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SUSTAINABLE AND DYNAMIC PARTNERSHIP

Research cooperation and researcher training between universities, research institutes and business and industry

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Description

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Abstract

The Academy of Finland appointed on 19 December 2003 a working group that was charged with the task of drafting recommendations for the promotion of researcher training and basic research serving the needs of business and industry as well as for the development of cooperation forms between the Academy and business and industry. The working group recommends that universities, research institutes and companies further develop and deepen their research cooperation.

Cooperation based on sustainable and dynamic partnership requires from all parties structural reforms, strong commitment as well as a change of culture and attitudes. The aim is that researchers at universities, research institutes and business companies shall work together in flexible international communities that carry out high-level research and development projects and provide researcher training to benefit all the parties concerned. The report includes a number of recommendations to achieve this goal.

The working group further recommends that universities and research institutes step up their efforts to identify opportunities for the application and commercialisation of research results and encourage researchers to start their own businesses and to work more closely with business companies. Business companies need to develop their core areas of expertise by making good use of high-level research, by promoting researcher training among staff members and by recruiting a larger number of PhDs.

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Tiivistelmä	Suomen Akatemia asetti 19.12.2003 työryhmän, jonka tehtävänä oli valmistella ehdotus Akatemian toimenpiteiksi elinkeinoelämää palvelevan tutkijankoulutuksen ja perustutkimuksen edistämiseksi sekä Akatemian ja elinkeinoelämän yhteistyömuotojen kehittämiseksi. Työryhmä esittää yliopistojen, tutkimuslaitosten ja yritysten välisen yhteistyön ja vuorovaikutuksen syventämistä ja tiivistämistä. Kestävään ja dynaamiseen kumppanuuteen pohjautuva yhteistyö edellyttää kaikilta osapuolilta rakenteellisia uudistuksia, sitoutumista sekä kulttuurin ja asenteiden muutosta. Tavoitteena on, että yliopistojen, tutkimuslaitosten ja yritysten tutkijat muodostavat joustavia kansainvälisiä yhteisöjä, jotka toteuttavat kaikkia osapuolia hyödyttäviä korkeatasoisia tutkimus- ja kehityshankkeita sekä kouluttavat tutkijoita. Raportissa esitetään runsaasti suosituksia tämän tavoitteen toteuttamiseksi. Työryhmä suosittaa, että yliopistot ja tutkimuslaitokset tehostavat toimenpiteitään tutkimustulosten sovellettavuuden ja kaupallisen hyödynnettävyyden tunnistamiseksi ja realisoimiseksi sekä kannustavat tutkijoita yrittäjyyteen ja yhteistyöhön yritysten kanssa. Yritysten tulisi kehittää ydinosaamistaan hyödyntämällä toiminnassaan korkeatasoista tutkimusta, edistämällä henkilökuntansa tutkijankoulutusta ja palkkaamalla tohtoreita nykyistä enemmän.	
Asiasanat	Yliopisto, tutkimuslaitos, yritys, tutkimusyhteistyö, tutkijankoulutus, tutkijanura, innovaatiojärjestelmä, liikkuvuus, kansainvälisyys	
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Contents

Summary

Research cooperation between universities, research institutes and business companies is very much in a state of flux at the moment. The main contributing factors include the scarcity of economic resources; the increased costs of research; growing competition in the wake of accelerating globalisation; and the ever shorter science, technology and product development cycle. Although Finland has made strong progress in this field, there is still plenty of scope for further developing research cooperation between the public and private sector. Steps are needed to deepen the existing cooperation and to build up the necessary confidence. Key to this effort is a mutual understanding and appreciation of one another's basic goals and objectives.

In a knowledge-based economy the organisations of business companies, universities and research institutes complement one another in an efficient, orderly fashion. Businesses put the jointly developed know-how to good use in new economic innovations; universities use this know-how for purposes of research and education. Close collaboration increases the capacity for regeneration and renewal in research, enhances the social impacts of research, promotes the creation of new innovations and thus increases the competitiveness of the national economy as well as the development of a society that is based on knowledge and know-how. The working group has the following vision of research cooperation between the public and private sector:

Researchers at universities, research institutes and business and industry shall work together in flexible international communities that carry out high-level research and development projects and provide researcher training to benefit all the parties concerned.

The foundation for these communities lies in an open and confidential relationship of systematic cooperation that cuts across all levels of operation – in a sustainable and dynamic partnership. Intersectoral and international mobility is a natural and integral part of the research career at all its stages. Agreements are in place on immaterial property rights to the satisfaction of all community partners, which are supported by high-quality research and innovation environments. The achievement of a sustainable and dynamic partnership in cooperation as outlined in the vision above will require structural changes, dedication and commitment as well as a change of culture and attitudes – a new culture of cooperation.

In the current conditions of advancing internationalisation and knowledge-based economy, good cooperation between business companies, universities and research institutes has become a key factor for national success. Finland is well-placed to further develop this cooperation in such a way that it can maintain the head-start it already has gained.

This report focuses on the promotion of researcher training and basic research that serve the interests of business and industry through deeper and closer cooperation

and interaction between universities, research institutes and business companies. Research institutes are included on account of their significant role in conducting strategic research. Polytechnic cooperation with universities, research institutes and businesses is dealt with separately by a Ministry of Education appointed working group concerned with the development of research activities at polytechnics (Opetusministeriö 2004c).

The working group's main recommendations are as follows:

- The achievement of the vision of closer cooperation between universities, research institutes and business and industry will require a significantly higher level of R&D investment by the public sector as well as further investments by business and industry in R&D and longer-term research. A growing proportion of public research should be funded through open competition. Furthermore, a new programme should be set up in Finland for the development of scientific infrastructures, backed by the funding tools necessary to create internationally competitive research environments.

- Universities and research institutes should step up their efforts to identify and realise opportunities for the application and commercialisation of research results and encourage researchers to start their own businesses and to work more closely with business companies. One way of doing this is through arrangements which allow researchers to work simultaneously in business companies. Businesses need to develop their core areas of expertise by making good use of high-level research, by promoting researcher training among staff members and by recruiting a larger number of PhDs.

- The Academy of Finland and the National Technology Agency Tekes should work closely with businesses, universities and research institutes to provide competitive funding for fixed-term, high profile research and technology units working in fields that are important to the national economy. At these units researchers from universities, research institutes and businesses work together to conduct internationally high-level medium-range and long-term research.

- Universities should join forces with research institutes and businesses to develop and expand both pre and post doctoral researcher training so that it better meets current needs at the workplace level. This can be done by increasing studies that support interdisciplinarity, international exchange and cooperation, entrepreneurship and business know-how and by providing training in management skills and immaterial property rights. Doctoral students should be supervised in their scientific work and studies by a steering group including representatives from outside the university, preferably from business and industry if this is relevant to the content of the dissertation thesis.

- Researchers from universities and research institutes should be able flexibly to spend periods working in business and industry, while business and industry researchers for their part should be given the opportunity to work at universities and research institutes. The Academy of Finland and Tekes should develop new

funding instruments and provide information on existing instruments with a view to promoting intersectoral mobility at all stages of the research career. These mobility efforts should focus most particularly on the postgraduate and post doctoral stages. For purposes of promoting intersectoral mobility it is important that employers recognise merits achieved in different sectors, encourage researcher mobility and reward people for intersectoral cooperation. Researchers and businesses should take more active advantage of international programmes that support researcher mobility and industry-academia cooperation.

- Steps should be taken significantly to increase the number of foreign researchers and especially foreign PhD graduates among Finland's R&D personnel. Today, the proportion of foreign researchers in Finland is clearly lower than in the EU countries on average. In the future it is important that universities, research institutes, businesses and research funding agencies work more closely with one another in an attempt to bring more foreign researchers into Finland. To this end it will be necessary not only to provide internationally high-quality research environments, but also fixed-term competitive posts for high profile foreign researchers sponsored by universities and funding agencies.

- The Academy of Finland should revise the criteria and conditions for funding doctoral studies of employed persons so that research grants are made available not only for the completion of doctoral theses but also for earlier stages of researching the thesis. Steps should also be taken to secure the integration of employed doctoral students into graduate schools or university research teams. The Academy should join forces with businesses and universities to create funding opportunities and practices that would allow people who are employed in business companies to work on their doctoral thesis at universities or research institutes and attend graduate school or other forms of supervised researcher training, and at the same time to remain in the employ of their company. Doctoral students at universities should for their part be able to research their thesis at a business company without this affecting their contacts and connections with the graduate school or similar. Responsibility for the supervision of doctoral theses should be shared by the university and business company.

- Business companies should contribute to supporting Academy and Tekes funded research, technology and centre of excellence programmes that are relevant to their own operation. This would also give them access to programme planning and decision-making.

Foreword

The Academy of Finland appointed on 19 December 2003 a working group that was charged with the task of drafting recommendations for the promotion of researcher training and basic research serving the needs of business and industry as well as for the development of cooperation forms between the Academy and business and industry. In doing this, the working group was to address at least the following aims:

- advancing interaction between business and industry and basic research;
- reinforcing the preconditions and knowledge base for innovation;
- developing researcher training with a view to the needs of business and industry;
- promoting researcher mobility between industry and academia, bearing in mind the opportunities offered by international mobility;
- securing access to an adequate supply of researchers, increasing the appeal of the research profession, and offering new kinds of career options; and
- deepening interaction and dialogue in view of the increasing internationalisation of research.

The working group's term ended on 31 December 2004.

The working group was chaired by Academy of Finland President **Reijo Vihko** until 29 February 2004; and from 1 March 2004 by Academy of Finland President **Raimo Väyrynen**. Its members were Executive Director **Antti Hautamäki** (Finnish National Fund for Research and Development Sitra; deputy member Director **Tapio Anttila**); Assistant Director **Riitta Juvonen** (Chemical Industry Federation of Finland; deputy member Director General **Hannu Vornamo**), Director **Sakari Karjalainen** (Ministry of Education), Senior Vice President **Markku Karlsson** (Academy of Finland Board; deputy member Vice President **Marko Hakovirta**, Metso Oyj), Professor **Riitta Keiski** (Academy of Finland Board), Professor, Vice Rector **Marja Makarow** (University of Helsinki), Senior Vice President **Tiina Mattila-Sandholm** (Academy of Finland Board), Director General **Martti Mäenpää** (Technology Industries of Finland; deputy member Director **Pekka Pokela**), Director **Erkki Ormala** (Nokia Oyj), Vice President, Research **Anneli Pauli** (Academy of Finland; Vice Chair), Chief Policy Advisor **Hannele Pohjola** (Confederation of Finnish Industries EK), Vice President, Administration **Juha Sarkio** (Academy of Finland), Director **Liisa Savunen** (Academy of Finland) and Executive Director **Mervi Sibakov** (National Technology Agency Tekes) until 31 July 2004 and from 1 August 2004 Executive Director **Riikka Heikinheimo**. Secretary to the working group was Senior Science Advisor **Janica Ylikarjula** from the Academy of Finland.

The working group consulted the following experts: Ms Kirsi Kärkkäinen (VTT Finland), Docent Pekka Lappalainen (University of Helsinki), MSc (Eng.) Juha Lipponen (Metso Oyj) and Government Secretary Karri Puustinen (Ministry of Trade and Industry). Furthermore, the working group joined the Ministry of Education development group for researcher training in attending a seminar arranged at the Helsinki University of Technology on the development of researcher training as well as industry-academia interaction in researcher training.

1 Background

Science, technology and innovations[1] today have a greater impact on society than ever before. They are crucially important to national competitiveness, economic growth, employment and welfare. As jobs in both production and R&D will continue to move to countries where the ratio of know-how to costs is most favourable for business companies, Finland will have to rely for its competitiveness on the quality of its innovation system, on a high level of know-how and on the innovative and effective application of new knowledge. Basic research that generates new knowledge and new methods is a necessary, but not yet a sufficient condition for the development of new innovations; that also requires effective social institutions and an input from business and industry.

In its most recent review of the quality and impact of scientific research in Finland (2003b), the Academy of Finland observes that the standard of scientific work in the country as well its visibility remain very high. Key strengths of Finland include the high level of education in the country, a culture that looks favourably upon training and education, and a high level of R&D investment relative to GDP. In 2003, R&D expenditure in Finland amounted to 3.5 per cent of GDP, with the business sector accounting for 71 per cent and the public sector[2] for the remaining 29 per cent of this. However, only a small proportion of PhDs work in the private sector. In 2003, less than 15 per cent of all PhDs worked in business sector R&D jobs, and no more than some 3 per cent of all R&D personnel in the business sector had a PhD (Appendix Table 1 and Table 1). These figures do not, however, give an accurate account of the total number of PhD graduates in the business sector because PhDs also work in other than research positions, for instance as experts or in other jobs requiring a high level of expertise. In the present situation it is not easy and indeed not always even possible for PhDs to move from one career path to another, and the opening up of such pathways between different sectors would be particularly important.

***Table 1**. R&D personnel in 2003*

Source: Statistics Finland

Sector	R&D personnel		Education								
			PhDs		Other university degree		Other vocational education		No vocational education/ unknow		Sum of sha-res
	Total	%	Total	%	Total	%	Total	%	Total	%	%
Businesses	40 089	54	1 214	3	15 862	40	21 661	54	1 352	3	100
Public sector	34 684	46	7 298	21	15 215	44	9 724	28	2 447	7	100
All total	**74 773**	**100**	**8 512**	**11**	**31 077**	**42**	**31 385**	**42**	**3 799**	**5**	**100**

[1] For the purposes of this report, innovations are considered to include so-called social innovations as well.

[2] The public sector is here defined as comprising universities, polytechnics, university hospitals, government administrative branches including government research institutes, other public institutions and private non-profit institutions.

Among the weaknesses of the Finnish innovation system are the low volume of research, which is explained by the country's small population; the fragmentation of research across a number of small units; and most particularly the inadequate utilisation and application of new knowledge. Finland produces a great deal of knowledge-based innovations, but only very few of them lead to successful product development or the launch of new companies. A specific problem for a small country such as Finland is presented by the small size of its markets, which is a major disincentive for investment in R&D (Helpman 2004). Indeed, research-intensive companies often operate internationally.

The challenges of international competition and the requirements of opening up are putting universities under increasing pressure to reassess their principles and policies. For the business sector, too, globalisation is creating increasing pressures of competition, forcing companies to concentrate on their core areas of expertise and to outsource more and more of their operations. Business companies rely for their competitiveness to an ever greater extent on the know-how they have developed and acquired and that they control. Cooperation with universities and research institutes has become an integral part of the development of business know-how. For SMEs in particular, this cooperation offers much greater opportunities to participate in research than would be possible if they had to rely on their own funding alone.

Many knowledge-intensive companies today are leaders in their own fields of expertise; their know-how is sometimes more advanced than that offered by universities or research institutes. In many cases, however, the know-how of businesses is highly specialised and focused on their core area of business. This needs to be complemented by know-how from adjacent fields of expertise, which they often seek in collaboration with other companies, universities and research institutes.

Universities and research institutes are expected to maintain and develop know-how on a much broader front than is possible in business companies. Indeed, innovations are often created on the interface of various different disciplines, by linking and developing know-how from new vantage-points and from several different fields in interactive networks involving several agents and operating on an equal level. More and more often now, these value-creating and value-sharing knowledge networks are international. Business success dictates that companies must be actively involved in these international networks together with other companies and R&D organisations. As a consequence, the policy frontiers between both states and between the public and private sector have to be completely redefined.

International trends in development have caused the science, technology and product development cycle to become ever shorter and faster. In the IT sector, for instance, many new scientific innovations are brought to the marketplace in new products or services in a matter of months rather than years. Continuous interaction between universities and industry provides a great opportunity to speed up the innovation process and to bolster competitiveness. The importance of research cooperation between the public and private sector is further underlined by the scarcity of economic resources and increased research costs. Close contact and connections between universities, research institutes and business and industry

facilitate the immediate application and commercialisation of research results and help to direct research in the public sector also towards socially and economically relevant issues.

Industry-academia cooperation helps to maximise the scientific, economic and social benefits reaped from investments in research and to secure the vitality of scientific research as well as its capacity for renewal and regeneration. Intersectoral exchange and interaction helps researchers to weigh the true significance of their work and their line of research from a broader perspective and to understand the social impacts of their research.

In a knowledge-based economy the organisations of business companies, universities and research institutes complement one another in an efficient, orderly fashion. The innovation process is no longer a linear one where ideas developed in basic research gradually mature through applied research and product development into innovations and where there are separate organisations and funding systems for each consecutive stage of development. It is now understood that innovation is an interactive system of parallel development processes with various feedback loops in which basic research, applied research and product development are interspersed with one another and are in constant interaction with one another.

These changing views of innovation activities were a major motivation behind the appointment of this working group. Another underlying motivation was the recommendation made in the Academy's survey on the employment, placement and demand of PhDs (2003a) regarding the development of industry-academia cooperation. Tekes has long financed both university and industry projects where academia and business have close collaboration. These projects, however, have been aimed specifically at practical application. There remain various obstacles to effective research and product development cooperation between the public and private sector, from legislative issues to cultural differences and prejudices. It is imperative now to lower these obstacles.

In keeping with the working group's assignment, this report focuses on the promotion of researcher training and basic research that serve the interests of business and industry through deeper and closer cooperation and interaction between universities, research institutes and business companies. Research institutes are included in the discussion on account of their significant role in conducting strategic research. Polytechnic cooperation with universities, research institutes and businesses is dealt with separately by a Ministry of Education appointed working group concerned with the development of research activities at polytechnics (Opetusministeriö 2004c). The aim of this Academy-appointed, broadly-based working group has been to find new ways in which to intensify research cooperation between industry and academia and to develop innovation environments that benefit all the parties concerned. Science and technology have traditionally followed their own separate paths, but over time they have begun increasingly to converge, at least at a conceptual level. The challenge now is nothing more or less than how to carry forward this synthesis in such a way that universities, research institutes and business companies can all maintain their own distinctive characteristics that lie at the heart of their success.

2 Vision for research cooperation between universities, research institutes and business and industry

The working group has the following vision of research cooperation between the public and private sector:

Researchers at universities, research institutes and business and industry shall work together in flexible international communities that carry out high-level research and development projects and provide researcher training to benefit all the parties concerned.

The foundation for these research communities lies in an open and confidential relationship of systematic cooperation that cuts across all operational levels – a sustainable and dynamic partnership. High quality makes these communities sought-after partners in cooperation both nationally and internationally. Intersectoral researcher mobility is a natural and integral part of the research career at all its stages. Agreements are in place on immaterial property rights to the satisfaction of all community partners, and the community is supported by high-quality research and innovation environment (Figure 1).

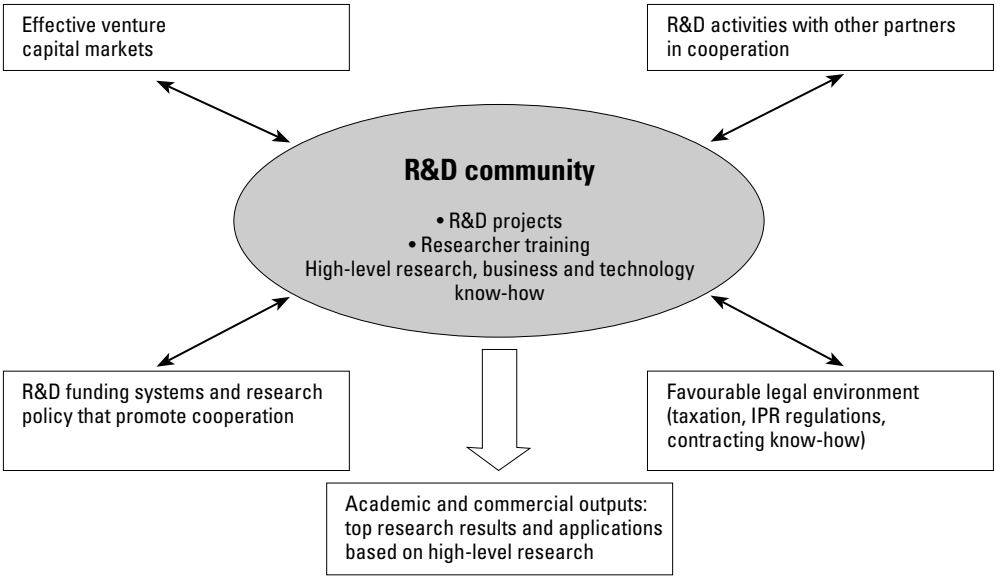

Figure 1. *Favourable innovation environment*

A favourable innovation environment requires the interplay of all components of the innovation system such as the effectiveness of venture capital markets as well as R&D funding mechanisms that promote cooperation and a continuous strategic development effort on the part of ministries, funding agencies and other R&D policy-makers.

For reasons of securing an internationally high standard of research it is imperative that universities specialise to a greater extent than is currently the case. Steps are needed to strengthen the division of labour and strategic cooperation between universities: it is important not only to provide for broad, moderate coverage, but also to maintain a sharp focus. High-level, internationally competitive research requires major investments in infrastructure and hardware. In Finland it is not possible for any individual actor to maintain an extensive research infrastructure at the highest international level; no such organisation can keep up with the rising costs. A broad, shared use of facilities in the context of a new national infrastructure programme would secure access to adequate resources for research infrastructure projects in areas of key national importance.

All R&D organisations must define their core areas of expertise and their main goals. The choice of partners in cooperation that share the same strategic orientation shall be based on considerations of know-how complementarity. It is important that all partners are committed to these choices.

The achievement of the vision outlined above will require of all the parties involved structural changes, agreement over a common set of rules and standards, dedication and commitment as well as a change of culture and attitudes – a new culture of cooperation. Business cooperation does not have to reflect adversely on scientific quality or compromise academic freedom. It is in the best interests of business partners to make use of the best possible basic research available. Industrial relevance and the scientific excellence of research results serve to reinforce each other.

The working group has the following recommendations:

- It is imperative that the target set out in the Finland in the Global Economy report, i.e. that public investment in R&D is increased by at least seven per cent a year, is met during the current decade. Together with a strong effort in researcher training, the attainment of this target will provide a solid platform for research cooperation between universities, research institutes and business companies. At the same time it sends a clear message to business companies to retain key areas of their R&D operations in Finland.

- Most of the increased research funding should be allocated on a competitive basis. This will guarantee adequate resources so that the best teams and projects can produce internationally high standard research. The funding made available should support the regeneration and specialisation of research and the research system as a whole.

- Several companies should increase their R&D funding and invest in long-term research together with universities and research institutes, which also strengthens business competitiveness.

- A new programme needs to be set up in Finland for the development of scientific infrastructures, involving not only ministries and other public sector agents but

also business and industry. The funding required for effective implementation of this programme must also be made available.

- The know-how and resources that are scattered across small units must be integrated into larger, more efficient systems that where necessary cut across sector boundaries. They should also be networked internationally.

3 Research cooperation between the public and private sector

3.1 The foundation for cooperation

Finland has a sound culture of cooperation between different actors in the research and innovation system; indeed in many countries the capacity for cooperation within the Finnish innovation system is regarded as an example that deserves to be followed. According to the World Economic Forum scoreboard, Finnish universities and industry have closer research cooperation than anywhere else in the world (2002). Although Finland has made good progress in industry-academia cooperation, there is certainly no cause for too much self-satisfaction. Continued effort is needed to further develop this cooperation, to deepen cooperation and to build up the necessary confidence.

Recently there have been increasing calls in Finland for an active and more diverse innovation policy, e.g. by the Finland in the Global Economy report; the reports of rapporteurs Jussi Huttunen, Markus Koskenlinna and Jorma Rantanen; as well as the strategy drafting by the Science and Technology Policy Council. The rapporteurs have dealt in their reports with government research institutes, technology transfer organisations as well as universities and polytechnics. The common message of these reports is that in order to succeed in the ever-tougher scientific, technological and economic competition, Finland must be prepared to break down attitude as well as institutional barriers.

Universities, research institutes and businesses do not inherently share common goals, but they can certainly further the attainment of their respective goals by means of cooperation. The roles and functions of the various partners in the research and innovation system are no longer isolated and detached from one another in the way they used to be. Instead of looking upon basic research, applied research and product development as mutually conflicting or incompatible activities, it is important to see that cooperation can benefit all parties. Each party, nevertheless, has its own identity and culture: the purpose is not to streamline and harmonise them all, but rather to make better use of their complementarity.

The new University Act that enters into force on 1 August 2005 will assign a third function to universities in addition to the two existing tasks of promoting research and providing education on the basis of this research: this is the duty to have closer exchange and interaction than is currently the case with the rest of society. Ultimately, the aim is to make the knowledge and know-how produced in university research more readily available and accessible to society and industry. However, the pursuit of this third task must not lead to the sole aim of maximising profits. In order that the cooperation and confidence between universities and industry can be deepened, it is important to make sure that the preconditions for cooperation are strengthened in developing universities' goals and incentive systems.

The polytechnic system has different goals from universities. Polytechnics are responsible for providing education that is designed to meet workplace needs and for applied R&D that promotes regional development and innovation process, not for conducting scientific research as at universities. For the innovation system to work properly it is extremely important that universities and polytechnics have good cooperation and that the differences between their respective roles are appreciated.

A key objective for industry-academia cooperation both in research and researcher training is not only the transfer of knowledge, but shared learning and the sharing of knowledge. In this cooperation both industry and universities are at once producers and end-users of information. The know-how developed in common processes is put to use by business companies in new economic innovations, by universities and research institutes in the development of research and teaching. The contribution of universities and research institutes to cooperation consists above all of their in-depth research know-how and new ideas to fields that are important also to the national economy and businesses, as well as of their contacts with the international science community and highly trained leading experts. Industry, for its part, has a wide range of research knowledge as well as an in-depth knowledge of new technologies, innovations and the markets. Through open exchange and interaction, business companies can actively support the development of research and education at universities.

Cooperation requires mutual trust and confidence, an appreciation of other partners' expectations as well as predictable costs. In this regard the mutual understanding and appreciation of one another's basic goals is paramount. Smooth cooperation requires that universities are capable of adapting and responding quickly to the changes taking place in society. Industry, for its part, shall ensure its long-term cooperation with key partners irrespective of the financial pressures arising from short-term objectives.

One of the major obstacles to intersectoral research cooperation is that people in industry and academia do not know enough about each other, their ways of working, their goals and competencies. Personal contacts are of paramount importance in this respect. University alumni could play a key role in maintaining contact between academia and industry: they can introduce current business perspectives in university education and act as partners in cooperation in various research projects. According to a recent questionnaire at Lappeenranta University of Technology, more than one-half of the responding alumni were prepared to collaborate with universities (Saksa et al. 2004).

The working group has the following recommendations:

- Actors in the public and private sector should work to improve their interaction with a view to creating a common understanding and thereby new cooperation. In the early stages of this interaction research management at universities, research institutes and business companies have a key role to play. In some cases it might be useful to set up industry or cluster-based forums dealing with questions related to research cooperation. The partners involved must be able

to respond quickly and to make strategic changes and choices in line with the forums' proposals.

- The various partners should make public their principles of R&D cooperation and establish clear channels of contact to provide for easy and effective communication between universities, research institutes and business companies. Furthermore, universities should establish close contacts with their alumni, especially with PhDs in business and industry with a view to facilitating contact and communication.

- Universities should be offered financial incentives in the context of management by results regimes with a view to increasing long-term research cooperation with industry and networking with other universities, knowledge producers and end-users.

3.2 Common rules and standards

With the continuing growth and ever greater complexity of industry-academia cooperation, there is also a growing need for a clear set of rules and standards for research cooperation, both for purposes of improved predictability and the avoidance of conflicts of interest. The question of immaterial property rights (IPR) is paramount: these refer among other things to patents, trademarks, designs, utility models and copyright; the exploitation of IPRs refers also to the transfer of rights of ownership and use. IPRs give the holder the exclusive right to exploit an innovation and to release rights of ownership and use. On the other hand, IPRs can also be used to prevent rivals from exploiting innovations or to protect investments already made. IPRs are of great significance both to individual researchers and to businesses in the context of cooperation and global competition.

From the individual researcher's point of view, IPRs guarantee the researcher's personal right to gain recognition and financial benefits from the innovation. Since the researcher rarely has the know-how or the financial resources that are necessary for the identification and exploitation of innovations, it may be necessary to resort to the help of a university, intermediary organisation, companies or venture capitalists. Usually this kind of support will require that the rights are transferred from the researcher either to the university or to the company, but even in this instance the researcher will be entitled to be recognised as the inventor or other contributor. Tekes requires routinely that IPRs are transferred to the organisation in receipt of funding in all public research projects, and provides funding for project costs due to patenting. Both for reasons of researcher success and the continuity of his or her work it is also important to ensure the right to publish research results without unreasonable delay. Any problems are best avoided by clearly agreeing upon the relevant principles in advance. In certain fields it should also be possible to rank patents alongside publications in applications for competitive funding.

As far as public funding agencies and universities are concerned a key consideration with respect to the use of IPRs is that returns from public investments shall benefit the whole of society, primarily in the shape of domestic business. In competitive research

funding it is important to identify such innovations that have high applicability in society or business and industry. IPR legislation and procedures should be such that it is possible to have as consistent and predictable interaction between innovation producers and end-users as possible. There may be several end-users of a given innovation, but as the birthplace of researcher-driven innovations universities are best placed to promote the identification and use of these innovations. This requires adequate investment in resources from universities, and the role of a link between researchers and industry is not without its contradictions.

In business, innovations are used for purposes of creating new markets. Some innovations can be produced by businesses themselves, or businesses may take advantage of innovations made by university researchers, for example. For knowledge-based business companies, IPRs provide protection for the investments they have made as well as secure their competitive position in further developing their products for the marketplace. In some fields a patent portfolio is a strategic investment designed to secure the general platform for operations. IPRs may also have a key role in acquiring capital investments. If there remains any uncertainty about the ownership of IPRs, venture capitalists will not be interested in the company. A venture capitalist may be interested in investing in an existing company with a view to financing a new innovation, or in providing the initial capital funding for the start-up of a small company formed by researchers.

Joint projects of cooperation often involve various contractual arrangements. The most important types of contract in the context of research cooperation are agreements on commissioned research, research funding agreements, research subcontracting agreements, consortia agreements on joint research projects and agreements for the transfer of rights. Key preconditions for successful contractual cooperation are mutual confidence among the partners involved, predictable costs and effective problem-solving models.

The attainment of the best possible end-result would also require harmonised contracting models that support the aims of commercialisation in the best possible way. There is a practical awareness of the existing problems and in addition to an ongoing national contracting models project, there are various intra-university development groups at work. Launched in 2003 with funding from the Finnish National Fund for Research and Development Sitra and the Ministry of Trade and Industry, the contracting models project involves a wide range of actors from the innovations field. The aim of the project has been to strengthen expertise in contracting and to streamline as well as increase mutual understanding about contracting procedures through the adoption of best practices and common standards.

In conclusion then, the various parties in the field have somewhat contradictory interests. Nonetheless, the contribution of all parties is needed and cooperation is essential to the promotion of innovation. Effective contracting procedures and rules regarding immaterial property rights are among the most crucial preconditions for intersectoral research cooperation. If the parties are not fully content with the arrangements in place, research cooperation will be significantly complicated

if not completely impossible. Indeed, the key challenge is to create harmonised, clear and predictable rules, standards and models of cooperation. Cooperation requires advance contracts, predictable costs as well as predictable rights of use and ownership.

Work is currently under way to draft new legislation on university innovation. The purpose of the new act will be to clarify and harmonise the transfer of rights for innovations made at universities and to facilitate the identification and commercial application of inventions. A further aim is to support and facilitate the requisites of universities to use the research results.

The working group has the following recommendations:

- Universities and research institutes should significantly step up their efforts to identify and realise the application and commercialisation of research results. Key actors in this regard are universities' and research institutes' innovation and invention ombudsmen, university development companies and Employment and Economic Development Centres as well as business companies.

- Universities should develop a harmonised set of contracting models, standards and procedures for both funding arrangements between researchers and universities and business companies and for IPR transfers. These models and procedures must be acceptable to business and industry partners as well.

3.3 Forms of cooperation

Major forms of R&D cooperation between the public and private sector include collaboration through joint research projects; commissioned research; so-called sponsored research; consultation and expert assistance; and the application by businesses of research results and innovations made in the public sector. Other important forms of cooperation include university teaching provided by researchers from the private sector, cooperation in researcher training, researcher mobility between organisations, the joint use of equipment and other infrastructure, spin-off companies and informal networks and other contacts. Cooperation through joint research projects shall benefit all the parties that are also actively involved in the research effort and that contribute to funding. Commissioned research funded by a business company is based upon the company's own needs, but this research should nonetheless be scientifically challenging to university or research institute researchers. "Sponsored research" should be driven by academic interests: the business partner will not necessarily be involved in the research itself, but only provides necessary funding. The business will, however, expect to gain added value from the research as well as new ideas and inspiration for its operation.

According to the KOTA database annual research funding from domestic business companies to Finnish universities has risen from just over 30 million euros in 1999 to more than 47 million euros in 2003. Research funding from foreign companies has increased even more, doubling from less than five million to more than 10 million euros. In 2003, business funding to universities accounted for about 5.5 per cent of

universities' total budgets and business research funding to universities for 7.3 per cent of universities' research funding. In 2004 up to 32 per cent of VTT Finland's turnover came from the private sector.

A growing trend in recent years has been for business companies to support universities through donated professorships. The donating business has no say in the choice of the person appointed to the chair, but it can to a great extent influence the scope of the professorship and in that way strengthen research and teaching in that particular field. In 2003, universities received a total of more than 14 million euros in donations, in 2004 it is estimated that the figure will rise to more than 24 million euros. On the Academy's initiative several R&D organisations have submitted a proposal to the Ministry of Finance that donations received for research purposes be exempted from tax up to a ceiling of one million euros instead of the current figure of 25,000 euros.

Internationally, too, the need for increased industry-academia cooperation has received ever greater attention; the issue has been addressed among others in the recent reports by the EU Commission, the European Science Foundation ESF and the OECD Science and Technology Policy Committee. Funding organisations in various countries have sought to respond to the growing need for cooperation by introducing various funding instruments. The US National Science Foundation has introduced a form of funding that supports long-term cooperation between industry, academia and public administration (Industry/University Cooperative Research Centers, I/UCRC Program). Centers involved in the programme aim to produce high-level basic research that is directly relevant to industry. Most of the funding for these centers comes from business companies, but even so the comparatively small sums contributed by the NSF have a major impact on the implementation of industry-academia cooperation.

In the Netherlands the Dutch government introduced in 1996 a new funding instrument called Leading Technology Institutes (LTI), which the OECD has described as one of the most purest forms of public-private cooperation (OECD 2003c). The aim of LTIs is to intensify the economic and social benefits received from high-level research. At these institutes business companies, universities and research institutes engage in high quality, multidisciplinary mid- and long-term research in fields that are particularly important to the Dutch economy. Altogether there are four LTIs. Basic funding is provided by ministries as well as the companies, universities and research institutes involved. The researchers hired by the institutes work together with researchers from the private and public sector in programmes and projects of various duration. The institutes run for a fixed period: funding decisions are made for six years at a time, and the institutes are required constantly to demonstrate the quality and relevance of their operation (Leading Technology Institutes 2004). There are no comparable research units that are run jointly by businesses, universities and research institutes in Finland.

There are, however, various other forms of close collaboration between universities and industry in Finland. The Helsinki Institute for Information Technology (HIIT) is a joint research institute of the University of Helsinki and the Helsinki University

of Technology which conducts internationally high-level strategic research in information technology and related multidisciplinary topics, especially in areas where Finnish IT industry has a significant role. HIIT works in close cooperation with Finnish universities, research institutes and industry. Its aim is to achieve significant scientific impacts which will also benefit industry and the progress of the Finnish information society. Oy Keskuslaboratorio – Centrallaboratorium Ab (KCL) is a private research centre that serves the pulp, paper and board industry. KCL's research laboratory primarily provides services for partners, and research projects are carried out closely with financiers. KCL seeks actively to develop interdisciplinary innovations by networking with leading experts in different fields and by setting up closer relations with academia among other things through increased exchange of experts.

One example of a Finnish business that invests heavily in R&D is Nokia, which runs its own research center to strengthen the company's technological competitiveness and renewal. Nokia Research Center also engages in long-term research in a global network that involves both universities and other companies in the same field. Like many other businesses, Nokia provides significant funding for research in the public sector. On the other hand, the company itself receives public funds for its own R&D purposes.

The significance of industry-academia research cooperation varies across different industries and companies. The share of R&D spending of turnover is highest in the electronics and chemical industries (Appendix Table 2). For some companies research is not a major current concern, and some will only be interested in cooperation if the results promise easy and immediate applications. Other companies for their part work closely with universities and research institutes even if the risks involved are high and even if there are no guarantees of immediate commercial applications.

As is clear from Appendix Tables 3 and 4 which describe business innovation in 2000-2002, the proportion of businesses with product and service innovations and businesses with innovation-related cooperation increases proportionately with the number of personnel in the company. On average 64 per cent of businesses with innovation activities also have innovation-related cooperation with universities, research institutes or other business companies.

Biotechnology companies have much closer contact with universities than businesses in other branches in general. Public research investment has generated a large number of small companies in this field on the basis of academic research. Many of these companies continue to work closely with universities and research institutes and are located in the close vicinity of universities. Indeed, it has even been suggested that some of these companies have become overly dependent on public funding, which may have had the effect of undermining their capacity to take risks.

More than 80 per cent of all biotech companies set up in Finland in 1991-2001 had cooperation with domestic universities or research institutes, some 30 per cent had cooperation with foreign universities or research institutes (Luukkonen

2004). Biotechnology applications are often based on international level research and know-how. Almost one-third of staff at biotech SMEs have a PhD; if major multibranch companies in the biotech sector are included, the proportion is one-quarter.

The contribution of the electronics and electrical industry to the Finnish national economy has increased considerably since the 1990s and now accounts for more than one-quarter of total Finnish exports. The close research cooperation that businesses have maintained with universities and research institutes has been very important to the growth of this sector. In addition to a handful of major corporations a large number of smaller businesses have been set up, many of which started out as subcontractors to bigger companies. The electronics and electrical industry invests more in R&D than any other industry in Finland, around two billion euros a year. Nokia alone accounts for about one-half of the R&D expenditure in the private sector. The electronics and electrical industry is characterised by a high demand for a well-trained and competent workforce. However, in 2003 no more than around 2.3 per cent of the R&D personnel in this industry had a PhD, which is slightly less than the average for all industries at 2.6 per cent (Appendix Table 1). In the chemical industry, for example, the proportion is much higher: 6.2 per cent of R&D personnel here have a PhD.

The working group has the following recommendations:

- The Academy of Finland, Tekes and other R&D funding agencies should support the networking of universities, research institutes and business companies as well as their joint projects.

- The Academy of Finland and Tekes should join forces with business companies, universities and research institutes to provide competitive funding for fixed-term, high-level research and technology units working in fields that are important to the national economy. At these units researchers from universities, research institutes and business companies work together to conduct internationally high standard medium-range and long-term research. This will support the formation of internationally significant research units that have sufficient critical mass and that will attract high-level foreign researchers.

- In addition to public sector investment in R&D the ceiling for tax-exempt donations intended for research purposes should be raised to at least one million euros. This would provide a more solid foundation for financial support from private sources to science and technology.

- Research-driven entrepreneurship requires an ability and a willingness to take risks. People working at universities should receive more encouragement to start their own businesses. One way of doing this is by means of innovative arrangements that would allow people to work simultaneously in research and teaching at universities and in business companies.

- University campuses should be developed with a view to making them more attractive places for both established and new companies by using business incubators and science parks. Geographical proximity facilitates the formation of industry-academia links and highly visible centres of know-how are also attractive targets for foreign researchers, businesses and investments.

4 Researcher training and the research career

4.1 R&D personnel in the innovation system

Finland's success will continue in the future to depend on a highly educated and skilled workforce. A competent research community is an important asset for business and industry, universities, research institutes and society at large. In Finland the number of people working in R&D has increased sharply since the early 1990s both in the university and the business sector, and in 2001 the numbers working in R&D as a proportion of the total labour force were higher than in any other OECD country at around 1.6 per cent (OECD 2004b). According to Statistics Finland the number of people working in R&D in 2003 stood at around 75,000, just over half of whom were employed in the business sector (Table 1). Around 40,000 of the R&D personnel or less than 53 per cent had a university degree. The number of R&D personnel with a PhD was over 8,500, around 11 per cent. Indeed, the labour market can still easily accommodate a greater number of PhDs, given that these people have the right competencies and that employer attitudes towards hiring PhDs become more favourable. The number of PhDs has increased considerably in Finland since the 1990s. According to the KOTA database a total of 1,399 doctorates were granted in Finland in 2004. The Government has set the target for 2008 at 1,600 new PhDs.

A key condition for business success in the increasingly competitive international marketplace is that there is a sufficient level of know-how and innovation. As the situation stands today, PhDs account for no more than 3 per cent of business companies' R&D personnel (Table 1). According to the Academy's survey of the employment, placement and demand of PhDs (Academy of Finland 2003a), companies with PhDs on their staff thought they would have a greater need for recruiting PhDs in the future than did other companies. In business and industry, however, employees' job tasks are determined on the basis of their skills and competencies rather than on the basis of the degree they have completed. In research in particular, PhD graduates should possess more in-depth expertise than others with an academic degree, and they may bring with them new ways of thinking and greater creativity and innovation into the business. In international business a PhD will often afford an added element of credibility as well.

One problem with respect to the professional research career is presented by the high age of persons completing their Master's and PhD degrees. In Finland, the mean age of graduating PhDs in 2003 was 36 years. The age upon completion of the PhD should be lowered especially among people who continue their studies full-time immediately after completing their first degree. According to the KOTA database the completion of higher university degrees in 2003 took on average six years, while just one-third graduated within the target of five years. As Finnish students begin their university studies relatively late, their contribution to working life remains short by international comparison. It is expected that the changeover to a two-tier degree structure from 1 August 2005 as part of the Bologna process will help to reduce

graduation times. The PhD should be seen as an intermediate step en route to a professional research career, expert assignments or other tasks requiring a high level of skills and expertise.

The working group has the following recommendations:

- Businesses should develop their core expertise by making use of high-level research, promoting researcher training among staff members and hiring more PhDs.

- By the end of the current decade PhDs should account for at least 6 per cent of business companies' R&D personnel, twice the current figure. In many basic industries this will require a much greater investment in high-level R&D activities by increasing the number of PhDs in their staff.

4.2 PhDs in multiple roles

Increasing pressures of competition and expertise in the global economy are placing ever greater demands on the skills and competencies on the workforce today. Researcher training shall provide the necessary knowledge and other competencies for a professional career in research and for employment in different sectors of society, not just at universities. PhDs are expected to show a capacity for theoretical thinking, the ability to develop new ideas, generate hypotheses and obtain and process data analytically and critically. They must also have a sound knowledge of the key research methods in their field of study, willingness to specialise as well as good skills of oral and written communication and a versatile command of languages. Researcher training teaches a systematic approach to problem-solving. Nowadays PhDs are also expected to show an interdisciplinary approach and competencies, a knowledge of IPR principles, management and organisational skills, skills of cooperation, interaction, networking and negotiation, business know-how as well as skills of popularisation and science communication. Not all PhDs can obviously master all these skills. In spite of the demands of broad-ranging skills and competencies, the key aim is still to achieve an in-depth knowledge of one's own field of study. In today's society there is a need for all kinds of PhDs, both business-minded experts with wide-ranking skills and more specialised scientists. Finland faces a whole host of challenges with regard to the development of the professional research career. These challenges are currently being considered among others by the Finnish Council of University Rectors and the Ministry of Education working group under Chancellor Eero Vuorio.

Industry-academia cooperation in the field of researcher training still leaves much to be desired. It would be extremely important for business companies to be closely involved in basic education and researcher training because universities produce a significant proportion of the skilled labour force that is later recruited by businesses. Companies do not know enough about researcher training, universities for their part do not have a very clear picture of what business companies expect of graduating PhDs. Business cooperation helps university researchers to gain a better understanding of the skills that are most in demand in business and to take account of

these requirements in their teaching and supervision. When they move to the private sector, people with a researcher training might lack the kind of knowledge and skills that are best learned in business. It is therefore important the universities encourage postgraduate students to get involved in research cooperation with businesses. This also facilitates the recruitment of researchers into business companies.

Where doctoral theses are researched in joint projects with business companies, it needs to be borne in mind that the research done by the postgraduate student must meet the university requirements set for doctoral theses as well as reflect the doctoral candidate's own personal ambitions, even though the company may have a say in setting the goals and objectives of the research. The scientific and social relevance of one's own research must be considered even at the stage of researcher training; efforts should also be made towards active publication and application of the research knowledge produced. University departments and laboratories that have close contacts with businesses will have greater appeal among students because they are likely to offer better prospects for employment in the private sector as well.

The working group has the following recommendations:

- Universities should join forces with research institutes and businesses to develop and expand both pre and post doctoral researcher training so that it better meets current needs at the workplace level. This can be done by increasing studies that support multidisciplinarity, entrepreneurship and business know-how and skills as well as by providing training in management skills and immaterial property rights.

- Researcher training should give due attention to skills of internationalisation, skills of cooperation and interaction, and understanding the function of the innovation system, which are all necessary and crucial to successful job careers upon completion of the PhD.

4.3 High-level and international researcher training

High quality is central to successful postgraduate researcher training: it guarantees the training of top-level experts who are capable of further developing know-how and innovations in international communities as described in the vision outlined above.

Among the aims of the graduate school system that was launched by the Ministry of Education in 1995 are to raise the overall standards of researcher training, to intensify researcher training and lower the age of PhD graduates and to increase cooperation between universities, research institutes and business and industry. There are currently 114 graduate schools in the country with a total of 1,426 graduate school places funded by the Ministry of Education. In addition, an estimated 2,500 postgraduate students are studying at graduate schools with other funding.

A clear distinction can be made between two main pathways to the PhD: full-time studies upon completion of the first degree or researching the PhD while working. The

graduate school system has helped to systematise and raise the level of researcher training. However, graduate schools do not yet represent the main pathway of PhD training because over one-half of all PhDs graduate from outside the graduate school system. In 1998–2002, more than 60 per cent of all PhD graduates came from outside graduate schools (Valtiontalouden tarkastusvirasto 2003).

For purposes of further developing graduate schools and setting up new ones, it is important to be able to predict the need for PhDs in different disciplines and to assess the long-term foundations for the competitiveness of the national economy. In both cases it is essential to take into account the interests and priorities of business and the public sector.

As the number of doctoral theses continues to rise and efforts are continued to lower the age of PhD graduates, special attention must be given to maintaining the quality standards of dissertations and to comparing researcher training and doctoral theses internationally. From this point, the high-quality review system of dissertations as well as the prereview and public examination systems are of paramount importance. Special effort must be invested in the supervision of postgraduate studies and the doctoral thesis. One factor which reflects adversely on the consistency and quality in doctoral theses is the lack of systematic researcher training especially outside graduate schools. Postgraduate students might also have very different goals with respect to their doctoral training and careers after the completion of the PhD. Steps are needed to help postgraduate students working outside universities to create significantly closer links with universities and graduate schools.

Internationalisation should be an integral part of researcher training. PhDs must have the skills and competencies to work actively in the international science community. Scientific visits to foreign countries and the presentation of one's own research work at international conferences must be part of the training of every doctoral student. Indeed, at many graduate schools this is now standard practice. It is particularly difficult for postgraduate students who are not enrolled at a graduate school or who are not in the employ of universities or research institutes to gain the necessary international experience and skills; they often lack the funding to work abroad and to attend international conferences.

The working group has the following recommendations:

- Clear quality criteria should be established for the successful selection of postgraduate students in order to guarantee the highest possible level of future PhD graduates. People who have spent longer periods in working life will particularly need to upgrade and update their knowledge as applicable in keeping with the universities' requirements before embarking on their postgraduate studies.

- Universities should appoint a steering group to assume responsibility for better and more versatile supervision of the postgraduate student's scientific work and studies. This group should involve scientifically competent experts and include representatives from outside the university, preferably from business and industry

if this is relevant to the content of the dissertation thesis. The supervisor shall also pay attention to the postgraduate student's employment prospects.

- Clear and flexible procedures are to be agreed upon separately so that postgraduate students who are working outside universities can maintain close contact with universities and so that doctoral theses produced in joint research projects with business companies would be of as high quality standards as possible and so that there is adequate supervision of the progress of these projects and their collaboration.

- Business companies should be more closely and systematically involved in planning and running graduate schools that are directly relevant to their own operation, either directly or through their umbrella organisations. In reviewing graduate schools applications it is important to take account of the graduate school's planned and realised contacts with business and industry.

- National graduate school courses and other researcher training cooperation should be increased and joint eLearning environments established with a view to raising the quality of researcher training and increasing its availability. This would also allow a greater number of postgraduate students from outside universities to take part (cf. the principles of certain MBA programmes).

- As a rule, researcher training should include studies abroad. This is supported by systematic cooperation with foreign graduate schools and postgraduate training programmes, which the Academy of Finland should seek to promote in its own work. Tuition and teaching materials at graduate schools should primarily be in the English language, thus allowing foreign postgraduate students to attend courses. Furthermore, foreign top-level researchers should be recruited into teaching at graduate schools. The Ministry of Education, the Academy of Finland and universities shall take account of the extra funding required by internationalisation when deciding upon the funding allocated to graduate schools.

4.4 A professional career in research

The target set by EU leaders at their Barcelona Summit in 2002 was that R&D funding within the Community should reach 3 per cent of GDP by 2010. According to the European Commission, this implies a need for an extra 700,000 researchers (EU 2003a). Although this target is probably too high to be realistic, there will certainly be a great demand for researchers. The impending retirement of the babyboom generation will also come into play here. The increased need for researchers cannot be met simply by getting in more people from outside Europe, but this will require a concerted training effort in Europe. In order to secure an adequate supply of competent researchers, it is necessary to invest in a comprehensive and high-quality education system.

PhDs in Finland have had little difficulty finding work. According to statistics maintained by the labour authorities, the number of unemployed PhDs in 2003 stood at 286, or just 2.2 per cent of all PhDs. No differences were seen in the jobless

rate for male and female PhDs. Having said that, it is interesting that all the unemployed women PhDs were under 50 and all the unemployed male PhDs were over 50. In contrast to many other countries there is still considerable interest in Finland towards postgraduate studies, with an average five applicants showing up for every graduate school vacancy. However, the number of applicants varies widely from one discipline to the next. Steps are now needed to make a professional career in research a more attractive option with a view to securing the quantity and quality of researchers. This will help at least to some extent to dissuade Finnish businesses from relocating R&D operations abroad. In 2004, almost 40 per cent of Finnish industry R&D expenditure was generated outside the borders of the country and around one-quarter of all research jobs were in other countries.

The position of researchers is fraught with various uncertainties. The growth of external funding in the public sector is driving up the number of fixed-term researchers and undermining the continuity of their livelihood. Furthermore, many doctoral students and researchers rely on personal grants for their income, which means they may lack various social security benefits such as occupational health care services, annual holidays and pension benefits; the amount of grants received is also disregarded in determining sickness and maternity benefits. Nowadays some foundations do provide additional funds to individual grant recipients for purposes of organising insurance cover, or even grant appropriations for hiring the person concerned. The pay level of researchers, especially in the public sector, is often very low in view of their level of education.

Existing career path models are a major factor with respect to the appeal of a career in research. In Finland research careers are often carved out in one and the same organisation. Unless it is possible to offer an attractive career path or opportunities for advancement to PhDs, the most talented students might well decide against a career in research. Pay level, job security and the variability of job tasks all have a major impact on their appeal. Competition and fixed-term job contracts especially in the early stages of the research career are nevertheless an integral part of the job and have to be accepted.

One factor that works against the appeal of studying to the PhD level is that the degree is not considered a particularly valuable asset in all business and industry sectors or in the public sector, but is even seen as an obstacle to employment. It is felt that a person who has taken a PhD is too theoretically oriented and narrow-minded, and it is assumed he or she will have inflated pay demands. According to a questionnaire survey among SMEs, views on the skills and competencies of PhDs and business companies' needs are quite far removed from one another (Välimaa 1998).

Images and role models are extremely important to young people's career choices. Science and a career in research should also appear as an attractive option to the general public and to young people in particular. In this regard science communication and career guidance at school have a key role to play. According to the Finnish Science Barometer 2004, more than 60 per cent of people aged 18-70 said they followed science, research and technology, and 57 per cent regarded

research as useful to society and the economy. However, people may have outdated perceptions of choosing an occupation, and the best talents do not necessarily find their way into research. Special attention should be paid to increasing the number of women researchers, especially in engineering sciences and in certain natural sciences. Around one in three PhDs working in the public sector and no more than around one in five in the private sector are women (Appendix Table 1). With this a considerable know-how potential is lost. The Ministry of Education research career working group mentioned earlier is focusing in closer detail on the development of the professional research career, on increasing the appeal of research careers and promoting women's researcher careers, taking account of the requirements of internationalisation at different stages of the research career.

The working group has the following recommendations:

- To recruit the most talented students with the right mindset into research, both the public and private sector should work to develop more predictable research career paths and make it easier for talented young people to progress along these paths. The researcher's profession would have greater appeal if the pay were better, if career paths were more flexible and if there were better opportunities for national and international mobility. Furthermore, employers should refrain from unnecessarily fragmenting researchers' job contracts into truncated periods.

- The Ministry of Education working group that is looking into the development of research careers should also pay attention to the role of industry-academia relations in researchers' career development.

- In order to increase awareness of the researcher's profession and to make it a more attractive option, researchers should be encouraged to publish their results in the Finnish and Swedish language as well. Courses should be arranged for researchers and doctoral students on skills of science popularisation as recommended by the Science and Society Working Group (Opetusministeriö 2004b).

4.5 Researchers' two-way mobility

A key foundation for in-depth and long-term intersectoral research cooperation is that there is flexible and active movement of researchers and students between business companies and universities. Virtaharju (2002) has studied the mobility of people with a higher education (at least a lowest level tertiary degree) in 1988-1998. Mobility was defined in the report as the number of employees who had changed jobs relative to the total number of employees. According to the findings, employee mobility is very much influenced by business cycles: during periods of recession mobility tended to decline, when the economy was growing it began to increase again. Throughout the period under review, the mobility of people with a tertiary education was higher than average, but the variation in their level of mobility was lesser than among other employees. Mobility declined with increasing age. Most of the mobility consisted of movement within business companies or other organisations such as universities or research institutes. At universities, however,

around one-half of the mobility in 1998 came from the outside; intra-university mobility accounted for no more than 4 per cent. In the 1990s, one-third of the mobility of persons with a doctoral degree consisted of movement within companies or other organisations, in around 40 per cent of all cases PhD graduates moved from one company or organisation to another and changed industries.

One of the aspects highlighted in the ongoing debate around alternative research careers is the importance of increasing intersectoral cooperation. The communication from the EU Commission *Researchers in the European Research Area: One Profession, Multiple Careers* (EU 2003b) points at the necessity of having different career options and at the need to create pathways between "academic" and "industrial" research careers. The movement of researchers between universities, research institutes and businesses is a key factor both nationally and internationally in the dissemination of research knowledge.

It is important that PhDs are offered different career and mobility options both within and between the public and private sector. Upon completion of the PhD it is a natural step to move from university to work in business, for instance. Skills and competence requirements are changing rapidly and unpredictably, and people should therefore be encouraged to intersperse periods of work with further studies and training.

Working in business and industry does not necessarily yield the kind of merits that are appreciated and recognised at universities – publications in esteemed journals and experience in training researchers. Business companies for their part do not always appreciate the qualifications gained in academia. Among the factors that continue to impede mobility among researchers from one sector to another are differences in pension rules, cultural differences and prejudices. Although there has been some effort to harmonise work-related benefits in the public and private sector, there still remain significant differences in pay, incentive systems and holiday benefits, for instance. Provisions entered in job contracts and other formal obstacles to the intersectoral mobility of people in research positions should be addressed in a working group involving all contracting parties with a view to harmonisation and compatibility between the public and private sector.

The Government decree on University Degrees has been revised in keeping with the Bologna process, one of the aims of which is the European harmonisation of degrees. The changeover to a two-tier degree structure will facilitate international comparability of degrees and by the same token international mobility among researchers. However, the Bologna process is still to resolve the question of how doctoral training ties in with the two-tier degree structure. It is important to avoid any decisions here that will have an adverse effect on the quality of doctoral degrees. A fast track to the doctorate has its advantages both to the individual researcher and to society at large, but this must not be allowed to erode standards of scientific and practical know-how. What society needs first and foremost is competent and capable PhDs.

The working group has the following recommendations:

- Researchers from universities and research institutes should be able flexibly to spend periods working in business and industry, while business and industry researchers should for their part have the opportunity to work at universities and research institutes. The Academy of Finland and Tekes should develop new funding instruments and disseminate information on existing instruments with a view to promoting intersectoral mobility at all stages of the research career. The mobility efforts in the public and private sector should focus specifically on the postgraduate and post doctoral stages. In this regard public funding agencies can have a significant catalyst role. Employers should promote mobility through their leave of absence and sabbatical policies.

- For recruitment purposes employers should recognise the different kinds of merits achieved in different sectors as well as encourage researcher mobility and reward researchers for intersectoral cooperation. The recognition of merits can be facilitated by producing portfolios which describe the researcher's merits more extensively than traditional CVs.

- In filling university posts it is important also to consider the applicants' practical experience, especially in fields of applied research.

- Universities should use private sector experts to a greater extent as teachers and supervisors.

5 International exchange and cooperation

International cooperation is absolutely crucial for the research and education environments of a small country, and it must be an integral part of all R&D operations. It is important to have comprehensive and effective international networks for the joint production and use of new information and innovations. Numerous studies have shown that countries can broaden their knowledge base not only through their own investment in R&D, but also through extensive international trade with other scientifically advanced countries and by trying to attract R&D-oriented foreign investment (Bayoumi et al. 1999).

Global competition for talented researchers has continued to intensify and they are increasingly emerging as a global production factor. As well as encouraging Finnish researchers to work more often abroad, it is also important to have foreign researchers visiting and working in Finland. Given our country's small population base, Finland is not in the position to produce enough world-class researchers to satisfy future demands. As well as bringing in new information, foreign researchers add new ideas and views into Finnish science. In most cases they also continue to maintain contact with their Finnish partners after they have returned home. Lower pay levels than in many other industrial countries and higher tax rates are among the reasons why there are still comparatively few foreign researchers in Finland. Other problems for foreign researchers and doctoral students include the difficulty of obtaining long-term residence permits, which in turn causes problems with social security benefits (Puustinen-Hopper 2005).

Finland can compete for foreign researchers by offering internationally high-level research and training environments, such as modern research infrastructures, that are needed for cutting edge research. Internationally renowned Finnish researchers and research teams are another important pull factor for foreign researchers looking to work in Finland. A safe society and women's opportunities to combine an academic career with family life could be important incentives in the effort to recruit high-level researchers into Finland.

The new University Act will greatly improve the prospects for foreign nationals to study in Finland in that it gives them the right to complete their degrees in other languages than Finnish or Swedish. During 1991–2003 the number of foreign students on university degree courses in Finland doubled, and the number of postgraduate students tripled (Figure 2). However, in 2003 the proportion of foreign students (including those not taking a degree in Finland) was no more than 5 per cent of all students.

Finnish university teachers and researchers make comparatively few one-month or longer foreign visits; according to the KOTA database the figure in 2003 was less than 600. The number of visits by foreign researchers to Finland was almost twice as high. However, the proportion of foreign nationals in Finland's R&D personnel was clearly lower than the average for EU countries. Over the next ten years almost one million persons will be retiring from the Finnish labour force, and an estimated

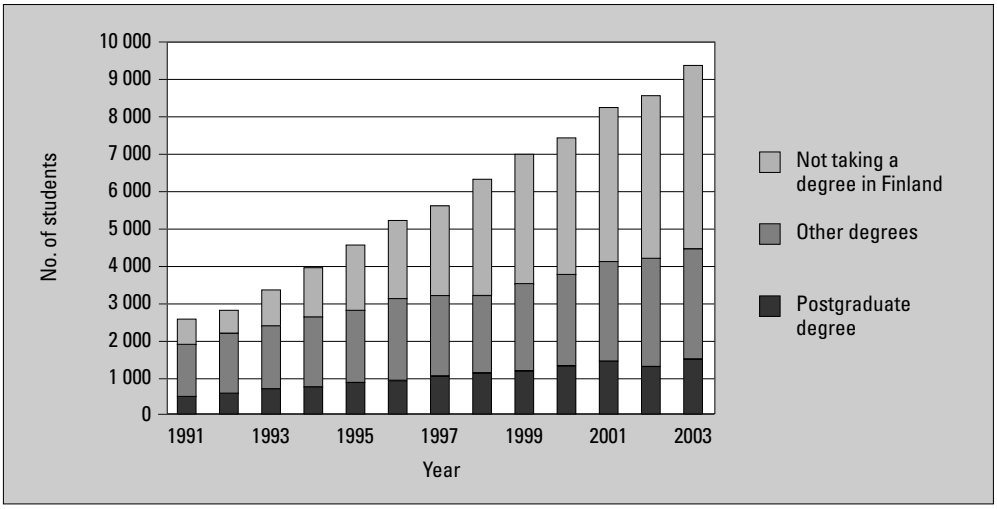

Figure 2. *Number of foreign students in Finnish universities in 1991-2003*

Source: KOTA database, Ministry of Education

15,600 out of the 20,000 employed persons with a researcher training will be exiting the labour force by 2020 (Poropudas 2004). At the same time, the need for highly educated personnel will continue to increase, which further underlines the importance of attracting foreign researchers into Finland.

Business companies are actively seeking out the best expertise from around the world and relocating their R&D operations in areas which offer the best prospects for the development of know-how potential and cooperation. Nonetheless, geographical proximity makes for easier cooperation and facilitates networking. In addition to a competent and professional workforce, a favourable business environment such as an encouraging taxation system is a key factor in seeking to keep businesses' R&D operations in Finland and in attracting foreign investment and business into Finland.

EU's framework programmes provide funding for joint international R&D projects and networks of cooperation. Among the key aims of these programmes are to reduce overlap in research and to strengthen cooperation among research teams in Europe. In practice all the various schemes operated under the umbrella of framework programmes offer tools of cooperation for R&D actors. In addition, the framework programme comprises a separate CRAFT programme where projects are launched on the basis of SMEs' own R&D needs. Collective research funded through the framework programme refers to research carried out by a research organisation at the behest of industrial associations/groupings that benefit large numbers of SMEs and the whole industry. Research conducted under the CRAFT programme and in collective research programmes may be concerned with any technology and product development problem. In general, the Commission has highlighted the importance of SMEs participating in various schemes under the framework programme.

Researcher training and mobility are integral parts of the EU's framework programmes. European measures aimed at strengthening researcher training and researcher mobility are important in promoting interdisciplinarity, advancing the internationalisation of research careers and in assuring the quality of researcher training. In the current, sixth framework programme international and intersectoral researcher mobility is promoted most particularly through the Research Infrastructure and the Human Resources and Mobility programmes. One specific form of support for industry-academia cooperation is represented by the "Transfer of knowledge" action under the latter programme, which provides university researchers or doctoral students the opportunity to work for fixed periods in a business company or vice versa. Finnish researchers have not been very active in seeking personal funding through the Marie Curie action, but the funding offered for networking purposes has attracted some considerable interest. So far business companies have made only limited use of the funding opportunities offered for intersectoral cooperation.

A new instrument in the forthcoming seventh framework programme is represented by so-called technology platforms. The purpose is to support these platforms by means of both private and public sector funding. The close networking of technology platforms with national research will also promote the broad use and application of research results in national industry and especially in SMEs. Technology platforms and the results they produce are furthermore expected to strengthen business conditions for European SMEs and to promote their innovativeness.

The working group has the following recommendations:

- Steps are needed to recruit more foreign top-level researchers into Finnish research teams. In this respect it is important to look into possibility of joint international arrangements whereby taxation at source rules are applied to people who work in Finland for less than six months during a calendar year. It is also important not to ignore the resources available in Finland's neighbouring regions. The overall aim should be significantly to increase the proportion of foreign nationals in Finland's R&D personnel from the current level. However, this must be based on research cooperation and researcher mobility that is in the best interests of both parties.

- A political decision-in-principle should be made regarding the aims and means of the internationalisation of the university system. Implementation of these aims should be nationally coordinated.

- Universities, research institutes and business companies should work more closely with one another in order to get foreign researchers into Finland. It is the joint responsibility of the Government, Parliament and research funding agencies such as the Academy of Finland and Tekes to make the attainment of this objective possible.

- In order for Finland to attract more foreign researchers into the country it is necessary to provide not only high-level research environments but also to take other measures such as fixed-term, competitive posts intended for high-profile

visiting foreign researchers and funded by universities and funding agencies. Steps are needed to make it easier for foreign researchers to get work permits, and their families' needs must also be taken into account.

- The Science and Technology Policy Council and ministries should work to create a favourable environment for the future establishment in Finland of significant international research institutes or major research infrastructures and in this way make Finland a more attractive option to high-level foreign researchers.

- Performance negotiations between universities and the Ministry of Education should take account of earlier achievements in international cooperation and networking.

- Periods of work spent abroad and international merits should be taken into account in filling vacant posts.

- Researchers and businesses should make more active use of the international programmes that support the mobility of researchers and industry-academia cooperation, such as the EU's framework programmes.

6 Funding agencies as promoters of cooperation

6.1 The role of the Academy of Finland

The Academy of Finland provides funding for high-level scientific research, serves as a science and science policy expert and works to strengthen the position of science and research. During 2005, the Academy will be making funding decisions worth around 200 million euros, and the research projects it supports represent some 3,000 full-time research equivalents.

The Academy has two funding instruments that provide direct support for cooperation between industry and academia, i.e. Doctoral studies of employed persons and Grants for hiring post doctoral researchers, where applications are filed by a university or other public research organisation collaborating with a business company or public administration. These funding instruments are intended for persons who are at the early stages of their research careers. In order to establish the success of Academy funding instruments designed to support the cooperation of universities, research institutes and business companies, a questionnaire was sent out in summer 2004 to persons who had received funding through these two instruments in 1995–2002.

The aim of funding for the doctoral studies of employed persons is to support the doctoral studies of people working for industry, business, research institutes, or public administration. Those in postgraduate researcher training remain in the employ of their employer throughout the training period, and the employer is compensated part of the salary expenses. Funding is granted for a period of no more than 18 months for purposes of completing a doctoral dissertation. 39 per cent of those who had received this funding were in the employ of a research institute, 32 per cent worked in government or local administration and 29 per cent in the business sector. Almost half of the respondents had completed their thesis on time, and only one project had been discontinued. The grant for further training was regarded as extremely important and even decisive for the completion of the thesis. About one in six of the 79 responding grant recipients moved to a new academic job or university post.

The purpose of the Academy grant for hiring post doctoral researchers is to advance the professional competence and independence of young researchers who have recently earned their doctorate. Apart from doing their own research, the job of post doctoral researcher involves supervising theses in their own field of expertise and providing teaching in this field. The post doctoral researcher has a job contract with the university or other public research organisation that will receive the funding awarded. According to the survey the post doctoral projects that involved collaboration with business and industry had created ample job opportunities. Upon completion of the funding over half of the 51 responding post doctoral researchers had continued their career in academic jobs, while less than one-third moved to

work for a business company. Among the biggest positive impacts of this funding instrument was the growth of know-how and knowledge assets.

The working group has the following recommendations:

- The Academy of Finland should revise the criteria and conditions for its support of doctoral studies of employed persons so that funding is made available not only for the completion of doctoral theses but also for earlier stages of researching the thesis. Furthermore, it is recommended that the conditions for funding be revised so that in the case of persons working in the private sector, the funding could be paid to the company as is currently the case, via the university, or directly in the form of a personal grant if the person has a permanent job contract with the employer. The social security of postgraduate students should not be affected, nor should their pay level significantly decrease. Given the importance of securing the integration of employed postgraduate students into graduate schools or university research teams, applications should include both a study and a supervision plan signed by the student and the university supervisor as well as a plan of the thesis study complete with timetable and budget. The Academy should work closely with industrial associations to provide information about this form of funding primarily to business companies.

- The Academy of Finland should join forces with businesses and universities to create funding opportunities and practices that would allow postgraduate students employed in business companies to work during their study leave on their doctoral theses at universities or research institutes and at the same time attend graduate school or other forms of supervised researcher training, and to remain in the employ of their company throughout. University doctoral students should for their part be able to research their doctoral thesis at a business company without this affecting their contacts and connections with the graduate school or similar. Responsibility for the supervision of doctoral theses would be shared by the university and business company.

- The Academy of Finland should set up a new form of funding for PhD graduates that is designed to support no more than 12-month periods of work at universities for people in the employ of business companies, or for corresponding periods of work in industry for people in the employ of universities. This would also improve the application of the knowledge and know-how of established researchers both at universities and in business companies. This kind of funding would help to increase interaction between universities and businesses, facilitate the integration of research and knowledge from universities and businesses, increase researchers' knowledge of different kinds of research environments and their opportunities to move from one career path to another.

- In making its funding decisions the Academy of Finland should also consider the relevance of the research plan in terms of the application of the research results and the end-users of the results, when relevant regarding the research theme. Cooperation should be continued and intensified in the processes of reviewing applications received by the Academy and Tekes.

- Business companies should contribute to supporting Academy and Tekes funded research, technology and centre of excellence programmes that are relevant to their own operation. This would also give them access to programme planning and decision-making.

6.2 The role of the National Technology Agency Tekes

Tekes provides funding for research projects at business companies and government research institutes, universities and polytechnics. In 2004, Tekes provided direct funding to 778 research projects at universities, research institutes and polytechnics with the total sum amounting to 172 million euros. Funding is also channelled to the public sector via corporate funding, because Tekes-funded R&D projects are closely networked with the academic world.

Tekes funding is aimed at strengthening the foundations of technological know-how in Finland and at promoting its application in Finnish business. Indeed, the application of research results is one of the key criteria in decision-making on academic research funding. Cooperation between universities and businesses is best organised through strategic, long-term cooperation forums, good examples of which are many joint Tekes and Academy programmes.

Although the development of the research career is not in itself a funding criterion, Tekes projects do each year produce a large number of academic theses and degrees, and many of their results are published in international scientific journals and in patent applications. Various project contents (strategic basic research, medium-range research and applied research) allow for considerable variation in the time span of application. Tekes also encourages researchers to international mobility and covers the costs arising from researcher mobility as part of its project funding. Tekes funding is always awarded to the applicant's organisation, while the work itself is done by the researchers. This guarantees adequate funding for the costs of researcher exchange and avoids any potential problems with social security loopholes that might otherwise affect researcher exchange.

The working group has the following recommendation:

- Tekes should work closely with various funding agencies to make sure that funding is made available to research in sufficiently large amounts with long-term effects. This will also allow for the needs of researcher training and professional research careers to be better taken into account. It is important both from the point of view of science and technology development that Finland has as competent and motivated experts as possible in all relevant fields and that the career development of these people is supported by all funding agencies.

7 The challenges of cooperation

The challenges for the development of research cooperation and researcher training between universities, research institutes and business companies is to deepen and intensify this cooperation, to raise its quality standards and to strengthen international exchange and cooperation. Cooperation is needed at all levels and it requires broad-mindedness, openness, and flexibility on the part of all parties.

Researchers are the single most important executors of research cooperation between the public and private sector. Although this cooperation also directly benefits the work done by researchers themselves, they need to be rewarded for this cooperation by their employers. Universities need to invest in the development of more diverse researcher training, bearing in mind the employment of PhDs in different sectors of society. Both universities and research institutes should improve their cooperation with the business sector by increasing the number of joint projects, by taking account of business companies' expertise in focusing and designing research and by making better use of the expertise of PhD graduates working in business for teaching and supervision purposes.

Businesses should base their operation as broadly as possible on high-level basic research. This can be promoted not only by increasing business R&D investment, but also by developing various forms of cooperation and intensifying research cooperation with universities and research institutes. Hiring PhDs deepens and diversifies know-how in businesses.

Promoting the intersectoral mobility of researchers working at universities, research institutes and businesses is a challenge for all parties concerned. Particularly important in this regard is the recognition of different kinds of merits in recruitment. All parties also need to address the challenge of making a career in research a more attractive proposition and in this way to ensure an adequate supply of researchers. Each responsible organisation should also implement the recommendations made by the Science and Technology Policy Council regarding the structural development of the public research system.

Ministries, funding agencies and other players in R&D policy should work to promote intersectoral research cooperation and researcher training and to create a favourable environment for them. In developing new funding instruments it is important that funding agencies support cooperating units, joint projects, intersectoral mobility and wide-range researcher training. The Ministry of Education should apply the tools of management by results to encourage universities to work closely with other universities, research institutes and businesses. One of the major challenges with respect to the legal environment is to develop harmonised contracting models, rules and procedures for funding arrangements and IPR transfers between researchers, universities and business companies.

Several working groups are currently addressing issues that tie in closely with the assignment of the present working group; these include the research career working

group and the biotechnology working group appointed as well as the working group by the Ministry of Education exploring Academy of Finland funding instruments. It is expected that these working groups will take onboard the recommendations made in this report. The Academy of Finland will monitor the implementation of the proposals and recommendations made by the working group.

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Appendix Table 1.
R&D personnel in 2003

Source: Statistics Finland

Sector	R&D personnel		Education							
			PhDs		Other university degree		Other vocational education		No vocational education/ unknown	
	Total	Women	Total	Women	Total	Women	Total	Women	Total	Women
Business companies	**40 089**	**8 519**	**1 214**	**262**	**15 862**	**3 170**	**21 661**	**4 711**	**1 352**	**377**
Food, beverages etc.	782	432	38	20	262	143	460	255	22	13
Textiles, leather products	203	114	1	1	56	27	131	81	15	5
Wood and wood products	209	37	1	–	52	8	153	28	2	1
Pulp, paper, paper products	993	455	25	6	433	121	515	318	20	11
Publishing and printing	99	13	4	–	41	6	48	6	6	1
Refined petroleum, rubber and plastic products	911	247	20	5	288	80	537	143	66	19
Chemicals, chemical products	2 454	1 501	190	75	863	451	1 215	848	187	127
Glass and stone products	294	65	7	2	130	27	150	36	7	–
Metal, metal products	1 198	140	25	2	431	56	726	82	16	–
Machinery and equipment	3 393	310	42	5	993	101	2 295	192	63	11
Electrical and optical equipment	16 991	2 758	388	46	6 820	1 118	9 108	1 465	674	129
Transport equipment	575	33	3	1	115	9	454	23	2	–
Other manufacturing, recycling	228	32	3	1	47	13	172	18	5	–
Manufacturing total	*28 330*	*6 137*	*747*	*164*	*10 532*	*2 160*	*15 965*	*3 494*	*1 086*	*319*
Agriculture, forestry and fishery	45	10	3	–	15	9	22	1	5	–
Mining and quarrying	64	17	3	–	29	6	23	11	9	–
Electricity, gas and water supply	177	20	3	–	95	15	79	5	–	–
Construction	761	145	10	1	200	50	543	92	9	1
Wholesale trade and commission trade	675	271	29	12	234	95	397	160	15	3
Transport and storage	98	23	4	1	31	3	57	17	6	1
Post and telecommunications	849	181	9	2	469	93	360	80	11	6
Computer and related activities	4 818	631	120	13	2 345	303	2 254	310	99	5
Research and development	1 816	650	202	58	769	240	764	317	80	35
Technical services	1 756	302	47	5	800	132	892	164	17	1
Other business activities	493	92	31	4	255	49	202	36	4	3
Other industries	208	41	5	1	88	14	104	23	10	2
Other industries total	*11 759*	*2 382*	*466*	*97*	*5 331*	*1 010*	*5 696*	*1 217*	*266*	*58*
Public sector	**34 684**	**16 285**	**7 298**	**2 444**	**15 215**	**7 306**	**9 724**	**5 416**	**2 447**	**1 119**
Universities	19 101	8 165	5 092	1 623	8 723	4 139	4 151	1 967	1 135	436
University central hospitals	1 932	1 491	328	143	536	349	1 068	999	–	–
Polytechnics	3 016	1 504	239	114	1 536	861	1 231	527	10	2
Administrative branches	9 644	4 561	1 453	505	3 912	1 679	3 011	1 723	1 268	654
Other public institutions	259	147	55	10	127	68	67	59	10	10
Private non-profit institutions	732	417	131	49	381	210	196	141	24	17
All total	**74 773**	**24 804**	**8 512**	**2 706**	**31 077**	**10 476**	**31 385**	**10 127**	**3 799**	**1 496**

Appendix Table 2.

Business R&D expenditure by industry and number of employees in 2002 and 2003

Source: Statistics Finland

	R&D expenditure in 2002	R&D expenditure in 2003	Share of turnover in 2002 [1]
	million euros	million euros	%
Industry			
Food industry	49.5	46.3	0.6
Textile and wearing apparel industry	11.1	10.8	0.7
Wood processing industry	97.2	94.8	0.5
Chemical industry	321.6	285.9	2.2
Metal and engineering industry	367.0	355.4	1.4
Electronics industry	1 732.1	1 963.5	5.9
Other manufacturing	38.7	43.5	0.5
Manufacturing total	*2 617.1*	*2 800.2*	*2.4*
Electricity, gas and water supply	14.4	7.9	0.2
Construction	39.9	41.2	0.3
Wholesale trade and commission trade	75.9	61.7	0.2
Transport, storage and communication	114.1	85.2	0.6
Computer and related activities	229.0	235.0	4.6
Research and development	175.7	150.7	[2]
Other business activities	89.7	128.1	1.9
Other industries	19.2	17.9	0.3
All total	**3 375.1**	**3 527.9**	**1.6**
Number of employees			
0–9	76.7	68.4	
10–49	272.2	240.5	0.9
50–99	143	158.1	1
100–249	342	274.6	1.3
250–499	316.4	301.7	1.4
500 +	2 224.9	2 484.7	2.1

[1] Share of turnover calculated only for enterprises with more than 10 employees
[2] Share of turnover not comparable to other industries

Appendix Table 3.
Innovation in business companies in 2000–2002

Product and service innovations in 2000–2002 and as a proportion of turnover in 2002 by industry and number of employees

Source: Statistics Finland

	Product or service innovations		New products or service innovations in the marketplace	
	Share of businesses	Share of turnover	Share of businesses	Share of turnover
	%	%	%	%
Industry				
Food, beverages, etc	40	8	31	3
Textiles, leather products	26	12	24	9
Wood and wood products	20	3	16	1
Pulp, paper, paper products	35	9	28	6
Publishing and printing	21	3	14	1
Refined petroleum, rubber and plastic products	40	10	37	5
Chemicals, chemical products	49	6	35	4
Glass and stone products	27	4	15	2
Metals, metal products	15	6	10	4
Machinery and equipment	46	22	32	9
Electrical and optical equipment	52	71	40	10
Transport equipment	29	14	26	13
Other manufacturing, recycling	23	8	14	2
Manufacturing total	*31*	*27*	*23*	*7*
Electricity, gas and water supply	15	1	14	1
Construction	9	6	6	3
Wholesale trade and commission trade	20	4	16	3
Transport and storage	9	1	5	1
Post and telecommunications	29	11	18	7
Computer and related activities	55	20	45	11
Research and development	46	16	33	11
Technical services	32	3	24	2
Other business activities	14	4	13	2
All total	**24**	**18**	**18**	**5**
Number of employees				
10–49	19	5	14	3
50–100	33	5	25	3
100–249	47	9	36	5
250–499	66	8	45	5
500+	72	28	58	6

Appendix Table 4.
Innovation in business companies in 2000–2002

Innovation cooperation by industry and number of employees

	All business companies	Business companies with innovation activities
	Cooperation	Cooperation
	%	%
Industry		
Food, beverages, etc.	32	63
Textiles, leather products	22	65
Wood and wood products	25	81
Pulp, paper, paper products	40	81
Publishing and printing	11	38
Refined petroleum, rubber and plastic products	43	75
Chemicals, chemical products	43	71
Glass and stone products	26	70
Metals, metal products	16	64
Machinery and equipment	35	65
Electrical and optical equipment	49	79
Transport equipment	27	52
Other manufacturing, recycling	22	73
Manufacturing total	*28*	*67*
Electricity, gas and water supply	22	84
Construction	9	68
Wholesale trade and commission trade	14	52
Transport and storage	3	17
Post and telecommunications	33	80
Computer and related activities	45	67
Research and developmen	71	79
Technical services	29	74
Other business activities	14	86
All total	**20**	**64**
Number of employees		
10–49	15	59
50–100	30	63
100–249	46	74
250–499	66	79
500+	83	95