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RESEARCH AND DEVELOPMENT IN ESTONIA

1996 - 1999

STRUCTURE AND TRENDS

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I have persistently kept asking what Estonia's Nokia could be. This has even become part of local folklore. Yet the conclusion drawn by many Estonians, including several prominent figures, that the President is looking for one single product like Pippi Longstocking once looked for Spunk - is somewhat unexpected. As a matter of fact, the President of Estonia is not supposed to seek Estonia's Nokia. I am seeking it for you. For those who are too lazy to do it themselves. However, it is every Estonian proprietor's task to look for their own so-called Nokias, and find at least six of them annually.

The key factor to innovation is man. I have used this example of Nokia to draw attention to the product that Estonia does not make in large quantities - this is world-class labour force. A study loan taken with the intention to get proper education and training would constitute a safe investment in any case, for the borrowers will, sooner or later, rise to such high and well-paid positions that returning the loan is as easy as anything.

Having adopted Western-type business culture and well functioning marketing mechanisms, it is now primarily in the field of intellectual property that Estonia, in order to survive in the third round, needs to be able to create surplus value. Estonian enterprises must be able to come up with innovative high technology products. For this, it is vital that three components of success - scientific ability, entrepreneurship, and funding blend together in harmony. Alas, in Estonia all three are in short supply.

Estonia is unlike California or Cambridge in that that here the re-search outcomes do not inspire entrepreneurs, and entrepreneurs in their turn are distrusted by banks. It is in changing this situation, and only here, that the state can play a considerable role. It can channel its efforts in three directions: encouraging entrepreneurs, developing research, and acting as a catalyst at the initial stage.

Let us next return to the central theme of my presentation - our most precious strategic resource are the people, and this resource has to be brought into fuller use. The state must reinvest the collected taxes in the taxpayers. The proportion of spending on education and research in the state budget should grow threefold.

The relationship between research and application is well illustrated by the Nobel Prize in economy: consistently, this prize has been awarded for research work that is at least 20 years old. Which means that the studies that are going to influence science twenty years from now cannot expect to get any recognition today. In other *words, science that is - even so mostly with no good reason - considered to be practical, more often than not overlooks an opportunity for practical application. That brings back to mind what Academician Artsikhovski said: we can never tell in advance which branch of the tree will bear the golden apple of success.*

From the speech by Lennart Meri, President of Estonia,
at the Annual Conference of Hansapank on May 5, 1999

J. Barrow (1998) has presented a classification of civilisations, based on probable activities. The succession is as follows:

type I: *capable of building objects, the dimensions of which are comparable to the size of builders (buildings, constructions both on land and underground);*

type II *capable of detaching genes and transforming living beings, capable of interpreting the genetic code;*

type III *capable of transferring molecules and changing intermolecular bonds;*

type IV *capable of manipulating atoms, i.e. using nanotechnology and creating artificial intellect;*

type V *capable of dealing with atomic nuclei and using them in technology;*

type VI *capable of using elementary units of matter (quarks and leptons), and using them to diversify substances and processes;*

type Ω *capable of manipulating time and space.*

On our Mother Earth we have entered the second stage and have introduced some characteristic features of types III and IV. True enough, an atomic bomb refers to type V, but the atomic bomb and a chance that it might be used would rather be qualified as a disaster. We are moving along this civilisation ladder and the higher we reach, the more complicated are the phenomena, and the more interrelated with one another. Are we ready to move ahead?

Is the world ready for changes? Albert Einstein is believed to have said: "I don't worry about the future. It will simply come very soon." One can agree with the second part of the statement, however, not with the first one. "The quicker we move, the more cautious we must be," Jorma Ollila, general director of Nokia has admitted.

An extract from the essay "Teadusest uue aja künnisel"
/Science on the threshold of a new era/ by Jüri Engelbrecht
Akadeemia, 2000, No 6, 1204-1223

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1. INTRODUCTION

At the beginning of the 21st century, trends like globalisation of economy, development of new technologies, deepening social and environmental crises, and value changes in general have posed a serious challenge for science. Knowledge and skills as well as the ability to apply them effectively have become the basis for ensuring global competitiveness of countries and nations, welfare and life quality of people. Therefore, especially considering European integration, the Estonian system of research and development must be ready to participate in international co-operation and act as an effective partner in the envisaged European Research Area. But are we in actual fact ready?

Every three years the Research and Development Council prepares a survey of the general state of science in Estonia and of changes that have taken place since the previous period. The last survey covering the period from 1993 to 1996 was published in 1997.

The objective of the present overview is to:

- describe the general state of Estonian science;
- analyse both the quantitative and qualitative changes that have occurred in Estonian science in recent years;
- highlight the strengths and weaknesses in the system of science in Estonia..

In compiling the survey, we used the reviews of science and technological innovation compiled by the Ministry of Education and the Ministry of Economic Affairs, the evaluations made by the European Commission, and activity reviews of the Estonian Science Foundation and the Science Competence Council. The compilers of the present survey are grateful to Dr.Toivo Räim from the Ministry of Education, to Ms.Ülle Must from the Estonian Foundation of the European Union Education and Research Programs “Archimedes”, and to Dr. Meelis Sirendi from the Estonian Science Foundation for the data, and to Acad. Jüri Engelbrecht, President of the Estonian Academy of Sciences, for his help and critical remarks in the process of the survey.

2. CHANGES IN THE STRUCTURE OF THE RESEARCH AND DEVELOPMENT SYSTEM

The foundations of the present national organisation of research and development were laid by the reform of research and higher education that began in 1990. The reform aimed at fostering competitiveness of Estonian science in the open world by means of organisational measures. The latter included preparation of legislation regulating R&D, improvement of the system of financing of science and the network of research institutions, adjustment of research trends to changes taking place in the economic and social spheres, and to the national needs and possibilities. Special attention was paid to raising the efficiency of co-operation between research institutes and universities, and to the integration of research institutions into universities.

In 1990, the Estonian Science Council was established to advise the government on strategic issues of R&D. In the same year, three foundations were set up to mediate the funding of national R&D, namely, the Estonian Science Foundation to fund research, the Estonian Innovation Foundation to fund market-oriented applied R&D, and the Estonian Information Foundation to develop the national information system (this foundation has been abolished by now). In December 1993, the Estonian Science Council was reorganised to form the Research and Development Council (RDC) presided over by the Prime Minister.

In 1994, the Organisation of Research Act was passed by the Riigikogu (the parliament of Estonia) and in 1997, its revised version - the Organisation of Research and Development Act was passed laying down the new structure, principles of management, financing, and state supervision of the R&D system. The law enacted the reorganisation of the Estonian Academy of Sciences, transforming the Academy's institutes into independent state research agencies. The Act thus established a legal basis for the existence of flexible research structures, for financing of R&D, and for evaluation of research results.

In 1997, the Estonian Science Foundation and the Estonian Innovation Foundation were reorganised into private law foundations. The functions of the Innovation Foundation remained unchanged, whereas the Estonian Science Foundation' s sole aim from now on was to allocate research grants on the basis of public competition. In the same year, the Science Competence Council was founded at the Ministry of Education as a consultative body to tackle questions of target financing and expenses of infrastructure.

Between 1996 and 1998, most of the former research institutes of the Estonian Academy of Sciences were integrated with the universities of the country. The aim of this move was to better relate basicl research with degree courses and to use the existing resources more efficiently. However, despite various suggestions made by the Research and Development Council, no satisfactory reorganisation plan has yet been found for agricultural institutes. In 2000, there were 67 institutions in the register of research and development institutions: 16 state agencies, 7 public legal persons, 22 agencies of public legal persons, 21 private legal persons, and 1 local government agency. The structure of the Estonian R&D system is shown in Fig. 1.

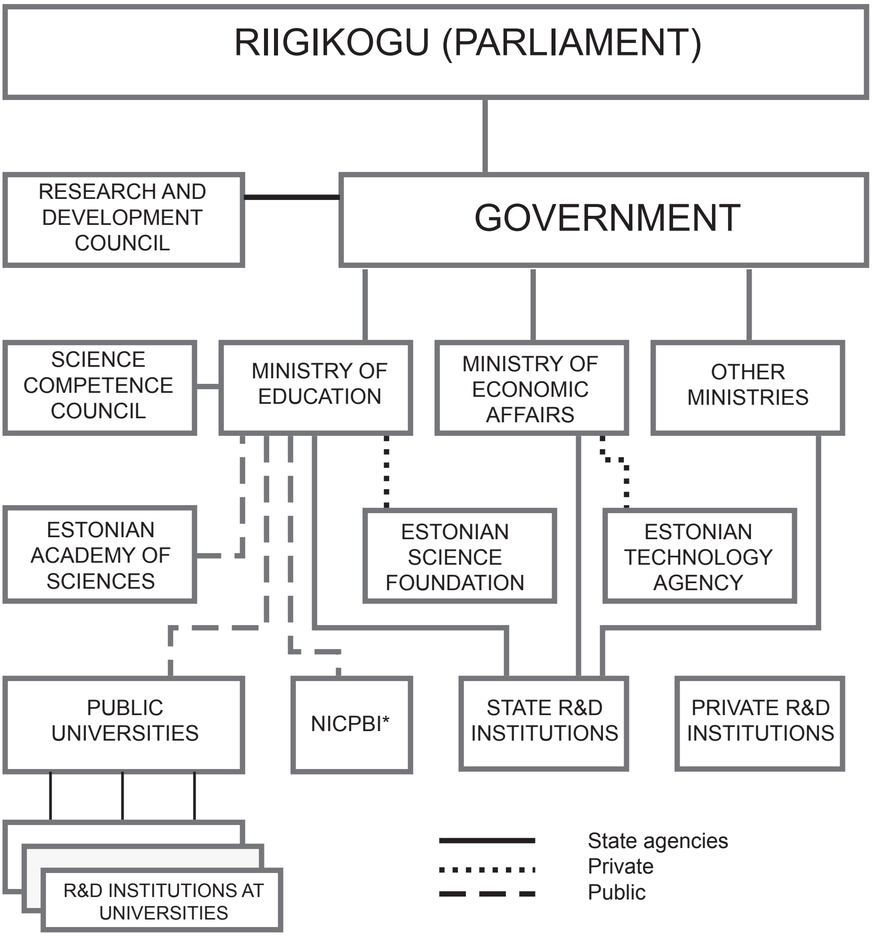

Figure 1. The structure of the Estonian research and development system in 2000 (* National Institute of Chemical Physics and Biophysics)

Particular hallmarks in the life of Estonian science are the Medical Faculty' s study and research building at the University of Tartu, which was completed thanks to a loan from the World Bank (total expenditure was over 270 million kroons), and the annexe to the Estonian Biocentre - opened as the CITRINA laboratory building. The latter can be easily the biggest investment (30 million kroons) made into Estonian science by the private sector.

An important role in knowledge transfer is played by centres of excellence and innovation support structures, such as science and technology parks, and innovation and incubation centres. In the developed countries, they have had an essential function in setting up technological small and medium enterprises (SMEs) as well as in supporting R&D, technology transfer, and regional development. The EU Pre-structural and Structural Funds have key significance in developing innovation support structures in Estonia, which are in the process of being instituted in Tallinn and Tartu. The Tartu Science Park Foundation has been operating since 1992, focusing primarily on fostering extensive research-based enterprises by way of creating and developing the necessary infrastructure and service network. The Tallinn Technical University Innovation Centre Foundation was set up in 1998 in order to bridge the gap between the R&D outcomes of Tallinn Technical University and the technological needs of industrial enterprises. In Jõhvi, a regional innovation centre has been established to promote, on the one hand, utilisation of the potential powers of the Ida-Virumaa industrial region, and on the other, technology transfer.

In the framework of the national PHARE project (the Higher Education and Science Reform (HESR)), centres of strategic competence were established at the University of Tartu and Tallinn Technical University. The objectives of these centres are to purposefully apply the universities' research potential, to concentrate the resources and use them reasonably, prioritising four fields: materials science, gene technology, information technology, and environmental technology. The Archimedes Foundation, which was set up in 1997, can also be considered as a support structure of Estonia's higher education, research and development. This foundation organises evaluation procedures of higher education and science in Estonia, performs the functions of a national contact point of the Fifth EU Framework Programme, and co-ordinates the development of the information system of the Estonian R&D and a joint project of the Estonian Innovation Relay Centre (ESTIRC).

The government plays an important role as shaper of the innovation policy and as trouble-shooter to the system. However, despite the existence of a legal and institutional framework for organising R&D in Estonia and the evolving network of innovation support structures, the innovation system has its weak spots. First of all, a source of difficulties is little interest shown by enterprises in the innovation process, the fact that the financial instruments for supporting innovation are limited, and the efforts of the parties belonging to the system are unco-ordinated. Planning and implementation of innovation policy and international-scale comparison are inhibited because of insufficient statistics which fail to mirror the actual situation, and absence of technology- and innovation-focused studies which would support the above process.

In 2000, the most urgent topic on the agenda is raising the effectiveness of the R&D system management by reinforcing the institutions that belong to the system and by strengthening co-operation between them. Among the most relevant changes is the reform of the Research and Development Council and the reorganisation into the Estonian Technology Agency of the Estonian Innovation Foundation that used to operate within the area of administration of the Ministry of Economic Affairs. The task of the Technology Agency is to improve and invigorate the state's activity in stimulating technological development and innovation, and to improve co-ordination within the innovation system. The establishment and development of the Technology Agency is a precondition for increasing state allocations and channelling them in more effective and productive ways. The Technology Agency will be completed in three years.

Notwithstanding the above achievements, the network of innovation support structures needs to be furthered and extra resources procured in order to make both the infrastructure and services conform to internationally comparable standards. The work of the centres of strategic competence, which were established a few years ago, needs to be revised, because their initial aims - application-oriented research and links with industry - have not been realised as initially envisaged.

3. FINANCING OF RESEARCH AND DEVELOPMENT

3.1. SYSTEM OF FINANCING

Between 1991 and 1995, the state budgetary funds for research were allocated by the Estonian Science Foundation (EstSF); the decision makers were the top scientists belonging to the Council of the Estonian Science Foundation. The money earmarked for research was divided into basic funds which were set aside for research agencies (to ensure their operation) and personal research grants which were awarded following a public competition. Technological innovation was funded by the Estonian Innovation Foundation set up in 1991.

In 1996, the procedures of funding Estonian science were altered. According to the Organisation of Research Act passed in December 1994, the state funds for science were divided into three parts: research grants, target funds for research institutions, and allocations to cover the infrastructure expenses of state research institutions. Both the distribution of targeted research money to single research institutions and the allocation of research grants remained within the discretionary powers of the Council of the EstSF. The system of research grant allocation itself did not change to a notable degree. The infrastructure subsistence and maintenance costs (incl. salaries paid to the administration) of research institutions were to be covered by the owner, i.e. by a ministry or a local government from its own budget. In 1996 for the first time part of the budgetary research funding was directly allocated to the Estonian Academy of Sciences and also to the Research and Development Council.

An essential event for science was the passing by the Riigikogu of the Organisation of Research and Development Act on March 26, 1997 which stipulated that the financing of research and development from the state budget should be effected by way of target financing, national programmes, and research and development grants (subsection 14 1.2), and that the infrastructure costs of research and development institutions should be covered by the founder of the institution (subsection 14 1.3). Section 15 of the Act established the procedures for target financing: that separate science topics must be financed on the basis of proposals put forward by the Science Competence Council at the Ministry of Education. The new procedures took effect in 1998.

The principles for financing were specified in the joint memorandum of the Science Competence Council, the Council of the Estonian Science Foundation, and the Council of the Estonian Innovation Foundation. According to the memorandum, the aim of target financing is to ensure continuation of scientific research vital for Estonia. This would, on the one hand, contribute to the development of the country as a whole and on the other, secure a well-earned payment and social guarantees to efficient researchers. The primary aim of research grants is to support high-level research initiatives, new ideas and endeavours, whereas the aim of development grants is to promote development and innovation with the object of enhancing competitiveness of domestic production and services.

In the year 2000, the aggregate amount of state funding of R&D decreased by 8.7 million kroons as compared with 1999; out of that, target financing decreased by 5.4 and research grants by 5.6 million kroons (see Table 1). At the same time, targeted grants increased a little.

Table 1. Financing of research and development from the state budget between 1995 and 2000 (million kroons)

Year	Target finan-cing	Financing of infra-structure	EstSF research grants	Other targeted grants	Total
1996	93,9	34,0	58,4	3,0	189,3
1997	102,3 a	39,5	68,3	7,7	217,8
1998	118,3	48,0 b	72,9	15,5 c	254,7
1999	161,4	58,3 b	76,6	38,8 d	335,1
2000	156,0	57,5 b	71,1	41.8 d	326,4

Source: State Budgets of the Republic of Estonia

a including centres of strategic competence

b financing of the whole infrastructure

c centres of strategic competence and scholarships to doctoral students

d scholarships to doctoral students, participation fee of the Fifth Framework Programme and state R&D programmes

3.2. RESEARCH GRANTS

The Estonian Science Fund and its legal successor, the Estonian Science Foundation (EstSF), has awarded research grants since the time it was founded. Research grants are allocated to projects submitted by way of a public competition. The EstSF awards research grants to projects in all fields of basic and applied research to support, on the basis of peer review, high-level and internationally competitive research initiatives, new ideas and endeavours, and as of 1999, also the work of master and doctoral students. The financing of research projects is effected on the basis of the results of a public competition. Criteria for vetting the applications include the originality of topics, competence of the researchers implementing the project, the standards and results of their research work so far, interdisciplinarity, and relevance of the project for the economic and social sphere.

The EstSF awards grants to representatives of all the sciences and specialities fostered in Estonia. All those doing research which would meet the above criteria can apply. The EstSF competition takes place once a year. The duration of a project can be between one and four years.

Year by year, the EstSF has become more exacting about the standards of projects and the correctness of reporting. In case of weak results the applicant cannot expect be awarded again. Projects running in an unsatisfactory manner may be suspended or even closed. Each year 300-400 reviewers from Estonia attend the reviewing of final reports of grant projects. Since 1995, foreign experts from Finland, Sweden, Russia and other countries have been involved in the evaluation of applications.

During the nine years of its operation, the EstSF's research grant competitions have been very popular among the researchers. In view of the fact that science funding in Estonia has been exceedingly modest compared to that in other countries, the EstSF's evaluation committees have been rather benevolent. As a result, only a relatively low percentage of grant applications have been rejected and a large number of small research grants have been awarded. In 1999, the EstSF Council decided that they would not, as a rule, consider research grants below 50,000 kroons*) per year. The aim was to reduce the overall number of grant projects and, especially, to be more exacting about the quality and efficiency of research. Thus, if in 1996 the value of a research grant was 69,000 kroons on average, then in 1999, all in all 846 research grants were awarded, including follow-up grants, the average cost per grant being 90.2 thousand kroons.

Table 2 gives an overview of state grant allocations and their distribution between different fields of science in 1996-2000. The proportions have remained the same for the last seven years. Table A-1 (see Appendix) shows grant distribution to institutions in 1996-1999. The use of grant money varies considerably by expenditure items in different speciality groups/institutions. As a rule, grant holders spend their payroll money on employing support staff and/or involving undergraduate and postgraduate students in research. The percentage of money spent on equipment varies greatly, depending first and foremost on the specific nature of the realm of research, but because of limited grant resources this expenditure tends to be very low in many institutions.

The EstSF has taken great care to rejuvenate the ranks of Estonian researchers, primarily by way of involving postgraduate students in grant projects (Table 3). For the future of Estonian science, it is of utmost importance to involve students and postgraduate students

*) 1 Estonian kroon (EEK) equals exactly 8 DEM

Table 2. Allocation and distribution of research grant money by fields of science, in million kroons

Field of science	%	1996	1997	1998	1999	2000
Exact sciences	14,3	8,4	9,8	10,6	11,0	10,2
Chemistry and molecular biology	10,3	6,0	7,0	7,5	7,9	7,3
Bio- and geosciences	11,4	6,7	7,8	8	8,7	8,1
Engineering	16,7	9,8	11,5	12,1	12,8	11,9
Medical sciences	16,9	9,9	11,6	12,2	13,0	12,0
Agricultural sciences	11,0	6,4	7,5	8,0	8,4	7,8
Social sciences	9,8	5,7	6,7	7,1	7,5	7,0
Humanities	9,6	5,6	6,6	7,0	7	6,8
Total	100,0	58,5	68,6	72,9	76,7	71,1

Source: Estonian Science Foundation

because at present nearly 40% of the researchers are over 50 years old. In 1999, only two per cent of all the research grant holders were under 30 and 4.1 % were younger than 35. At the same time, 31 % of the grant holders were 51-60 years old, whereas 25.3 % were over 60.

Table 3. Involvement of undergraduate and postgraduate students in grant projects

	1997	1998	1999
Doctoral students	337	379	347
Master students	374	358	236
Undergraduates	113	154	90

Source: Estonian Science Foundation

Introduction of the research grants system has given a competitive edge to Estonian scientists on the international arena, especially in the EU framework programmes. At the same time, one needs to note that there are some negative aspects to the grants system, resulting, however, not so much from the activities of the EstSF as from the proportions of money allocations to separate fields of science. The proportions, unfortunately, have remained the same throughout many years. Hence in some sciences the grant competition is considerably less fierce than in others which is why the quality requirements set to projects are not equal. This has largely inhibited interdisciplinary research. As a solution to the problem, therefore, interdisciplinary expert committees have been set up since 2000.

3.3. TARGET FINANCING

Target financing means funding by research topics. The period of financing may be between three and five years.

Up to 1997, it was the EstSF who dealt with questions of target financing (see 3.2 above). In 1997, eight institutions (the Institute of Islands, the Võru Institute, the Centre of International Environmental Biology, the Institute of Preventive Medicine, the Estonian Institute of Agricultural Engineering, the Estonian Institute of Agrarian Economics, the Estonian Agrobiocentre, the Estonian Plant Biotechnology Research Centre EVIKA) were refused financing due to their low standards of research and efficiency. It was considered reasonable that the applied research carried out by these institutions would be funded either by the respective ministries or/and their commissioning clients. Distribution of target money for research by separate institutions is given in Table A-2 (see Appendix).

In 1997, by a regulation of the Government of Estonia, the Science Competence Council (SCC) was founded, its main function being to make recommendations to the Minister of Education about target funding of research topics of R&D institutions and, pursuant to the procedure of its formation and functioning, to make recommendations for funding, firstly, the infrastructure of the R&D institutions within the area of governance of the Ministry of Education, and secondly, research related to doctoral studies.

Both the SCC and the EstSF have been guided by the following principles in their work:

a) in judging the value of a research topic both the quality of the results obtained so far as well as the quality of the expected outcomes are heeded;

b) vitality of the research topic with no required quality guarantee is not considered a sufficient argument for funding;

c) the research topic must involve an optimal number of implementers and have optimal funding to which eligible limits can be set;

d) if all the generally accepted requirements are met, the implementers of successful research projects must be secured financing for a certain period of time (between three and five or more years), and the rules apply to everybody without exception.

The first round of judgement showed that all the accepted research topics were necessary for one or other reason, and many research topics were directly related to solving some specific topical problems of the country. Nevertheless, several applications failed to get funding either because of their low quality, unclear aims, or their applied nature without elements of scientific research. Applied research designed to meet the immediate needs of the country should be effected via direct orders or programmes in accordance with the procedure stipulated by the Organisation of Research and Development Act or, alternatively, the Government of Estonia should establish certain priorities (so far there are none). In the latter case, however, it must be ensured that the scientific research meets the quality requirements set, and the implementers are competent.

The SCC base their recommendations first and foremost on quality. No percentage distribution either between different fields of science

Table 4. Distribution of target finance to separate fields of science in 1998-2000

Field of science	EstSF research grants %	Target financing % / million kroons					
	1993-2000	1998		1999		2000	
		%	mln kr	%	mln kr	%	mln kr
Natural sciences	36,0	37,0	43,8	40,0	64,6	41,0	64,0
exact sciences	14,3	15,0	17,8	14,0	22,6	14,0	21,8
chemistry and molecular biology	10,3	9,0	10,7	10,0	16,1	10,0	15,6
bio- and geosciences	11,4	13,0	15,4	16,0	25,8	17,0	26,5
Engineering	16,7	21,0	24,9	22,0	35,5	21,0	32,8
Medical sciences	16,9	13,0	15,4	13,0	21,0	13,0	15,6
Agricultural sciences	11,0	12,0	14,2	10,0	16,1	10,0	15,6
Social sciences	9,8	7,0	8,3	6,0	9,7	6,0	9,4
Humanities 9,6	10,0	11,8	9,0	14,5	9,0	14,0	

Source:Science Competence Council

Note: As of 1998, target funding has been allocated on the basis of research topics or R&D institutions has been prescribed (contrary to the percentage distribution established by the Research and Development Council among fields of science for research grants awarded by the EstSF). In preparing the SCC's recommendations, reviewers of different fields of science work in close cooperation with the EstSF and the Medical Science Council of the Ministry of Social Affairs. The distribution of targeted money to separate fields of science is given in Table 4.

An important area of the activity of the SCC has been extending support to the young generation of researchers. As early as in 1998, the SCC allocated resources of target finance to postdoctoral fellows in order to sustain the development of young successful doctoral degree holders (see Table 5). When financing the research part of doctoral studies, the SCC has proceeded from the universities' suggestions about financial support for research purposes to state-financed doctoral students, discriminating between the first- and second-year, and third- and fourth-year doctoral students. Basing its judgements on the number of doctorates conferred by a particular university in the previous year, the SCC has allocated a part of doctoral students' funding directly to universities.

Table 5. Grants to postdoctoral fellows and doctoral students from target funding (million kroons)

	1998	1999	2000
Postdoctoral fellows	3,5	4,5	3,1
Doctoral students	7,0	14,0	14,0

Source: Science Competence Council

The SCC also makes recommendations about how to cover infrastructure expenses. But even though the SCC has laid down certain principles, the database showing infrastructure expenses is incomplete. Problems are posed by expenditure on maintenance of major equipment, functioning of holdings, etc.

In the years 1997-1999, resources were allocated from the targeted money in order to start research programmes and give other kind of support. Among them, let us mention the programmes of integrating the non-Estonian population, of promoting the Estonian language and culture, of furthering public health, and of developing Estonian economic strategy, and of financial support to the centres of strategic competence at the University of Tartu and Tallinn Technical University.

The share of target financing, inclusive of other targeted support allocated through the Ministry of Education, has grown. In 2000, for example, target financing formed 50 %, infrastructure expenses 15.6 %, the EstSF's research grants 22.8 % and other targeted support 11.9 % (see Table 1).

After the new system of financing was launched, the proportions of target financing per separate fields of science have changed very little. Only the share of natural sciences has been somewhat increased, mainly on account of bio- and geosciences (see Table 4).

3.4. DEVELOPMENT GRANTS

State financing and coordination of development and innovation have been effected through the Estonian Innovation Fund (EIF). The EIF as a non-profit state organisation was founded by the Government of Estonia in 1991 to support technological development of Estonian economy by way of funding. In 1997, the fund was reformed into a foundation under the name the Estonian Innovation Foundation. The aim of the foundation - to raise technological competitiveness of economy - got a more concrete expression with the Estonian State Innovation Programme in 1998. In 2000, however, the EIF was reorganised to become the Estonian Technology Agency.

As a rule, the EIF allocated development grants by way of cofinancing, which means that the primary provider of funding was the implementer of the project and/or other persons interested in its outcomes. A development grant for implementing a specific innovative project could thus be one of the following sub-types or a combination of them: 1) irrevocable aid; 2) non-commercial loan; 3) surety or guarantee; 4) capital investment. The grant awarded was up to 50% and the loan up to 75% of the total cost of the project.

Appropriations from the state budget to the Innovation Foundation that decreased more than 2.5 fold between 1993 and 1996 and thereafter grew to reach nearly 30 million kroons in 1998-1999 have been too small to be able to effectively promote the rise of development business.

The projects to be funded were selected by the Council of the Innovation Foundation from among applications submitted for public competition. The council made its decision considering the innovativeness and economic efficiency of the projects. Irrevocable aid was provided to support R&D yielding economic and social profit, thus for projects having a practical output and for developing infrastructure supporting innovation. Loans given by the Innovation Foundation were non-commercial, the interest rate and conditions of which can be more favourable and the rate of risk higher than that in case of bank loans. In the years 1996-1999, as in earlier periods, the interest rate was 8-12 %.

Loans were extended in order to introduce products and technologies in the phase prior to production when favourable loans could not be interpreted as contributing to unfair competition. Compared to the support mechanisms used by the state fund, the articles of association of the foundation additionally prescribed a possibility to support the implementation of projects by making extra investments (to the stocks or shares of the business undertaking the innovative project), or by surety or by giving guarantees. Whereas the Commercial Code and the Accountancy Law do not permit showing of a capital loan in the enterprise's own capital, the foundation did not use capital investments.

Between 1996 and 1999, the foundation funded 166 new projects, allocating to them all in all 125 million kroons, 60% as loans and 40% as irrevocable aid. 2/3 of the payout was revenue from the state budget and 1/3 redeemed loans. The projects that were funded mostly aimed at developing and introduction of new products, replacement of primitive manufacturing schemes with those yielding more surplus value, or the development of infrastructure necessary for innovation. Year by year, the average support by the Estonian Innovation Foundation has increased. For example, in 1993-1996, each of the 214 projects was supported by a little more than 400,000 kroons, whereas in 1996-1999, the Estonian Innovation Foundation supported 205 projects with the average amount of support per project being 611,000 kroons. An overview of the financial activities of the Estonian Innovation Foundation in the years 1996-1999 is given in Table 6.

On the advice of the Research and Development Council the State Innovation Programme planned an accelerated increase in financing technological development between 1998 and 2002, so that by the year 2002, the appropriations to technological development would form 0.5 per cent of the gross domestic product (GDP). Although the Government of Estonia approved this goal the planned rate appeared unachievable when preparing and executing the state budgets. The lag was great and has increased year by year.

Table 6. Financial activities of the Estonian Innovation Foundation in 1996-1999

Year	From the state (million kroons)	Loans paid back (million kroons)	Projects financed		Money paid out (million kroons)		
			total	new	loans	grants	total
1996	9,0	8,9	32	28	10,3	4,1	14,4
1997	20,0	10,4	51	43	15,7	4,7	20,4
1998	30,0	11,2	60	53	28,0	17,7	45,8
1999	27,6	12,2	62	42	27,4	17,4	44,8
Total 96-99	86,6	42,7	205	166	75,2	50,2	125,4

Source: The Estonian Innovation Foundation

The State Innovation Programme had a favourable effect on starting up new projects. Universities and other research institutions responded more actively than other agencies. Therefore a clear trend became evident that in the funding by the Foundation the share of irrevocable aid increased (only 5-6% of the total financing in 1993-1994 and almost 40% in 1998-1999). In universities, the application of research results and the development of infrastructure promoting innovation have given considerable results. If until 1999 a typical feature of the projects submitted by research institutions was that manufacture as the outcome of the project was planned to be performed by some already existing enterprise, then in 1999 several projects were launched in parallel by a research institution and its spin-off firm specially founded for the purpose of manufacturing the novel research-based production (for example, development of gene technology at the University of Tartu and the corresponding production and service at the partnership Quattromed; development of DNA chip technology at the Estonian Biocentre and the corresponding testing services at the partnership Asper, Ltd).

Year by year, the cost of the projects submitted was higher. Because of limited funding, the applicants had to either decrease the planned scope of their projects or to spread the time of completion of the project over a longer period. As a result, the delay weakened the intended effect, giving a good reason to worry that competitors would occupy the expected place on the market. In 1999, several years long projects already prevailed.

In financing both research and development projects, however, the basic source of problems has been the questionable quality of the projects submitted, because the applicants often fail to have a complex vision of how the project should be completed. For example, the projects proposed by research and development institutions have paid little attention to appraisal of the possible applications of their research outcomes and involvement of probable beneficiaries in the development work; at the same time, the projects proposed by enterprises either have been short of technological innovation or have insufficiently estimated the total amount of resources and their possible suppliers, beginning from the development phase and ending with putting the product onto the market, etc.

More attention should be paid to transfer of ideas and knowledge to competitive products and services. Until 2000, the budgetary allocation to technological development and innovation through the Innovation Foundation has been substantially smaller than outlined (in 1999, 67 % and in 2000, 39 % of the planned amount). As a result, there has been no considerable improvement in the technological developmentof economy, nor has the business sector been involved in development. For comparison: in 1996, state funding of technological development through the Innovation Foundation made up less than 5% and in 1999 less than 10 % of the science budget of the Ministry of Education.

At the present moment, the strategic documents of the Government of Estonia prioritise state support to technological development and innovation, which are regarded as a prerequisite for sustainable economic growth of a small country with limited resources; and according to these documents a considerable increase in respective state allocations is envisaged.

3.5 STATE PROGRAMMES AND OTHER EXPENDITURES ON R&D

Until now, the share of state R&D programmes has been small. As of 1998, when the Government of Estonia endorsed the procedure of preparing state funded programmes, the ministries have

1) the State Targeted Research and Development Programme for Public Health in 1999-2009 (the Ministry of Social Affairs). The total cost is planned as follows: 3.5 million kroons in 1999, and from 2000 to 2009 up to 7 million kroons a year depending on the possibilities of the state budget;
2) the State Programme The Estonian Language and the National Culture for the years 1999-2003 (the Ministry of Education). The total cost is planned to be 26 million kroons;
3) the State Programme of the Preservation and Development of the South Estonian language and Culture (the Ministry of Culture, at the stage of being started).

Different ministries have allocated considerable resources to R&D, procuring funds from other programmes and sources. The studies by the Secretariat of the Research and Development Council indicate that between 1996 and 1999 the ministries (excl. Ministry of Education) spent on R&D approximately 140 million kroons, i.e. 35 million kroons a year on average. This money has obviously not been shown in the statistics of science funding.

Besides the above-mentioned state programmes and expenditures financed from the state budget, the PHARE National Higher Education and Research Reform Project for the years 1996-1999 deserves to be noted, in the framework of which the EU supported Estonia with ca 45 million kroons. The project involved Tallinn Technical University, the University of Tartu, the Estonian Biocentre,the National Institute of Chemical Physics and Biophysics, and the TU Institute of Physics. The goal of the project was to foster integration of universities and research institutions, and to develop the existing research potential in priority areas, such as gene technology, materials science, environmental technology, and information technology. Within the framework of the programme, as an incentive, young scientists working abroad were paid scholarships to make them return and get employed in Estonia.

6. PARTICULAR FEATURES OF R&D IN ESTONIA

In Estonia, expenditure on R&D is very small.

For 1995-1999, gross domestic expenditure on research and development (GERD) in Estonia was 0.6% the of the gross domestic product (GDP). In international comparison this indicator is very low, constituting only a third of the corresponding average indicator of the EU member states (1.8% of GDP, 1998). In developed industrial countries, expenditure on R&D generally constitutes 2-3% of the GDP, of which the business enterprise sector's share is approximately 60-70% (Figure 2). As the Estonian GDP is ca 4-5 times lower than the average GDP in the EU, the actual amount of money is even smaller than the percentage indicator. Compared with other EU-associated countries, Estonia is outranked by Slovenia, Hungary, the Czech Republic, Poland and Malta, having the same position with Romania and Bulgaria, and overtaking the other Baltic States (see Appendix Table A-3).

Although in current prices the total R&D expenditures have almost doubled since 1995, in real terms the growth has remained rather modest. The growth per year was 4.3% at constant 1995 prices for the period under observation. The Regular Report Estonia 2000 made by the European Commission also points out as the most serious weakness of the Estonian R&D activity the small amount of total expenditures, suggesting that measures should be immediately taken to increase the total expenditure and involve the private sector.

For the period under observation, the main investor in R&D in Estonia has been the public sector

Expenditure by the public sector comprises all allocations by the government to R&D, irrespective of whether the implementers of R&D are institutions of the public sector, the higher education sector, or business enterprises. In 1998, the share of the public sector's spending on R&D in Estonia was 62.5% of the total (see Table 7). In EU member states the corresponding figure for 1998 was 36%. Yet the contribution to R & D by Estonia's public sector is smaller than that of the EU member states on average (0.45% of GDP in Estonia, as against 0.66% of the GDP in the EU in 1998; see Appendix Table A-4).

Financing of R&D from the state budget did not surpass 2 % in 1992-1999. The financing was mainly effected via the science budget of the Ministry of Education, which primarily funds basic and applied research. From the state budgetary funds planned for

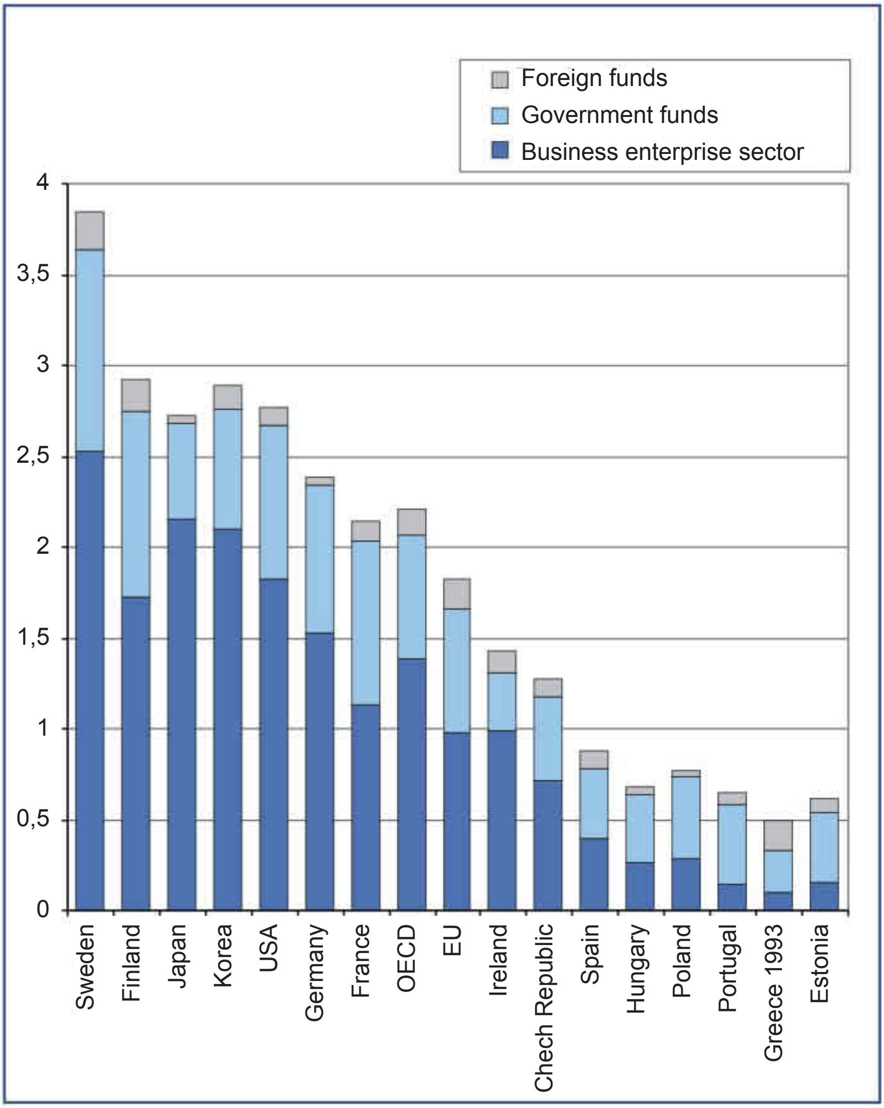

Figure 2. Financing of R&D in some OECD member states in 1997

R&D for the period under observation only the part of research was effected, getting 93 % of state funded R&D appropriations. At the same time, financing of technological development has noticeably lagged behind of what was outlined in the State Innovation Programme. In 1999 it constituted only 39 % of the planned amount.

Table 7. Financing of R&D in Estonia in 1995-1999

Year	Total R&D expenditures		Government sector			Business enterprise sector		Foreign funds	
	million kroons	% GDP	% GDP	% of the state budget	%-GERD	% GDP	% - GERD	% GDP	% - GERD
1995	253,0	0,6	0,45	2,0	71,4	0,08	13,0	0,05	9,5
1996	305,7	0,6	0,41	2,1	70,7	0.06	10,1	0,07	10,8
1997	387,9	0,6	0,40	2,1	67,1	0,05	8,5	0,09	14,4
1998	387,2	0,5	0,40	1,9	77,7	0,04	8,4	0,04	8,5
1999	435,8	0,6	0,46	1,9	79,1	0,06	9,4	0,04	8,4
1998*)	460,5	0,63	0,39	1,9	62,5	0,15	23,2	0,04	6,5
1999*)	572,8	0,76	0,49	2,0	64,7	0,18	23,9	0,04	6,4

Source: Statistical Office of Estonia
*) According to revised data by the Statistical Office, the results of the first polls of the business enterprise sector in 1998 and 1999 have been taken into account.

The state financing of R&D has ensured the high level of basic research in some disciplines but the connection between the emergence of new knowledge and the development of new technologies on the basis of this knowledge has remained weak. Estonia has good preconditions for gaining success in biotechnology and gene technology, information and communication technology, technology of materials, industrial technology, and environmental technology.

The share of business enterprises in R&D is small.

Spending on R&D by business enterprises is the indicator of a country's long-term competitive ability. The shortcoming of the existing statistics is the absence of data about the business enterprisesector before 1997. It was not before 1998 that the Statistical Office of Estonia also involved the business enterprise sector into its R&D observations. It was found that R&D expenditures by business enterprises for 1998 were only 0.15% of the GDP, constituting 23% of the aggregate R&D expenditure. (In 1997, the EU business enter-prises, on average, invested in R&D 0.98% of the GDP, i.e. 53% of the total expenditure.) Only every 39th business enterprise employing more than 20 persons spent on R&D. R&D expenditures by business enterprises formed only 0.13% of their net turnover.

At the same time it deserves mention that in addition to Estonian development work, business enterprises order research from abroad in amounts exceeding the domestic amount ca 1.4 times*. The reasons may be, for example: a) the foreign origin of the owners of enter-prises; b) distrust of the work of own scientists and engineers; c) ordering from a well-known foreign firm will decrease risks; d) lack of awareness about what our own researchers can do; e) lack of the corresponding competence in Estonia. Consequently, there is a good reason to think and investigate why Estonian scientists lose such a challenging opportunity for demonstrating their talents.

Business enterprises act as a driving force to innovation. Therefore their needs must be carefully heeded when developing innovation and planning innovation policy. In Estonia, despite growing competition, the ongoing problem is that expenditures by business enterprises on development have remained relatively low compared to international indicators. Looking at the problem from the business enterprises' point of view, the reasons may be the lack of long-term strategic planning, limited skills in technological change management, low awareness of the possibilities provided by the innovation system, and insufficient resources for carrying out development projects. From the state' s point of view, the reasons are the hitherto inadequate stimulation of development activities of business enterprises, which is expressed in inadequate investments and measures in support of technological development and innovation, towards building up the national system and support structures for innovation.

The share of resources from foreign sources that increased up to 14.4 % between 1995 and 1997 has decreased to 6.5 % and is now at the same level with the EU average. The decrease can partly be explained with the fact that the business enterprise sector was included into the statistics. Another reason may be, especially considering the great growth of 1997, a single large investment (such as the extension to the Estonian Biocentre).

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* Note: International R&D statistics is based on domestic R&D and therefore investments in foreign countries are excluded, the same principle is followed in Estonia.

Here it may be worthwhile to consider the Greek experience - after its accession to the European Union the share of foreign R&D resources grew from 11.6% in 1989 to 30% in 1993. The European Union has allocated large sums to Greece to support its R&D infrastructure. We can hope for an increase in the volume of foreign funding in the following years when Estonia's successful performance within the Fifth EU R&D Framework Programme will be reflected in the reports.

The main economic sectors involving R&D are the business enterprise, higher education and government sectors. In Estonia like in other associated countries and the EU member states with less advanced industry, the major part of R&D is implemented in the government and higher education sectors, the share of the business enterprise sector being only 20-30%. In 1998, in Estonia 80% of the R&D activity was conducted in the government and higher education sectors, leaving only 19% to the research laboratories of the business enterprise sector (Table 8). There are no data about the business enterprise sector before 1997 because no corresponding observations were performed

Within the framework of a structural reform, most of the institutes of the Estonian Academy of Sciences merged with universities and more than half of the R&D resources have now been concentrated into universities. In 1995, research done in universities formed 28% and in the government sector 72% of the total R&D expenditures, while in 1999 the share of R&D work in universities was 67% as against 32% in the government sector's institutes.

The share of applied research and experimental development has increased from 47.3% in 1995 to more than 50% in 1998 and 1999 (Figure 3). Notwithstanding a slight rise, the share of experimental development is still small. In highly developed OECD countriesdevelopment activity forms up to 60% of total R&D. As the state has been the main investor in R&D in the period under discussion and business enterprises have not spent much on development, the characteristic feature of Estonian R&D is its orientation towards research. In 1998 the total R&D funding was divided as follows: basic research received 48%, applied research 39.2% and technological development 12.8%; the ratio accordingly being 1:0.8:0.3. In the developed countries the ratio is reversed with emphasis on development which forms up to 60% of the total amount of R&D.

Table 8. Intramural R&D expenditures by Estonian research institutions in 1995-1999

	GERD-		Government sector			Higher education sector		Business sector	
Year	million kroons	% GDP	million kroons	% GDP	% GERD	% GDP	% GERD	million kroons	% GERD
1995	250,6	0,6	179,9	0,44	71,8	70,7	28,2		
1996	299,7	0,6	192,6	0,38	64,3	103,3	34,5		
1997	379,7	0,6	139,6	0,21	36,8	220,2	58,0		
1998	375,7	0,5	107,4	0,15	28,6	252,7	67,3		
1998*	450,9	0,61	107,4	0,15	23,9	252,7	56,0	88,8	19,3
1999	435,8	0,6	141,6	0,19	32,5	291,7	66,9		

*results of the first poll of the business enterprise sector have been considered

Note: higher education sector - universities and other institutions of higher education with their subordinate establishments; government sector - institutions and units financed by the state or local governments, whose main activities do not consist in the manufacture of goods or provision of services for sale and which do not belong to the higher education sector; business enterprise sector - all firms, organisations and institutions whose main activities consist in the manufacture of products or provision of services (except in the field of higher education) for sale at economically reasonable prices.

Types of R&D by fields of science are very different (Figure 4). For example, in 1999 the volume of applied research and development in agriculture was 91% (of which development formed 43%) and in engineering 74% (development forming 23%), but in natural sciences the volume was 30%, of which development formed only 6%. On the one hand, this characterises differences between fields of science, on the other hand, it refers to the potential natural sciences have for development work.

The distribution of R&D expenditures by fields of science has changed very little between 1996 and 1999 (Figure 5). The main financial source is state funding which accounts for more than 80%.

Only state financing of engineering is a bit lower - 64%. 28% of engineering sciences rely on the resources contributed by business enterprises, the same is done by 14% of agricultural sciences and 2-3% of the rest.

The spending on scientists working in different fields varies as well (Table 9). If in 1999, 267 thousand kroons were spent per scientist in agricultural sciences, then in medical sciences, natural sciences and exact sciences the respective figures were 190, 166 and 152 thousand kroons. The spending per scientist was lowest in social sciences and humanities - 125 and 118 thousand kroons, respectively.

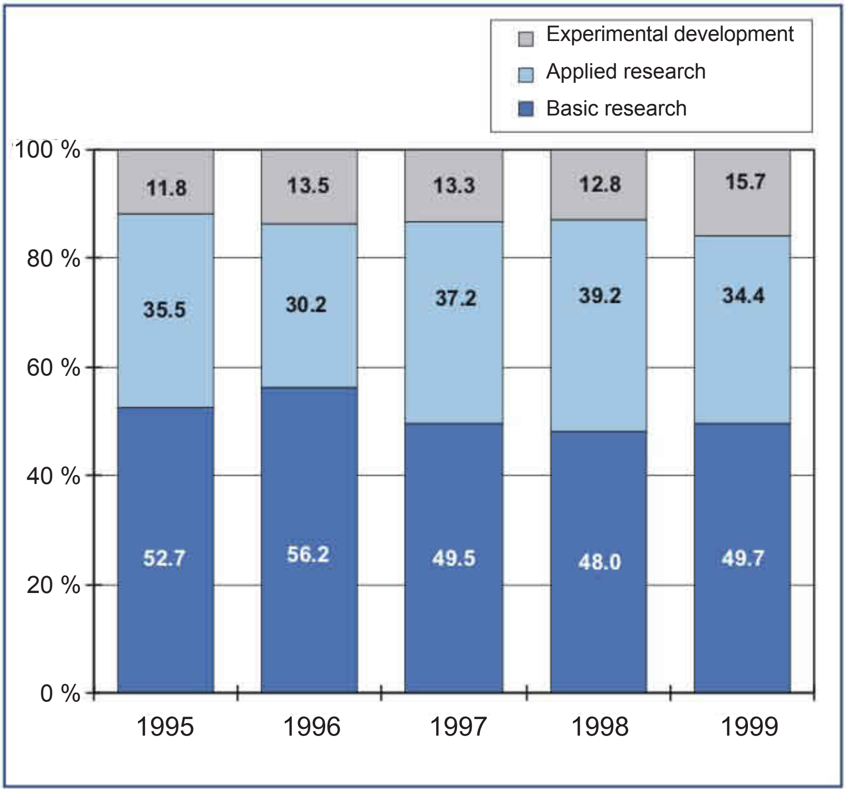

Figure 3. R&D in 1995-1999

Table 9. Expenditures per researcher by fields of science in 1999

Field of science	Number of researchers in full-time equivalent	R&D expenditures per researcher (thousand kroons)
Natural sciences	888	166
Engineering	557	152
Medical sciences	253	190
Agricultural sciences	200	267
Social sciences	319	125
Humanities	402	118
Total	2622	166

Source: Statistical Office of Estonia

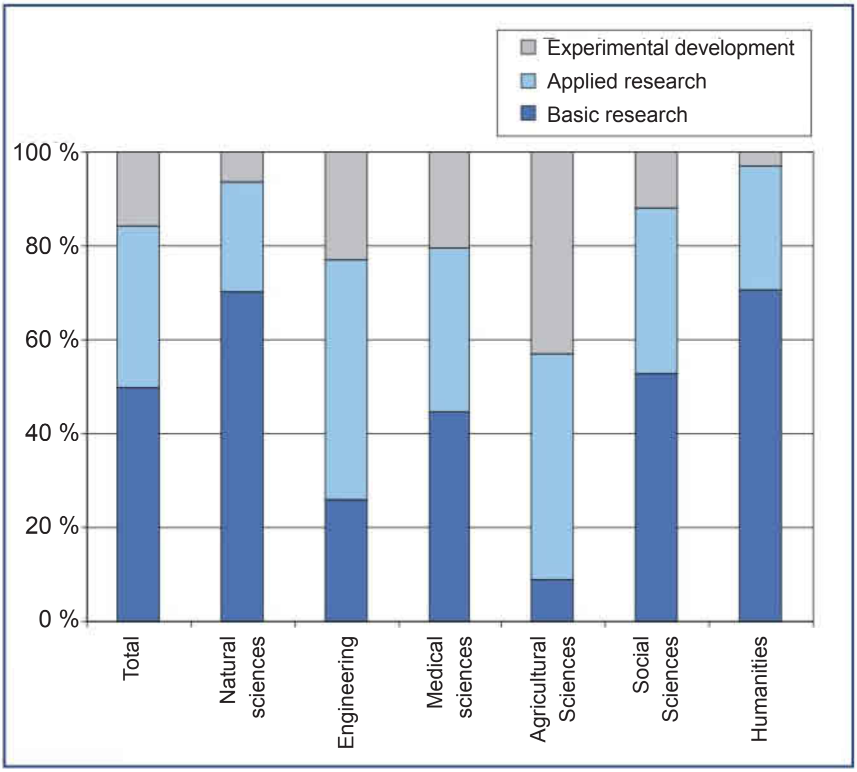

Figure 4. Types of R&D by fields of science in 1999

One can understand that in humanities and social sciences expenditures are smaller, because the share of experimental work requiring expensive equipment is smaller. But 125 and 118 thousand kroons, respectively, only serve to cover the salaries if the monthly salary per person is 8,000 kroons, and together with the social tax it will make 124,000 kroons a year. Obviously, expenditures on scientists in natural sciences and especially in engineering are too small to allow for high-level experimental work.

Expenditures on the workforce in Estonia form ca 50% of the total R&D expenditure. This is comparable with the corresponding figure of the Nordic countries but the absolute value of a researcher's salary in Estonia remains far behind that of his/her Western counterparts.

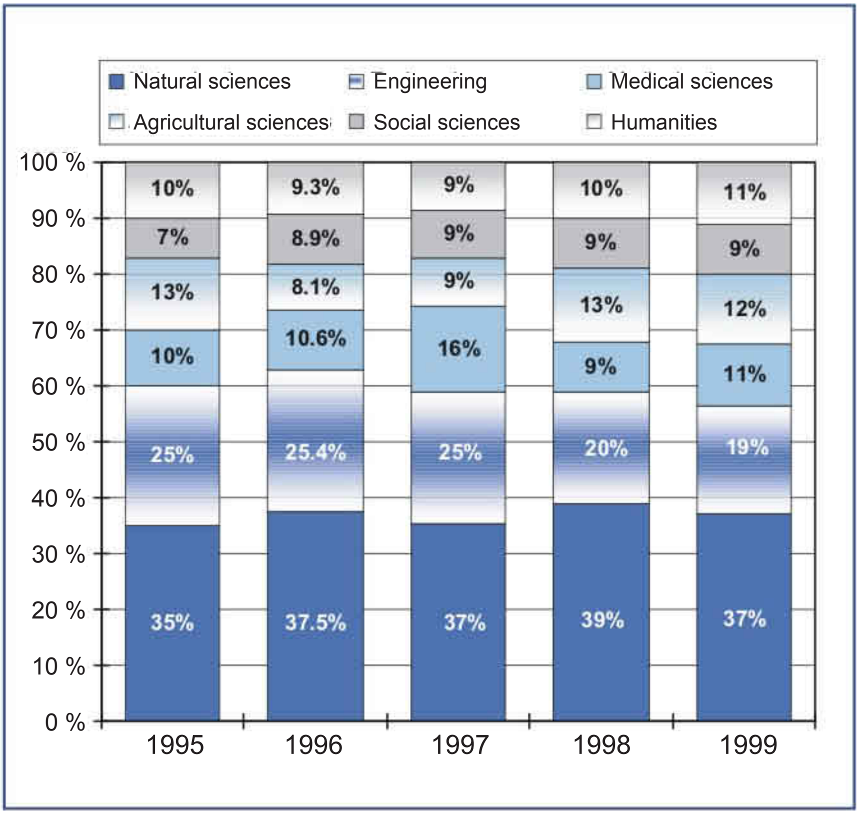

Figure 5. R&D expenditures by fields of science in 1996-1999

CONCLUSIONS

Although the existing system of financing operates well, there are several organisational bottlenecks and problems that need to be resolved:

- the proportions of financing separate fields of science remained almost the same for years;
- the financing of technological development has essentially lagged behind compared to the financing of research;
- total R&D expenditure is very small;
- share of business enterprises in R&D is small;
- upon drafting the research budget, the guiding role of the Research and Development Council has remained weak;
- the situation around opening new relevant topics of research resembles a vicious circle - there being no stable working teams, the level of applications is low and they fail to get a positive appraisal;
- lack of a possibility to purchase modern research equipment;
- lack of extra funding for maintenance of the existing large size equipment (cryostations, electronic microscopes, etc.);
- shortage of extra funding for maintenance of holdings relating to folk culture and natural history;
- lack of means for motivating and stimulating successfully performing research collectives (centres of excellence);
- due to limited budgets, institutions lack ways and means to ensure jobs to fresh doctoral degree holders.

4. HUMAN RESOURCES

Human resource as an R&D input is expressed by the number of researchers and professionals engaged. The largest drop in the number of researchers was in 1992-1995 (see Figure 6). Between 1996 and 1999, the total number of researchers declined by ca 15% first and foremost on account of those who had no higher academic degrees, technicians and other supporting staff. While the number of top scientists - holders of doctoral and candidate of science degrees - has also decreased since 1991, the number of scientists holding master's degrees has gradually grown, which gives hope that in future the number of top scientists will not diminish.

The largest number of researchers is engaged in natural sciences, engineering and humanities (see Table 9). In 1998, when for the first time the business enterprise sector was observed, the total number of researchers was 3045, including 291 employees in the business enterprise sector (data are given in full-time equivalent, excluding technicians and other supporting staff). So there were 4.3 researchers per 1,000 employees. This is less than the average EU indicator (5.0) and also that of the OECD countries (5.5), although Estonia still belongs to the middle group (see Table 10). In 1997, this number for the Czech Republic, Poland and Hungary was 2.4; 3.2 and 2.8, respectively. In the same year this number in the leading industrial countries such as the USA, Japan, Sweden and Finland was 7.4; 9.2; 8.6 and 8.3, respectively. At the top was also Iceland whose indicator was 9.1.

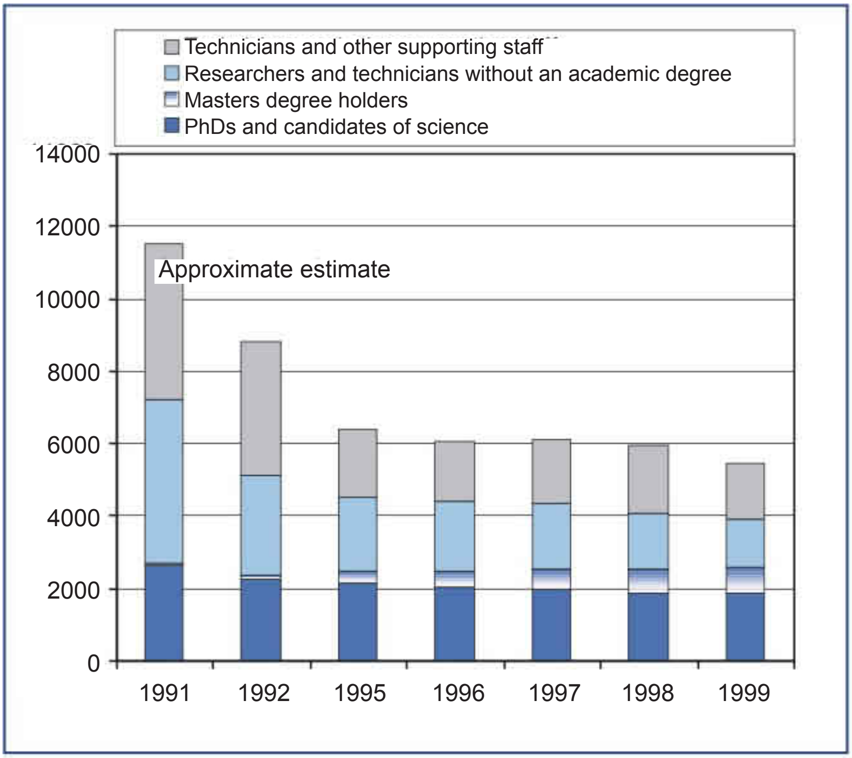

Figure 6. Personnel engaged in R&D in 1991-1999

Table 10. Number of researchers per 1,000 labour force in some OECD countries and in Estonia in 1998

Japan	9,2	Germany	5,9	Austria	3,4
Iceland	9,1	Switzerland	5,5	Italy	3,2
Sweden	8,6	Canada	5,3	Spain	3,2
Finland	8,3	Belgium	5,3	Poland	3,2
Norway	7,6	United Kingdom	5,1	Hungary	2,8
USA	7,4	Netherlands	5,0	Portugal	2,7
Australia	6,7	Korea	4,8	Czech Republic	2,4
Denmark	6,1	New Zealand	4,5	Greece	2,0
France	6,0	Estonia	4,3	Turkey	0,8

Source: OECD and Statistical Office of Estonia

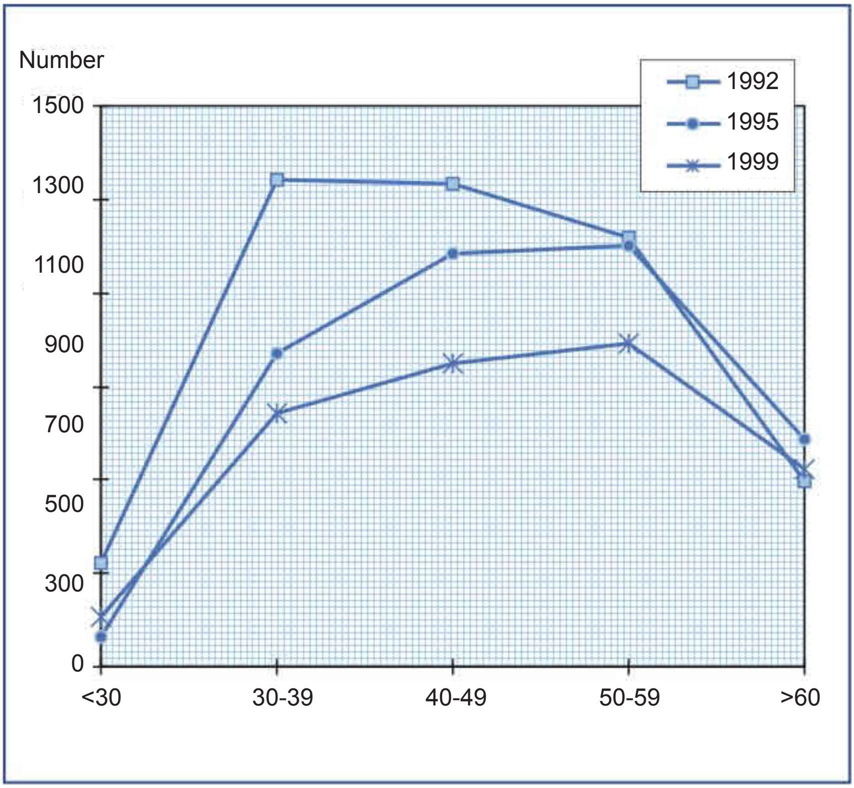

Figure 7. Age dynamics of researchers

The dynamics of distribution of researchers by age shows that the tendency of swift aging characteristic of 1992-1996 has now been stopped (Figure 7). Compared to the year 1995, the percentage of researchers under 30 years of age has risen approximately by 10%.

Nevertheless, a large majority belong to the age group of 50-60 year olds.

The rise in the number of young scientists can be put down to increased efficiency of master and doctoral studies at universities. If in 1996 the efficiency of higher degrees courses was ca 25%; then now we can say that the situation has improved, for in 1998, 49% of the students admitted to the two-years long master's course completed with a master's degree, and in 1999, this figure was already 60%. This is 2.5 times more than in 1995-1997 (see Figures 8 and 9).

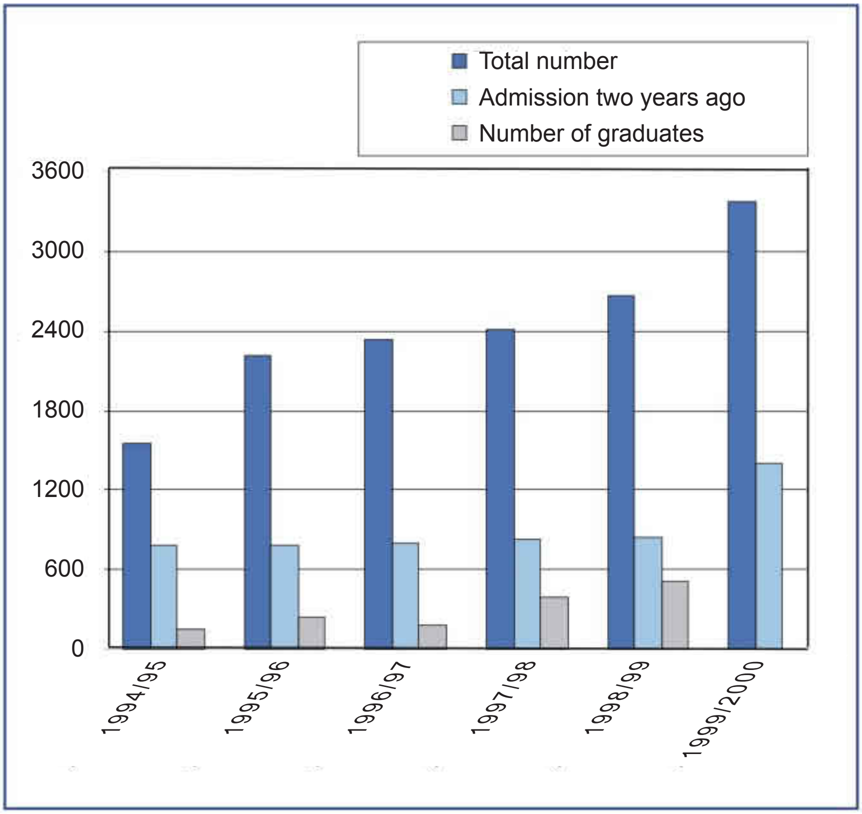

Figure 8. Master's courses in 1994-1999

In 1992, universities started to run doctoral courses and four years later 15% of those admitted had been awarded the Ph.D. degree. Year by year the percentage of graduates has grown, reaching 45% in 1999. Thus the effectiveness of doctoral courses has increased three-fold. Naturally, both the effectiveness of doctoral courses and the number of doctoral students vary with different universities and different fields of study. The situation has been especially bad in such specialities as commerce, business administration, and law, where there are slightly more than 4-5 doctoral students per 1,000 students and only a few have got their doctorate in the last four years. The situation is better in natural sciences with 200 doctoral students per 1,000 students and accordingly a larger number of graduates of doctoral courses as well. The effectiveness of doctoral courses appears to be lowest at Tallinn Pedagogical University.

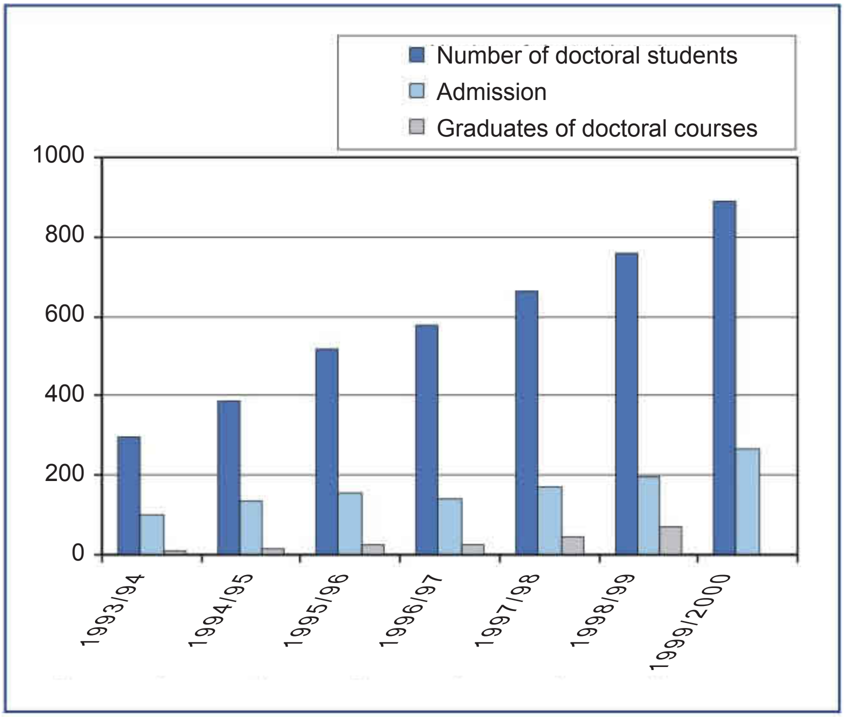

Figure 9. Doctoral courses, 1993-1999

The slow increase in the number of Ph.D. degree holders cannot ensure reproduction of the potential of Estonian science and higher education, to say nothing about providing the industry with academically trained employees. To ensure continuity of academic education and research, Estonia would need ca 80 new Ph.D. holders per year. Wanting to follow the example of developed countries, we would need another 80 Ph.D. holders annually to provide employees for research institutions outside the public sector. But following the corresponding ratio of Finland and Sweden, we might even need 200 new Ph.D. holders yearly. Between 1991 and 1998, on average 38 students, including external students, got the Ph.D. degree in Estonia and 5-10 students abroad. Provided that the efficiency is normal, the present admission (260-270) should ensure the higher education potential necessary for Estonia.

The other critical indicator is that graduates of doctoral courses are relatively old. Their normal age is considered to be 30. The average age of graduates receiving their doctorate at the University of Tartu is 34, at other universities 41-43. The average age of external graduates at the University of Tartu is 43, at other universities 55.

Only 20% of the graduates in engineering, agricultural sciences, so-cial sciences, and humanities are under 36. In that respect, the situation is the best in natural and medical sciences and the worst in social sciences (excl. psychology).

Both the Science Competence Council and the Estonian Science Foundation (EstSF) have, apart from their main task, paid much at-tention to the problem of succession, promoting young successful postgraduate students and Ph.D. holders in their career pursuits and helping them rise to top positions in our research and development institutions. Every year up to 3% of target funding goes to postdoctoral fellows for completion of two-year projects. The EstSF favours the research projects that involve doctoral students and postdoctoral fellows. Better conditions for involving young researchers were provided by the amendment to the Organisation of Research and Development Act in 1999, made on the initiative of the EstSF, that equated research grants to master and doctoral students with state fellowships, exempting them from the need to pay the social tax. For example, in 1999, 347 doctoral students, 236 master students, and 90 undergraduate students took part in research grant projects.

5. PATENTS AND PUBLISHING

Important parameters characterising R&D include data about publication of research articles, citation, and filed patent applications (the so-called bibliometric indicators).

Apart from being a source of scientific and technical information, a patent is also a legal document. Patent information is well classified (on the basis of International Patent Classification) and available. As the requirements set to patent applications coincide internationally to a sufficient degree, the number of filed patent applications as a relevant figure has been included among the OECD main R&D indi-cators.

Patenting activity, showing the scope of R&D results application, is very low in Estonia. For the period under discussion, the number of domestic patent applications per year has fluctuated between 12 and 20, whereas the number of foreign applications has multiplied (see Table 11). In Estonia the number of patent applications per 10,000 inhabitants is 0.1, while in the EU member states the average indicator is 2.5. To achieve this level, Estonia should submit about 350 patent applications yearly.

Table 11. Number of filed patent applications in Estonia

Number	1994	1995	1996	1997	1998	1999
Patent applications	482	82	213	375	463	619
among these from Estonia	16	16	12	15	20	13
Patents registered			22	108	82	103

Source: Statistical Office of Estonia

The low patenting activity may be put down to paucity of inventions having an application potential, because the national motivation system is oriented towards basic research. But there are other reasons as well, such as insufficient knowledge of intellectual property, lack of market, and the cost of a patent. For example, registration of a patent together with a state duty costs between 8 and 10 thousand kroons on average. To hold a patent (maximum for 20 years), it is necessary to pay a growing state duty in average over 4,000 kroons per year.

As regards publications, data are more pleasing. Even though the number of scientists has decreased, the number of publications in international journals has grown. Unfortunately no general database is available about the scientific articles published earlier on in Estonia. The publication data of the former institutes of the Estonian Academy of Sciences have been recorded until 1994. Between 1996 and 1998, the Estonian Science Foundation compiled and administered a scientific publications database of all the research institutions of Estonia including universities (Table A-5, see Appendix). In 1999, the Estonian Science Foundation stopped updating the database because the Ministry of Education stopped funding it. Unfortunately, no resources have been found since then to continue this work.

To evaluate scientific publications at the international level, the Science Citation Index (SCI) database is used, which comprises entries from 3,000 leading scientific journals of ca a hundred specialities, the Social Science Citation Index (SSCI) database including data from 1,400 journals (and in addition selectively from 7,000 journals) of ca fifty specialities in social sciences, and the Art and Humanities Citation Index (AHCI) database comprising data from 1,100 journals (and selectively from 7,000 journals) of ca 25 specialities in humanities.

According to these databases, the number of publications in the Citation Index database journals has gradually grown (Table 12, A-6 see Appendix). For instance, if in 1996 there were altogether 439 Citation Index publications from Estonia, then in 1999 the number of publications had already risen to 623. In this respect, the University of Tartu and the Tallinn Technical University outstrip others, the leaders among research institutes being the Tartu University Institute of Physics and the National Institute of Chemical Physics and Biophysics.

Table 12. Number of Estonian science publications in the Citation Index (SCI, SSCI, A&HCI) databases in 1996-1999

1995	1996	1997	1998	1999
382	439	512	585	623

More than 50 % of international level publications get written in collaboration with foreign authors, among them scientists from the the leading Western European laboratories (for Table A-7 see Appendix). According to publications, collaboration is closest with Swedish, Finnish, German, US, Russian, French and British researchers. All in all, between 1996 and 1999, articles were published jointly with re-searchers from as many as 38 countries

The per capita amount of international publications (according to the Citation Index database) is smaller in Estonia than in most developed countries but at the same level with the Central European countries (Table A-8 see Appendix). Comparing the number of publications with R&D inputs such as financial and human resources, we see that for the same amount of money (US$ 1 million) 107 articles get published in the Citation Index database journals in Hungary, while the respective figure for Estonia is only 13. This indicator would place Estonia last among the OECD countries (for Table A-8 see Appendix). The same applies to the so-called researcher's productivity indicator, i.e. the number of publications per researcher. In Es-tonia this indicator is 0.20. From among the 28 OECD countries we outstrip, for example, Mexico, Hungary, Iceland, Turkey, Poland and Portugal. Here it must be emphasised, however, that we cannot make far-reaching conclusions on the basis of international Citation Index publications data because they are incomplete and fail to comprise studies of practical value of many new technologies.

6. INTERNATIONAL CO-OPERATION

Participation in international R&D is important for small countries as it contributes to their development and helps them obtain extra resources. Successful participation in joint international R&D programmes also serves as an indicator for evaluating a country' s international competitiveness in the field of R&D.

As a member of the European Research Area, it has been important for Estonia to take part in EU research and development programmes, for instance, the Third and the Fourth Framework Programmes, COST, EUREKA, etc. Estonia is a full member of COST, an associated member of EUREKA, and belongs to the network of Innovation Relay Centres (IRC). Regarding the Fourth Framework Programme, it needs to be mentioned that in addition to the

INCO-Copernicus programme which was meant for the Central and Eastern European countries, Estonia participated in most sub-programmes (Table A-9 see Appendix), being one of the most successful candidate countries (Table 13).

Table 13. Effectiveness of EU candidate countries in the Fourth Framework Programme

Country	EUR thousand per million inhabitants	Successful applications per 10,000 inhabitants	% of successful applications
Bulgaaria	0,81	2,10	17%
Czech Republic	1,07	2,98	21%
Estonia	2,72	5,97	27%
Hungary	1,54	3,84	23%
Latvia	0,96	2,33	22%
Lithuania	0,66	2,03	23%
Poland	0,37	0,99	23%
Romania	0,42	0,96	20%
Slovakia	1,01	2,70	20%
Slovenia	3,54	7,80	24%

Source: European Commission

Encouraged by its success in the Third and Fourth Framework Programmes, Estonia was the first candidate country to become associated with the Fifth Framework Programme as a full member. For Estonian research institutions and business enterprises that meant participation on equal terms with the EU member states. In keeping with the conditions of the association agreement. Estonia pays a participation fee of ca 89 million kroons. As distinct from the Third and Fourth Framework Programmes, in the Fifth Framework Programme the Estonian representatives act as observers in the programme committees. In addition to that, Estonia participates in preparing the Sixth Framework Programme and in designing the European Research Area.

The European Research Area is the EU's new initiative, its objective being to raise European competitive ability through international R&D co-operation. To realise the idea of a joint research area, it is planned to adopt the principle of reciprocal opening-up of national research programmes, to create co-operation networks and co-ordinate the activities, to create a Europe-wide network of centres of I excellence, to initiate jointly financed large-scale target programmes and projects, to support research infrastructures within the European sphere of interest, to increase and vary mobility grants to scientists both in the EU and third countries, and to increase the share of women in R&D.

More than 260 project applications (as of 15 Aug. 2000) with Esto-nian involvement were submitted to the projects competition opened within the framework of the Fifth EU Framework Programme. 20-25 % of the applications were successful, which is comparable to the respective average figure for the EU member states. Estonia has been more successful in the programmes related to the quality of life and the administration of life resources, and those related to energy, environment and sustainable development. Through the successful projects Estonia will receive ca 150 million kroons, which is much more than the participation fee. Estonia's success was also ac-knowledged in the European Commission's Progress Report 2000.

Apart from taking part in the EU research and development projects. Estonian research institutions and teams have co-operated with their counterparts in a large number of countries (see the Research and Development Council's website www.tan.ee). The proceeds from this co-operation may be estimated at around 115 million kroons for the period 1995-1999.

The Estonian Academy of Sciences, one of the co-ordinators of international co-operation, has signed research-related co-operation agreements with academies of 19 countries. To provide a financial mechanism for exchange of scientists with other countries on equivalent terms, the Academy has established the Estonian Aca-demic Foundation for International Exchange. All the research insti-tutions and universities can participate in this exchange.

Estonian scientists have actively participated in foreign competitions for visiting scientists. For example, in 1996-1999, 19 one-year DAAD scholarships for postgraduate courses at German universities and 17 1-3 months fellowships for working at German universities were won by Estonian university graduates.

The Government of the Republic of Estonia has signed co-operation agreements in the fields of economy, research, engineering and culture with the Governments of the People's Republic of China, the Republic of Hungary, the Republic of Poland, the Republic of India, the Republic of Slovenia, the United States, the Republic of Turkey, the Arab Republic of Egypt, the Republic of Italy, the Republic of Greece, the Republic of Croatia, the Ukraine, and the State of Israel.

Estonia has joined the international society founded for the promotion of co-operation between scientists from the former republics of the Soviet Union (INTAS), which comprises all the EU member states, the European Union, Iceland, Israel, Norway, Switzerland, Latvia, Slovenia, Romania and Hungary. Membership will enable Estonian scientists to participate as partners in programmes directed to the newly independent states.

In 1999, the Estonian Academy of Sciences and the Estonian Science Foundation joined the European Science Foundation which is the association of research funding organisations in the European countries. This entitles Estonian scientists to participate in co-operation networks, programmes and conferences of the European Science Foundation.

7. EVALUATIONS AND OPINIONS OF R&D IN ESTONIA

The first international evaluation of research in Estonia was carried out in 1991-1992 on the initiative of the Estonian Science Foundation and the Estonian Science Council. The Royal Swedish Academy of Sciences helped to perform it. The second evaluation was carried out by the Estonian Research and Development Council in 1994. Both evaluations focused on the standards of research content, but the possible ways for raising the efficiency of the system of research were also analysed. Some of the recommendations made have been implemented by now. Integration of research institutions and universities has appreciably improved and the number of publications in internationally recognised journals has increased. At the same time, there are still many persisting problems, for example, the age of scientists, the orientation and insufficient interdisciplinarity of research in some fields of science, a weak material base, inadequacy of infrastructures for the needs of research and technological development, and inefficient links between research and business enterprises.

In addition to the evaluations mentioned above, two evaluations of the Estonian innovation system have been performed, namely, an analysis made in 1997 by Coopers & Lybrand at the request of the European Commission, and the other one commissioned by the Ministry of Economic Affairs in 1999 from the Finnish expert Hannu Hernesniemi. Although different aspects were analysed, the analyses complemented each other, pointing out similar final conclusions and recommendations for the development of the Estonian R&D system.

Both reports stated that:

- Estonia is orientated towards basic and applied research;
- Estonia has a legal basis for and institutional organisation of R&D, but these need to be developed further to determine more explicitly the functions of different parties and to make co-operation more effective;
- Estonia has been able to generate and maintain a strong scientific potential in certain disciplines which is a precondition for the development of genetic and biosciences; as well as information, communication, materials, production and environmental technologies;
- Estonia is one of the most developed countries among the Central and Eastern European countries by indicators of information infrastructure and communication technology, and has thus preconditions for developing this sector;
- in some fields of R&D, relatively successful integration into international co-operation networks has taken place, which is expressed by the active and successful participation of Estonian research and development institutions in international R&D co-operation programmes;
- an active inflow of foreign investments has been accompa-nied by technology transfer.

The following aspects were pointed out as weaknesses and problems:

- the funding of R&D by the state and business enterprises is insufficient;
- the national innovation system of Estonia is weak - leading, supporting and bridging institutions/organisations of innovation are insufficiently developed and cannot function properly in the innovation system as a whole. The variety and amount of support instruments promoting technological development

and innovation are insufficient to cover the chain from the idea stage to the product by means of different grants, loans, risk capital, start-up financing, and tax benefits. Links be-tween research, higher education and industry are weak;

- the number of domestic patents is small;
- the lack of information about the needs of enterprises - there are very few studies about the needs of Estonian industry in the field of technological development;
- neither the society nor top politicians have yet realised the need to develop and finance the national R&D and innovation system, and fail to see their leading role in the development of the state;
- national statistics for R&D is not comparable to international data. Information about technological development and innovation in the business enterprise sector is insufficient
- the age of scientists and the small influx of young scientists are serious problems..

The expert opinions and recommendations mentioned above served as the basis for preparing the section on innovation in the National Development Plan, and working out the strategy for R&D in Estonia.

In the spring of 2000, the first evaluation of science pursuant to the Organisation of Research and Development Act was carried out in Estonia. According to the Organisation of Research and Development Act, each research and development institution is subject to evaluation at least once every seven years. The aim of evaluation is to assess research and development institutions and research topics implemented by them to ensure state funding to internationally rec-ognised R&D, to find the shortcomings in the activities of R&D insti-tutions and to make recommendations about the development of scientific research relevant to the Republic of Estonia. As recom-mended by the Science Competence Council, the evaluation will, first and foremost, concern separate fields of science.

In 2000-2001, it is planned to evaluate primarily natural sciences (exact sciences, chemistry and molecular biology, bio- and geosciences), and social sciences. Evaluation of research institutions representing narrow fields of science will make it possible to better assess the standards of one and the same field in different institutions but, depending on the type of institution and the fields of research cultivated there, the evaluation may take more than a year. The evaluation data will be made public and the final expert reports will be available on the homepage of the Research and Development Council (www.tan.ee).

8. CONCLUSION

1) Many important research results, active international co-operation, and the success of Estonian researchers on the international grants market show that the country's research has considerable potentiali-ties.

2) Like other areas, the research and innovation system has under-gone many changes: reorganisation of the work of research institu-tions, international and domestic evaluation of research topics, al-tering the bases of funding R&D, remodelling the academic degree courses to meet the international criteria.

3) A legal basis has been established in Estonia both for the exis-tence of flexible research structures, for financing R&D and for evaluating research outcomes.

4) The main problem faced at present is lack of social agreement in the questions of long-term development of R&D, expressions of which are the absence of both a national R&D policy and clearly defined priorities with regard to its funding, and the generally insufficient allocations to R&D from the state budget. Therefore, a long-term R&D policy must be worked out and get approved by the legis-lative body.

5) The R&D policy worked out as a result of public discussions must determine the priority fields of research and priority courses of ac-tion, and the amounts and proportions of R&D funding by the Gov-ernment for the next period (for at least four years). This would help avoid the recurrent gap between the planned strategic measures and the actual amounts of funding. Also, in the process of preparing the state budget, it would avoid the situation that preference is given to the fields yielding a short-time effect instead of planned long-term R&D investments.

The passing of the Organisation of Research Act and the Organisation of Research and Development Act, on the one hand, and the introduction of the research outcomes orientated financing system on the other, as well as the restructuring of the network of universities and other research institutions have established a framework for R&D in the now independent Estonia striving to join the EU. It is now the task of researchers to fulfil this framework with a high quality content. At the same time, the politicians' attitude towards R&D has remained lukewarm as they fail to perceive the importance of R&D for the economy and social sphere of the country. This attitude finds a clear expression in the inadequate financing of research and ex-perimental development from the state budget.

Table A-1. Estonian Science Foundation's grant allocation by institutions, 1996-2000

Institution	Sums allocated, thousand kroons				
	1996	1997	1998	1999	2000
UNIVERSITIES					
University of Tartu (TU)	19 013	23 359	25 452	26 942	24 866
TU Institute of Physics	2 887	3 616	3 744	4 289	3 918
Tallinn Technical University (TTU)	5 636	6 950	7 412	8 042	7 840
TTU Institute of Cybernetics	1 391	1 511	1 562	1 618	1 799
TTU Institute of Chemistry	1 634	2 017	1 673	1 894	1 732
TTU Institute of Geology	1 032	1 233	1 115	1 114	1 027
TTU Estonian Institute of Economics	461	444	427	431	305
TTU Institute of Oil Shale	110	137	140	105	200
Estonian Agricultural University (EAU)	4 975	6 448	7 036	4 379	3 797
EAU Institute of Animal Science				2 747	2 386
EAU Institute of Experimental Biology	566	673	572	661	482
EAU Institute of Zoology and Botany	1 875	2 143	2 358	2 008	1 821
EAU Forest Research Institute					813
EAU Estonian Plant Biotechnical Research Centre EVIKA	100	185	154	190	200
EAU Polli Institute of Horticulture			78	105	99
Estonian Academy of Art	24	101	208	138	92
Tallinn Pedagogical University (TPU)	921	1 214	1 809	1 886	1 703
TPU Institute of Ecology	1 236	1 335	1 218	1 391	1 351
TPU International Centre of Environmental Biology	10			35	
TPU Institute of International and Social Studies	535	572	451	598	501
Estonian Inter-University Population Research Centre	400	373	555	428	340
Estonian Academy of Music	53	80	164	173	122
EuroUniversity				90	200
Concordia International University Estonia	15				
Estonian National Defence and Public Service Academy			30		
Estonian Joint Military Educational Institutions					43

RESEARCH INSTITUTES UNDER MINISTRY OF EDUCATION					
Tartu Observatory	1 366	1 480	1 933	1 718	1 507
Estonian Biocentre	1 209	1 532	1 442	1 176	1 154
Institute of History	959	782	960	1 053	840
Institute of the Estonian Language	1 824	1 432	1 247	1 512	950
Estonian Literary Museum	283	363	536	807	1 099
Estonian Association of the History and Philosophy of Science		60			
PUBLIC INSTITUTES					
National Institute of Chemical Physics and Biophysics	2 937	3 540	3 702	3 771	3 280
ESTONIAN ACADEMY OF SCIENCES					
Under and Tuglas Literature Centre	230	225	154	60	65
Estonian Mother Tongue Society		96	153		
Estonian Naturalists' Society	75	38	59	14	
Estonian Academy Publishers				55	
MINISTRY OF SOCIAL AFFAIRS					
Institute of Experimental and Clinical Medicine	900	992	1 216	1 562	1 712
Estonian Institute of Cardiology	459	397	462	642	621
Mustamäe Hospital	117	29	30	40	
Health Protection Inspectorate				20	
Tallinn Nõmme Hospital	65	70	67	70	
Institute of Preventive Medicine	298	198			
Tartu Oncology Hospital	40	48			
Tallinn Central Hospital	43				
Estonian Seamen’s Hospital					130
MINISTRY OF AGRICULTURE					
Estonian Research Institute of Agriculture	426	475	507	487	405
Estonian Agrobiocentre	365	374	282	292	216
Jõgeva Plant Breeding Institute	285	222	190	203	111
Estonian Institute of Agricultural Engineering	141	112	159	170	110
Estonian Institute of Agrarian Economics	110	180	180	190	185
Tartu Eco-engineering Centre	50	55			

MINISTRY OF ENVIRONMENT					
Estonian Marine Institute	655	663	715	755	765
Building Research Institute	50	35	45	50	
Geological Survey Centre of Estonia	15	20	20	20	15
Estonian Meteorological and Hydrological Institute	234	195	155	160	80
Information and Technology Centre	61	73	50	50	50
Estonian Institute of Forest Research	329				
Centre of Forest Protection and Silviculture		70			
MINISTRY OF ECONOMIC AFFAIRS					
Estonian Energy Research Institute	765	815	705	586	340
MINISTRY OF CULTURE					
Theatre Vanemuine	5			15	15
Estonian National Museum	123	184	178	177	90
Art Museum of Estonia	35	8	32	16	108
Estonian History Museum	25	29	48	53	60
Museum of Estonian Architecture					30
STATE CHANCELLERY					
Estonian State Archives	120	210	225		
Estonian Historical Archives	300	301	364		
National Archives of Estonia				596	387
LOCAL AUTHORITIES					
Pärnu Institute of Health Resort Treatment and Medical Rehabilitation	65	50	200	215	190
City Archives of Tallinn			25	27	25
Tallinn Suburban Investigation Bureau				20	
Tallinn Botanical Garden	67	53	32		
Art Museum of Tartu		70	70		
VARIA					
Academic Baltic-German Cultural Society of Tartu	85				
Aptest Ltd	50				
JFE Ltd	50	70			
STINGER Ltd	48				
Publishing House Avita					12
Estonian Society of Archaeology		71			

Estonian Institute for Open Society Research					65
Estonian Institute of Humanities					20
Estonian Union of Art Critics		59		65	
Estonian Business School		90			
Estonian Farmers' Federation	25				
Estonian Institute for Future Studies		120	105	70	71
Estonian Maritime Administration		17	18	18	10
Estonian Enterprise Institute	25	30		33	
Individual applicants	222				
Restoration House "Kanut"					7
Cybernetica Ltd			145	238	301
A.S.A.P. MED.			60	70	
Institute for European Studies					45
Centre of Rural Development Ltd			37	55	
Tartu University Clinicum Foundation	50	48	118	70	83
Tartu Veterinary Laboratory		63	63		
Veterinary and Food Laboratory				65	60
Institute of Law	42	50		33	41
Tartu Society of Legal Psycho-logists and Sociologists Joint Venture ECORA		98			
TOTAL	58 500	68 580	72 866	76 650	71 100

Source: Estonian Science Foundation

Table A-2. Target financing by institutions, 1996-1999

INSTITUTION	1996+ extra money	1997	1998 (thousand kroons)	1999 (thousand kroons)	2000 (thousand kroons)
University of Tartu total	16 298	23 537	42 404	56 380	55 102
among this					
University of Tartu	16 298	23 537	32 204	42 590	41 461
TU Institute of Physics	5 291	5 432	6 700	9 310	9 476
TU Science Competence Centre			3 500	4 480	4 1650
Tallinn Technical University total	11 403	11032	29 250	36 270	34 933
among this					
Tallinn Technical University	11 403	11 032	13 750	17 675	117 513
TTU Science Competence Centre			3 500	3 315	2 461
TTU Institute of Chemistry	3 617	3 318	3 700	4 785	4 607
TTU Institute of Cybernetics	4 345	3 542	3 900	4 900	4 776
TTU Institute of Geology	3 106	2 572	3 300	4 345	4 491
TTU Estonian Institute of Economics	2 056	1 407	1 100	1 250	1 095
TTU Institute of Oil Shale	798	501			
Estonian Agricultural University total	8 639	10 048	17 236	21 650	20 062
among this					
Estonian Agricultural University	8 639	10 048	7 821	9 755	9 421
EAU Institute of Animal Science			2 890	3 600	2 774
EAU Institute of Zoology and Botany	3 303	3 154	3 975	5 135	4 838
EAU Institute of Experimental Biology	2 641	1 940	2 200	2 735	2 618
EAU Estonian Plant Biotechnical Research Centre EVIKA	416		350	425	411
Tallinn Pedagogical University total	1 989	1 845	5 044	6 495	6 034
among this					
Tallinn Pedagogical University	1 989	1 845	1 694	1 970	1 800
TPU Institute of International and Social Studies	1 131	909	1 550	1 895	1 519
TPU Institute of Ecology	1 931	1 930	1 800	2 325	2 306

TPU Estonian Interuniversity Population Research Centre				305	409
Estonian Academy of Music	72	91	200	500	500
Estonian Academy of Arts	100	122	250	355	359
National Institute of Chemical Physics and Biophysics	4 759	4 810	6 050	8 895	8 625
Under and Tuglas Literature Centre	617	465	550	770	795
Institute of the Estonian Language	2 674	2 415	2 900	3 915	2 494
Institute of History	2 211	1 712	2 000	2 560	2 531
Estonian Literary Museum	1 594	1 141	1 300	1 720	3 146
Estonian Biocentre	1 316	1 677	1 925	2 545	2 501
Tartu Observatory	3 414	3 027	3 800	5 210	5 132
Institute of Experimental and Clinical Medicine	3 236	2 399	3 161	4 325	4 228
Estonian Institute of Cardiology	951	775	900	1 300	1 330
Jõgeva Plant Breeding Institute	1 922	1 178	1 500	1 860	1 170
Estonian Research Inst. of Agriculture	1 943	1 324	1 300	1 585	1 427
Estonian Energy Research Institute	2 608	1 872	1 200	1 460	1 390
Estonian Marine Institute	3 024	2 150	2 950	3 605	3 391
Estonian Agrobiocentre	1 181				300
International Centre of Environmental Biology	304				
Institute for Islands Development	120				
Võru Institute	120				
Institute of Preventive Medicine	1 873				
Estonian Institute of Agricultural Engineering	416				
Estonian Inst. of Agrarian Economics	617				
Estonian Institute of Forest Research	1 753				
Total	103 791	96 325	123 920	161 400	156 000

Source: Science Competence Council and Estonian Science Foundation

Table A-3. Research and development in the EU candidate countries

Country	GDP per capita (euro)	Gross domestic expenditure on R&D (GERD)			
		financed by public sector, %	GERD/ GDP, %	GERD per capita, (euro)	GERD per degree holder, (euro)
Bulgaria	1350	80	0.87	11.7	5647
Cyprus	12120	-	0.26	26.5	30000
Czech Republic	4745	38	1.64	75.6	30840
Estonia	2850	70	0.60	16.7	9843
Hungary	4390	51	0.74	33.7	19985
Latvia	2330	55	0.45	10.4	4437
Lithuania	2230	72	0.57	12.7	8553
Poland	3550	58	0.75	26.6	23130
Romania	1650	45	0.58	8.5	6196
Slovakia	3100	32	1.06	33.0	16952
Slovenia	7830	48	1.44	112.5	53393
EUR15	19090	37	1.82	373.0	

Source: EC RDT Information No 22. Supplement 99

Table A-4. Financing of research and development in some OECD member states in 1997, and in Estonia in 1998

Country	Researchers per thousand labour force	Gross domestic expenditure on R&D - 1997				
		GERD/ GDP (%)	Financing		GERD per capita (PPP USD)	GERD per researcher (PPP USD)
			Share of public sector (%)	Share of business enterprise sector (%)		
Australia	6.6	1.70	46.0	47.5	368	111218
Austria	3.4	1.63	44.6	51.2	368	224241
Ireland	5.8	1.43	22.2	69.4	296	116875
Iceland	9.1	2.03	55.9	37.7	457	90527
Japan	9.2	2.91	18.1	74.0	715	146813
Canada	5.4	1.61	31.9	60.2	380	135810
Korea	4.7	2.89	22.9	74.0	419	193294
Portugal	2.7	0.65	68.2	21.2	95	70370
France	6.0	2.24	40.2	50.3	476	180108
Sweden	7.8	3.85	25.2	67.7	787	209610
Germany	5.9	2.32	35.6	61.7	511	178443
Finland	6.7	2.78	30.9	62.9	569	172871
United Kingdom	5.0	1.87	30.8	49.5	383	156910
USA	7.4	2.77	30.6	65.7	794	209151
OECD	5.1	2.21	31.3	62.4	453	187584
EUR15	5.0	1.82	37.2	53.9	373	162763
Czech Republic	2.5	1.28	36.8	60.2	155	114649
Hungary	2.6	0.68	56.2	36.1	72	69923
Estonia	4.3	0.63	62.5	23.2	32	15500

Source: OECD R&D indicators

Table A-5. Publications by scientific staff of public and state research institutions, 1996–1998**

Institution	Scientific articles in foreign journals of Citation Index			Scientific articles in other foreign journals			Theses of international conferences			Monographs, collections, brochures published abroad		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
University of Tartu	313	316	304	230	277	193	107	97	*	23	28	36
TU Institute of Physics	76	75	68	9	4	6	10	11	24	0	0	1
Tallinn Technical University	52	81	70	35	48	56	118	147	188	13	13	7
TTU Estonian Institute of Economics	3	5	4	9	28	2	5	2	8	5	4	0
TTU Institute of Geology	22	21	32	14	3	21	6	3	0	1	3	4
TTU Institute of Chemistry	23	29	34	2	0	1	4	6	3	0	0	0
TTU Institute of Cybernetics	23	9	14	3	0	4	15	14	33	0	1	0
TTU Institute of Oil Shale	3	4	5	1	0	1	0	0	0	0	0	0
Estonian Agricultural University	7	25	106	19	34	93	12	65	47	2	1	4
EAU Institute of Experimental Biology	11	5	2	3	7	6	1	4	0	0	0	0
EAU Institute of Zoology and Botany	30	21	57	9	10	14	13	5	0	2	2	2
Tallinn Pedagogical University	8	10	12	37	48	50	17	23	19	1	12	2
TPU Institute of International and Social Studies	3	2	1	18	26	13	6	0	4	1	6	1
TPU Institute of Ecology	7	19	27	0	11	7	0	6	3	0	0	1
Estonian Academy of Art	0	0	*	2	3	*	2	2	*	0	0	*
Estonian Academy of Music	0	0	*	4	5	*	1	0	*	0	0	*
National Institute of Chemical Physics and Biophysics	79	70	61	4	0	2	3	0	4	0	1	0
Under and Tuglas Literature Centre	1	0	7	0	5	4	0	0	0	0	0	0
Institute of History	24	0	0	9	17	20	2	1	0	0	2	2
Estonian Biocentre	20	*	*	1	*	*	0	*	*	0	*	*
Institute of the Estonian Language	1	0	21	5	8	14	29	4	0	1	2	1
Estonian Literary Museum	0	1	2	4	7	5	9	2	2	0	0	2
Tartu Observatory	22	32	46	10	4	0	7	7	0	0	0	0
Estonian Marine Institute	4	13	7	1	1	6	9	14	2	0	1	2
Estonian Energy Research Institute	1	7	2	6	3	6	12	15	11	0	0	0
Estonian Institute of Cardiology	5	6	8	7	3	3	0	8	7	2	0	0
Institute of Experimental and Clinical Medicine	17	16	13	7	3	2	0	5	0	0	1	4
Estonian Research Institute of Agriculture	1	2	0	3	1	3	4	5	1	0	1	0
Estonian Institute of Agricultural Engineering	0	0	0	2	*	2	2	4	*	0	*	0
Jõgeva Plant Breeding Institute	0	0	*	1	4	*	2	1	*	0	0	*

* * according to data given to the Estonian Science Foundation   * data not available

Table A-6. Articles by Estonian institutions published in journals belonging to the Citation Index database of social sciences, humanities and natural sciences, 1996–1999

Institution	SCI, SSC, AHC 1996	SCI, SSC, AHC 1997	SCI, SSC, AHC 1998	SCI, SSC, AHC 1999	Total 1996–1999
University of Tartu	193	225	290	281	989
TU Institute of Physics	68	70	66	59	263
National Institute of Chemical Physics and Biophysics	41	37	41	26	145
Tallinn Technical University	20	22	27	54	123
EAU Institute of Zoology and Botany	7	27	15	27	76
Estonian Agricultural University	3	11	15	23	52
Tartu Observatory	21	15	18	15	69
Institute of Experimental and Clinical Medicine	8	14	12	20	54
TTU Institute of Chemistry	12	14	16	15	57
EAU Institute of Ecology	4	8	15	15	42
Estonian Biocentre	5	6	11	15	37
TTU Institute of Geology	8	11	2	11	32
Estonian Marine Institute	2	7	6	7	22
Tallinn Pedagogical University	0	1	8	10	19
TTU Institute of Cybernetics	14	6	2	3	25
Estonian-Swedish Institute of Suicidology			12		12
EAU Institute of Experimental Biology	2	2	1	3	8
Mustamäe Hospital		1	2	3	6
Oncology Centre	1	1	1	3	6
Tallinn Children's Hospital	2	1	2	2	7
Institute of Cardiology	0	2	1	2	5
Tallinn Central Hospital		1	2	1	4
Estonian Energy Research Institute	1	1	1	1	4
Centre of Marine Education	1		1	2	4
Estonian Meteorological and Hydrological Institute	2	2		1	5
Tondi Electronics Ltd			1	2	3
Estonian Research Institute of Agriculture	2	2			4
Geological Survey of Estonia			1	1	2
Information Centre at the Ministry of Environment	1	1		1	3
Pelgulinn Maternity Hospital		1	1		2
Institute of Preventive Medicine		2			2
Ministry of Social Affairs				2	2
Tallin Comput&Inform Institute		2			2
AMP Eesti			1		1
Union of Arteriosclerosis				1	1
Asper Ltd				1	1
Bional		1			1
Centre for Diagnostics		1			1
Bank of Estonia				1	1
Estonian Oil Shale Ltd				1	1
Estonian-American Business College			1		1
Elcoteq		1			1

Emors Ltd			1		1
Garon Ltd	1		1		2
HTI-LAB			1		1
Radiation Protection Centre				1	1
Kohtla-Järve Hospital				1	1
Kuressaare Hospital				1	1
Seamen’s Hospital				1	1
Nigula Nature Reserve				1	1
Family Health Centre		1			1
TTU Institute of Oil Shale	2			1	3
Rakvere Hospital	1	1			2
State Agency of Medicines			1		1
Plant Protection Institute				1	1
Tallinn Botanical Garden			1		1
Tallinn Dental Clinic		1			1
Tallinn Zoo			1		1
Tallinn Waterworks			1		1
Tartu Flora Ltd			1		1
Tartu National Hospital		1			1
Tartu Centre of Ecology		1			1
Transplantaat			1		1
Vastseliina Hospital			1		1
Maritime Administration				1	1
Blood Centre				1	1
Viljandi Hospital		1			1
Viljandi Polyclinic		1			1
LEX	4				4
Institute of Forest	1				1
Heart Centre	2				2
Edk-Ltd					0
Eltex	1				1
Tallinn Dental Polyclinic	1				1
Tartu Oncology Clinic	1				1
Veterinary Laboratory	1				1
Finnish Institute in Estonia		1			1
Institute of International and Social Studies	2	3			5
Literary Museum	1	1			2
Institute of History		1		1	2
Institute of Humanities		2		1	3
Private person 34, Gonsiori Ots, L			1		1
Concordia International University Estonia		1			1
EKE ARIKO Consult Ltd				1	1
Institute of Experimental and Clinical Medicine	1			1	2
Magdaleena Hospital				1	1
Pirita-Kose Children’s Sanatorium	1				1
Academy of Sciences (Merry Bullock)	1		2		3
Total	439	512	585	623	2159

Table A-7. Articles written in joint authorship with Estonian scientists, 1996–1999 (according to SCI, SSCI, A&HCI)

Country	SCI	SSCI	AHCI	Total
Sweden	244	9	0	253
Finland	247	6	0	253
Germany	180	2	0	182
USA	147	16	0	163
Russia	92	1	0	93
France	84	2	0	86
United Kingdom	72	6	1	79
Italy	46	3	1	49
Denmark	48	0	0	48
Netherlands	38	3	2	43
Spain	37	1	0	38
Canada	32	4	0	36
Norway	32	2	0	34
Latvia	24	0	0	24
Poland	21	0	0	21
Switzerland	18	2	0	20
Japan	17	1	0	18
Czech Republic	16	1	0	17
Mexico	17	0	0	17
Hungary	14	2	0	16
Australia	15	1	0	16
Lithuania	14	1	0	15
Belgium	11	1	1	13
Israel	11	1	0	12
Ukraine	11	0	0	11
Slovenia	7	1	0	8
Ireland	6	1	0	7
Bulgaria	7	0	0	7
Greece	5	0	0	5
Belarus	5	0	0	5
Slovakia	4	0	0	4
Argentina	4	0	0	4
Austria	2	1	0	3
China	3	0	0	3
India	2	0	0	2
Portugal	1	0	0	1
Brasilia	0	1	0	1
Turkey	0	1	0	1
Total	1534	70	5	1608

Source: Citation Indexes, Institute for Scientific Information

Table A-8. The number of scientific publications in the OECD countries in 1997, and in Estonia in 1999

Country	Per 10,000 inhabi-tants	Country	Per R&D expendi-ture (USD million)	Country	Per scientist and engineer
Switzerland	19.3	Hungary	107.2	Switzerland	0.58
Sweden	16.7	Switzerland	105.0	New Zealand	0.48
Denmark	14.1	New Zealand	97.6	Greece	0.48
Finland	13.6	Greece	96.0	Austria	0.48
Netherlands	11.7	Ireland	93.0	Netherlands	0.48
UK	11.7	UK	91.5	UK	0.44
New Zealand	11.5	Belgium	91.5	Canada	0.41
Australia	11.4	Sweden	84.4	Belgium	0.39
Canada	11.1	Canada	82.6	Denmark	0.39
Norway	11.0	Denmark	78.9	Sweden	0.37
Iceland	10.7	Spain	77.4	Italy	0.36
Belgium	9.7	Finland	76.3	Spain	0.34
USA	9.5	Czech Rep.	68.1	Australia	0.32
Austria	8.3	Austria	67.2	Finland	0.30
France	8.1	Poland	63.6	France	0.29
Germany	7.8	Australia	62.4	Ireland	0.28
Ireland	7.0	Netherlands	57.6	Czech Rep.	0.28
Japan	5.5	Norway	56.9	Norway	0.26
Spain	5.3	USA	52.8	USA	0.26
Italy	5.1	Italy	48.2	Germany	0.25
Estonia	4.3	Germany	46.8	Estonia	0.20
Greece	4.1	Portugal	46.5	Mexico	0.19
Czech Rep.	3.8	France	45.8	Hungary	0.18
Hungary	3.7	Iceland	45.5	Iceland	0.18
Portugal	2.9	Turkey	37.5	Turkey	0.18
Korea	2.4	Japan	33.0	Portugal	0.15
Poland	2.2	Mexico	30.2	Poland	0.12
Turkey	0.7	Korea	21.8	Japan	0.10
Mexico	0.5	Estonia	13.1	Korea	0.08
				OECD average	0.25

Source: ISI Citation Index. OECD R&D indicators

Table A-9. Estonian participation in the programmes of the Fourth EU Framework Programme, 1995–1999

Programm	Number of Estonian institutions in applications	Number of Estonian institutions in accepted applications	Support by EU, million kroons
INCO COPERNICUS International RTD Cooperation. Specific actions for CEC/NIS Countries	187	48	37.2
Telematics	27	4	1.7
Communication and technologies	1		
Information and technologies	5	1	1.0
Industrial materials, measurements and testing	1		
Environment and climate	17	3	1.2
Marine science and technology	8	8	6.5
Biotechnology	9	3	5.9
Biomedicine and health	20	8	2.0
Agriculture and fisheries	17	7	data missing
Non-nuclear energy (Joule)	2	1	0.2
Non-nuclear energy (Thermie)	4		3.7
Transport	3	3	1.6
Targeted socio-economic research	9		
Dissemination and optimization of results			
Training and mobility of researchers	6		
All programmes (incl. INCO COPERNICUS)	316	86	60.8

Source: European Commission

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* *Only those R&D-active institutions, organisations and companies which had their (English) web-page available at the time of publishing this book, were included.*

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Laser Diagnostic Instruments	*113a Kadaka Rd., 12915 Tallinn ESTONIA* *http://www.esman.ee/ldi.tallinn/* *Fax: (372) 650 7305* *Phone: (372) 656 7337* *E-mail: ldi@esman.ee*
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