ■	■ ■	■ ■	■ ■	□	■	■ ■	□	■	□
Intermediary Infrastructure	Technology transfer offices in HEIs	■	■ ■	■ ■	■	■	■	■	■ ■	■ ■	■
	Commercialisation enterprises, transfer institutes in HEIs	□	■ ■	■ ■	■	■ ■	■	■	■ ■	■ ■	■
	Science parks and incubators in HEIs	□	■	■ ■	■	■	□	■ ■	■ ■	■ ■	■ ■
	Intermediaries at the level of industry associations etc.	□	□	□	■	■	□	■	■ ■	■	□
	(Semi-)public technology and innovation consultants for SMEs	■	■	■	■ ■	■ ■	■	■	■	□	■
	Regional consulting networks	□	■ ■	■ ■	■ ■	■	■ ■	■ ■	■	■	■
	Information service provision for technology transfer	■	■	■	■	□	■	■	■	■	■
	Significance of private intermediaries	□	■ ■	□	■ ■	□	□	■	■ ■	■ ■	□
	Joint industrial research networks at sector level	■	■ ■	□	■ ■	□	□	■ ■	□	■ ■	■ ■

Note: ■ ■: high significance; ■: important; □: less important/missing

Source: national reports

- Direct interaction between industry and science is eased by spatial proximity between the actors involved, reducing transaction costs and raising awareness for the situation and needs of the partner. Therefore, ISR-related policies often follow an explicit regional approach and attempt to build up regional innovation networks.
- Industry representatives often mention the lack of transfer capabilities in public science (with respect to both individual researchers and the organisation) as a major barrier to interaction. Therefore, policy attempted to overcome this bottleneck by employing a variety of measures, including the establishment of technology transfer offices, ISR-related training for academics, and awareness measures. Transaction costs should be reduced, information asymmetries eliminated, and professionalism increased in transfer activities.
- Promotion of start-ups from science is currently a well-established element of ISR policy in Europe. Although first approaches date back to the 1970s and 1980s, (with the establishment of incubators and science parks) it gained new attention in the second half of the 1990s, and almost all countries introduced new supportive measures. Many of them are based upon regional approaches, combining infrastructure (incubators), consulting and pre-seed financial support.
- There are also a number of policy initiatives in the field of strengthening the use of IPR in public science, including financial support, expert advice, and administrative support. Nowadays, most universities run their own technology transfer/liaison offices, or have access to consulting networks that support scientists in patenting and licensing activities.

In recent years, also some new types of ISR supportive measures have been established:

- ISR promotion became increasingly thematically oriented and special programmes have been introduced in new fields of technology, such as biotechnology, multimedia, and new materials. The technology focus of ISR promotion is particularly strong in Finland, Germany, Sweden and the UK.
- The second half of the 1990s also saw an increase in programmes aimed at establishing joint R&D facilities and promoting long-term oriented networks of competence between industry and science. For many programmes, the US university-industry research centres have been a good practice model. In many countries, a competitive bottom-up approach was carried out, i.e. the design of the co-operation between industry and science, the thematic focus, and the volume of joint R&D activities was freely decided by the participating consortia, and the best proposals were selected by an independent Jury (see the Centres of Competence Programmes in Austria and Sweden, as well as similar initiatives in the UK).
- Some countries have started to tackle perceived bottlenecks in ISR through an integrated, comprehensive approach by implementing measures that address various fields of ISR at the same time. The German federal government announced an action programme in

March 2001, putting special emphasis on adjusting institutional settings in public science, giving support for commercialisation and start-up activities, and raising the absorption capacity in SMEs. In the UK, the government started several new initiatives in 1998/99 to stimulate ISR. In Japan, the Basic Law for Science and Technology of 1995 attempted to remove several legal barriers to interaction and to establish incentives in public science. In Italy, a new law (no. 297) addresses the reorganisation of the universities and the simplification of procedures for the support of scientific and technological research, for the diffusion of technologies and for the mobility of researchers.

Areas of ISR which have received relatively little attention by public policy so far are further professional education for enterprise employees in public science institutions and the co-operation between enterprises and HEIs in curricula planning and the design of higher education courses.

Effective public support for ISR often needs a long-term approach as it attempts to change structural features of innovation systems and traditional attitudes and behaviour of actors. Therefore, a long-term-oriented, strategic, science and technology (S&T) policy may be regarded as a favourable element of ISR-related policy. Furthermore, responsibility for ISR-related policy areas is often split up amongst several authorities and this complicates the co-ordination of policies. Finally, a strategic vision of S&T policy can give important orientation points to private actors and public science institutions, leading to a convergence in the direction of R&D and innovation activities, including the utilisation of synergies. In this respect, Finland and Ireland may be viewed as good practice examples. Italy has just started to make similar efforts to those that Finland and Ireland made during the 1980s and 1990s, respectively. In the UK, there was also a shift towards a coherent S&T policy at the end of the 1990s, putting a main emphasis on the long-term oriented strengthening of ISR. In Germany, increasing effort is directed towards a more stringent, comprehensive policy of promoting different types of ISR, including a new Action Programme on ISR. In Austria and Sweden, a re-orientation of S&T policy towards ISR is just under way.

Legislative issues (i.e. laws and legal regulations affecting ISR) are perceived by most national experts as having only small effects on the performance of ISR, in a positive or negative sense. However, in some areas there are impeding regulations for ISR:

- In most countries analysed, many researchers in public science fall under the umbrella of civil servants law. Due to retirement regulations, wage systems, and legal mobility constraints (e.g. leave of absence etc.), there are low incentives for these researchers to move into industry, even when there are significant differences in salaries. Furthermore, civil servants law sometimes restricts secondary activities, including carrying out R&D for private clients.
- Employment regulations applicable in public science institutions are often characterised by a low flexibility concerning individual arrangements on salaries, working times, and duration of employment contracts. This may complicate the temporary exchange of

researchers between industry and science and makes it difficult to attract researchers from industry to move into public science.

- There are quite different regulations concerning the use of IPRs in public science. In Austria, Finland, Germany and Sweden, there is the system of 'teachers exception' in HEIs which means that the IP of inventions belongs to the individual researcher who is free to decide whether to apply for IPRs and to commercialise a patent. This regulation is viewed as a method of increasing the propensity to patent but gives little incentives to engage in commercialisation activities as they are costly and the future royalty income is very uncertain. Therefore, the elimination of the 'teachers exception' is under discussion in these countries and in this regard, the German Federal Government has proposed a new regulation that will shift IPRs to the HEI. At the same time, the supportive infrastructure for commercialising patents in HEIs is improved in these countries. In the other countries and generally in the PSRE sector, IPRs belong to the organisation, and there exist different schemes for individual remuneration of patenting activities and for commercialising inventions (e.g. patent offices). As a result, both the number of patent applications and the royalty income is positively affected by such a regulation.
- Aside from this direct ISR-related legislation, other fields of regulation may have a significant effect upon ISR, including: taxation (e.g. tax credits for R&D), regulation on start-ups (e.g. liberal regime for new firm set-up), anti-trust law (e.g. fostering market competition, reducing market entry barriers) and overall IP regulation (e.g. rapid adjustment of patenting regulations to new scientific developments). The USA is often mentioned as providing generally favourable legal framework conditions for ISR. However, the effect upon the level of ISR is not straightforward as the example of Japan cited in Hane 1999 shows. Although the general legal framework of the areas outlined above is not very different, the level of ISR is much lower in Japan.

The institutional setting in public science is strongly affected by the effectiveness of public research organisations in knowledge and technology transfer to industry. There are very different models of how technology transfer is incorporated in an organisation. Some institutions have as their main mission, the support of enterprises in their R&D efforts and actively carrying out technology transfer, while other institutions focus heavily on excellent scientific research, the transfer being a (arbitrary) by-product of their activities. Leaving some national peculiarities aside, the following broad categories of public science institutions can be distinguished:

- Universities represent the major public science institution in all of the countries analysed. Their primary common characteristic is carrying out research and education in an organised and unified way, with education viewed as a public service financed by separate government funds for universities. The orientation of research activities is very highly related to the international scientific community and freedom of scientific research is viewed in many countries as a constituent element of their research activities. However, the university sector is highly heterogeneous containing obviously transfer oriented

institutions (often called universities of technology), specialised universities in the field of arts, theology, economy etc., and private universities with a greater focus on education (except in the USA, where they are among the main R&D performers in science). Universities are by far the dominant public science institution (in terms of R&D activities) in Austria, Belgium, Ireland and Sweden. In all other countries they represent at least more than half of all public R&D capacity.

- Polytechnics and higher education colleges play an important role in the education system in many countries, including Belgium, Finland, Germany, Ireland, Sweden and the UK. Their level R&D activities are very small, however, due to the specialisation of education activities. In some countries, polytechnics also play an active role in innovation-related co-operation with SMEs, offering practice oriented consulting and technology advice. Therefore, some countries attempt to strengthen this element of the public science system with respect to ISR, e.g. by increasing R&D capacity and by establishing separate transfer infrastructures. In Germany, there is a long tradition of this policy and the Steinbeis transfer centres represent a good practice case for involving polytechnics in ISR and making their special knowledge available to SMEs.
- Primarily transfer oriented PSREs exist in all EU countries analysed and are mostly regarded as part of an innovation support infrastructure provided by the government. The main common characteristic is that carrying out technology transfer is the main mission of these PSREs. As a consequence, contract research in industry is a prominent activity and a major source of income. Within this type of institution, there are several organisational approaches, such as the Fraunhofer Society in Germany which is comprised of about 50 specialised, medium-sized institutes, VTT in Finland (and similarly ARCS in Austria, VITO in Belgium and ENEA in Italy) and these offer a wide range of applied research within one single organisation, as do the large number of independent semi-public research institutes in Sweden.
- Large public research centres are often devoted to carry out R&D in fields perceived as strategic by the government. Until the 1970s and 1980s, they were often associated with nuclear or space research, and in the UK and the USA, military oriented research centres still represent a large fraction of PSREs. In the 1990s, some of them were downsized or re-directed towards civil research, including a stronger transfer objective. Therefore, in some countries such as Austria, Germany Italy and the UK, the boundaries to primarily transfer oriented PSREs are not so strict. Large public research centres are often equipped with research facilities as a precondition to several types of basic research in natural sciences and therefore act as a co-operative partner for other basic research institutions, such as universities.
- PSREs specialised in basic research are an institution type with special relevance in Austria (Academy of Sciences), Germany (Max-Planck-Society, some Leibniz-Institutes), and the UK (research council institutes). They should complement and strengthen basic

research carried out in universities but often produce new knowledge also relevant to enterprises.

- Departmental PSREs carry out research and R&D services (such as testing, measuring, standardisation) as part of the public services provided by the government. In countries with a federal system, they also have a strong regional focus. Departmental PSREs are significant in Germany, Italy, the UK, the USA and Japan.

There are several characteristics of the institutional setting (i.e. the way R&D is organised, ISR activities are handled, and contacts with industry are institutionalised) which either positively or negatively affect ISR activities by providing incentives or barriers to individual researchers and research teams. Among the incentive schemes which are very common in the countries analysed are the following:

- Competition oriented financing of HEIs and PSREs has increased in all countries during the last two decades (see A.1) and has reached a high level of significance in many countries. Most often, a competitive model of R&D financing in public research is associated with a re-organisation of the way R&D is carried out, i.e. project organisation, control, and application of a stricter time schedule to achieve project outputs. These behavioural changes in research may be viewed as a precondition for contract and collaborative research with industry. Furthermore, cuts in basic financing put pressure on public science institutions to look for additional funding, including money from industry.
- In recent years, universities have been given a 'third mission', i.e. knowledge and technology transfer to industry and the community was incorporated as a part of their main objectives. In the UK, Sweden, Finland, Germany and Ireland, such changes in the institutional objectives of HEIs took place, although to varying degrees, and only partially accompanied by effective institutional reforms. In the USA, a 'third mission' was a constituent for many HEIs from their conception while in many countries there are primarily transfer-oriented universities, often called Universities of Technology.
- There are different types of individual incentives for ISR activities depending on the type of institution and the type of ISR. For example, such incentives cover compensation for ISR activities in the field of teaching obligations, sharing income from royalties, premiums and one-time extra earnings, and access to additional funds for strategic research.
- In order to foster technology transfer to science-based industries, many PSREs specialise in certain technologies and establish dense networks with the enterprises in the respective fields of technology. Their main objective is to support innovation by carrying out both strategic and applied research, including a large fraction of joint R&D projects. Good practice examples for such technology-specific PSREs with an institutional setting favourable for technology transfer can be identified in Belgium (VIB, IMEC), Germany (some of the Leibniz-Institutes, most of the Fraunhofer-Institutes) and Ireland (in the field of food and agriculture). In Finland, Germany and the UK, there are similar specialised

institutes within the HEI sector, often organised as separate Institutes (see Digital Media Institute at TUT, "An-Institutes" at German universities) or as research laboratories run jointly by the university and enterprises. The latter approach is very common in the USA and they are known as University-Industry Research Centres (UIRC) which are commonly held as best practices in technology specific co-operation. The specialised PSREs often have industry representatives on advisory boards or even as shareholders.

Some incentive schemes for stimulating ISR activities in public science institutions are rather rare today, however. The most worth of mention is the absence of considering technology transfer activities in evaluations in HEIs. While there is an increasing trend to base research financing in HEIs on performance indicators (research assessment exercises), these performance indicators do not cover ISR activities in an appropriate way. This is a clear disincentive for individual researchers to invest time and resources in establishing and maintaining industry contacts and to re-orient their research efforts towards industry needs. However, many academics perceive the consideration of transfer activities in research evaluations as inadequate as it diverts from pure scientific research, which should be the main objective of HEIs in the field of research.

The provision of intermediary structures is an approach for fostering ISR followed by every country. The main purpose is to compensate for several failures in the knowledge market resulting in a low level of interaction between industry and science. Such market failures are related to high transaction costs and significant information asymmetries. By providing support in the terms of searching for partners, negotiating contracts, and building up mutual trust, an attempt to overcome these inherent barriers to interaction is made. Today, there are a huge variety of supportive intermediaries. The following types exist in most of the countries considered in our benchmarking exercise:

Technology transfer offices (TTOs) in HEIs: Separate offices providing consulting, administrative support, and also sometimes direct financial support for technology transfer activities by researchers of their organisation, including support in the fields of IPR, start-ups, contract research, training and education, and dissemination of R&D results to industry (presentation at fairs, contact forums etc.). In Belgium, Finland, Germany, Sweden, the UK and the USA, almost all HEIs and PSREs have such TTOs and this type of intermediary is also quite common in all other countries.

Independent commercialisation enterprises: In order to improve commercialisation efforts, some HEIs and many transfer oriented PSREs have established separate companies responsible for commercialising R&D results, including licensing of patents and carrying out R&D consulting. This type of intermediary is receiving increasing attention as it is expected to provide higher levels of organisational flexibility and better incentives for effective commercialisation than the TTO model.

Technology and innovation consultants for SMEs: In some countries, there are specialised consulting networks which attempt to stimulate the use of scientific knowledge and co-

operation with science by SMEs. In Germany, both industry associations (Chamber of Commerce) and semi-public networks at regional levels (such as the Steinbeis transfer centres) offer consulting services and technology advice to SMEs and try to act as intermediaries in establishing science contacts. In some countries, there are also regional consulting networks that focus on SMEs as their main clients in industry.

Intermediaries at the level of industry associations: Attempts to foster ISR by using intermediaries is also a major issue at the level of industry associations, chambers of commerce and other sectoral representation bodies. The main purpose of intermediary infrastructures provided by these actors is the support of their membership enterprises in innovation activities as a part of a broader strategy to raise competitiveness. Among other methods, building up and maintaining science contacts is one activity and includes the organisation of fairs where meetings can take place. In some countries, there is a long tradition of industry-based intermediaries with strong science links, such as the AiF-network in Germany, which offer enterprises easy access to scientific knowledge available in PSREs and HEIs in the fields of technology relevant to the particular sector.

Science and technology parks: Starting in the 1970s in the UK, science and technology parks are now a wide-spread form of providing infrastructure support to ISR activities. Although differing largely in size and structure, some common features may be identified. Science and technology parks are located close to HEIs or PSREs, most often follow some form of public-private partnership involving stakeholders from industry, science and (local) government and provide infrastructure for joint R&D facilities and for enterprises looking for close contact with public science institutions. Many science parks also run *incubators* for start-ups from science. In some countries, university assigned incubators often show a particular technology focus and some are regarded as promising approaches (Belgium, Finland, Ireland, the UK).

Information provision services, information brokers: This is a rather new form of fostering industry-science links by using new information and communication technologies. In most countries databases exist on competence, research activities and co-operation experiences in public science institutions, on the technologies in enterprises or research institutes, on innovation projects and technology demand by enterprises, and on new technologies (patents, other types of inventions) introduced by enterprises and public science. Many of these services are currently internet-based and allow for direct contact between the potential partners. A major shortcoming of such a service is the large number of them and their small degree of knowledge on the availability of such services among the target groups.

The significance of public intermediaries in ISR must be seen against the significance of private enterprises offering intermediary services to enterprises and public science institutions. In some countries including Belgium, Germany, the UK and the USA, these private intermediaries play a prominent role. Together with representatives from industry associations, they often criticise public activity in intermediaries for distorting markets for consulting services.

Furthermore, in some countries there are special networks for joint industrial research among enterprises which partly covers the tasks of intermediaries. In Germany, there is the AiF-network of more than 100 sectoral research centres, in Belgium and Sweden there are many semi-public thematically oriented PSREs, and in the USA there are more than 500 joint research ventures carrying out R&D for enterprises in the respective sectors. As these joint industrial R&D consortia also have close contacts with the science sector, they can act as a bridge between private and public research.

Despite the large number of intermediaries which exist today in each country, there is no clear evidence on their effectiveness in fostering ISR. According to most experts, many intermediaries are rather small and therefore, often lack a critical mass to stimulate ISR effectively. Critics of publicly financed intermediaries focus on the following issues:

- The network of intermediaries is often too large, their supply of services difficult to survey and often, unknown to the target group.
- Many intermediaries do not specialise in certain services but attempt to provide a huge package of support services which often do not correspond properly with their level of available resources.
- There is a growing supply of private intermediary services and public intermediaries may upset competition.
- The effectiveness of intermediaries is rather limited. As most of the critical success factors for ISR (such as appropriate incentive schemes and institutional settings, the level and orientation of R&D activities at both industry and science, legislation) cannot be shaped by intermediaries themselves, they often fail to foster ISR given the existing barriers to interaction.

C.1.4 ISR and National Innovation Systems: the Main Conclusions

In Figures C.1.2 to C.1.11 an attempt is made to summarise the different national models of how industry-science relations work in each of the countries analysed. Therefore, the level of interaction and the major forces that either facilitate or restrain the transfer of knowledge and technology between the two sectors are characterised. Special attention is paid to the various framework conditions for ISR and their likely effects on the performance of ISR. The main lessons learned from comparing the "national models of ISR" are summarised below:

- First there are high-technology specialised countries (Finland, Sweden and the USA) with an enterprise sector strongly oriented towards science-based industries, a strong and diversified science-base and favourable market conditions for high-tech innovation (which in fact would have at least partially stimulated the development of a high-tech industry). The high industry demand for scientific knowledge in high-tech industries is associated with an ISR-oriented public science base, and the combination of demand and supply factors which cause a high level of ISR (the somewhat lower intensity in ISR displayed in

Sweden can be attributed to a lack of data for some channels). Such national innovation systems may be characterised as "science-based technology leaders".

- Another group of countries (Belgium, Germany, and the UK) have a less pronounced high-tech orientation of industry but rather follow a cumulative path of technology development along traditional technology trajectories (such as engineering & machinery, chemicals, vehicles, electrical machinery, base materials). Their domestic markets seem to be less challenging with respect to new technology breakthroughs, and the enterprise sector is more strongly oriented towards rapid adoption of new (process) technologies in order to utilise scale economies. ISR is a major feature in these countries too, although interactions seem to rest more on short-term oriented R&D collaboration in order to solve specific technology problems along a given technology trajectory.
- A third group of countries (Austria, Ireland and Italy) show innovation system characteristics that focus more on fast-follower strategies in technology diffusion in traditional industries, and niche-market strategies that demand close interaction with customers and suppliers. Such innovation systems typically focus more on incremental product innovations and sources of innovation are much more market based than science based. As a consequence, demand for interaction with science is lower in industry as the science system would not have developed a strong orientation towards technology transfer. Nevertheless, such innovation systems show remarkable technology performances with respect to productivity growth and market shares in their niche markets.
- A special case is Japan. Despite knowledge production structures that are rather similar - at least on an aggregate level - to those in Germany or the UK, and despite a significant high-tech sector in microelectronics and communication technologies, the intensity of ISR is considerably lower. This rather low level of ISR is not a current phenomenon but a typical feature of the Japanese innovation system in the post war period. The Japanese innovation system shows that a high-technology strategy can be successfully realised by enterprises without making use of science by using a traditional way of interaction, i.e. carrying out joint research and commercialising new scientific findings. However, public science plays an important role in industrial innovation in Japan too. Its main contributions include supplying industry with a sufficiently large number of well-trained graduates, to serve industry as technology consultants on an informal base, and to disseminate information on new research findings, including technology inventions made at universities, within personal networks, in exchange for general donations by enterprises for research.
- Care must be taken, however, not to oversimplify the relation between knowledge production structures and the intensity of ISR. Behind the aggregate pattern, there is a high diversity in the level of industries, fields of technology, and public science institutions. Within a certain sector or field of technology that show similar market conditions for enterprises and demand for scientific knowledge in all countries, variations

in ISR are high. The same is true for some types of interaction between industry and science that are less dependent upon industry structures, such as mobility or training & education. Such variations cannot be attributed to differences in knowledge production structures but must have different causes.

- To some extent, these variations may be explained by factors subsumed under the term "cultural attitudes". In countries with a low level of ISR, national experts report little awareness for, or even objection to, interaction with the other side by both industry and science. It is unclear however, what the cause and the effects are as low demand for interaction favour institutional settings, incentive schemes, and individual behaviour not oriented towards facilitating ISR. In Japan, cultural and social traditions, as well as the specific history of industrial innovation, appear to favour little strong interactions between industry and science. In the case of Belgium and the UK, a high awareness for technology transfer between public science and industry can be identified as facilitating factors for the observed high level of ISR in these countries.
- Among the policy-related framework conditions, policy initiatives aimed towards encouraging ISR (such as promotion programmes and an ISR-oriented science and technology policy) are reported as being most influential. Especially strong positive impacts may be identified for Finland, Germany, Ireland and the UK, where S&T policies follow explicitly an ISR-focussed and long-term oriented strategy, supported by several promotion programmes and other financial incentives. In Belgium, Italy and Japan, public promotion of ISR appears to be less significant, both in volumes and influence upon ISR. In the case of the USA, ISR are promoted more indirectly through strong public support for R&D and technology development in enterprises (especially in strategic areas such as military research, space research and health research, and for SMEs) and by providing or supporting ISR-oriented infrastructures in public science, such as university-industry research centres. The extent to which such policy initiatives successfully address barriers to ISR, and the critical factors in the design of such measures, will be discussed in C.2 in the context of the different areas of ISR a certain programme relates to.
- There are different types of legal regulations which act as barriers to ISR but their impact on ISR performance is viewed in general to be small, by national experts. There are, however, some exceptions including personnel mobility and the use of IPR in public science. Civil servant laws and inflexible administrative regulations in public science are reported to act as a barrier to the mobility of researchers. Concerning IPR regulations, there seems to be a trade off between a regime that allows individual researchers to hold IP on their inventions (this regulation stimulates patenting but restricts commercialisation of IPR) and one which leaves IP in the domain of the employer (i.e. the HEI or PSRE). The latter regime provides a better framework for IPR commercialisation but rests on additional incentive schemes to stimulate individual researchers to get engaged in patenting activities. There is some doubt whether a proper incentive scheme can be established in institutions such as universities where individual researchers have to follow divergent objectives (high quality basic research, education of graduates). Despite the

great attention paid to the issue of IPR in public science, our benchmarking results suggest that this is in fact, a rather minor channel of knowledge transfer between industry and science, and that there may be some overemphasis on it when compared with other important areas, such as training, education and personnel mobility.

- An institutional setting in public science favourable to ISR activities is a major precondition for utilising the potential for co-operation between industry and science, while unfavourable settings in some types of public science institutions seem to impede ISR to some extent. One example is the lack of consideration of ISR activities in evaluation and a centralised transfer approach in some large public research centres which gives little incentives for individual researchers to increase engagement in the field of industry contacts. On the other hand, some institutional peculiarities foster ISR although this is only a side effect of the regulation, e.g. the practice of temporary working contracts for research assistants and project oriented employment in HEIs and PSREs in Germany which results in great outward mobility of young researchers, including mobility to industry. Another example is the low education orientation of natural sciences and engineering in the Belgium university system (i.e. a strong effort on research activities) which make these institutes an attractive partner for industry.
- Although all countries analysed show an extensive intermediaries infrastructure, there are only a few examples of them displaying a significant effect upon the level of ISR. Some types of intermediaries, such as tech/innovation centres/"centres of expertise" in Finland and Ireland, SME-oriented transfer networks in Germany, science parks and professional commercialisation units in HEIs in the UK and the USA, and joint industrial research networks in Germany, are good practice examples. Their respective success is related to certain shortcomings in the national knowledge markets which are specifically addressed by the intermediaries.

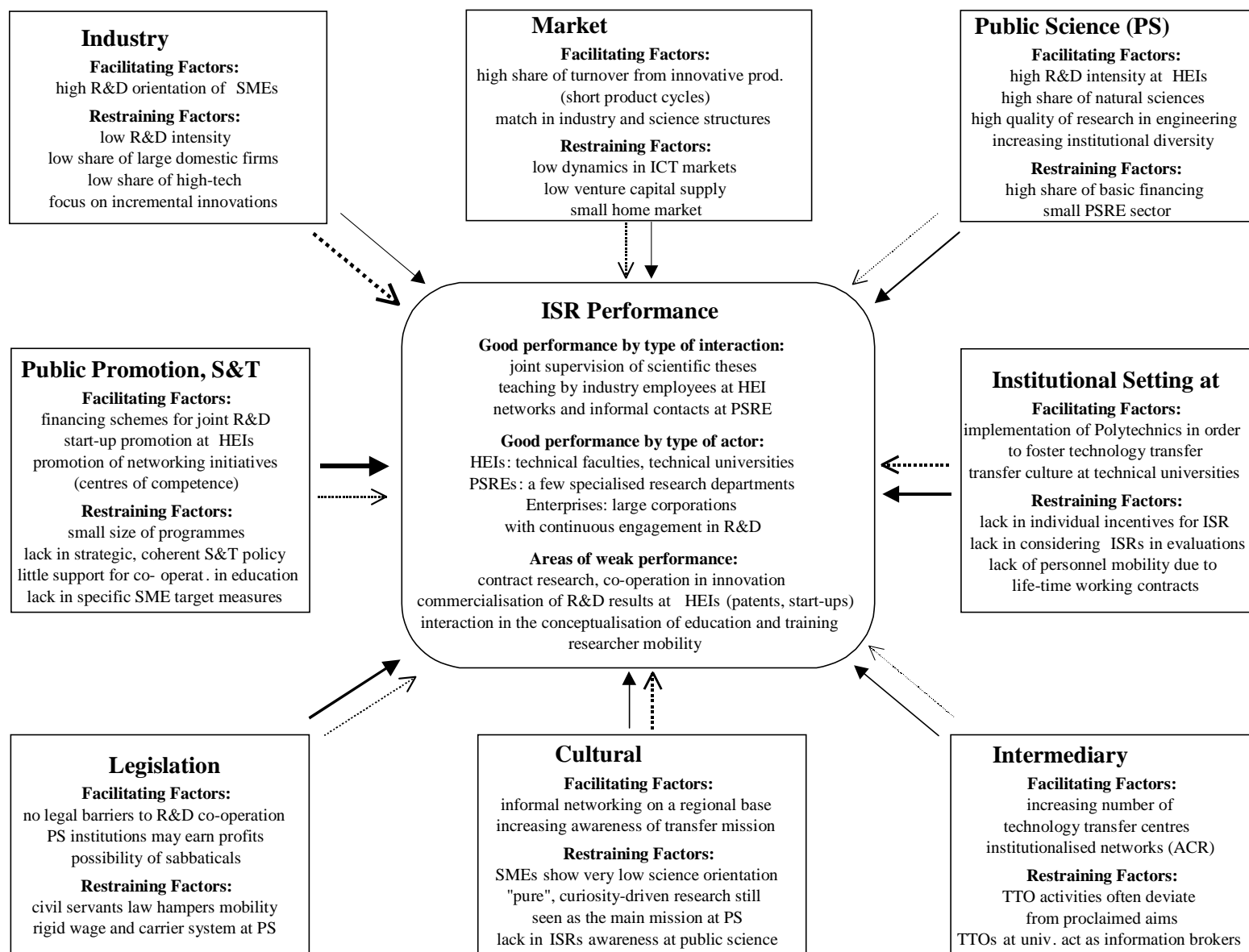
The role of policy-related framework conditions for efficient and effective industry-science relations within a national innovation system may be summarised in the following.

- Firstly, policy-related framework conditions mainly have a supportive role in the way they can foster the utilisation of interaction potentials given by the knowledge production structures. Appropriate measures include:
 - promotion programmes which address certain market failures prevailing in specific technology markets, such as uncertainty, appropriateness, high development costs, or lack in information;
 - a legal framework which avoids explicit barriers to interaction and eases interaction in the various fields, such as mobility, start-ups and IPR;
 - an institutional setting in public science which provides positive incentives for ISR activities (e.g. ISR as a part of evaluation criteria, integrating industry in

strategic decisions on research orientation, individual incentives for ISR activities);

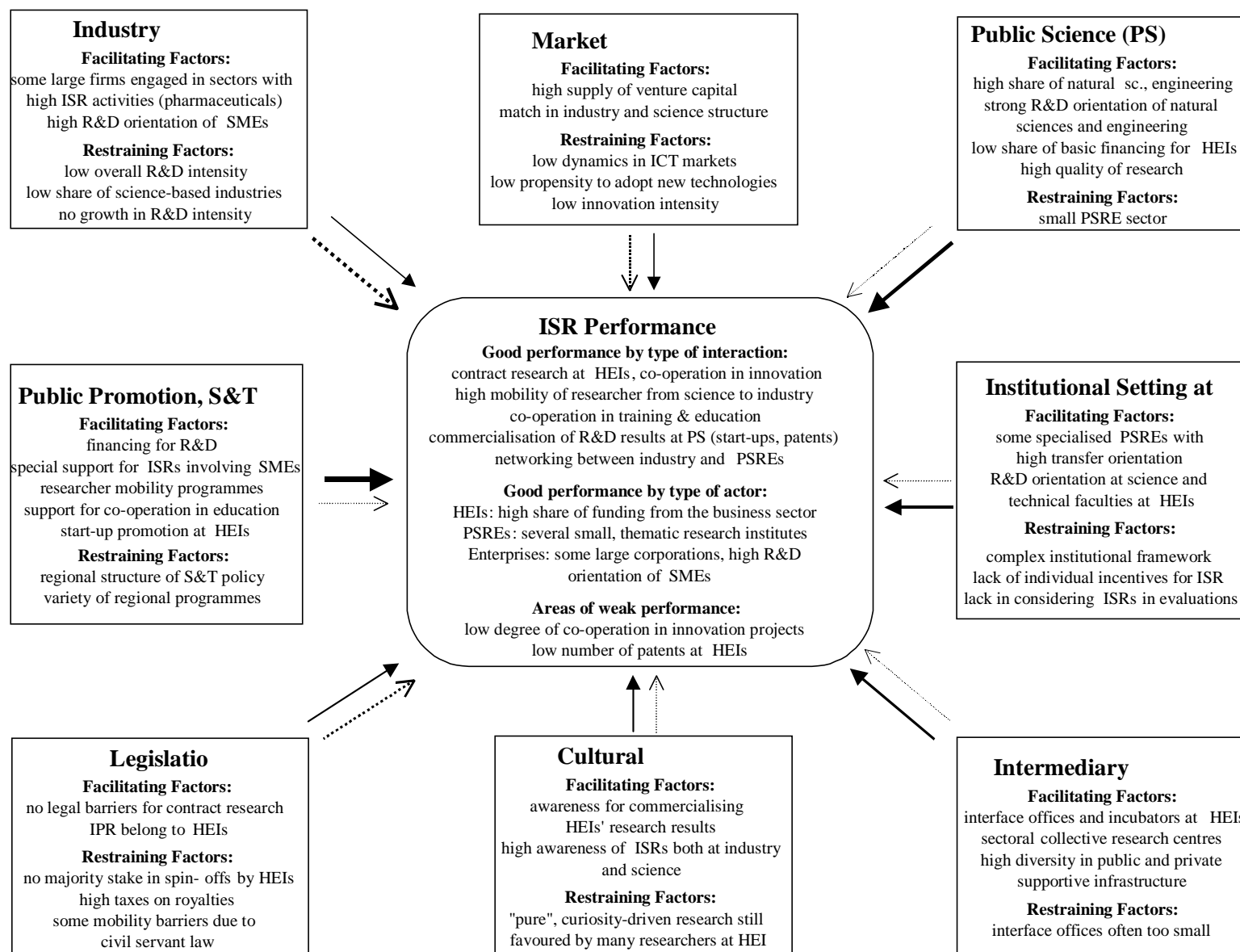
- establishing specialised intermediaries which address specific shortcomings and barriers via consulting, information and supportive services, such as in the fields of IPR and licensing, and start-ups.
- Secondly, a long-term oriented, strategic Science and Technology Policy may be a way for adapting knowledge production structures, i.e. to strengthen R&D activities, to change market characteristics with respect to innovation stimulating demand structures, and to re-orient public science towards the long-term needs of technology developments. Major elements of such a strategic S&T policy which have been applied successfully in Finland and Ireland and are currently being aimed at in Italy, are for example, strong public investment in R&D, a strategic vision of technology policy, the provision of co-operation and interaction oriented programmes in innovation policy, market reforms that foster competition, technology adoption and innovation in future growth markets. The success of such policies depends strongly on sustaining efforts (i.e. following the strategy over a long-term period) and the willingness to make behavioural changes in both enterprises and public science institutions.

Figure C.1.2: "National Model of ISR": Austria



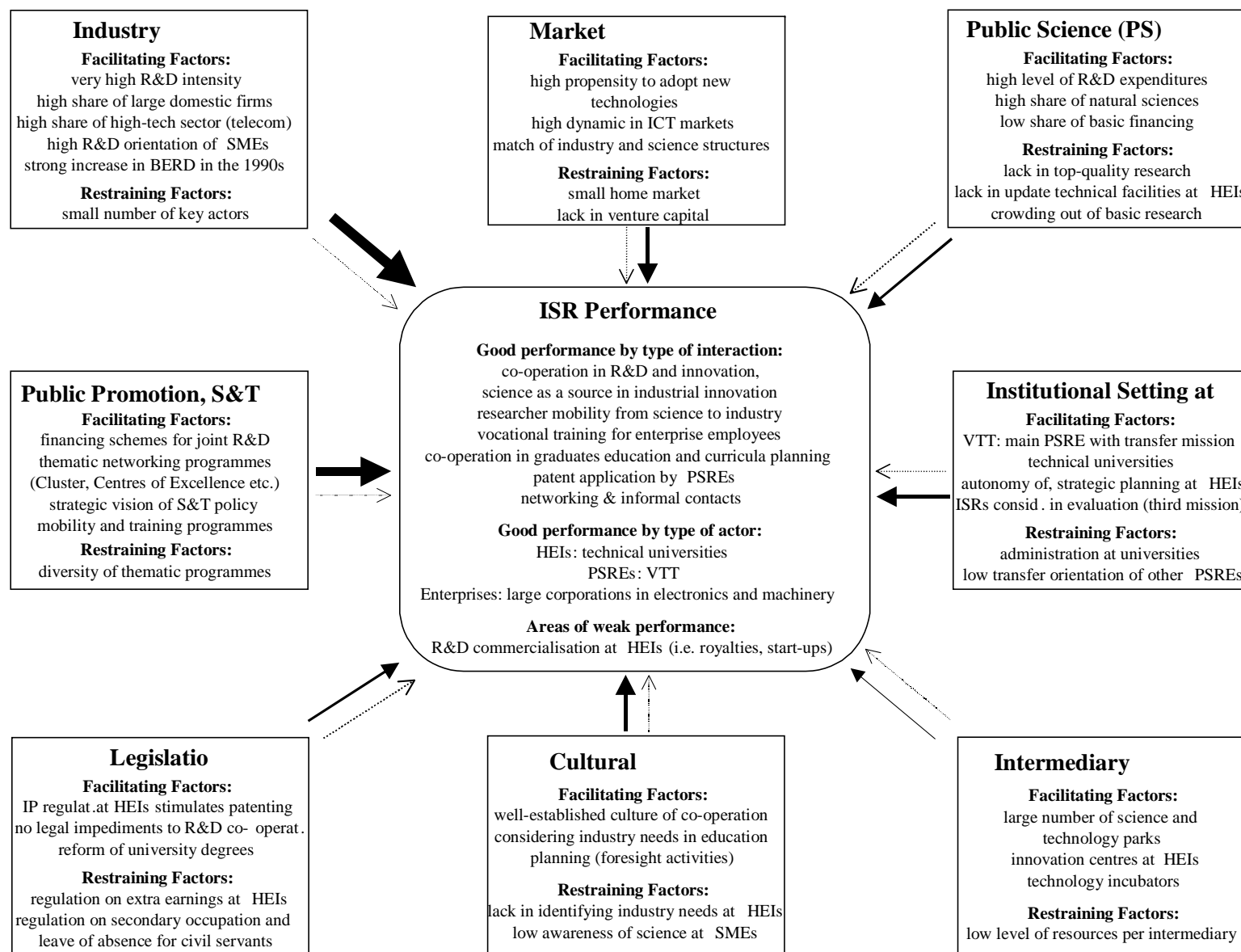
Source: survey and presentation by the authors

Figure C.1.3: "National Model of ISR": Belgium



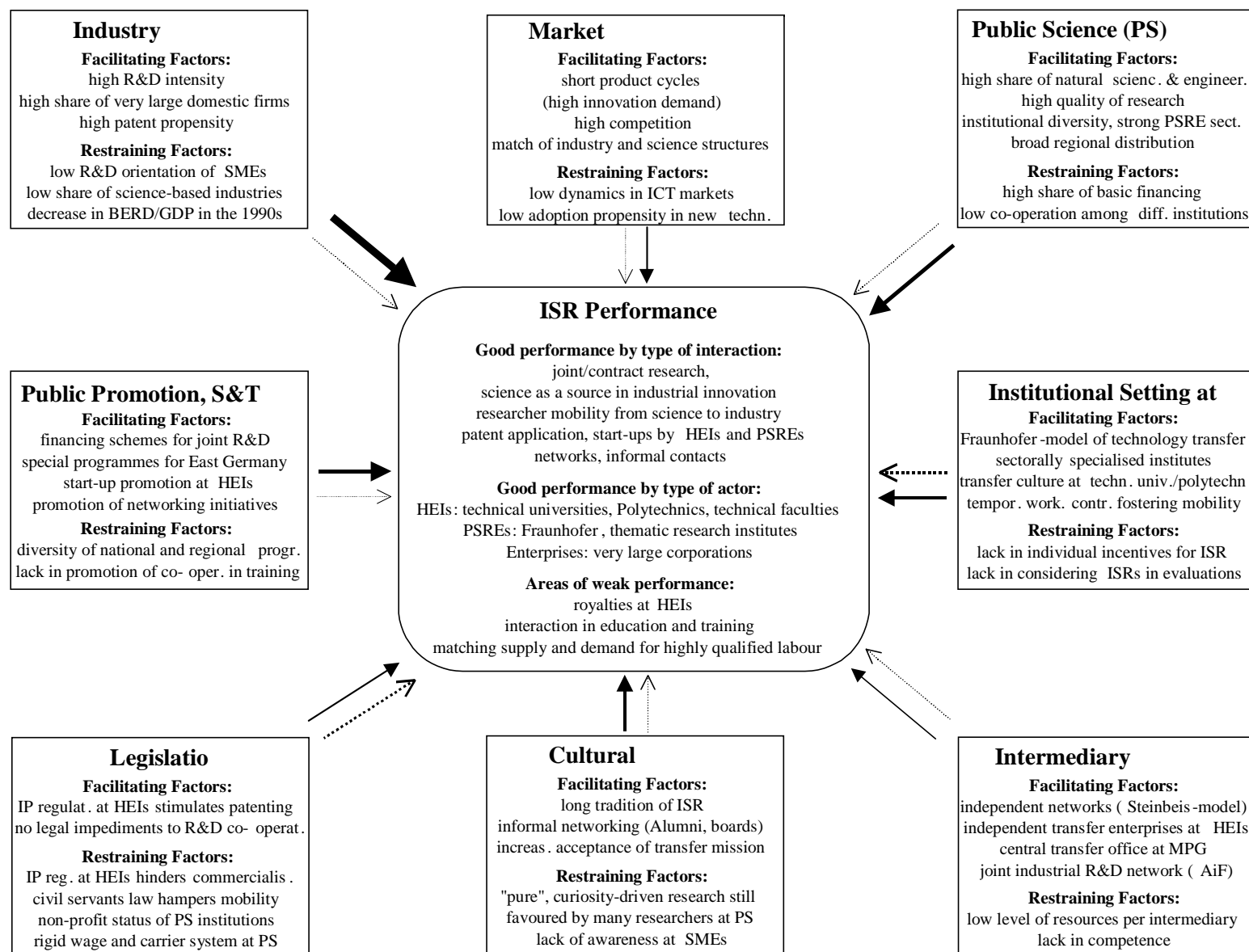
Source: survey and presentation by the authors

Figure C.1.4 "National Model of ISR": Finland



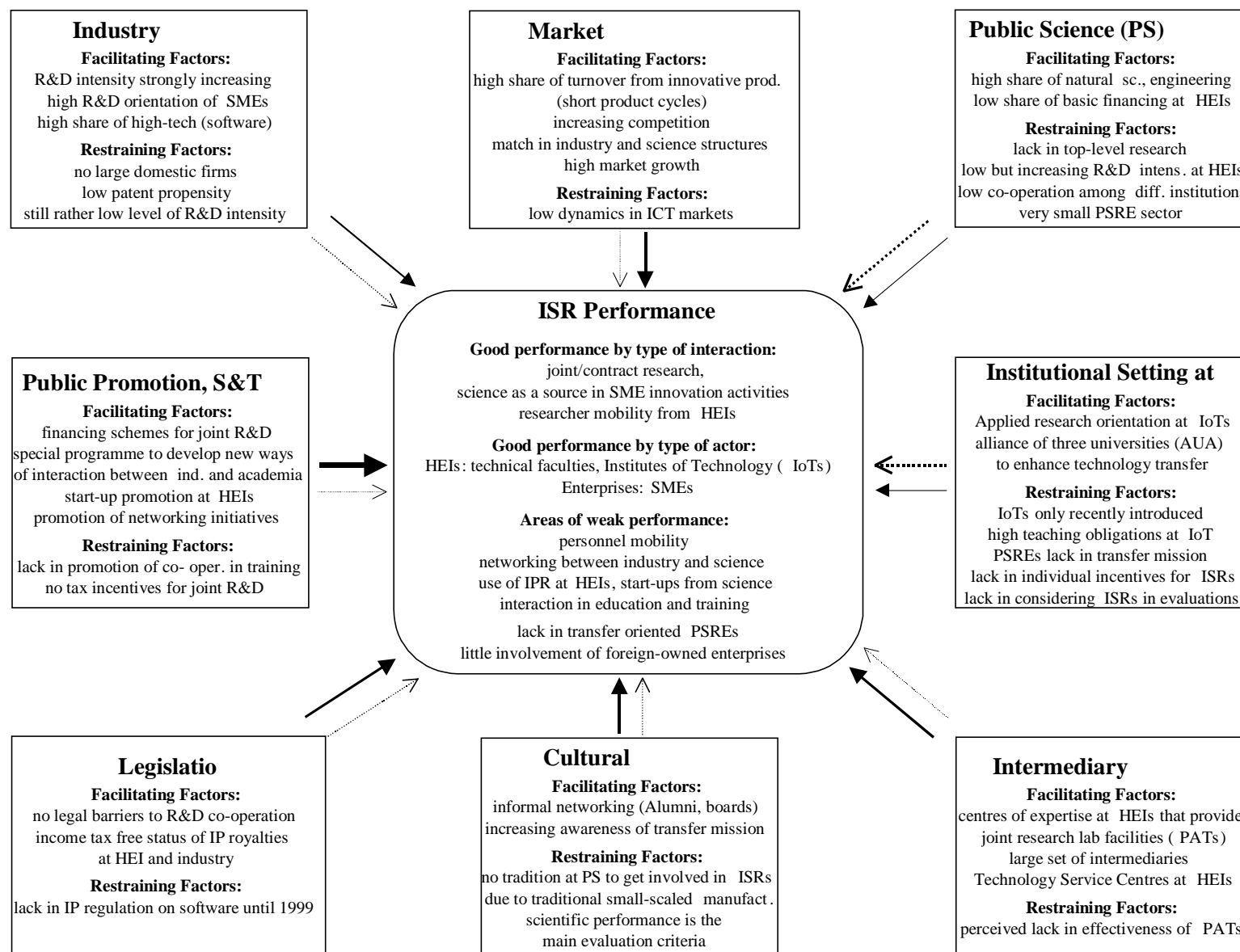
Source: survey and presentation by the authors

Figure C.1.5: "National Model of ISR": Germany



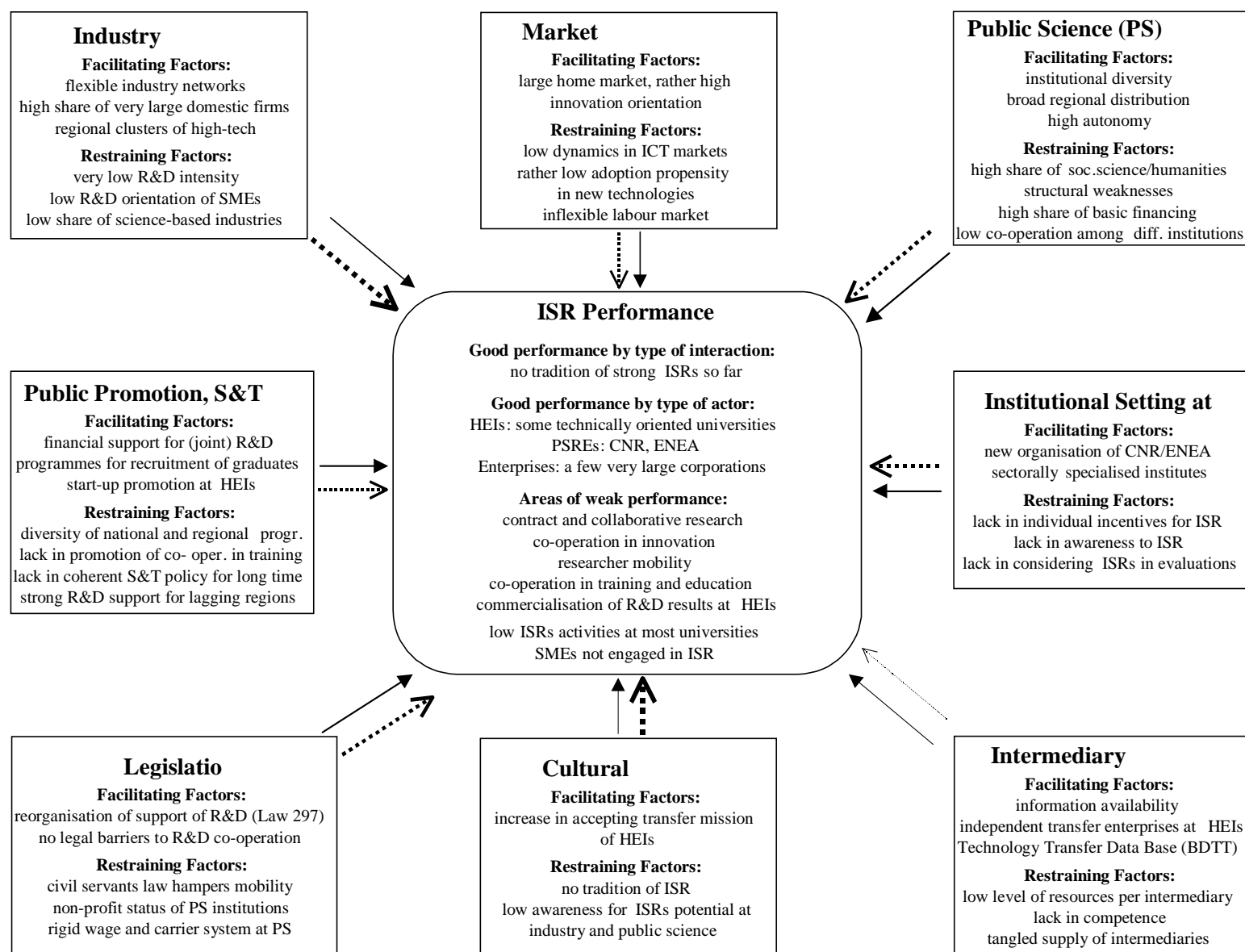
Source: survey and presentation by the authors

Figure C.1.6: "National Model of ISR": Ireland



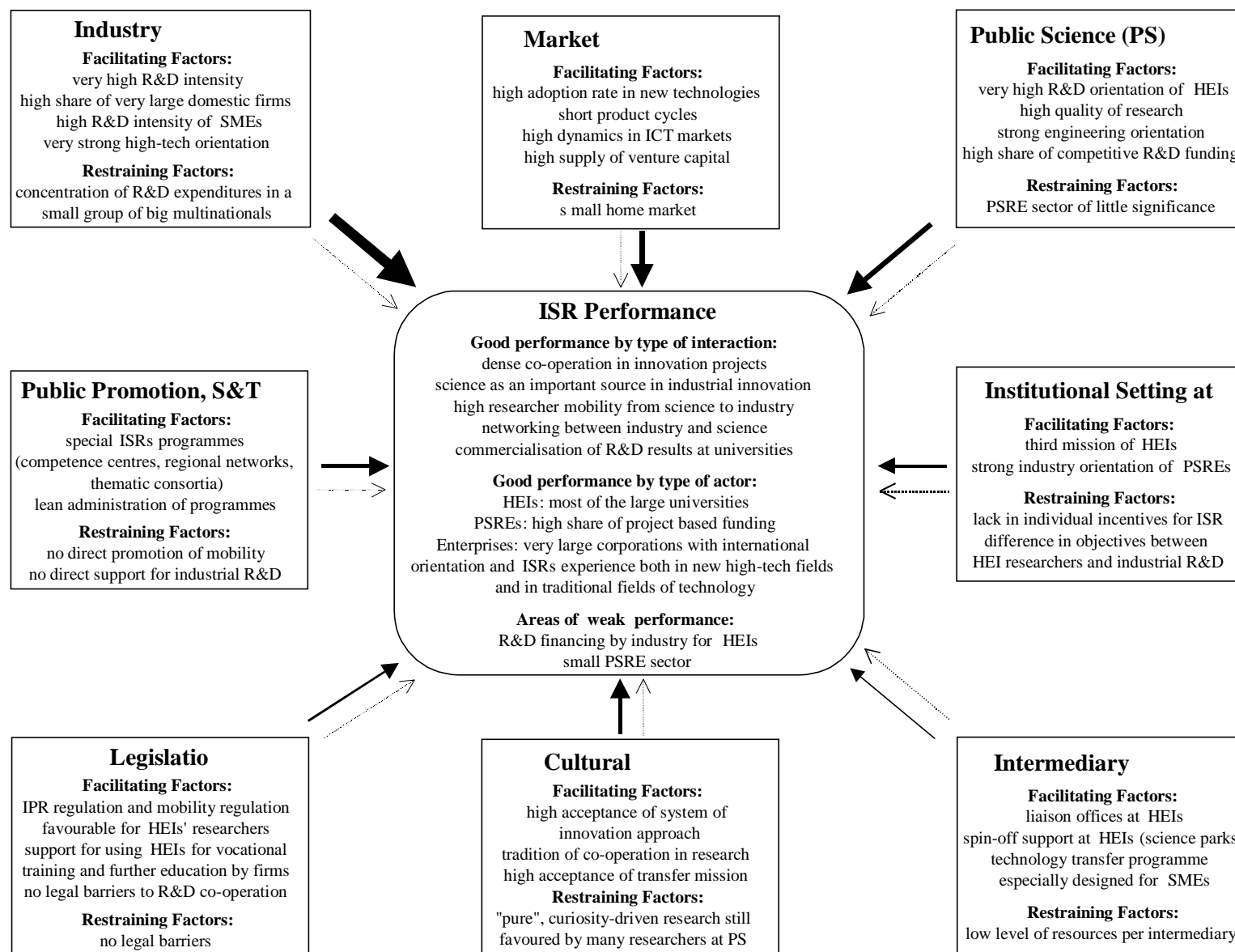
Source: survey and presentation by the authors

Figure C.1.7: "National Model of ISR": Italy



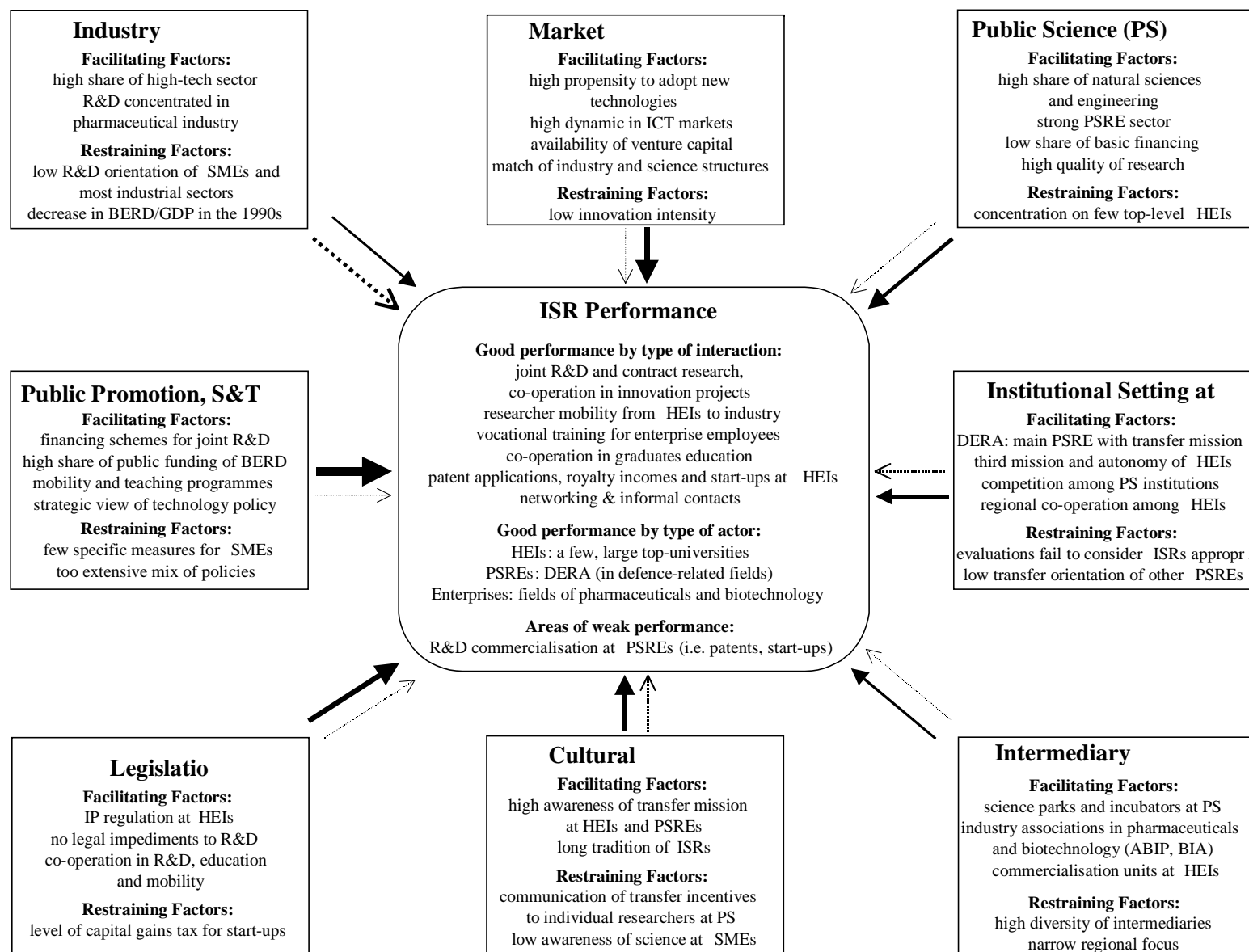
Source: survey and presentation by the authors

Figure C.1.8: "National Model of ISR": Sweden



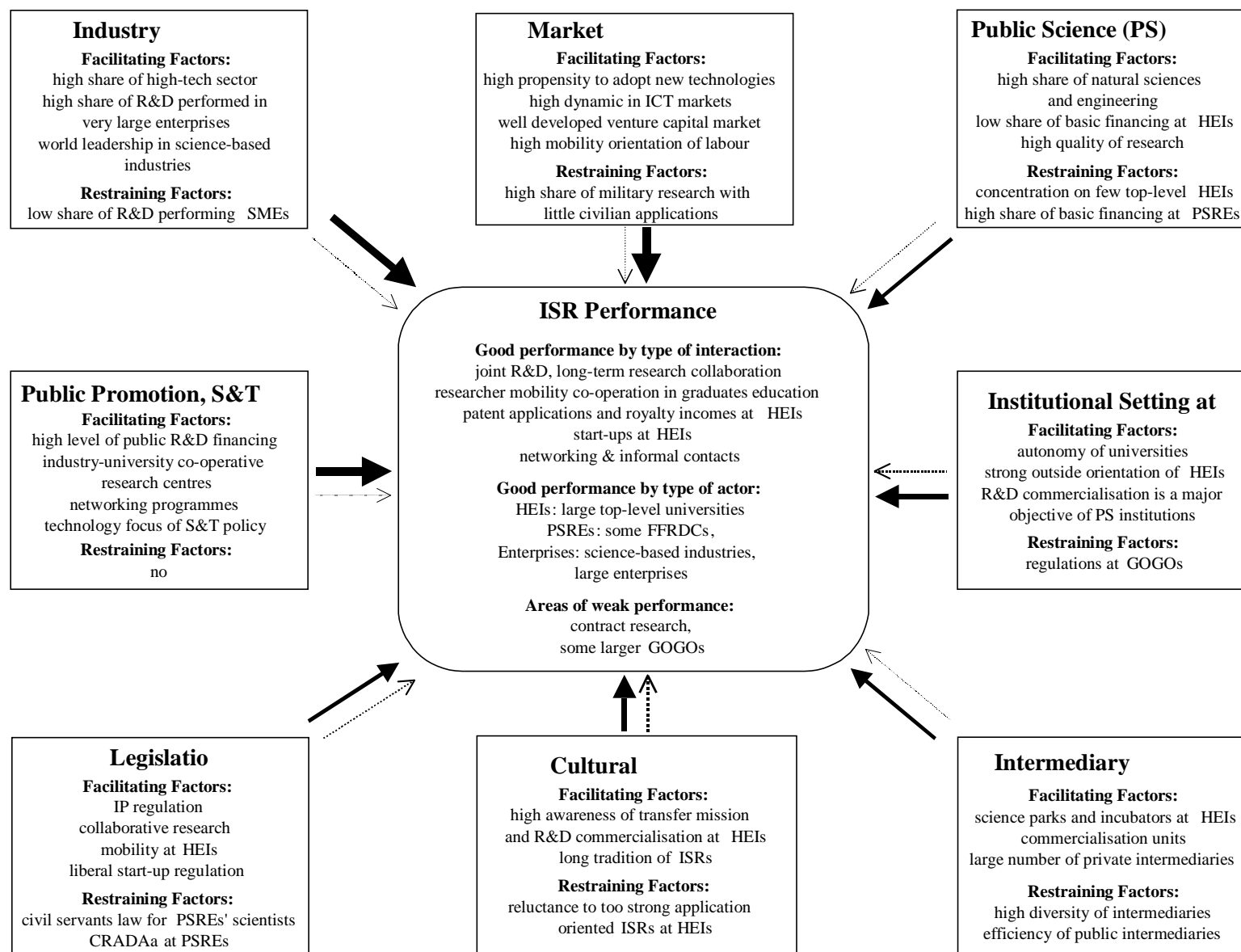
Source: survey and presentation by the authors

Figure C.1.9: "National Model of ISR": the UK



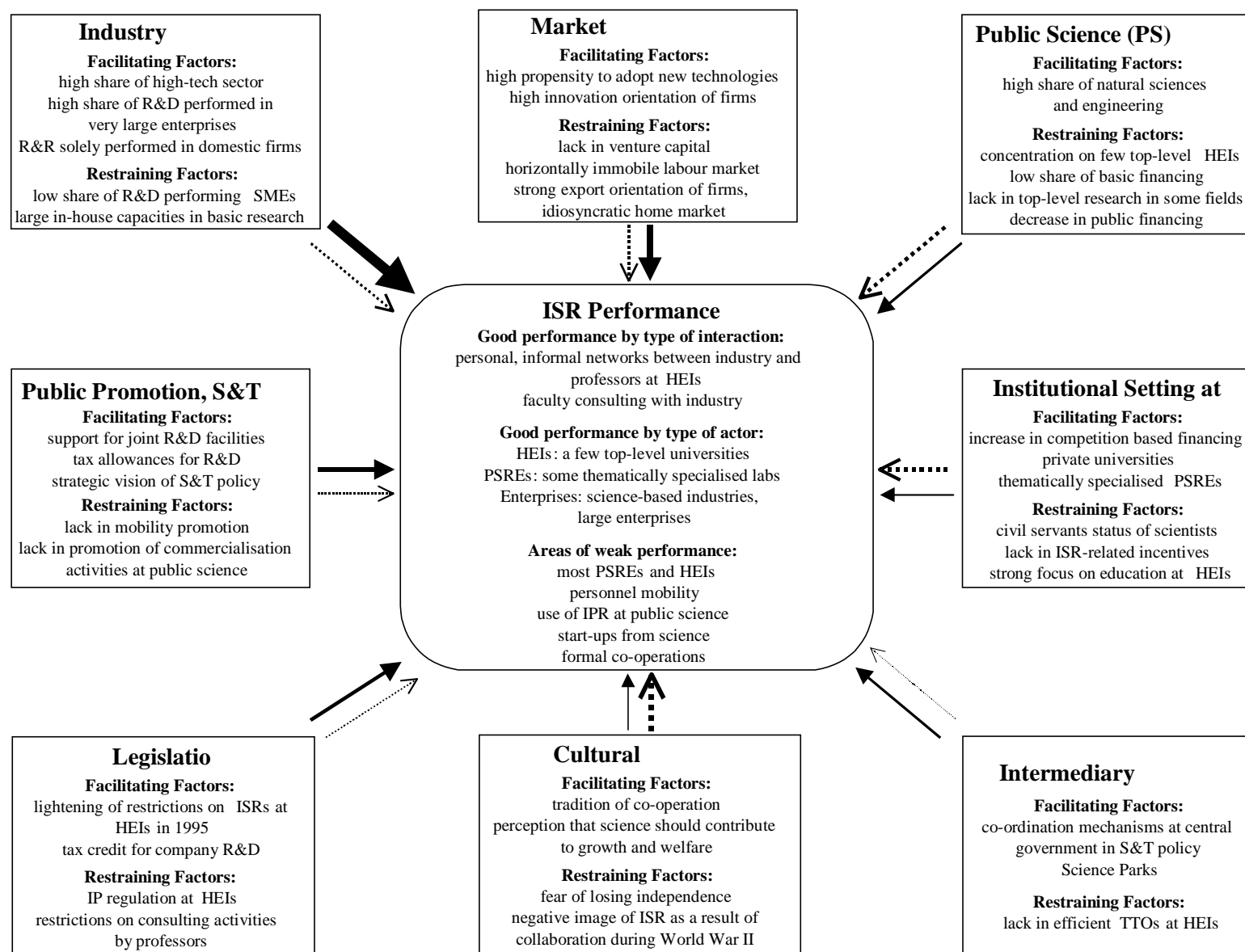
Source: survey and presentation by the authors

Figure C.1.10: "National Model of ISR": the USA



Source: survey and presentation by the authors

Figure C.1.11: "National Model of ISR": Japan



Source: survey and presentation by the authors

C.2 Benchmarking Framework Conditions in Different Areas of ISR

Comparing ISR on a national level provides a valuable insight into some general mechanisms of how industry and science exchange knowledge and technologies, which types of general framework conditions affect the propensity of individual actors to interact and the smoothness of knowledge transfer. Analysis on the aggregated level of ISR of all countries in the study also shows however, that there is a high variety in both ISR performance and the framework conditions within each country, with respect to different *channels of interaction*, different *types of actors* (both in industry and science) and different *fields of technology* (i.e. knowledge market segments). In order to learn from practices in ISR, these specific areas of ISR must be looked at more closely.

In the following paragraphs, we investigate in some more detail, several areas of ISR that have been found to be critical for its successful contribution to innovation and technological change in an economy. The main purpose of this section is to identify good practice in shaping framework conditions in the following areas of ISR:

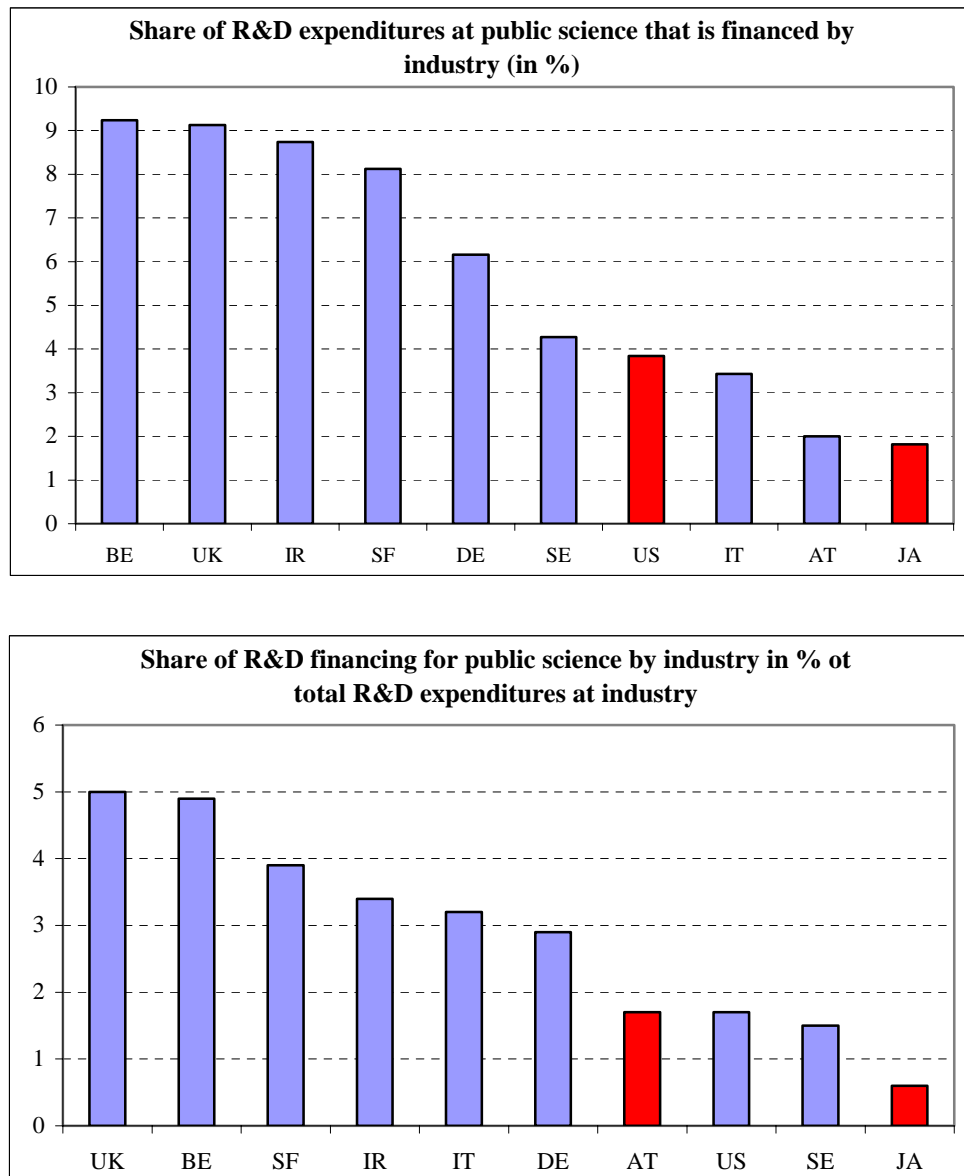
- collaborative research as a means of effective knowledge transfer (C.2.1),
- direct commercialisation of R&D results achieved in public science through the creation of new enterprises (C.2.2),
- employing IPRs as a mechanism for research commercialisation (C.2.3),
- interaction between industry and science in the field of human capital, i.e. researcher mobility, and co-operation in training and education (C.2.4.),
- stimulating SMEs to use public science as a resource in innovation processes (C.2.5),
- strengthening industry-science links in those industries that have special ties to science, i.e. 'science-based industries' such as biotechnology and pharmaceuticals, information and communication technologies, and new materials (C.2.6),
- institutional settings for ISR in public science institutions, paying special emphasis to transfer oriented PSREs (C.2.7).

C.2.1 Collaborative research between enterprises and public science institutions

In most studies focusing on the various types and extent of relations between enterprises and public science institutions, great importance is assigned to collaborative research. *Per definitionem* this type of relationship is characterised by a critical amount of face-to-face contact, which enables the transfer of the implicit parts of knowledge that are crucial for technology development and creation. Although much knowledge is coded and publicly accessible, a major part of the essential knowledge is intangible. It has not been coded because it is specific, complex and often tacit. Apart from individual experience, implicit

knowledge may be acquired through the interaction of different people with complementary sets of knowledge by social exchange relations such as talking and listening or demonstrating and copying (Machlup 1980). Collaborative research also results in a mutual orientation of partners through developing a common language, contracting rules and standardisation of processes and routines. If repeated, collaborative research may develop into stable research networks that constitute a major element of national innovation systems.

Figure C.2.1: R&D Financing by Industry for Public Science Institutions



Source: OECD (2000), calculations by the authors

Figure C.2.1 attempts to give some indication of the relevance of R&D collaboration between industry and science in the countries covered in this report. It shows first, the share of R&D expenditures in public science institutions that is financed by industry, i.e. an indicator of the extent to which public science research is oriented towards direct contribution to industrial

innovation through joint R&D. Second, it shows the share of R&D funds in industry that are allocated for R&D carried out in public science institutions.

Both of these indicators provide some information on the relevance of direct co-operation between industry and science in R&D projects. However, in some countries, direct R&D collaboration is only partially reflected by financial flows. In the PSRE sector in the USA for example, collaborative R&D typically takes place without direct financial contribution from industry to compensate for the costs associated with joint research projects in PSREs. Rather, these costs are covered by the PSRE itself. In Japan, and also in some other countries, R&D collaboration is organised on an informal basis and is dependant upon personal relationships between researchers from industry and science, and need not result in R&D financing by industry. Furthermore, researchers in public science often carry out technology consulting for enterprises on a private basis and receive personal income that is not registered as industry financing for R&D in public science. Moreover, R&D financing by industry for research carried out in public science institutions covers not only collaborative research but also commissioned research without joint R&D activities, and donations for general research activities.

Figure C.2.1 reveals (i) that R&D collaboration between industry and science represents only a small fraction of the total R&D activity in both industry and science, and (ii) that there are considerable differences in the significance of R&D collaboration among countries. These country variations can be associated to differences in industry demand for scientific knowledge, in institutional settings and incentives, and in public promotion of this type of interaction.

Amongst other factors that influence the extent of collaborative research, the demand for scientific knowledge is of great relevance. With regard to science relations, it is important to distinguish between two types of R&D activities. One is research in the sense of an exploratory search for new scientific and technological knowledge. Its aim is to find technological solutions within core technology fields. It results in technology solutions that can be patented, technology platforms and new instruments and methods. The other kind of activity is work on the development of new or improved products and processes. In terms of R&D resources, most is spent on these development activities with a large part on the improvement of products and processes and finding new applications for technologies already existing in the market i.e. used in existing products and processes. Enterprises collaboration with public science primarily involves the exploratory research activities, whereas the development projects mainly involve co-operation with customers and suppliers. An important prerequisite for collaborative research between enterprises and public science institutions is therefore, the existence of an exploratory part in R&D activities on both sides.

Policy-related framework conditions affect the propensity of economic actors to enter into collaborative research activities in a variety of ways. The legal framework is, in most countries, neutral in its effect, i.e. while it is directed mainly towards not preventing collaborative research, it does not have a positive affect on the extent of collaborative research

either. However, the institutional setting in public science is reported to be a major stimulating factor for collaborative research in some countries. Finland and Sweden, for example, have carried out reforms at their HEIs in order to demonstrate the recognition of the so-called societal mission or societal effectiveness of the universities, and other HEIs as a "third mission" alongside the traditional scientific and educational missions. This entails a redesign of evaluation criteria, administrative support for industry co-operation, incentives and support for orienting research towards the needs of society, raising awareness for knowledge and technology transfer at all levels of the institution, and providing individual incentives to engage in transfer activities. Similar efforts are reported in several other countries, such as Germany and the UK. Taking the "third mission" seriously also means however, establishing a mechanism to balance activities in HEIs between research, education and transfer activities. Furthermore, a flexible approach towards research collaboration and the dissemination of research results is needed, acknowledging all the different channels of interaction in the same way and allowing researchers and enterprises to decide on how to organise co-operation. In some countries, collaborative research is stimulated indirectly by building up competence and expertise in HEIs within areas of strategic importance, which are relevant to innovative enterprises.

Even in the case of coherent research orientation in industry and science, and favourable institutional settings, several generic barriers impede research collaboration including divergent objectives and specific market failures on the knowledge market. Research policy attempts to overcome these barriers by providing additional incentives and compensating for market imperfections. Today, a variety of such public promotion programmes are run in the different countries analysed. Most often, they provide financing for joint R&D activities to both enterprises and public science institutions in order to compensate for transaction costs, uncertainty of the outcome of R&D, and the presumably high spill-overs of the new knowledge produced in joint R&D projects. They are generally viewed to be highly influential to the level and direction of collaborative research. Good practice in promoting collaborative research rests upon three main pillars:

- 1 Thematic focus of research promotion that is based on a bottom-up definition of fields of technology, i.e. thematic areas are not set by policy but are open to joint initiatives by enterprises and public science institutions, including elements of technology assessment and market potential analysis, in order to select the most promising themes.
- 2 Restricting public support within thematically focussed programmes to those research consortia that submit the highest quality proposals based on peer review from industry and science (competition-based selection of addressees).
- 3 Providing some kind of infrastructure for joint R&D activities, either a physical one (e.g. research laboratories or centres) or an immaterial one (e.g. legal entity such as a separate enterprise whose shares are held jointly by enterprises and public science

institutions) in order to facilitate a long-term orientation of the joint effort and to provide a base for appropriating research results.

Examples for a good policy practice of collaborative research are competence centre programmes and other programmes that aim to establish thematically focussed and long-term joint R&D infrastructures. Such programmes can be found in Sweden and Austria (Centres of Competence) as well as in the USA and Japan (University-Industry Research Centres). They constitute an effort to build bridges between science and industry by creating excellent academic research environments in which industrial companies participate actively and persistently in order to derive long-term benefits. The programmes provide funding for collaborative research groups in the course of a multi-year research programme, which is pre-competitive and focused. Collaborative competence centres are established within a specified time frame. They are selected for funding in a competitive process according to specific quality criteria. The main objective of the programmes is to establish long lasting co-operative relations between enterprises and scientific institutions. In implementing platforms for collaboration for a number of years, a wide scope for the establishment of social exchange relations between partners is provided and the formation of a joint language, a joint culture and common goals is supported. Together, they should guarantee a sustainable base for co-operation without public support.

Table C.2.1: ISR via Collaborative Research: Main Conclusions

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
One of the most preferred ways of knowledge interaction by enterprises	SMEs do have generic disadvantages; thus reducing entry barriers for co-operation with HEIs very important
Avoiding legal impediments of research co-operation	Legal framework is no major barrier for collaborative research in any country
Appropriate institutional setting is important	Third mission for HEIs; individual incentives; administrative flexibility
Public financing of ISR is a major stimulus	Some types of supportive measures are to be found in all countries
Design of policy measures is important	Competitive bottom-up approach that supports long-term orientated joint thematic infrastructures (University-Industry Research Centres, e.g. Competence Centre Programmes)

Source: compilation by the authors

C.2.2 Start-ups from Public Science

Universally, research based start-ups from the public science sector have become an increasingly popular form of technology transfer and one of the favoured commercialisation strategies of HEIs and PSREs. Since the 1980s, and especially in the last few years, the number of start-ups from public science has risen. Academic start-ups are seen as "translators and mediators between academic research and industry", or even more pointedly as indicators of the public sectors ability to develop commercially relevant knowledge, of its entrepreneurial capacity, and of the depth of knowledge transfer between the public and private sector (OECD 2000b). Ideally, academic start-ups represent a form of co-operation

embedded in other forms of interaction such as joint R&D, joint publications or researcher mobility.

Table C.2.2 shows the significance of start-ups from public science in the late 1990s for those countries having quantitative information available. Due to different definitions, no uniform concept of what constitutes a academic start-up exists and therefore, international comparisons are complicated (see OECD 2000b). Nevertheless, it is immediately obvious that the total number of academic start-ups is very small. There is only one academic start-up for approximately every 1,500 enterprises founded, whereas every eighth new firm is a corporate spin-off (OECD 2000b). Thus, start-ups from public science account for no more than a tiny percentage of new firm creation. With respect to the total number of researchers in science, the start-up ratio is on average 2 to 4 per 1,000 R&D personnel in HEIs and 2 to 3 per 1,000 R&D personnel at PSREs. Their importance as a mechanism for technology transfer is not in question but their limited magnitude in the economy must be kept in perspective.

Table C.2.2: Start-ups from Public Science in Selected Countries: Number of Start-ups (annual average) per 1,000 researchers in HEIs and PSREs

<i>Country</i>	<i>HEIs</i>		<i>PSREs</i>	
	<i>value</i>	<i>reference period</i>	<i>value</i>	<i>reference period</i>
USA	> 3	1997-98	n.a.	
Germany	3 - 4	1997-99	2 - 3	1997-99
Austria	3 - 4	1995-99	1	1997-99
Finland	2 - 3	1995-98	1	1997-99
Belgium	< 1	1995-99	3	1997-99

Source: see Table C.1.1

When looking at policy-related framework conditions for start-ups from public science, it should be noted that academic start-ups are affected by the same economic environment which generally determines the level of new firm formation in an economy. The financing conditions on capital markets, especially the availability of venture capital, the degree of competition and the openness of markets for new entries, anti-trust law and market regulation influence the creation of new enterprises. If these general framework conditions for firm formation are favourable one might expect a large number of academic start-ups too, while unfavourable market and regulatory environments will result in low start-up figures. Thus, the level of start-up activities in public science institutions is not directly related.

The creation of a new firm in order to exploit the commercial potential of new research results depends heavily on the type of research carried out in public science institutions, both with respect to the time horizon of research (long-term oriented fundamental, versus short-term oriented research which is near to application) and the field of research (i.e. the market for new research findings). Consequently, start-up activities differ by the type of public science institutions. The objectives and resources of a technically oriented contract research organisation, like the German Fraunhofer Society, VTT in Finland, or VIB in Belgium, are different from those of an educational institution like most universities. Hence, the institutional distinction must be considered when looking for good practices.

Concerning the different approaches to promote start-ups, there is no one single success model for implementation. Nevertheless, some general good practice principles in facilitating academic start-ups through policy-shaped framework conditions may be identified:

- Provide pre-seed capital, i.e. financial support, in stages before a new firm is created.
- Focus managerial and financial support on specific sectors in order to address the specific barriers prevailing in a certain market.
- Follow institution specific approaches in promoting academic start-ups in order to address the specific situation (mission, research orientation, business networks etc.) at an institution.
- The provision of infrastructure such as incubators may support new firm founders by reducing transaction costs but their main function is to raise awareness in public science that starting an enterprise is a career option, and close ties should be kept between start-ups and their parent institution.
- Institutional reforms in public science towards more flexibility and autonomy in research commercialisation will raise the willingness of researchers to engage in start-up activities.

Although in countries where HEIs or PSREs are allowed to take equity stakes in companies (e.g. Belgium, the UK, and the USA), this does not seem to be an important source of capital. The access to external financing may thus play an essential role in allowing start-up firms to survive. It is not only the motivation to create start-ups but also to attract pre-seed capital funds. The emergence of seed capital funds is thus an important incentive for entry into start-up activity and a private venture capital market is an important facilitator for start-ups from science. However, special attention should be paid to financing in very early stages ("pre-seed financing") when uncertainty is high, the business ideas not yet well developed, and the size of projects is too small for private venture capital. Here, public seed capital that covers the costs for developing a business plan and carrying out R&D to develop a marketable product or service, is a major element for a comprehensive financing environment.

Policies have to encourage human mobility and flexibility of public institutions as well if start-ups are to fulfil their mediator role. Hence, the rise in frequency of new firm creation seems to have happened in parallel to the adoption of national, regional, and even institutional policies (see Belgium). Improving the management of public research organisations or regulations governing researchers mobility are separate roles of the government in terms of building incentive structures.

Academic start-ups tend to be concentrated in certain sectors and technologies - primarily in the life sciences, information and communication technologies, and advanced producer related services such as software, management consulting and technical services. Policies spurring the transfer of public research results through the promotion of spin-offs should address the specific market environments in the respective sectors, i.e. follow a sector specific

approach, such as the BioRegio or BioProfile programmes in Germany which give special support to start-up activities in biotechnology.

A good scientist need not be a good entrepreneur. One of the main barriers to start-ups from science is perceived as the lack of entrepreneurial climate in universities and a lack of managerial knowledge in the case of researchers. Start-ups from the science sector have to be promoted, in addition to the access to financial funding, via supportive measures like consulting services. With the establishment of specialised professorships for entrepreneurship and start-ups, the managerial skills of students and the awareness building initiatives, the level of academic spin-offs created can be raised.

If start-ups should play an intermediary role between the public and private sector, contacts between researchers from both sectors are essential. In many countries however, public sector employees are restricted in getting involved in private ventures and this limits the interaction a start-up firm can have with its parent institution. Such restrictions refer to secondary occupations, leave of absence and the right to take ownership in enterprises. Notably, in most countries, full professors have the status of civil servants. In particular, university researchers may acquire tenured positions, i.e. guaranteed lifelong employment at the university may create rather high barriers to becoming an entrepreneur. Since founding an enterprise is related to high risks and the potential gains are by no means sure, the opportunity costs are quite high. Additional supportive measures have to take this into account. Therefore, the main target group should be younger researchers and assistant fellows in public science who should be encouraged and supported in private ventures.

To foster start-ups from public science, the UK and many other countries, followed an "infrastructure based approach". A large number of science parks located at or nearby universities or large PSREs have been established, forming incubators for start-ups. Not surprisingly, informal contacts and personal and organisational networks are very supportive and stimulating mechanisms. Networking contacts are thus critical for spin-offs and relevant information should be locally available.

Table C.2.3: ISR via Start-ups: Main Conclusions

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
Start-ups from public science are only a limited approach to knowledge and technology transfer	Number of start-ups is very small if compared to total new firm formation, but constantly increasing
Entry barriers vary between economic sectors	Sector-specific programmes are most promising
Growing policy awareness for academic start-ups	Entrepreneurship is increasingly included in curricula in HEIs
Keep a close relation between start-ups and public science	Informal meetings, involving researchers at start-ups in higher education programmes
Access to financial sources, support for start-up costs	Public seed capital, especially for very early stages of firm creation; incubators that reduce start-up costs
Managerial skills are important	Consulting services on business practices
High variety in public promotion programmes	Institution specific approach and incentives for academic institutions/researchers to promote start-ups

Source: compilation by the authors

C.2.3 Intellectual Property Rights (IPRs)

Currently in all countries covered by our study, the commercialisation of research results through IPRs receives increasing attention, although the use of IPRs in public science is still relatively low and seems to play only a limited role in the field of knowledge interaction between science and industry. However, at least in some countries (e.g. USA, UK, Germany) the use of patenting for the validity of research is increasing, both in HEIs and PSREs. Table C.2.4 provides an overview of the situation in those countries for which reliable data is available. The highest level of annual patent applications per 1,000 researchers in HEIs (natural sciences, engineering and medicine only) can be observed in the USA (more than 35), followed by Germany (19) and the UK (15). Within the PSRE sector, Germany, Belgium and Finland report rather high levels of patent activities. In all countries, royalties are by no means a major income source for public science, except at US universities where they amount to 2.3 % of the total R&D expenditures.

Table C.2.4: Commercialisation of Research Results from Public Science through IPRs: Patents and Royalties

<i>Country</i>	<i>HEIs</i>				<i>PSREs</i>		
	<i>Patent applications per 1,000 researchers</i>	<i>Royalties in % of R&D expenditures</i>	<i>Period</i>	<i>Treatment of IPRs</i>	<i>Patent applications per 1,000 researchers</i>	<i>Royalties in % of R&D expenditures</i>	<i>Period</i>
USA*	> 35	2.3	1997	central	n.a.	0.15	1997
Germany	19	n.a.	1997	individual	20	0.7	1997
Finland	n.a.	n.a.	-	individual	12	0.3	1999
UK	15	0.5	1996-97	central	n.a.	n.a.	-
Japan	5-10	< 0.01	1994	central	n.a.	n.a.	-
Belgium	n.a.	n.a.	-	-	15	n.a.	1997-99

* granted patents

Source: see Table C.1.1

The legislative framework for employing IPRs as a medium for transferring research results is quite different between the countries. At PSREs, IP on inventions typically belongs to the institution, while in HEIs different approaches exist. Some countries have a centralised regulation, i.e. IPRs belong not to the inventor but to the university or even the state (e.g. Austria, or Wallonia/Belgium until 1998). The UK may be a role model for this "centralised" approach. Here, HEIs have their own specialised IP management and support centres (technology licensing offices) which are engaged in the commercialisation of inventions made by their researchers. Royalties gained from patenting are shared between the HEI (as IP owner), the individual inventor(s), the inventors department, and the licensing office (to cover costs associated with the administration of IPRs) according to varying distribution methods. The situation is different in countries such as Germany, Sweden or Finland. Here, IPRs in HEIs belong to the individual inventor who is free to decide whether and how to use them for protecting and commercialising inventions. In Sweden this has been critically discussed over the last few years, and in Germany and Finland it is expected that this IP regulation will be changed such that IPRs will belong to the HEIs. In some countries, HEIs have established

special supportive infrastructures for inventors, for example giving financial assistance to cover fees or costs of patent lawyers, consulting etc.

The views of national experts diverge in respect to which model induces the best incentive system for HEI researchers to engage in patenting activities. Some experts argue that scientists lack the principal management and marketing knowledge to commercialise their inventions. In addition, scientists usually see their role in producing new knowledge as a public good (and disseminate it through publications). Also, the evaluation criteria for an academic career are based on this principle in all countries. Since patents are by definition property rights to exclude the public from using the new knowledge or technology freely, they do not fulfil the criterion for scientific publication. Thus, the incentive for HEI researchers to patent their research results may be low, independent of the legislative framework. This low incentive is reinforced by the high costs for patenting and licensing, and the high uncertainty on potential revenues from licensing. Some experts argue that giving the individual HEI researcher the IPRs will stimulate the output of academic research by giving them the incentive to gain royalties from his/her invention.

One critical point concerning the commercialisation of HEIs research results via IPRs must be mentioned (see Nelson 2001). There is a certain trade-off between (i) increased appropriateness of new knowledge via IPRs and thus their commercial exploit potential, and (ii) potential gains for the whole economy through spill-overs caused by the public good nature of new knowledge. Moreover, patenting activities are associated with high costs such as running a specialised infrastructure, patenting fees, negotiation, transaction and controlling costs, defending IPRs etc. Only a small percentage of patents are actually developed further into a commercially marketable product (or process), and only a small percentage of these new products (or processes) are successful in the marketplace. Royalties are mainly restricted to just a few number of patents and in total, often do not cover the total costs for the management of IPRs in public science. Nevertheless, the individual HEI researcher should have the possibility to commercialise research results and this can be an important incentive for stimulating applied research. However, commercialisation of IPRs should not be regarded as a financing tool for HEIs as a whole.

Summing up, no overall good practice model can be obtained because to what extent HEIs should be engaged in producing public knowledge or proprietary knowledge is up to national policy. Nevertheless, in the latter case, it is obvious that the individual researcher needs support infrastructure for the handling of the complex and cost-intensive process of applying for a patent. Interesting examples for those supporting measures can be found for example, in Finland and Belgium.

The situation of IPRs at PSREs is quite similar amongst the countries and does not differ significantly to the situation of private business firms. IPRs usually belong to the institution. In general patents play a much more important role for PSREs than for HEIs. Examples of high patent activities at PSREs are to be found in almost all countries, especially at transfer

specialised institutions and in specific fields of technology such as engineering, pharmaceuticals, biotechnology.

Table C.2.5: ISR via Intellectual Property Rights: Main Conclusions

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
Commercialisation of research results through patents and licensing plays a rather minor role	Enterprises regard licensing of public science's patents as peripheral channel of technology transfer
Proper treatment of IPRs is a prerequisite of collaborative research	Ensure that a clear assignment of IP out of joint R&D activities, enable flexibility in designing IP agreements in joint R&D
Economic relevance of IPR highly differ between fields of technology	Engineering; pharmaceuticals and biotechnology
Legal frameworks in HEIs differ: "centralised" systems (i.e. IPRs belongs to the HEIs) versus decentralised (i.e. IPRs belongs to the individual researchers)	Divergent views on which model provides the adequate incentive scheme are to be found. Centralised systems may be more efficient concerning commercialisation but may reduce incentives for the researchers
Specialised supportive infrastructure is a prerequisite for successful use of IPR	Commercialisation units or independent commercialisation enterprises specialised on IP management
IPR need not be the optimal channel for ISR	Commercialisation via patents/licensing may be very costly and time-consuming and can result in lower spill-overs than via publications

Source: compilation by the authors

C.2.4 Interaction in the Field of Human Capital: Training & Education, Mobility of Researchers

The mobility of researchers between academia and the business sector can be regarded as one of the most important channels for disseminating new knowledge generated in public science. Of course, this type of knowledge exchange largely takes place through the employment of university graduates by enterprises. This process operates rather smoothly in all countries as is indicated by the comparatively low unemployment figures of university graduates. However, there is a periodic mismatch in the supply and demand for well-trained graduates in some fields of technology, currently informatics and information technologies. This is as a result of information asymmetries and the idiosyncratic behaviour of students who face the difficulty of properly assessing the likely future demand for certain types of qualifications at the time of starting their study. A way to overcome such mismatches, at least partially, might be a more dense co-operation of industry and science in curricula and teaching capacity planning in HEIs, including elements of foresight in order to provide study beginners with more accurate information on the development of demand for highly qualified labour. In Finland, for example, such type of co-operation is quite common.

Given the high pace of technological change in modern economies, qualifications have to be continuously up-graded and adjusted to new scientific and technology development through the further education and vocational training of employees. In most countries, universities and polytechnic colleges are engaged in such types of education activities although to varying degrees. In countries like Finland, the UK or Belgium, HEIs receive a significant income from further education and training. Although similar vocational training activities by HEIs

exist in other countries too, their significance seems to be somewhat restricted, especially if compared with other suppliers of vocational training (private enterprises, other public institutions). An interesting approach (which is however, not explicitly targeted towards training) is to be found in Sweden. Here universities must officially - as a third mission - co-operate with the surrounding society and inform about their activity. This can be interpreted as a mission to disseminate the research results gained at universities beyond narrow scientific circles.

Teaching by people from the business sector at universities (and polytechnic colleges) can also be an important factor for fostering ISR and transferring tacit knowledge. Students not only gain knowledge from a practitioners point of view but can also gain access to personal networks. Thus, such teaching may lay a springboard for future ISR activities. This kind of teaching from outside the university is quite common but according to national experts, is often restricted to business and management courses. It would be favourable to encourage teaching by R&D staff of private business enterprises. Actually, in some countries (e.g. Finland), sponsored and invited professors from the business sector have become more common. However, the problem of the wage gap between the private sector and academia still remains and reduces the incentive for qualified private business R&D personnel to engage in teaching activities in HEIs.

In addition to training & education, the mobility of researchers between public science and industry is another highly important channel of knowledge transfer. Besides the dissemination of new knowledge and consequent enhancement of the knowledge base of business firms, a high rate of mobility also has further positive side effects such as establishing personal-based networks between both sectors (and thus increasing trust and a common understanding of problems), and creating employment opportunities for young researchers. Through mobility, the university system can be open and the danger of being a 'closed club' can be avoided.

Table C.2.6 gives an overview of the mobility between academia and the business sector in some countries for which reliable data is available. Although the data situation restricts simple cross-country comparisons, empirical evidence shows that there are significant differences between countries on researcher mobility rates (annual number of researchers moving from one sector to the other per 1,000 researchers in the exiting sector). Rather high mobility rates are reported from public science to the business enterprise sector in Belgium, Germany, Finland and Sweden.

Table C.2.6: Mobility of Researchers Between Industry and Science (annual average in % of total number of researchers in the exiting sector)

<i>Country</i>	<i>From HEIs to industry</i>		<i>From PSREs to industry</i>		<i>From industry to HEIs/PSREs</i>	
	<i>value</i>	<i>period</i>	<i>value</i>	<i>period</i>	<i>value</i>	<i>period</i>
Belgium	~ 3	1995-96	~ 5	1995-96	0.4	1995-96
Germany	~ 5	1997-99	~ 3	1997-99	n.a.	-
Finland	~ 3.5	1994-95	~ 4	1994-95	0.4	1994-95
Sweden	~ 4	1994-95	~ 15	1994-95	0.6	1994-95

Source: see Table C.1.1

In all countries, the mobility from business to public science is much lower (when taking into account the differences in size of the two sectors). The main reason for this is the difference between salaries in the business sector compared to those in HEIs. Thus, HEIs have only limited possibilities to attract experienced human capital from the business sector. This may be an impeding factor for ISR because researchers from the business sector would not only bring with them practical R&D knowledge but also personal business related networks. The latter would enhance the principal potential for ISR because co-operation between HEIs and the business sector often follows such personal networks.

Regarding good practice in policy-related framework conditions that support industry-science links in the field of human capital, a proper regulatory framework in the field of labour law (civil servants law, pension systems, flexibility of wages), the avoidance of legal barriers to mobility, and the stimulation of interaction through promotion programmes, should be mentioned.

An important factor that determines mobility from public science to the private business sector is the regulatory framework concerning labour arrangements and laws. In countries with civil service status in HEIs (such as Austria), the incentive to move from academia to the business sector is very low. In addition, the pension system (for example in Germany where there is no possibility to transfer acquired pension funds to the new occupation) may hinder the mobility even further.

Legal regulations that are likely to influence the mobility of researchers do not play a major role in determining (positively or negatively) the mobility rate between public science and the business sector. All countries have, to some extent and in various kinds, sabbaticals or other kinds of temporary mobility and there are no restrictions to leaving the public science sector entirely.

Public promotion programmes to foster mobility between HEIs and the business sector do exist in a number of countries, although their scope and significance seems to be very limited in some of these countries (for example in Austria, the relevant programme covers only a few number of researchers). The diversity of these promotion programmes is high. Some programmes (for example in Wallonia and Flanders/Belgium, and the UK) address explicitly the joint supervision of Ph.D candidates, giving grants to students for carrying out doctoral research which addresses industrial problems and industrial research questions. Among the many policy measures in this field, the UK Teaching Company Scheme (TCS) is regarded as a good practice example. The scheme sets up partnerships between enterprises and HEIs through the formation of teaching company programmes. Enterprises take on graduates to work on specific projects jointly supervised by the HEI and the company. Other programmes provide financial support for the temporary employment of HEIs researchers at SMEs (e.g. Germany, Sweden) in order to enhance the knowledge base of SMEs and to foster their capacity to use other channels of ISR, e.g. joint research projects. In some countries (e.g.

Sweden) there are also programmes aiming towards the opposite direction, i.e. to attract qualified personnel from the business sector to temporarily join HEIs as visiting professors.

Table C.2.7: ISR and Human Capital: Main Conclusions

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
Mobility of personnel is a major channel of interaction and technology transfer: "Moving knowledge by moving people"	Institutional setting very significant (e.g. temporary employment contracts); employment regulation hamper mobility (e.g. civil service law, pension systems);
Mobility between HEIs and industry is a "one-way street"	Differences in salaries hamper the mobility from industry to public science
Public promotion programmes exist in a number of countries but their scope and significance is limited	Special orientation towards SMEs; Combining education and mobility (e.g. joint supervision of Ph.Ds); Mutual incentives and interactions; Enhancing awareness both in academia as well as in the business sector
Co-operation in vocational training and curricula planning is still low and public promotion programmes are widely missing	Involving foresight by industry in curricula planning in certain fields of technology

Source: compiled by the authors

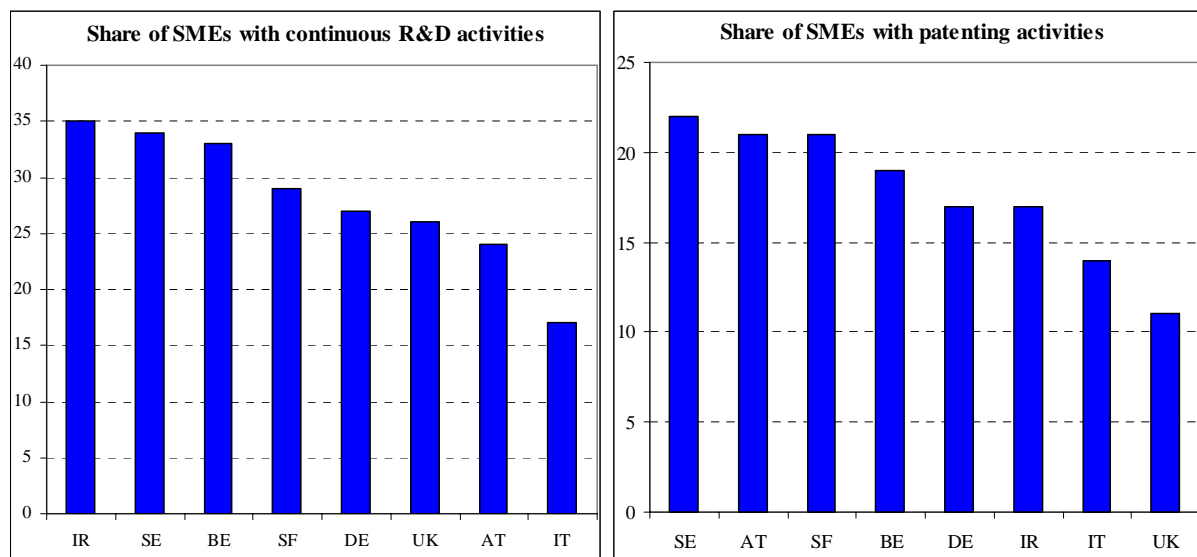
C.2.5 The Role of SMEs in ISR

In most countries, SMEs have only a modest significance for the overall R&D performance of the business enterprise sector. R&D expenditures by SMEs, i.e. enterprises with less than 250 employees, accounts for only about 10 % of total business R&D in the countries covered in this study. Nevertheless, they represent the vast majority of enterprises in absolute numbers. Thus, their behaviour in contacts to and co-operation in science, determines the absolute level of ISR. The SMEs level of ISR strongly depends on their absorptive capacities and their involvement in technology-oriented innovation activities, e.g. carrying out R&D on a continuous basis and developing new technologies. The share of innovative SMEs either performing R&D on a continuous basis or showing patent activities, is rather low in most countries (Figure C.2.2) and rarely exceeds a third of the total number of innovative SMEs. Moreover, between one third and two thirds of all SMEs are non-innovators and do not carry out any R&D or patent-oriented activities at all, and consequently have no innovation-related links to public science so far.

From the point of view of industry, it is essential to distinguish large firms from SMEs when discussing incentives and barriers to ISR. Large firms usually do not find it difficult to collaborate with public science institutions. Many of them have had a long experience in co-operation and have learned how to handle their science links. In addition, they often have both the financial and personnel resources (employment of graduated R&D staff) necessary for establishing and maintaining science links. The situation is very different at SMEs, with the possible exception of high-tech SMEs. Most of them have no experience in co-operation with universities. There are many barriers to co-operation, the most important being the lack of in-house R&D competence (i.e. lack of qualified personnel). Information asymmetries are another main barrier, i.e. most SMEs are not able to accurately assess the potential gains of

collaboration with science and overemphasise the potential burdens. Other barriers include a lack of information about potential partners in science and a great uncertainty about the outcomes of joint R&D efforts. Policy initiatives attempt to remove those barriers to interaction, either by providing funding for R&D and training of SMEs staff, offering consulting services to improve innovation management capabilities and to raise awareness of science, or by providing information services on potential science partners, often with a regional scope.

Figure C.2.2: Continuous R&D and Patenting Activities of Innovative SMEs (in % of all innovative SMEs)



Source: Eurostat (CIS2), calculations by the authors

While SMEs represent a large potential for increasing ISR, policy measures attempting to increase the involvement of SMEs in ISR have to take into account the specific barriers to entering into science links among different groups of SMEs. Non-innovative SMEs typically face very different barriers to SMEs already engaged in innovation activities or those with regular R&D and experience in new technology development. Regarding the former group, measures should concentrate on building up basic capacity for innovation and R&D (management tools, technology auditing, learning from other SMEs, improving the human capital endowment etc.) as direct science links are typically out of the scope for these SMEs. With respect to the latter group, programmes that support direct linkages to science institutions, e.g. through joint or commissioned R&D, using scientific information in innovation projects, co-operating in the education of graduates, or the mobility of researchers, should be favoured. Good practice in involving SMEs in ISR follows such a differentiated approach, focussing on training SMEs employees, mobility, financing of joint R&D, and providing information on knowledge and technology supply in science.

Without qualified personnel, SMEs face difficulties in acquiring and using new technologies, in moving onto technological, more advanced sectors or in participating in R&D projects. Some programmes address the temporary employment of HEI researchers within SMEs

(Germany, Sweden) in order to enhance the knowledge base of SMEs and thus to foster their capacity to engage in other channels of ISR. They aim to stimulate the transfer of knowledge, especially to SMEs, in traditional sectors that lack technical and financial resources to attract highly skilled graduates. Support can take the form of tax credits (Italy) or reimbursement of labour costs. However, it is not always easy to ensure a match between skills demanded and the qualification and research interests of graduates.

There is some evidence that programmes such as the Teaching Company Scheme (TCS) in the UK have been successful in making HEIs more aware of the education and teaching needs of SMEs. The Young Researchers Programme in Austria supports research activities of young researchers in joint projects with SMEs, the research topics for PhDs or Masters Theses being defined in co-operation with their supervisors from HEIs and enterprises. The programme facilitates the establishment of R&D resources in SMEs and provides job opportunities for young researchers. In Belgium, the KIV programme aims to stimulate SMEs with a limited innovative capacity to recruit highly educated people to work on innovation projects, coached by a research centre. The programme was established because many SMEs lack the structural capacity to carry out these projects in-house.

Other measures that address a shortage in qualifications in SMEs are innovation management capabilities. Most SMEs are too small to run a separate innovation or R&D units, and often there is no structured way of stimulating innovation, carrying out innovation activities, and managing knowledge. Good practice in this area refers to visiting & learning programmes, and reducing information asymmetries on the value and quality of the various private services offered in the field of innovation and technology management.

Many SMEs see the lack of information as a high barrier for co-operation with public science. Poor communication about what public science institutions actually do and what might be relevant for industry is a bottleneck for improving the interaction between science and SMEs. It is still difficult for SMEs to identify what type of research might help them and whom to contact. The search costs for SMEs are higher than for large companies. One approach to tackle this lack in information is to establish information platforms on research activities carried out in HEIs and PRSEs. They are of limited use, however, as they often fail to translate the information on public sciences research topics into the specific needs of SMEs.

The TUFF programme (Technology Transfer for SMEs) in Sweden created a system that gives SMEs better opportunities to make use of technology in their business development. A well co-ordinated network makes it possible for SMEs to find adequate technological service and for technology providers to reach the SMEs with their offers. The aim of this approach was to strengthen the ability of the companies to discover their needs for technology and consequently strengthen their ability to ask for technology. Exchange of experiences, mutual stimulation and consciousness raising among the group members were typical features of the activities of a group. Consultants assisted the companies in that effort. At the same time the infrastructure for technological services was adapted in Sweden so as to respond better to the needs of SMEs. Existing technology providers should be better co-ordinated in relation to

their clients. The Swedish Innovation Relay Centres played an important role in establishing such a co-ordinated infrastructure.

In Finland, the Technology Clinic initiative aims to bring together technological service providers, SMEs and financiers of technological support activities. In each technology clinic there are four organisations involved: the customer; SME; Tekes, the clinic co-ordinator; and the technological service provider. The financial support for SME projects can cover up to 60 % of the costs of the project, with the remaining part covered by the SME.

Another major area of public support to SMEs in the field of ISR is the financing of joint R&D. In some countries, this support is restricted to the participating public science institutions, and SMEs are forced to build networks in order to increase spillovers and facilitate mutual learning (see InnoNet in Germany). Such programmes typically address 'insiders', i.e. SMEs that have sufficient absorptive capacities. For SMEs that lack such capacities (i.e. 'outsiders' to the field of R&D), direct financial support for R&D activities, including the use of external R&D sources, is a commonly followed approach in most countries.

Table C.2.8: The Role of SMEs in ISR: Main Conclusions

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
SMEs represent a great potential for increasing interaction between industry and public science	Share of SMEs in total business R&D expenditures is low in all countries, but due to their high absolute number they play a significant role in ISR
Generic disadvantages of SMEs: Lack in in-house R&D-competence (esp. qualified personnel); lack in time resources; focus on incremental innovations that do not rest on new scientific knowledge, lack in awareness and information on potential gains from ISR, lack in experience in external co-operation	Promotion of ISR has to take into account these generic disadvantages, effort should be laid on increasing the general innovation management capabilities of SMEs
Enhancing the absorptive capacities of SMEs is crucial for involving SMEs in ISR	Special R&D financing (e.g. small amounts of venture capital), R&D co-operation programmes, reimbursement of labour costs for researchers, information platforms, regional thematic networks of SMEs (e.g. Cluster programmes), visiting programmes, specialised infrastructures (e.g. technology parks)
Policy measures have to differentiate among various groups of SMEs according to the level of innovation and R&D activities so far	"outsiders": R&D support, mobility programmes for SMEs without innovation and R&D activities so far; "insiders": special support for external R&D collaboration for SMEs with in-house R&D capacities

Source: compiled by the authors

C.2.6 ISR in Science-based Industries

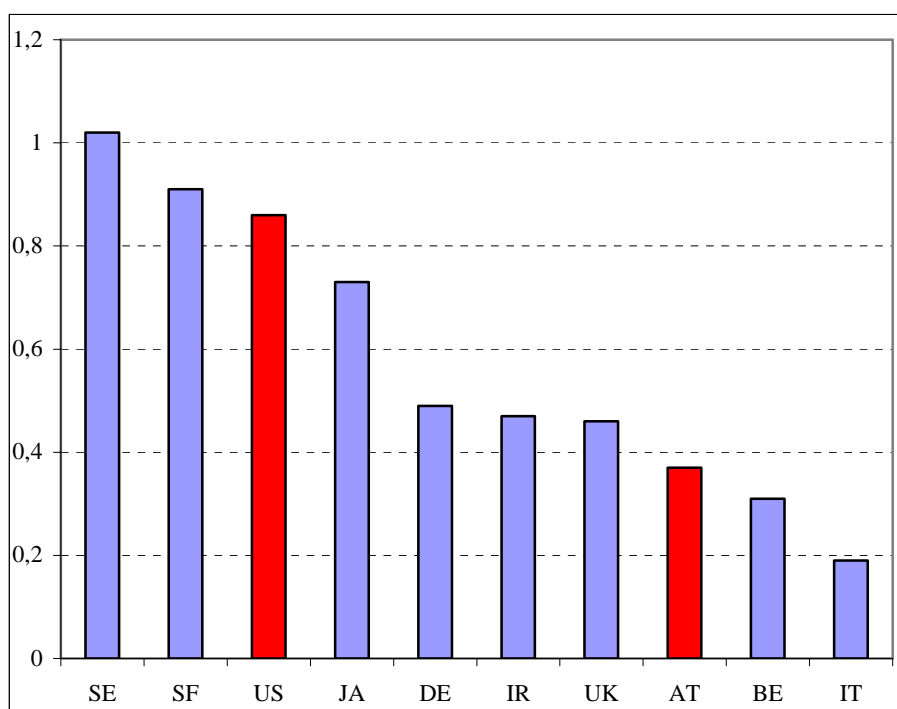
In his well-known taxonomy of industrial sectors, Pavitt (1984) identified so-called science-based industries (SBIs). These are industries with a general high R&D intensity and which are major driving forces of technological change, not only within their own sector, but with spillovers to the whole economy or even a whole society (e.g. biotechnology, information technology, microelectronics). As these industries are, by definition, in the early stages of

technology development, they face great growth potentials and are candidates for being base industries in new economic growth cycles.

With respect to R&D, SBIs are characterised by two main features. First, the boundaries between what is traditionally called basic and applied research are vanishing more and more. Hence, R&D departments of business enterprises may often be engaged in quite similar research areas as the departments in HEIs or PSREs, leading to close links (but also to severe competition) between business enterprises and academia. Second, innovation success and corresponding growth heavily depends upon an early orientation and adaptation of new technology developments for the needs of customers, i.e. close market interaction. Therefore, SBIs rely on close links both to science and to the market.

Our empirical analysis showed that countries with a high share of science-based industries report a high level of ISR too. Figure C.2.3 demonstrates the differences on the importance of science based industries between the countries. Countries with a strong orientation of their national innovation system on science-based industries are Sweden, Finland, and the USA.

Figure C.2.3: BERD Performed by High-tech Sectors as a Percentage of GDP



Source: OECD (2000), calculations by the authors

In realisation of the important role of science-based industries, all countries have designed special programmes to foster the development of these industries. As the propensity of these industries to co-operate with public science institutions is generally high, these programmes may have a significant impact on ISR even if they are not explicitly tailored towards ISR. Good practice in promoting ISR in SBIs covers, amongst others:

- stimulating direct collaboration in R&D between industry and science with a long-term perspective (see C.2.1 on collaborative research);
- concentrating public support for joint R&D in the very early stages of new technology development in order to establish and stimulate sufficient research capacities both in industry and science;
- stressing the importance of the application orientation and clients needs in developing new technologies;
- designing favourable general framework conditions for SBIs (e.g. access to venture capital, raising public awareness towards new technologies, fostering market competition); and
- gearing research in public science towards emerging new fields of technology.

Many countries run mission-oriented promotion programmes that typically focus on new technologies such as biotechnology & biomedicine, genetics, microelectronics, new materials, information technologies, and nanotechnologies. These programmes attempt to stimulate joint R&D and bring together research resources in industry and science. Many such programmes are part of a wider system of public research financing. Competence centre programmes (see C.2.1) usually have a high impact on ISR in SBIs since the probability to form consortia between business enterprises and public science institutions in these industries is higher than in more traditional industrial sectors. In order to foster ISR in SBIs, special new "public infrastructures", usually in the form of new PSREs, have been established. In some countries (for example Belgium) these institutions have the additional objective of promoting spin-offs in these new technologies, and thus provide seed financing capital. Some countries do have mission-orientated programmes that foster new technology clusters on a regional level. A good example of this approach may be the BioRegio programme in Germany. This programme is targeted towards promoting the location of biotechnology firms and the formation of start-ups in a restricted number of regions.

In a number of countries, science and technology parks have a thematic orientation in new technologies and are used as focus points for attracting the location of new technology orientated firms and start-ups. Furthermore, many countries have established diffusion programmes to enhance the adoption of new technologies by enterprises (especially SMEs), particularly in the new ICT sectors. In both cases, there are effects on the emergence of SBIs.

Another way to stimulate the emergence and growth of high-tech sectors is to provide special funds for research in public science that are targeted towards new technologies. In Japan, for example, several promotion programmes provide financing for such activities and should contribute to strengthening the public science base for SBIs. In Germany, so-called Lead Projects have a similar orientation, although more emphasis is laid on direct interaction between industry and science. The UK Foresight programme and similar programmes in many other countries also follow this approach.

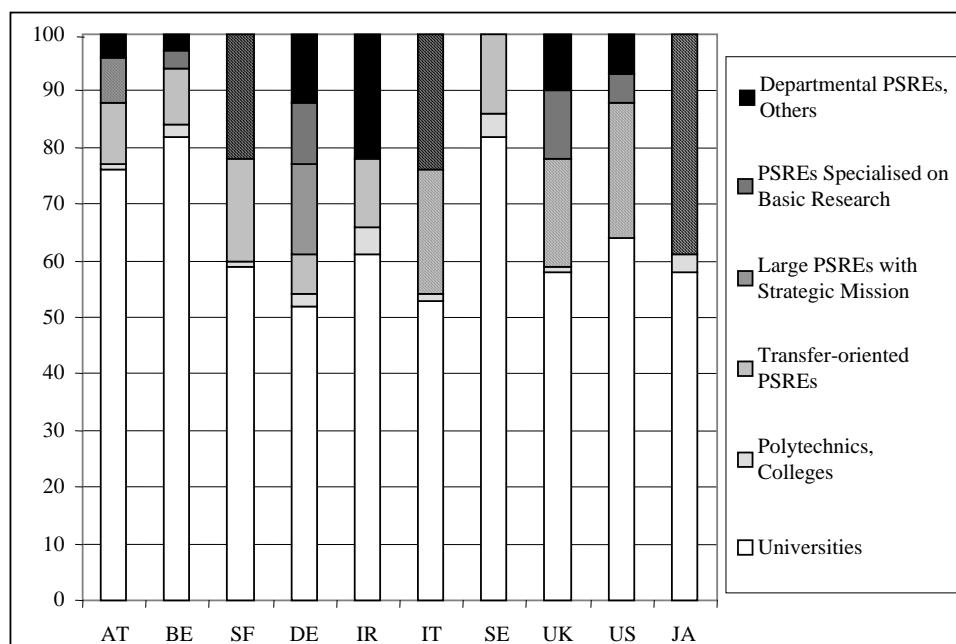
Table C.2.9: ISR in Science-based Industries (SBIs)

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
Boundaries between basic and applied research are vanishing in science-based industries ("transfer sciences"), high potential of direct transfer of new research results to the market	Commercialisation of research results through IPRs and start-ups is comparatively significant in SBIs
The share of SBIs in total business R&D expenditures varies heavily among countries	Sweden, Finland and USA are strongly specialised on SBIs
Given the high risks and costs, public promotion of ISR in SBIs is especially needed in the early stages of new technology development	Foresight programmes and special funds for new technologies within public research promotion, bottom-up approaches of defining emerging new fields of technology, stimulating private venture capital market as financing source for later stages of SBI-development
Networking programmes and bottom-up initiatives on a competitive level are most promising	Thematic "Centres of Competence" programmes based on a competitive bottom-up approach
Gearing research in public science towards new technologies	Thematic Centres of Competence programmes based on a competitive bottom-up approach

Source: compiled by the authors

C.2.7 Institutional Setting in Public Science

There is a great diversity of institutions in public science in all countries considered. This diversity reflects the history of institutional development of public science systems, the different missions assigned to public science, and priorities of science and technology policy with respect to the role of public science within a national innovation system. Figure C.2.4 shows the share of various types of institutions in total R&D performance in public science. Each type represents a specific organisational structure and mission that affect research orientation, institutional objectives, and incentives and barriers in the field of ISR.

Figure C.2.4: R&D Expenditures in Public Science


Note: Hatched areas indicate that no clear assignment to one of the types is possible.

Source: see Tab. C.1.4

Among the various success factors for effective knowledge and technology transfer between industry and science, an appropriate incentive system for researchers in public science which is designed to reward ISR-activities is one of the major elements. Such incentives should primarily stimulate direct transfer activities such as joint R&D, personal contacts with enterprises, mobility, and interaction in training. However, knowledge and technology transfer to industry is only one mission of public science, and carrying out basic research and providing education for the youth, remain the highly important activities of public science which may not be crowded out as a result of strengthening ISR. Therefore, institutional reforms in public science oriented towards strengthening transfer activities have to be compatible with positive incentives for these other main missions.

In the countries analysed, very different institutional structures and models of institutional settings may be observed. They reflect different structural frameworks of national innovation systems, different historical developments, and different social goals of the public research sector. Despite this diversity, some common features of good practice may be identified which cover critical success factors in institutional settings favourable for ISR activities:

- Public science institutions with a high record of ISR most often apply a decentralised model of technology transfer, i.e. the responsibilities for transfer activities are located at the level of researcher groups and individuals.
- Associated with a decentralised model is the provision of adequate administrative support which allows the researcher to concentrate on R&D efforts and knowledge exchange, leaving most administrative activities associated with transfer activities (such as legal agreements, financial issues etc.) to central organisational units. Furthermore, central support may also include the field of commercialisation of R&D results via patenting and licensing where specific legal and market know-how is demanded.
- Attractiveness for industrial partners demands competence in public science both in short-term oriented R&D and in long-term oriented strategic research. The main competitive advantage of public science in the knowledge market is its competence in generating new findings and new approaches to solving a certain problems. It is highly important that this competence is directly available within the same research group or department that is engaged in joint R&D with transfer activities to enterprises, i.e. individual researchers should be involved (not necessarily at the same time) in both types of research.
- Many public science institutions successfully engaged in ISR do not rest solely on contract research with industry. Rather, they show a balanced financing consisting of a mix of basic financing by the government for long-term oriented, strategic research, by industry financing during the course of contract research and collaborative R&D projects, and by a competition-based public financing, including funds for joint research with other, often more basic research oriented public science institutions.

- Another major success factor is carrying out strategic auditing on a regular basis in order to adjust research subjects to technology and market trends.
- Finally, a joint public-private set-up in terms of ownership, financing or advisory and steering board, stimulates industry contacts but is not a precondition for successful transfer activities.

Table C.2.10: ISR and the Institutional Setting in Public Science

<i>General Assessment / Critical Success Factors</i>	<i>Observations / Examples for Good Practice</i>
Institutional structures and settings vary considerably between and within countries	A decentralised model of technology transfer (responsibilities for TT activities are located at the level of research groups). However central support (adequate administrative, managerial and financial support) should be provided
Proper incentive systems are very important	ISR as part of institutional mission; considering ISR as evaluation criteria; individual remuneration of ISR activities
Fostering ISR has to be compatible with the main mission of HEIs (basic research and education)	Avoiding crowding out of basic research and education as a result of strengthening ISR
Adequate balance between applied and basic research should be achieved	A too strong focus on applied research may undermine the long-term potential; industry sponsored R&D should not exceed approximately 50 % of total R&D budget; ensuring significant publicly financed strategic R&D activities

Source: compiled by the authors

C.3 Synthesis and Concluding Remarks

In the following, we try to briefly summarise and synthesise the results from this benchmarking exercise. First, we summarise some major characteristics of knowledge production structures, ISR performance and policy-related framework conditions in the countries analysed. Then, we summarise the main findings concerning the way ISR works in the individual countries, the major driving forces for good ISR performance, and the role of framework conditions for ISR performance.

Knowledge Production Structures

Table C.1.2 summarises a selected number of indicators used to represent major aspects of knowledge production capacities and performance in the eight EU countries covered by this study. Knowledge production structures are at the very centre of many innovation studies carried out by the OECD and others, on an aggregated country level for two decades or so. As a consequence, a large set of indicators is available today, covering R&D investment by sector, specialisation patterns, high-tech orientation, innovation activities by SMEs, technology diffusion, structures in science, and many more (for a more comprehensive scoreboard of indicators, see OECD 1999a). The main result of such a compilation of indicators is well known. There are some countries strongly specialised on R&D activities (within the countries covered here: Finland, Germany, Sweden, USA, Japan) resulting in a

high-tech specialisation, high patent activities, and a rather high innovation performance, including the SME sector. Other countries are less geared towards R&D, such as Austria, Ireland and Italy, as far as the group of countries in this analysis is concerned.

In most countries with a strong enterprise R&D base, science also performs rather well and is measured either in terms of R&D expenditures as a share of GDP, the share of natural sciences and engineering and/or the project-oriented financing of HEIs, or by the international reputation of scientific publications (i.e. citation by others). This pattern of R&D performance is relatively stable over time although some countries could catch-up during the 1990s on a quite remarkable scale, such as South Korea or Ireland, while some others have lagged successively, for instance, the UK.

Our conceptual model on ISR (Figure A.2.1) suggests that countries showing a good R&D performance could also be expected to show intense industry-science relations. In addition to the level of R&D spending, the following structural characteristics are regarded as particularly important stimuli for ISR and are covered by indicators in Table C.1.2:

Share of very large enterprises in R&D performance: In general, they are equipped with high absorptive capacities, continuous research in early stages of the innovation cycle, and sufficient resources for financing external R&D. Consequently, they often hold extensive networks with universities and public research organisations.

Innovation orientation of SMEs: SMEs represent the vast majority of enterprises in each economy and are therefore, the main potential demand group on the knowledge market in quantitative terms. A prerequisite for using scientific knowledge and co-operating with science is innovation activity and significant absorptive capacities, in terms of continuous R&D and patent activities.

High-tech orientation of the enterprise sector: Science is a major source in industrial innovation in early stages of the innovation cycle and in industries with a high pace of technological progress and fundamental technological changes. Industries in mature stages of technology development are based more intensively on user-producer interactions, observation of competitors and other market signals (although market interaction is of very crucial relevance to the success of new technologies too).

Disciplinary orientation and excellence of science: Only a certain part of scientific research is relevant to industrial innovation. As a rule, it is that which is carried out in natural sciences and engineering, thus their share in total public science research characterises the knowledge supply potential of science. Another aspect is the excellence of scientific research carried out in these fields, indicating the quality of the knowledge provided to industry.

Financing of R&D: The way in which R&D is financed, both in the enterprise sector and in the HEIs sector, provides incentives or disincentives for ISR. In HEIs, the share of financing outside of General University Funds (which is usually the financing via projects based on a competition), indicates the necessity for active seeking of financial sources by universities,

and this is expected to stimulate industry orientation (as far as the research carried out is principally relevant to industry needs). Business R&D financed by the state is often associated with an orientation of R&D subjects towards government priorities, and those priorities may be associated with special strengths of the national science and technology system.

Market dynamics in new technologies: Market demand is the major stimulus for enterprises to carry out R&D and innovation projects. A demanding home market and a high pace of diffusion in new technology provide a favourable innovation climate which may also stimulate ISR.

The overall picture of our indicators on ISR-relevant knowledge production structures shows one group of countries with an above-average level on the majority of the indicators (Finland, Germany, Sweden, USA, Japan), and one group of countries with above-average level on some indicators (Austria, Belgium, Ireland, the UK). Italy is an exception with above-average values for only very few aspects of ISR-relevant knowledge production structures. We therefore would expect a similar pattern in the field of ISR performance and would associate deviations as being caused by a specific set of framework conditions.

Performance of ISR

Measuring the performance in ISR is considerably more difficult than measuring knowledge production structures. Table C.1.1 presents an attempt to collect indicators on different types of interaction, some based on 'hard' figures (also, their accuracy and reliability is rather low in many cases) and some based on expert assessments (which appear to be less exact, although they are often more reliable). When comparing Table C.1.1 and C.1.2, it seems that the structural features of a national innovation system, i.e. the knowledge production structures, are the main driving force for the observed level of ISR. Broadly speaking, three groups of countries amongst those analysed in this study, may be distinguished:

- (i) Firstly, there are high-technology specialised countries (Finland, Sweden and the USA) with an enterprise sector strongly oriented towards science-based industries, a strong and diversified science-base and favourable market conditions for high-tech innovation (which have in fact, stimulated the development of a high-tech industry, at least partially). The great industry demand for scientific knowledge in high-tech industries is associated with an ISR-oriented public science base, and the combination of demand and supply factors causes a high level of ISR (the somewhat lower intensity in ISR depicted in Sweden can be attributed to a lack of data for some channels). Such national innovation systems may be characterised as "science-based technology leaders".
- (ii) Another group of countries (Belgium, Germany, and the UK) have a less pronounced high-tech orientation of industry but rather follow a cumulative path of technology development along traditional technology trajectories (such as engineering & machinery, chemicals, vehicles, electrical machinery, and base materials). Their domestic markets seem to be less challenging on new technology breakthroughs, and

the enterprise sector is more strongly oriented towards rapid adoption of new (process) technologies in order to utilise scale economies. ISR are a major feature in these countries too, although interactions seem to rest more on short-term oriented R&D collaboration in order to solve specific technology problems along a given technology trajectory.

- (iii) A third group of countries (Austria, Ireland and Italy) show innovation system characteristics that focus more on fast-follower strategies in technology diffusion in traditional industries, and niche-market strategies that demand close interaction with customers and suppliers. Such innovation systems typically focus more on incremental product innovations, and sources of innovation are much more market based than science based. As a consequence, demand for interaction with science is lower in industry, as a result of the science system not developing a strong orientation towards technology transfer. Nevertheless, such innovation systems show remarkable technology performances with respect to productivity growth and market shares in their niche markets.

A special case is Japan. Despite knowledge production structures rather similar - at least on an aggregate level - to those in Germany or the UK, and despite a significant high-tech sector in microelectronics and communications technologies, the intensity of ISR is considerably lower. This rather low level of ISR is not a current phenomenon but a typical feature of the Japanese innovation system in the post war period. The Japanese innovation system shows that a high-technology strategy can be successfully realised by enterprises without making use of science in the traditional way of interaction, i.e. carrying out joint research and commercialising new scientific findings. However, public science plays an important role in industrial innovation in Japan too. It mainly contributes by supplying industry with a sufficiently large number of well-trained graduates, serving it as technology consultants on an informal base, and disseminating information on new research findings, including technology inventions made at universities, within personal networks, in exchange for general donations by enterprises for research.

Care must be taken however, not to oversimplify the relation between knowledge production structures and the intensity of ISR. Behind the aggregate pattern, there is a high diversity of the level of industries, fields of technology, and public science institutions. Within a certain sector or field of technology that show similar market conditions for enterprises and demand for scientific knowledge in all countries, variations in ISR are high. The same is true for some types of interaction between industry and science that are less dependent upon industry structures, such as mobility or training & education. Such variations can not be attributed to differences in knowledge production structures.

These general results on the level of aggregate indicators demand a deeper consideration of a country's ISR performance and the interaction of knowledge production structures and specific framework conditions for each type of interaction channel. Here, huge differences can be observed within each country regarding industrial sectors, institutions in science, academic disciplines, and sometimes between regions within a country (such as in the case of

Belgium). This diversity, which is largely concealed by the average figures and assessments presented in Table C. 1.2, makes it extremely difficult to identify a common pattern of ISR within one country, neither for a certain type of interaction nor for a certain field of technology. It seems rather, that there is a complex interaction between stimuli for interaction emanating from technology developments, market dynamics, industry structures and R&D investment on the one side, and several policy-designed framework conditions as well as cultural attitudes and other systemic features on the other side. The processes of how industry and science interact in each country can not be grasped adequately by studying only a few "key performance indicators".

The Diversity of Framework Conditions

Framework conditions for ISR can hardly be grasped by a set of indicators. They are the result of the operation of a large set of factors including history, constitutional setting, policy objectives and priorities (and changes in them over time), the strength of various lobby groups, and occasional idiosyncratic decisions by policy-makers. In our approach, we focus on four types of framework conditions, analyse their design and the way they affect incentives for and barriers to, ISR, for the various types of interactions. It is beyond the scope of this paper to report fully detailed findings but some general trends are worthy of mention and are outlined below.

In the field of *legislation* (i.e. laws concerning ISR), experts perceive it to have only small effects on the performance of ISR, both in a positive and negative way. But in some fields of interaction, legislation has high relevance in some countries. This is especially true for IPR and labour mobility but also for contract research regulations. Concerning IPR in science, very different models do exist, some of them following a centralised approach while others prefer the allocation of IPR to individual researchers. In some cases, experts in different countries perceive opposing views on the likely effects of each model. In the field of personnel mobility, civil servants laws impede mobility because of low transferability of, or non-transferable, pension funds to the private sector or because of "loyalty obligations". Bureaucratic regulations on the administration of contract research, high taxes on contract research incomes or pure academic evaluation criteria (and the allocation of basic and research project funds based on such evaluation) provide negative incentives for carrying out research, for or in collaboration with, enterprises.

In every country, a considerable number of *public promotion programmes* in the field of ISR exists. They attempt to foster ISR by providing funds for joint R&D projects, subsidies for employing researchers from science, venture capital for start-ups, training and further education programmes, joint research labs, awareness measures and many others. The effectiveness of different national programmes on the same issue seems to vary significantly. In order to identify critical success factors, careful consideration must be paid to the design, implementation and management of each programme, and how it fits into the specific barriers to ISR prevalent in the relevant segment of a national innovation system (e.g. type of enterprises, field of technology, type of interaction).

The provision of *intermediary structures* is another approach followed by every country to stimulate and support ISR. Amongst others, technology transfer offices (TTOs) in HEIs, technology and innovation consultants for SMEs, technology and science parks, incubators, information provision systems and contact platforms are widespread types of intermediaries. There is non-uniform evidence on their effectiveness and their role in ISR. While there is no doubt that comprehensive intermediary structures foster ISR to some extent, a clear good practice model is missing. According to most experts, TTOs are rather small and are therefore, often below the necessary critical mass to stimulate ISR effectively. In some countries, university assigned intermediary centres specialised in spin-off commercialisation and often having a certain technology focus, are regarded as promising approaches (Belgium, Finland, Ireland, and the UK).

Institutional settings in HEIs and PSREs strongly affect the effectiveness of public research organisations in technology transfer to industry. There are very different models of how technology transfer is incorporated in an organisation ranging from institutes with the main mission to support enterprises in their R&D efforts to establishments with a strong orientation on excellent scientific research, the transfer being a (arbitrary) by-product of their activities. With each model, a certain set of institutional barriers and incentives concerning interaction with enterprises are associated. Although a comparison of the various models between countries is fairly difficult due to them being embedded in their own specific innovation systems, some critical success factors common to all models could be identified. They include a decentralised model of technology transfer in the research organisation (i.e. responsibility at the level of researcher groups), a regular strategic auditing in order to adjust research subjects to technology and market trends, securing both short-term oriented R&D and long-term strategic R&D within the same research group or department (i.e. involving individual researchers in both types of research), and a joint public-private set-up in terms of ownership, financing or advisory and steering board.

Critical Success Factors and Good Practices

In order to learn from good practices prevailing in the countries analysed, we investigate in detail, the way in which good ISR performance in certain types of interactions, is achieved. We analyse the incentives stemming from the "knowledge market" as well as the specific framework conditions for ISR in that area. In each country, at least one example of good practice in framework conditions for ISR was identified reflecting the diversity of ISR and the shape of national innovation systems in Europe.

In summary, we identify the following critical success factors which are favourable for the interaction between industry and science and contribute to a high level of ISR. We do not restrict them solely to those factors which may directly be designed by technology policy but also list general characteristics of an innovation system. Although the latter quite obviously affects ISR, the relevance of these systemic features may not be tracked precisely.

- (i) High level of R&D in the enterprise sector, strong high-tech orientation of the enterprise sector
- (ii) High absorptive capacity and strong innovation orientation in the SME sector
- (iii) Presence of very large, domestic corporations in high-tech areas representing a huge R&D potential and having both a high need and the necessary capabilities to intensively interact with science
- (iv) Cultural attitudes favourable to ISR, i.e. an explicit industry orientation of science is perceived as positive
- (v) Coherent technology policy strategy designed to improve many elements and features of the national innovation system at the same time
- (vi) Financial promotion for joint R&D by thematic (i.e. "technology-oriented") programmes
- (vii) Joint R&D infrastructure for industry and science with a thematic focus developed by a bottom-up approach
- (viii) Provision of HEIs seed capital for very early stages of start-ups, including equity investment by HEIs and support networks
- (ix) Networks of specialised patent offices commercialising patents from a larger set of public science institutions in order to gain from specialisation and scale economies
- (x) Strong involvement of HEIs in the vocational training of researchers, managers and technicians at enterprises
- (xi) Mobility programmes and temporary working contracts for young researchers in public science
- (xii) Institutional settings in HEIs and PSREs which establish technology transfer to industry as the mission of an organisation and decentralise transfer responsibility

Some necessary caveats

When trying to derive conclusions from the rich and diverse empirical analysis presented in the preceding chapters, the scope and limits of comparative analysis of innovation systems (of which benchmarking is one approach³⁶) must be clarified.

- (i) First, there is not one single country which could be taken as a benchmark for performance of ISR. As performance of ISR can and should be measured by taking into account different dimensions (and hence indicators), a number of countries appear to perform well with respect to a majority of indicators - although the respective

36 See the papers of Barré and Polt et al. presented at the EU-conference on Benchmarking, Brussels 15-16 March 2001.

profile is again different for each country. This group of countries may be used as a 'control group' for comparison with the other countries.

- (ii) Second, even in countries where performance measures would indicate a low level of ISR, good practice examples can be found on improving the framework conditions for ISR. Thus, the comparison to good performing countries should not be restricted. Rather, a lot can be learnt by looking into individual policy measures across all countries.
- (iii) Third, though most of the framework conditions and policy measures address generic problems of innovations systems, the concrete shape of a specific framework condition or policy measure might be context dependent. This is also true with respect to efficiency whereby what might work in one country might not work in another. Thus, 'good practice' is always context dependent. These different contexts must be kept in mind when trying to emulate 'good practice' from other countries.

The learned policy maker therefore, will not use the results of this exercise as a toolbox to be applied mechanically to the perceived problems of ISR in his/her country. Rather, they would use them as a guide for policy learning and as an input to discussions which would entail the broad discussion of this comparison among the concerned actors, and the establishment of a shared vision among them, as the basis for future policy actions.

Finally, it has also to be borne in mind that, while ISR has, and will continue to become more important in economies which are increasingly based on the efficient production and use of knowledge, the use of scientific knowledge is but one type of knowledge used in the process of innovation. Other sorts of knowledge do play an important role as well - as do other dimensions of a National Innovation System. Thus, policy makers are well advised to improve ISR by taking up good practice examples and putting them into the context of the respective National Innovation System, thereby integrating the development of ISR into the broader policy context of improving the overall system.

Recommendations for creating favourable framework conditions for ISR

There are a huge variety of good practice examples in framework conditions for ISR. In order to learn from these good practices, the following must be considered:

- Good practice is always specific to the *market and institutional environment*, and addresses market failures and barriers stemming from this environment. To learn from good practice means first of all to learn to carefully identify these market failures and barriers, and then to select a proper mechanism to tackle them.
- As a consequence, good practice should be related to specific *fields of technology* and the way in which knowledge production, knowledge exchange and innovation takes place in these fields, and to the specific barriers to ISR that exist there.

Bearing this in mind, some general conclusions on **good practice** in shaping framework conditions for ISR may be derived:

- ISR-related policy initiatives must be embedded in a *comprehensive, stringent, and long-term oriented Science & Technology policy*. ISR-related measures need a long-term perspective in order to achieve sustainable changes in behaviours and structures.
- ISR-related policies must take into account the *various missions of public science* in the economy and society. Good practice in ISR policies therefore means a balance of technology transfer with education and fundamental research activities in public science.
- Joint research programmes that promote direct collaboration between industry and science are a well-established policy intervention mechanism that has a significant effect upon the level of ISR. Here, good practice particularly refers to thematically focussed programmes that apply a *bottom-up approach of defining joint research themes* (rather than a technology programme approach that defines technology fields of co-operation in advance), have a long-term perspective of co-operation, and rely (at least partially) on an 'infrastructure' approach, i.e. the establishment of institutions and/or facilities that are operated both by enterprises and science institutes which maintain co-operation after funding has ended (e.g. joint research centres, joint companies).
- With respect to collaborative programmes, a *competition-based approach* of allocating funding has proven to be effective. Such an approach stimulates the involvement of a large number of applicants but restricts funding to promising 'best practice' cases which may serve as further orientation points for other actors.
- Involvement of SMEs in ISR activities is a major issue in order to broaden the use of scientific knowledge in the enterprise sector. Good practice adopts a two-side approach: First, *absorption capacity in SMEs* with respect to R&D, innovation management capabilities, and the use of external knowledge and advice, should be strengthened and detached from any specific involvement in ISR. Second, SMEs with a sufficient in-house capacity for establishing science links may be stimulated to take up direct research and consult contacts with science. This may be realised through awareness measures (i.e. eliminating information deficits and changing attitudes towards science, e.g. by learning from positive experiences other SMEs have already had) and by direct financial support for the use of scientific expertise in their innovation projects, such as support for joint R&D, training and consulting involving public science researchers, mobility of researchers, and the use of IPRs by SMEs.
- Fostering the direct *commercialisation of research results* in public science is an important policy issue, especially in those fields of science where basic research may lead to new products and processes in a short time, and market dynamics rely heavily on the introduction of new scientific findings. Today, these field of science include such areas as biotechnology, genetic engineering, new materials, and new information and

communication technologies. Good practice in commercialisation covers, amongst others, the provision of supportive infrastructure which reduces transaction costs and information asymmetries in using IPRs (patent licensing offices), advisory support and pre-seed capital for start-ups, and several awareness measures that raise the perception of researchers of the commercial potential of the research results they have achieved.

Concerning the use of *IPRs in science*, policy initiatives should be aware however, not to overemphasise this issue by applying too general an approach. From the perspective of social returns, the largest benefit of ISR stems from translating new research results and scientific developments into products and services as fast and as broad as possible - and not from maximising licensing revenues by public science institutions. Consequently, the disclosure of new findings in public science through publication is to be preferred over the establishment of tight IPRs. Commercialisation of new research results by public science should focus more on direct entrepreneurial activities, such as start-ups or the direct co-operation with enterprises in innovation projects. The enforced use of IPR limits access to publicly financed research results by the broader community.

- *Reforms of institutional settings in public science* are especially successful when they consider the following issues: implementing ISR as part of the institutions mission; considering ISR activities in evaluations; providing both individual and organisational incentives; and linking industry and science through advisory boards. In many countries, a successful way of strengthening ISR was to establish *transfer-specialised institutes*, either at universities or within public research laboratories. Key success factors in these institutions include: the keeping together of basic and applied research within one research team; regular auditing of the research strategy in order to cope with changes in economy and society; direct transfer between researchers and industry (i.e. avoiding intermediaries); and individual remuneration for successful transfer activities.
- *Personnel mobility* and interaction in graduates education has received attention in some countries as being a major issue in ISR. Good practice is often related to exchange programmes which specifically address the personnel needs of SMEs, joint graduates education programmes that involve enterprises in the definition of the theme of a thesis and allowing students to carry out practical R&D work at the enterprise, and qualification programmes for industry researchers in HEIs.

As well as the high level of attention currently paid in most countries by ISR-related policies to certain issues such as IPR, academic start-ups, joint research, personnel exchange, other areas of similar relevance such as co-operation in curricula planning, vocational training, institutional reform, and individual incentive systems gained less attention and should be addressed more intensely by policy.

- Interaction in *education and vocational training* (further professional education) becomes more and more important in a knowledge-based economy. Rapid changes in the qualifications demanded, especially from highly-qualified employees, calls for continuous learning processes including the provision of the newest research results and developments

of methods to the business sector. Here, co-operation between HEIs and enterprises is important. HEIs should be made ready to offer training services for enterprise researchers either in formal ways (vocational training courses), or informally within joint research projects or temporary exchange programmes.

- In the field of higher education in the natural sciences and engineering, *redesigns of curricula* should involve both academia and industry. Also, attempts should be made to make studies more flexible and to increase joint graduates education by HEIs and industry (placements, lecturers by enterprise members, joint projects). In enterprises, awareness should be increased so that investment in such activities may pay off in future years (establishing of regular contacts with HEIs, access to well-trained graduates) without immediate direct returns.
- Among HEIs, the main *role of universities* within a national innovation system is (a) to provide society with well-trained high-qualified people and (b) to carry out fundamental research which may result in new insights into natural and social phenomena. This type of non-oriented basic research is generally out of the focus of industry research but often prepares the groundwork for fundamental technological breakthroughs. Therefore, academic research should first of all focus on the long-term, fundamental needs of society, taking into account inputs from government, industry and other actors. Other HEIs, such as polytechnics, are better suited for certain types of interaction with enterprises, namely small-scale projects and the provision of short-term expertise for SMEs. At *PSREs*, part of the resources should be devoted to direct interaction with industry in applied research or near-to-market development, by combining technology competence of public research and market knowledge of enterprises. Here, a balance must be struck between scientific competence building and institutional settings oriented towards technology transfer, and industry co-operation. Self-defined publicly financed program research in these institutions is one way to secure this balance, while research co-operation within *PSREs* with a different research objective is another one.

D. Appendix

D.1 References³⁷

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³⁷ The references include the literature cited in national reports, too.

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D.2 Questionnaire to Experts for Assessing Framework Conditions for ISR³⁸



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BENCHMARKING INDUSTRY-SCIENCE RELATIONS

Assessing Framework Conditions for ISR - Questionnaire to Experts

1. Benchmarking Industry-Science Relations (ISR)

Within the Framework of the EU-Benchmarking initiative “Benchmarking Europe’s Industrial Competitiveness”, a benchmark project on industry-science relations (ISR) is carried out. It makes an effort to compare, assess and improve a certain set of framework conditions for industrial innovation, i.e. the interaction between public research (referred to as “science”) and enterprises.

Benchmarking framework conditions is a difficult task as it demands the analysis of a large set of institutions and the way these institutions work, and it involves a large number of stakeholders. In order to observe framework conditions in ISR in the EU member states, we combine **two approaches**:

- Key performance indicators of ISR (output indicators) are identified on the base of existing statistics and studies. They cover the knowledge production capacity on the side of industry and science, the level of knowledge transfer and the knowledge absorption capacity in industry.
- Variables characterising the framework conditions for ISR, and information on the mechanisms how ISR work, will be collected by the means of **expert interviews**.

Industry-science relations (ISR) refer to different types of interactions between the industry and the science sector which are aimed at the exchange of knowledge and technology, including both direct and indirect transfer channels such as personnel and graduates mobility, joint research projects, contract research and consulting, licensing, start-ups by researchers

³⁸ References include the literature used in national reports, too.

from science, training for industry researchers, informal contacts, the use of scientific publications, training of students at firms etc.

Given this broad variety of relations, and taking into account the benchmarking project on selected aspects of ISR currently carried out at the OECD level, the project focuses on **framework conditions in four areas** of ISR:

- **legal environment**
- **public promotion programmes**
- **incentives and barriers**
- **personnel mobility and training**

2. What we are asking for

We ask you for a **qualitative assessment of the framework conditions for ISR** in your country and its likely impacts on the level of interactions, technology transfer and co-operation between industry and science in the four areas mentioned above.

3. How the questionnaire is organised

The questionnaire attempts to cover a wide range of framework conditions for ISR in the EU member states. It consists of five parts:

- legal environment for ISR (A)
- public promotion programmes for industry-science interactions (B)
- incentive systems for ISR and barriers to ISR (C)
- personnel mobility between industry and science (D)
- priorities for improving framework conditions on ISR (E)

In characterising and assessing the situation in each country by the means of a questionnaire, there is a trade-off between standardisation (in order to maximise the comparability between countries) and a high level of flexibility (in order to allow for adequately taking into account national specifics). We decided to put more emphasis on standardised questions both for ensuring comparability and to reduce the time necessary to complete the questionnaire. There is, of course, space for qualitative assessments, too (if there is not enough space for your comments on the questionnaire, please use an extra paper).

If you feel you have not sufficient information for a reliable assessment you can skip these questions, of course. Please note that all questions refer to the situation in your country!

4. Definitions

Within the questionnaire we use some central terms in a way which might differ from their usual connotation. In order to avoid definition of these terms in every single question, we list them below:

- “**Science**”: refers to publicly financed higher education and research institutions (Universities, Technical Colleges, Public Research Labs etc.)
- “**Industry**”: refers to the enterprise sector (both private and public owned) and covering both manufacturing and services
- “**ISR**” (industry-science relations): refer to different types of interactions between the industry and the science sector which are aimed at the exchange of knowledge and technology, including both direct and indirect transfer channels
- “**National**”: refers to framework conditions etc. effective for the total territory of a member state
- “**Regional**”: refers to framework conditions etc. effective only for a sub-territory of a member state
- “**Organisational**”: refers to framework conditions etc. effective only on the level of certain organisations such as universities, public research labs etc.

Thank you for your co-operation!

General Information

Please provide the following information:

Name:

.....

Organisation:

.....

Contact address (postal address, telephone, fax, e-mail):

.....

....

.....

....

Responsibility:

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A. Legal Environment for Industry-Science Relations

Relations between industry and science are directly or indirectly governed by the legal environment. Below we list a selected number of regulations often relevant to the way ISR work. Please **assess the general impact** of each field of **regulation on ISR** in your country, i.e. if the legal environment impedes or encourages knowledge interactions and technology transfer between industry and science or if the regulation it is of no relevance to ISR.

Regulation refers both to national or regional laws and to organisation-specific directives (e.g. at universities or public research labs).

If no general assessment is possible (e.g. if regulations differ substantially between organisations or regions in their impacts), please specify the most important regulations and assess their impact separately. In this case, please note the regional/organisational scope of these regulations.

	Impact on ISR					No relevance/ no impact	Regional/ organisational scope
	strongly impeding 1	2	3	4	strongly encouraging 5		
Intellectual Property regulations							
- Intellectual property rights at universities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<i>Please specify certain regulations if necessary</i>							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
- Intellectual property rights at public research labs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<i>Please specify certain regulations if necessary</i>							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
Employment-related regulations							
- Restrictions for researcher mobility from science to industry (esp. from “sensitive” research areas)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<i>Please specify certain regulations if necessary</i>							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							
- Civil servants law	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
<i>Please specify certain regulations if necessary</i>							
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>		
.....							

.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Major differences in career/earning options between industry and science	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Major differences in labour law/collective agreements between industry and science	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
Financing-related regulations						
- Regulation at the science side to carry out contract research for industry	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Regulation on non-profit status of public research	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Regulation at the science side on the share of income from contract research/licenses for industry	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						

.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Regulation on extra earnings for researchers in science from contracts with industry	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Regulation on the disposal over income from contract research for research units in science	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Regulation on equity investment by research organisations in firms (e.g. start-ups, joint R&D enterprises with industry)	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Central permission for contract research (at the level of research institutions, regional/national ministries etc.)	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						
- Tax relief to industry in the case of contract research to science	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>
<i>Please specify certain regulations if necessary</i>						
.....	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	<i>o</i>	
.....						

[illegible]

B. Public Programmes for Promoting Industry-Science Relations

Research and technology policy aims - amongst others - to foster co-operation and knowledge and technology exchange between industry and science. Public programmes (promotion programmes/measures/actions, financing instruments, infrastructure provision etc.) are a major instrument for supporting ISR. Please **assess** for the following types of public programmes their **relative significance** within the public measures directed at the promotion of ISR (in terms of policy priority, financial resources, range of target groups) and the way they work with respect to their objectives ("**effectiveness**" in promoting ISR). If certain types of programmes are not applied in your country, please note this separately.

If there are **substantial differences between individual measures within one type of programme** (e.g. if there are two measures with different significance/performance or there are measures on regional or organisational levels), please specify the most important measures and assess their significance/performance separately.

	relative significance within promotion of ISR					"effectiveness" in promoting ISR					such type of programme is not applied	
	low		high			low		high				
	1	2	3	4	5	1	2	3	4	5		
Public financial support for joint R&D projects between industry and science <i>Please specify measures/programmes if necessary</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Running joint research labs/centres involving both science and industry <i>Please specify measures/programmes if necessary</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Programmes for researcher mobility between science and industry <i>Please specify measures/programmes if necessary</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Spin-off programmes (start-ups from science) <i>Please specify measures/programmes if necessary</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Promotion of licensing science's patents by industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<i>Please specify measures/programmes if necessary</i>											
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Training programmes (vocational training for firm members at science)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<i>Please specify measures/programmes if necessary</i>											
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Graduate's education programmes (e.g. support for students writing their thesis at firms)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<i>Please specify measures/programmes if necessary</i>											
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Awareness programmes (e.g. develop a better mutual understanding between researchers at industry and science)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<i>Please specify measures/programmes if necessary</i>											
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Support for intermediary structures (technology transfer offices, technology/incubator centres, information systems etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<i>Please specify measures/programmes if necessary</i>											
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Other types of programmes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Please name the programme(s)/measure(s)/action(s) which you would regard as good practice in the promotion of ISR in your country, and describe the major approach and the strengths :											
---	--	--	--	--	--	--	--	--	--	--	--

.....
.....
.....
.....

C. Incentives for and Barriers to ISR

The level of co-operation, knowledge exchange and technology transfer between science and industry is strongly affected by the incentives for public research organisations and firms to get engaged in transfer activities. On the firm side, these incentives are mainly market driven (gaining competitive advantage, access to R&D resources, increase in profitability). On the science side, incentives are strongly affected by the specific institutional framework at universities and public research labs. In order to increase co-operation, knowledge exchange and technology transfer at the science side, institutional frameworks are adjusted and new incentive measures are introduced.

Please **assess** for the following list of **incentive measures at the science side** (universities, public research labs) their **relevance in the current practice of ISR**, i.e. if they support the establishment of relations between science and industry and the orientation of public research towards industry needs. If a certain type of incentive measure is not applied, please indicate this separately. If there are major differences in incentives by individual organisations, please indicate for which organisations the incentives apply. If other types of incentive measures are applied in your country, please note them.

	Relevance to ISR-performance					such type	Note on
	very low		very high			of incentive	organisational
	1	2	3	4	5	does not exist	differences
- Availability of research funds depends (at least partially) on level of ISR-activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
- Individual earnings for researchers from royalty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

incomes generated by licenses

- Individual remuneration for ISR-activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
--	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------

(increase in wage, special bonus etc.)

- Reduction in administrative and/or teaching obligations with increase in ISR-activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Extent/quality of ISR-activities is an explicit evaluation criteria at universities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Extent/quality of ISR-activities is an explicit evaluation criteria at public research labs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Special promotion programmes for ISR-activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

at universities (establishing ISR as a “moral obligation”)									
-	Special promotion programmes for ISR-activities	o	o	o	o	o		o	
at public research labs									
-	Awareness measures at universities	o	o	o	o	o		o	
(special awards, presentation of successful projects etc.)									
-	Awareness measures at public research labs	o	o	o	o	o		o	
(special awards, presentation of successful projects etc.)									
-	Other types of incentives: 	o	o	o	o	o			
Please assess the relevance of the following barriers both at the industry and at the science side for establishing relations, exchange knowledge and transfer technology among each other in your country.									
Relevance of barriers for ISR-performance									
<div> <div>industry side</div> <div>science side</div> </div>									
<div> <div>no</div> <div>major</div> <div>no</div> </div>									
<div> <div>relevance</div> <div>obstacle</div> <div>relevance</div> </div>									
<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>1</div> <div>2</div> <div>3</div> </div>									
-	Shortage in qualified personnel at industry	o	o	o	o	o		o	o
-	Shortage in qualified personnel at science	o	o	o	o	o		o	o
-	Shortage in capital/financing at industry	o	o	o	o	o		o	o
-	Shortage in capital/financing at science	o	o	o	o	o		o	o
-	Differences in R&D objectives	o	o	o	o	o		o	o
-	Divergent time schedules	o	o	o	o	o		o	o
-	Differences in organisational cultures/"languages"	o	o	o	o	o		o	o

- Lack of suitable partners (mismatch in supply and demand)	0	0	0	0	0	0	0	0	0	0
- Lack of information about R&D on the other side	0	0	0	0	0	0	0	0	0	0
- Lack of motivation/incentives	0	0	0	0	0	0	0	0	0	0
- Lack of administrative support	0	0	0	0	0	0	0	0	0	0
- Lack of technical capacities/resources	0	0	0	0	0	0	0	0	0	0
- Lack of entrepreneurial thinking at science	0	0	0	0	0	0	0	0	0	0
- Lack of scientific research interest at industry	0	0	0	0	0	0	0	0	0	0
- Uncertainty on outcomes of joint R&D	0	0	0	0	0	0	0	0	0	0
- Fear of leaking know how to competitors	0	0	0	0	0					
- Fear of loosing scientific independence							0	0	0	0

Your comments on incentives for and barriers to ISR:

[illegible]

D. Personnel Mobility Between Industry and Science

The education of well-qualified personnel for production, administration, marketing and research is a major contribution of universities and public research to innovation and technological change in industry. The effectiveness of higher education and research personnel training is strongly affected by the way demand and supply in human capital meet each other and by the mobility of researchers between science and industry. Please **assess** the **significance** of the following **measures** in the field of **higher education** in your country affecting the way demand and supply in human capital meet each other. If there are other important measures, please note them.

	Significance of measures					
	low			high		
- Teaching by firm members at universities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Vocational training programmes for industry at universities and public research labs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Co-ordinating structures for considering industry needs and changes in industry demand in university education programmes (curricula, new courses etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Long-term oriented and stable relations between firms or industrial sectors and university departments or universities in graduates mobility	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Financing of professorships/departments by industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Promotion programmes for hiring university graduates in R&D (esp. at SMEs)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Co-operation in graduates education between universities and industry (e.g. joint supervision of PhD and master thesis)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Institutional structures for matching supply of and demand for graduates (e.g. advisory boards, fairs)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Graduates organisations (alumni)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Others:						
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
.....	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please **assess** the (relative) **significance** of the following **mechanisms/channels** for the **mobility of researchers** from science to industry and vice versa in your country. If there are other important mechanisms, please note them.

	significance of mechanism					
	low			high		
- Advertisements in newspapers/magazines on job offers/demand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Special data bases on demand for and supply of researchers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Promotion programmes for researcher mobility from science to industry and vice versa	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Personal contacts based on joint research/contract research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Firm-university-agreements on personnel exchange (temporary appointments)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
- Sabbaticals for professors/researchers in science to change to industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[illegible]

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E. Priorities for Improving Framework Conditions on ISR

Please indicate in which areas of framework conditions improvements/adjustments should take place with high priority in order to improve the performance of ISR in your country. Please describe in few words the main approach for improvement/adjustment (e.g. deregulation, new legislation, financial support, institutional incentives, information, re-organisation of institutions) and the principal design of reform measures (e.g. national, regional, organisation-specific implementation; time horizon; main target group addressed).

General Legal Environment (**intellectual property rights, employment law, financing**)

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Strategic vision of research and technology policy

.....

Allocation of Public Financing of R&D (**target groups, technology focuses, basic vs. applied R&D**)

.....

Public Promotion Programmes (**promotion of joint R&D, personnel mobility, start-ups, awareness measures etc.**)

.....

Intermediary structures (**technology transfer offices, technology centres, information and contact platforms**)

.....

Measures at the university-level

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Measures at the level of public research labs

.....

Measures at the firm level

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