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EVALUATION OF ESTONIAN INNOVATION SYSTEM

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ABSTRACT: In this report the Estonian national innovation system (NIS) and especially the effectiveness of technology policy and the functioning of policy organisations is evaluated. The national innovation system is a set of institutions, which jointly and individually contribute to the development and diffusion of new technologies and provide the framework for the technology policy of a nation.

Estonian research and technology development (RTD) investments are very low in international comparison. RTD expenditure is only 0.5 percent of GDP. This is one quarter of that of the European Union and OECD countries. In particular, there is a lack of private technology development investments. Primary focus of the public investment is on basic research and on those fields of science that are not connected to industries. Anyhow Estonia has managed to attract a remarkable amount of foreign direct investment (FDI) per capita. FDIs have been important channels for technology transfer.

The evaluator agrees with the National Development Plan, suggesting that RTD intensity has to rise to 1.2 per cent of GDP in the year 2002. This means around EEK 1 bill, mostly financed by state. Later RTD financing should rise to 2.2 per cent of GDP (average intensity in the OECD and EU countries in 1995) until the year 2010, with increasing private financing.

The status of technology policy has to be raised, because technology development is the key factor for growth in the Estonian economy in the future. The evaluator suggests that parliament has to approve a master plan for developing and utilising new technology in Estonia. The Evaluator also proposes that a new Technology Agency with sufficient personnel, good premises and a developed network should replace the Innovation Foundation.

KEYWORDS: Estonia, Innovation system, Technology policy, Evaluation

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TIIVISTELMÄ: Raportissa arvioidaan Viron kansallisen innovaatiojärjestelmä, erityisesti teknologiapolitiikan tehokkuus ja politiikkaorganisaatioiden toiminta. Kansallinen innovaatiojärjestelmä on joukko instituutioita, jotka yhdessä ja erikseen edistävät uusien teknologioiden kehittämistä ja käyttöönottoa ja jotka tarjoavat kehyksen kansalliselle teknologiapolitiikalle.

Viron investoinnit teknologian kehittämiseen ja siihen liittyvään tutkimukseen ovat kansainvälisessä vertailussa vähäiset, vain 0,5 prosenttia BKT:sta eli neljännes sitä mitä ne ovat EU- ja OECD-maissa keskimäärin. Erityisesti yksityiset eivät investoi tuotekehitykseen ja tutkimukseen. Julkiset investoinnit suuntautuvat tutkimukseen sellaisille aloille, joilla ei ole paljonkaan yhteyksiä yrityksiin. Viro on kuitenkin onnistunut houkuttelemaan paljon ulkomaisia suoria investointeja (mitattuna per capita), jotka ovat olleet merkittävä teknologiasiirron kanava.

Evaluaattori yhtyy Kansalliseen kehityssuunnitelman tavoitteeseen, jonka mukaan tutkimus- ja tuotekehitysmenojen osuus pitäisi nostaa 1,2 prosenttiin BKT:sta vuonna 2002. Tämä merkitsisi noin 1 miljardia Viron kruunua, joka olisi aluksi pääosin julkista rahaa. Jatkossa, vuoteen 2010 mennessä, T&K menojen osuus pitäisi nousta edelleen 2,2 prosenttiin BKT:sta, mikä vastaisi OECD:n ja EU:n kehitystasoa vuonna 1995. Samalla yksityisten investointien osuus tulisi voimakkaasti kasvaa.

Teknologiapolitiikan merkitystä pitäisi Virossa korostaa, koska se on maan tulevan talouskasvun yksi tärkeimmistä lähteistä. Parlamentin tulisi käsitellä ja hyväksyä ohjelma (master plan) uuden teknologian kehittämisen ja käyttöön oton edistämiseksi. Evaluaattori ehdottaa myös, että uusi Technology Agency, jolla olisi riittävä henkilöstö ja muut resurssit sekä kehittyneet verkostot, korvaisi nykyisen Innovation Foundationin.

AVAINSANAT: Viro, Innovaatiojärjestelmä, Teknologiapolitiikka, Evaluointi

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Executive summary

In this paper, we evaluate the Estonian national innovation system (NIS) and especially the effectiveness of technology policy and the functioning of policy organisations. The national innovation system is a set of institutions, which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework for the technology policy of a nation.

The Estonian national innovation system consists of

- *Policy decision makers including advisors:* Parliament, Cabinet and Research and Development Council
- *Policy preparation and managing organisations:* The Ministry of Economic Affairs and the Ministry of Education and its expert bodies, the Academy of Sciences and the Science Competence Council as well as the Ministry of Finance as the fiscal authority, and in some degree other ministries
- *Policy financing and other supporting and bridging organisations:*

  The organisations that are responsible for competitive financing are the Estonian Innovation Foundation and the Estonian Science Foundation. The financing of science and higher education is channelled through the Ministry of Education.

  Other supporting and bridging institutes are science/technology parks, innovation centres and competence centres.
- *Target organisations:* Firms and other private and public research and development units. They are the "customers" of the system. Public research institutes and research units of universities can be regarded as the support units of firms.

Research and technology development is one of the key factors boosting economic growth. That is why a solid functioning of the national innovation system is very important.

Estonian technology investments and development

Estonian research and technology development (RTD) investments are very low in international comparison. RTD expenditure is only 0.5 percent of GDP. This is one quarter of that of the European Union and OECD countries. In particular, there is a lack of private technology development investments. Companies do not invest their money to develop new products or production technology. Public investment is also low, with a primary focus on basic research and on those fields of science that are not connected to industries.

As a result of low investment and the biased public focus, companies generally mention that they do not develop new products or production technologies. Another manifestation of this is very low domestic patenting activity. The number of domestic patent applications is very low in both absolute and relative terms compared to other countries.

However, there are also positive developments. Estonia has managed to attract a remarkable amount of foreign direct investment (FDI) per capita; only Hungary has been more successful among Central Eastern European and former Soviet Countries. FDIs have been important technology transfer channels. Productivity has increased by around 10 % per

year, which is four times higher than the average productivity increase in the OECD countries. It means that firms have managed to organise production better and increase their capacity utilisation in response to new markets opening and, thirdly, they also have invested in and introduced new machinery and other production technologies.

But in the long run, positive developments due to a favourable business environment (low costs, fair competition, a well-functioning society and proximity to CIS markets) are not enough. Estonia has to increase public and private investments in business-oriented research and technology development. At the same time, reshaping and improving the organisations of the national innovation system is needed.

The biggest problems of the Estonian national innovation system and suggestions for improvement

A crucial problem is low RTD financing. Despite its low level, it was even cut when balancing the budget in 1999. The evaluator agrees with the National Development Plan, which suggest that RTD intensity has to rise to 1.2 per cent of GDP in the year 2002. This means around EEK 1 billion for RTD and that the state's share is EEK 800 billion. Later RTD financing should rise to 2.2 per cent of GDP until the year 2010. This was the average intensity in the OECD and EU countries in 1995.

RTD investments and the needs of the national innovation system are not highly ranked among political decision-makers. This is partly because of poor policy preparation and insufficient information. The status of technology policy has to be raised, because technology development is the key factor for growth in the Estonian economy in the future. The evaluator suggests that parliament has to approve a master plan for developing and utilising new technology in Estonia. The government and its advisor, the Research and Development Council, are responsible for preparing the programme. The master plan for technology development defines national targets and their priorities and also gives a long-term financial scheme to implement needed technology policy.

The third problem is the poor functioning of central organisations of the national innovation system:

- The Research and Development Council suffers from poor background work. The Council is concentrated on science issues and neglects technology development. Policy preparing ministries do not get enough information about meetings. Politicians do not get valuable material from the Council and that is why the decisions of the RDC are not followed. We propose that the another of two vice presidents of the council come from industry, and that preparatory work is done in two chambers, one for technology development and one for science. We also propose that the Council denominate a secretary also for technology development, who works in the Ministry of Economy in order to get preparatory help and finally that key officials from the Ministry of Economy and Ministry of Education have the right to be present in the meetings. These would improve background work and enhance the weight of technology issues and the effectiveness of management due to an improved information flow.
- Planning and management of technology policy us under the responsibility of the Ministry of Economy. Its technology and innovation division needs more personnel and authorities in order to handle all the necessary management tasks. An important tool and partner of the minister should be the Innovation Foundation, but it is a private entity in law. An important area of work is international technology policy co-operation. The ministry should bear responsibility, for example, for policy issues connected to the EU’s 5th framework programme. The ministry should prepare strate-

gic targets for its technology policy management and criteria for assessing achievements.

- The Innovation Foundation is not functioning well enough. It does not have enough funding taking into account its tasks. As a private foundation, it is closed and not very co-operative. Also, its personnel resources, premises and networks are too modest to fulfil the needs of a modern technology agency. We propose that a new Technology Agency, one that is a public entity under the Ministry of Economy, with sufficient personnel, good premises and a developed network replace the Innovation Foundation. We also propose that the new technology agency be organised during the year 2000 and that necessary financing is obtained beginning from the 2001 and 2002 budgets, wherein RTD funding will be raised remarkably. The new technology agency will also take care of seed financing for start-up high-tech companies, provide support for patenting and related costs, and supply information about high-tech companies and projects to venture capital firms.
- Estonian technology supporting and bridging organisations are in an infant stage for many reasons. They have to incubate new high-tech companies from scratch. There are too few experts for providing the necessary supporting services. The organisations do not have solid financial backgrounds. Personnel costs are covered often only on project bases. Uncertainty hinders engaging new experts. The state, communities and universities should, together, define the necessary supporting and bridging institutions and their tasks. Then, the government and relevant partners should organise financing to cover the most important costs of the organisations. The restructuring of old holdings should solved separately.
- Resources tied to state research institutes are a sizeable, but very difficult to utilise, potential for Estonia. There is reason to conduct a good evaluation about the strengths of institutes and their optimal placement in the Estonian innovation system. Probably no simple solutions exist, but, rather, there will be different solutions depending on the institution. Some institutions could still be part of universities, if they mainly conduct basic research, or work under the ministries, if they have a clear social mission. Some could be private units or even companies, or their personnel could become part of firms' R&D departments. Some could form a new state technical research centre that sells partly subsidised R&D services to companies.

Many proposed improvements, increased tasks and effective use of financing demand a lot of newly educated labour. The education program should start immediately, along with co-operation with policy officials, main universities and the European Union.

Estonia is going to join the European Union along with two other Baltic states. They all have similarities with respect to their competitive edge. In this situation, it is their own policy measures, which can make them different and more competitive than the others. One measure, which is highly respected within the member states of the European Union, is investment in research and technological development. It could even be possible to get essential extra financing for this purpose to offset the possible negative impact of membership and to improve the competitiveness of Estonian industries for new common markets. This is a very well justified target for membership negotiation.

1. Introduction

Background

Rapid changes in economic developments in the 1990s have led to a transformation in industrial policy thinking in Estonia. Rather than talking about traditional industrial policy implemented through interventions in the product market and the direct subsidising and protection of individual sectors, today Estonia is moving towards competitiveness policy, which is rather focused on the creation of favourable conditions in the factor market. By supporting framework conditions and advanced factors of production (i.e. R&D, innovation, education and technical infrastructure) the aim will be to create comparative advantages for the development of a competitive industry sector.

So far, the support structures for innovation that the competitiveness of industry could benefit from have not been systematically developed. Technology transfer and development activities are not systematically supported, and the related entities have been founded at different times and for different motives. Due to the scope of activities, today's appropriate institutions should be divided into two specific groups:

- institutions providing financial support (foundations)
- institutions offering specific support services (science/technology parks, innovation centres).

In spite of the existence of the development plan in this field (Estonian National Innovation Programme 1998-2003 was approved by the Government in 09.06.98), several factors have impeded the implementation of this plan. Lack of transparency and an unclear division of responsibilities between relevant stakeholders, and insufficient experience in strategic policy planning and implementation in appropriate fields should be outlined as the main obstacles emerging in this process.

Objectives and deliverables of the study

Subtasks

The objective of the evaluation is to improve the efficiency of the Estonian innovation system to respond to the development needs of the economy. The Term of Reference of the Assignments[1] include the following subtasks:

- Assess the current state of the Estonian innovation system (incl. SWOT analysis)
- Map the existing support structures and identify their role and effectiveness

[1] During the project, additional subtasks were identified. So there are two terms of Reference of Assignment concerning this project. This is the final report for both because additional subtasks and deliverables were supplementary to the original one and they together form an entity.

- Evaluate the process of policy planning and delivery (incl. policy elaboration, programming, financing, implementation, distribution of responsibilities, monitoring and evaluation)
- Evaluate the operational principles and administrative capacity of the Estonian Innovation Foundation
- Define strategic tasks for the Technology and Innovation Division of the Ministry of Economy for managing the innovation system
- Identify the Estonian country-specific innovation pattern
- Determine the real customer needs of key industries

Deliverables

The requested deliverables of the evolutiont are the following:

- SWOT analysis of the Estonian innovation system submitted
- Charted innovation support structures with recommendations for further improvement of the optimal innovation support system submitted
- Analyses of the present Estonian National Innovation Programme (structure, content, transparency, sufficiency, applicability) and recommendations thereof submitted
- Analyses of the Estonian Innovation Foundation and recommendations thereof submitted
- Suggestions of criteria for the evaluation of the policy delivery system submitted
- Analyses of conformity of financing needs and possible resources
- Revised list of strategic tasks for the Technology and Innovation Division of the Ministry of Economic Affairs for managing the innovation system.
- Description of the Estonian country-specific innovation pattern: scientific specialisation, technological specialisation, export specialisation, pattern of productivity growth based on available statistics
- Summary of the customer needs based on interviews of the leading firms of key industries and industry associations.

Definitions

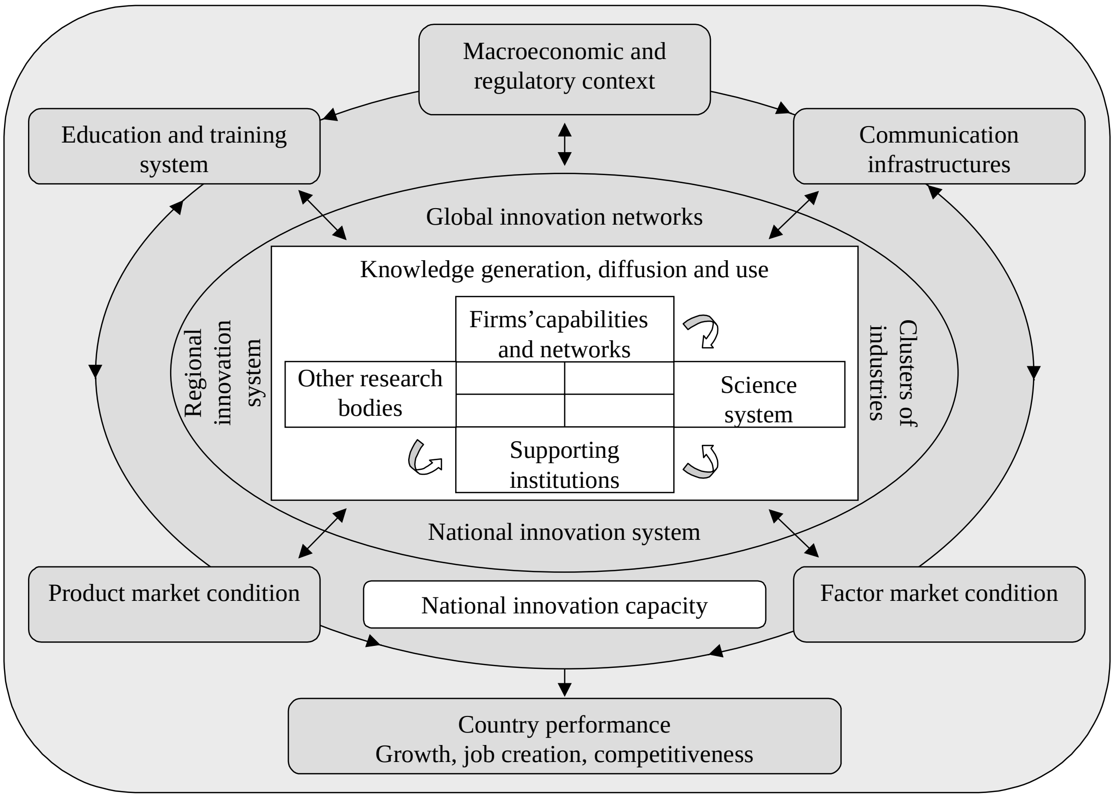
Later we use several key concepts rather often. Here are the definitions of those most often used as well as their abbreviations:

NIS, National Innovations System

National innovation system is defined as the set of distinct institutions, which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts, which define new technologies.

From this perspective, the innovative performance of an economy depends not only on how the individual institutions (e.g. firms, research institutes, universities) perform in isolation, but on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks).

Figure 1.1: Actors and linkages in the innovation system



Source: OECD: Managing National Innovation Systems

RTD, Research and Technological Development

Research and Technological Development includes basic, applied and experimental research as well as development and diffusion of new technology. New technology covers new products and improvements of old products as well as new production technologies (machinery, methods and processes) and improvements to existing ones. Diffusion of technology is the introduction of new technology.

R&D, Research and Development

Research and development is a more widely used concept than RTD. Research is used to define that part of scientific research, which makes the necessary ground for technology or other developments and improvements in firms or directly serves it. An important part of R&D is becoming acquainted with the results of research work and their active use for development in firms. Development can be defined as a group of activities aiming to increase absolute or relative (compared to the costs) value added of the company. Activities can include technological development but also other activities such as better organisation of production, marketing research and creating brands etc.

Diffusion of technology

Diffusion of technology is the introduction of new technology. Technology transfer channels are the use of others' inventions, contracting out of R&D, use of consultancy services, purchase of other enterprises, purchase of equipment, communication to other enterprises and hiring of skilled personnel.

Often used abbreviations

RDC = Research and Development Council Of Estonia

MoE = Ministry of Economic Affairs

IF = Estonian Innovation Foundation

SF = Estonian Science Foundation

FDI = Foreign Direct Investments

CIS = Commonwealth of Independent State

GDP = Gross Domestic Product

Content of the study

The study begins with an executive summary, presenting the most important conclusions of the evaluation and the main propositions provided on how to improve the functioning of the Estonian innovation system.

The Introduction presents a list of evaluation tasks and deliverables. They are based on the terms of assignment of the project. Chapter 2 examines the innovation pattern of Estonia. In this chapter we look at the inputs of the innovation system, such as R&D investments and human capital resources. We also examine the output of the innovation system: export success, productivity growth and patenting results.

In Chapter 3 we map the Estonian innovation system, i.e. what kind of actors there are. Chapters 4, 5 and 6 are the evaluation chapters. Chapter 4 contains the SWOT analyses of the national innovation system, an evaluation of the National Innovation Programme, which is the basis for Estonian technology and innovation policy, and an evaluation of the policy chain. The latter is based on the questionnaire that was conducted during the evaluation of the project. Chapter 5 concentrates in more detail on the Estonian Innovation Foundation, which has an important role in RTD funding and because there is considerable pressure to reshape it totally.

In Chapter 6 we place a great deal of emphasis on Estonian RTD financing, because its low level is the main hindrance to improving the effectiveness and results of the Estonian innovation system. The chapter also contains a suggestion for further RTD funding. In chapter 7 we present a detailed recommendation for how to improve the functioning and co-operation of different technology policy actors.

In many places an evaluation report might be very critical. The purpose is not to blame persons working in the national innovation system. They are doing valuable work with very limited resources. A lot of knowledge has accumulated, and there are many ideas on how to improve the system. This is a potential for the future. With larger investments increasing returns are garnered.

2. Estonian innovation pattern

There is no clear picture about the innovation pattern of Estonia. One of the biggest weaknesses of the Estonian innovation system is the lack of information concerning the real customer needs of firms - potential needs and realised needs. What is relatively more known is the supply side of research and development work when it concerns the public side of activities - the universities and research institutes. So far, comprehensive statistics on R&D activities of firms have not been compiled. The first comprehensive statistics will become available in the year 2000. Currently available statistics cover only those firms whose main line of business is R&D activities.

Indicators of innovation pattern

What is the innovation pattern of a country? Several elements describe the innovation pattern. Here we examine the input and output side of research and technological development activities:

Inputs:

- The normal input measure is R&D investment, covering public and private financing and expenditure in these sectors. Financing can be used for basic and applied research and direct product and process development. It is reasonable to also divide R&D investments according to lines of business or industry, when the investment in question is that of firms.
- Human capital investments in R&D can also be estimated by the number of students and graduates in different fields of science, researchers, and engineers engaged in R&D activities per worker (for example, researchers per 10,000 workers) and according to their corresponding number in different lines of business.
- In the case of small countries, technology transfer is the most important component in technology development. With regard to transforming economies, it is normally realised that technology transfer is connected to FDI. The total amount of FDI as well as its composition is an important input indicator of technology development.

Outputs:

- Revealed comparative advantage gives one starting point to assess the output of R&D investments. It can be measured, for instance, by success in export markets. A given country is more advanced than others in products where it has a relatively high market share. Sustainable competitiveness inevitably requires investments in R&D. An alternative approach is to look at the share of high-tech products in exports or how specialised the country is in industries ranked as high-tech industries.
- Productivity development is a widely used output measure of technological development. It is connected with production technology and process improvements.
- Patenting activity and its specialisation describes the results of scientific work and innovations in development work. The number of applications and accepted patents, trademarks and industrial designs as such gives an idea of the meaningfulness of R&D in a given country. The number of domestic applications compared to foreign applications gives information about the importance of domestic innovation activities. Finally, the distribution of applications according to content provides a picture of how

important R&D is for each sector or industry in the economy. The next step is to calculate the number of registered patents, trademarks etc, which are commercially beneficial. Finally, those patents, which are actually used in production, are the most valuable.

- Another rather similar kind of output is the number of articles published in respected journals and references to articles or books in those journals, although they are not so closely related to product and process development.

In the following text we present some features of the Estonian innovation pattern. This can, nevertheless, represent only the starting point. A more profound analysis is definitely needed, before setting the priorities for R&D investments as well as the indicators for evaluating the effectiveness of the investments.

Estonian innovation system inputs

R&D investment

Estonian inputs to RTD amounted to EEK 376 million in 1998. This sum is a little over 0.5 per cent of GDP. R&D intensity is a fourth of the average in the OECD countries and in the EU countries. An essential feature of recent financing is that the government's share is around 75 per cent of total financing. Even though government spending is low, it is private investment that obviously lags the most. On the other hand, we don't actually know the level of total private investment due to the lack of comprehensive statistics. So far, available statistics cover only those firms whose main line of business is R&D activities. Due to this lack of statistics, we cannot say anything about R&D intensity in different industries.

The Estonian RTD is still very much oriented to basic and applied research, which do not have very many links to the product and process development of industries. Nevertheless, the share of experimental development is displaying trend growth. RTD financing is reported in Table 2.1. In Chapter 6 we present international comparisons of the level of R&D financing as well as suggestions of the necessary level of Estonian RTD financing.

Table 2.1: R&D expenditures by kind of R&D activity, 1992–1998, thousand EKK

	Total expenditures	*Basic Research*	%	*Applied Research*	%	*Experimental Development*	%
1992	100 122	79 508	79.4	18 796	18.8	1 818	1.8
1993	130 155	80 343	61.7	38 705	29.8	11 107	8.5
1994	216 460	121 281	56.0	78 917	36.5	16 262	7.5
1995	250 604	132 014	52.7	89 042	35.5	29 548	11.8
1996	299 656	168 553	56.3	90 556	30.2	40 547	13.5
1997	379 741	188 144	49.5	141 272	37.2	50 325	13.3
1998	375 734	180 398	48.0	147 463	39.2	47 873	12.8
1999							

Source: Statistical Office of Estonia: Teadus, Science 1998

Human capital

There are approximately 4,000 scientists and engineers employed in research and development in Estonia. This level is rather high by international comparison. In Table 2.3 OECD countries and Estonia are sorted according to the number of researchers per 10,000 workers. Estonia is in the middle group just before the last Nordic country, Denmark, and ahead of Canada. If we change the Estonian figure to account for full-time researchers, the corresponding ranking falls but still remains in the middle group. Around 2,500 scientists and engineers work in universities, wherein they also conduct other activities, which explains why the number of full-time researchers is so much lower than the total number of researchers. The full-time equivalent of scientists has decreased steadily, falling to 2,750 in 1998.

Table 2.2: Distribution of scientists and engineers by field of science, 1960–1998

	Number of scientists and engineers										
	1960	**1970**	**1980**	**1990**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Natural sciences	402	1 144	1 466	...	1 533	1 451	1 535	1 335	1 339	1 266	1 203
Engineering	593	1 103	1 644	...	801	950	863	864	897	916	756
Medical sciences	204	315	470	...	535	517	545	550	519	513	445
Agricultural sciences	189	331	392	...	565	395	462	417	292	319	322
Social sciences	341	840	1 217	...	773	741	718	658	655	640	656
Humanities	480	949	897	...	827	942	956	679	706	673	675
Other sciences	18	25	159	...	70	..	..	..	..	..	..
TOTAL	**2 227**	**4 707**	**6 245**	**7 150**	**5 104**	**4 996**	**5 079**	**4 503**	**4 408**	**4 327**	**4 057**
Full time equivalence						***3 182***	***3 244***	***3 109***	***3 047***	***3 004***	***2 754***

Source: Statistical Office of Estonia: Teadus, Science 1998

Table 2.3: Researchers per 10,000 workers in OECD countries and Estonia

Highest		***Middle***		***Lowest***	
Japan	83	Denmark	57	Austria	34
United States	74	**Estonia I**	**57**	Italy	33
Norway	73	Canada	53	Spain	30
Iceland	72	Belgium	53	Poland	29
Sweden	68	United Kingdom	52	Hungary	26
Australia	64	Korea	48	Portugal	24
Finland	61	Switzerland	46	Czech Republic	23
France	60	Netherlands	46	Greece	20
Ireland	59	**Estonia II**	**39**	Turkey	7
Germany	58	New Zealand	35	Mexico	6

Note: Estonia I was calculated by using the total number of Estonian scientists and engineers. Estonia II was calculated by using the full-time equivalent. Data from the year 1995, Estonian data from the year 1998.
Source: Statistical Office of Estonia: Teadus, Science 1998

Going beyond the figures, we could claim that the portfolio content of the researcher staff is not that what is needed in order to develop Estonian firms, their productivity and new products for them. There are too few researchers with engineering and computer science backgrounds. Natural scientists are oriented towards basic research. Agricultural scientists are oriented more towards phenomena related to nature and towards farming, and not at all towards developing technology and products for foodstuff or wood industries.

We can get a wider picture of the new human skills available to satisfy the needs of the innovation system from statistics covering higher education (see Table 2.4). The modest number of PhDs in technical and social sciences received criticism in the Estonian national innovation program. The compilers of the programme estimated that Estonia should prepare 150-160 new PhDs per year in order to develop industry. Then, the number would be proportionally in line with that of the U.S. and Sweden. Currently, 10-15 new PhDs graduate each year in technical sciences and technology.

Table 2.4: The number of students in master's and doctoral courses

	Master's courses			**Doctoral courses**		
	Enrol-ment	Admit-tance	Gradu-ates	Enrol-ment	Admit-tance	Gradu-ates
Teacher training	294	198	65	15	6	-
Fine and applied arts	173	34	18	8	3	1
Humanities	291	59	44	99	32	4
Religion and theology	39	16	5	11	3	-
Social and behavioural science	259	114	29	59	18	1
Commercial and business administration	622	266	59	34	11	-
Law and jurisprudence	50	13	2	12	5	-
Natural science	204	66	62	208	43	17
Mathematics and computer science	80	28	14	43	13	-
Medicine and public health	208	166	204	403	145	73
Engineering	317	80	44	110	23	4
Architecture and town-planning	24	5	4			
Agriculture, forestry and fishery	146	53	25	41	15	6
Domestic science	6	-	-			
Mass communication and documentation	42	9	2	12	2	-
Other	67	28	9	16	5	-
TOTAL	**2 822**	**1 135**	**586**	**1 071**	**324**	**106**

Note: enrolment and admittance — 1998/99, graduates — 1997/98
Source: Statistical Office of Estonia: Teadus, Science 1998

Foreign Direct Investment

Estonia has been very successful at attracting foreign direct investments. Table 2.5 shows levels of net foreign direct investments. Cumulative FDI inflows cover the years 1989 - 1998. Despite the fact that Estonia regained its independence only in 1992, FDI per capita amounts to USD 950, which is the third highest among Central Eastern European and former Soviet countries.

Knowing the low R&D intensity of Estonia and its focus on basic research, there is full reason to argue that FDI and technology transfer through it has been the most remarkable source of technology development during the last decade. Good examples, which became familiar during the evaluation process, are Elcoteq, providing electronic manufacturing services, and the Imavere sawmill, with its most modern imported production technology. There are several other examples. In the record year of 1998, direct foreign investment was 10 per cent of GDP and nearly 20 times bigger than Estonian investments in RTD.

Table 2.5: Foreign Direct Investment, millions of USD

	FDI net inflows recorded in the balance of payments				**Cumulative FDI inflows**		**FDI inflows per capita**		**FDI inflows in per cent of GDP**	
	1996	**1997**	**1998**(1)	**1999**(2)	**1989-1998**	**per capita**	**1997**	**1998**	**1997**	**1998**
Albania	97	42	45	43	423	132	13	14	1.9	1.5
Bulgaria	100	497	401	700	1 323	159	60	48	4.8	3.1
Croatia	529	346	854	750	1 997	444	72	190	1.8	4.2
Czech Republic	1 388	1 275	2 485	3 500	9 957	967	124	241	2.5	4.5
Estonia	***111***	***130***	***575***	***350***	***1 382***	***953***	***89***	***396***	***2.8***	***10.6***
FYR Macedonia	12	18	175	30	242	121	9	88	0.5	5.7
Hungary	1 987	1 653	1 453	1 550	16 459	1 627	163	144	3.7	3.1
Latvia	376	515	220	150	1 604	642	206	88	9.3	3.5
Lithuania	152	328	921	400	1 534	415	89	249	3.4	8.9
Poland	2 768	3 041	6 600	6 500	15 066	389	79	171	2.2	4.5
Romania	263	1 224	2 040	1 345	4 510	200	54	90	3.5	4.7
Slovak Republic	251	177	508	500	1 762	326	33	94	0.9	2.5
Slovenia	178	295	154	210	1 192	596	148	77	1.6	0.8
CEEC and Baltic States	**8 212**	**9 541**	**16 431**	**16 028**	**57 451**	**184**	**30**	**53**	**1.1**	**2.1**
Belarus	73	198	141	188	456	45	19	14	1.5	1.0
Russia	1 700	3 752	1 200	3 500	8 901	61	25	8	0.8	0.4
Ukraine	526	600	700	600	2 626	52	12	14	1.2	1.7
CIS(3)	**4 520**	**7 703**	**5 104**	**6 703**	**23 687**	**34**	**11**	**7**	**0.4**	**0.3**
Total	**12 732**	**17 244**	**21 535**	**22 731**	**81 138**	**80**	**17**	**17**	**0.7**	**0.7**

(1) Estimation, (2) projection, (3) Includes also the rest of the former Soviet states
Source: EBRD: Transition report 1999

In this light, the Estonian Investment Agency is a very important tool in the Estonian Innovation System. Of course, modern technology also demands local human capital and a skilled labour force. Technology transfer is a package, where universities and vocational education and training have big roles.

Estonian innovation system output

Export success

In this paper, we have looked at the competitive edge of Estonian industries based on their apparent success in export markets. We have used two criteria that show a country's competitive edge:

a) If the trade balance of the product is positive, i.e. exports exceed imports, the country has a competitive edge in that product. Domestic producers are relatively stronger than importers.

b) The market share of the country in a studied product group is higher than the average market share of the country in world markets. This means that the country has specialised in that product in its exports.

These two conditions together indicate in which product the country in question has a competitive edge.

Available international foreign trade data are from the OECD, which consists of 31 countries. The most recent data cover the year 1997. So the data are slightly old. On the other hand, typically there are no dramatic changes from year to year in the competitive position of a nation as examined here. It takes years to reach the competitive edge, and, once reached, this competitive position will persist for a long period of time unless fatal errors are made or the business environment totally changes. The Russian crisis might be a potential source of dramatic change, but it has had similar effects on other exporters as well.

According to the results, the Estonian competitive edge in exports lies in very traditional industries like wood industries and furniture production, textile and clothing industries and foodstuff industries. In inorganic chemicals, there is also evidence of competitiveness in OECD exports. It is on these industries that Estonia currently has strength.

From a technology policy viewpoint, it is, of course, important to analyse the competitiveness factors explaining this success and the role of research and technology development in renewing the competitiveness. Technology development might be necessary in order to improve productivity and to create high-tech products (like enzymes in food production or anti-static materials for electronic industry work clothes). A central industrial policy target could be to gradually renew these industries, which have traditionally been low-tech industries, so that they use the latest technologies and produce the most advanced products.[1]

Cluster effects are also important. Very often, R&D inputs are more profitable in related and supporting industries of successful key industries.

When delivering R&D support, one should go to the more detailed data, which give a more accurate picture of competitiveness. For precise and focused financing, it is optimal to use most detailed, product-based data. Also, improvements in competitive positions are valuable information for decision-making, if financing is channelled to new products. Such improvements provide hints about the future success of the products. Later, foreign trade data can be used to evaluate the effectiveness of the financing.

[1] Suitable examples are the practices employed in countries like Denmark and the Netherlands in food industries, Sweden and Finland in timber production, and Denmark in furniture manufacturing. In the textile and clothing industry, good examples can be found in Italy, Great Britain, Germany and France, depending on the branch examined.

Table 2.6: Estonian Competitive Edge in OECD Exports in 1997

HS	Product Group	OECD Total Exports Million USD	Estonian Exports Million USD	Estonian Import Milloin USD	Estonian Trade Balance Mill. USD	Estonian Share of OECD Exports	Ranking
	All Items	***4 330 471.7***	***2 840.9***	***4 300.4***	***-1 459.5***	***0.07 %***	
	20 Top Estonian Products in Terms of Export Shares in OECD Exports in 1997						
18	Cocoa, cocoa preparations	8 817.7	130.4	132.7	-2.3	**1.48 %**	-A
44	Wood and articles of wood	46 877.1	326.5	57.9	268.7	**0.70 %**	**AA**
31	Fertilisers	10 049.3	56.2	57.8	-1.6	**0.56 %**	-A
16	Preparations of meat, of fish etc.	10 747.5	48.7	17.2	31.5	**0.45 %**	**AA**
04	Dairy produce: birds' eggs; honey	27 073.9	102.3	67.5	34.7	**0.38 %**	**AA**
63	Other made up textile articles	12 263.1	37.9	11.8	26.1	**0.31 %**	**AA**
52	Cotton	24 916.0	73.5	79.8	-6.3	**0.29 %**	-A
43	Furskins, artificial fur and articles	4 437.2	12.5	8.7	3.8	**0.28 %**	**AA**
56	Wadding, felt and special yarns	9 169.2	23.0	11.8	11.2	**0.25 %**	**AA**
09	Coffee, tea and spices	4 492.1	9.2	32.3	-23.1	**0.21 %**	-A
94	Furniture, bedding etc.	56 684.3	116.2	65.8	50.4	**0.21 %**	**AA**
17	Sugar and sugar confectionery	10 788.0	21.4	42.5	-21.1	**0.20 %**	-A
03	Fish, crustaceans, molluscs etc.	23 314.7	41.5	35.6	5.8	**0.18 %**	**AA**
25	Salt; sulphur; earths and stone etc	12 708.7	21.4	12.5	8.9	**0.17 %**	**AA**
62	Clothing accessories, not knitted	72 155.7	120.3	55.8	64.5	**0.17 %**	**AA**
14	Other vegetable products	240.4	0.4	0.0	0.4	**0.15 %**	**AA**
81	Other base metals	4 716.0	6.2	2.1	4.1	**0.13 %**	**AA**
32	Tanning and dyeing extracts	30 643.4	38.4	47.5	-9.1	**0.13 %**	-A
65	Headgear	2 310.5	2.8	1.9	0.9	**0.12 %**	**AA**
28	Inorganic chemicals	30 152.6	35.7	25.7	10.0	**0.12 %**	**AA**
	20 Top Estonian Products in Terms of Trade Balance with the World in 1997						
44	Wood and articles of wood	46 877.1	326.5	57.9	**268.7**	0.70 %	**AA**
62	Clothing accessories, not knitted	72 155.7	120.3	55.8	**64.5**	0.17 %	**AA**
94	Furniture, bedding etc.	56 684.3	116.2	65.8	**50.4**	0.21 %	**AA**
04	Dairy produce: birds' eggs; honey	27 073.9	102.3	67.5	**34.7**	0.38 %	**AA**
16	Preparations of meat, of fish etc.	10 747.5	48.7	17.2	**31.5**	0.45 %	**AA**
63	Other made up textile articles	12 263.1	37.9	11.8	**26.1**	0.31 %	**AA**
61	Clothing accessories, knitted	59 080.8	48.0	32.3	**15.7**	0.08 %	**AA**
56	Wadding, felt and special yarns	9 169.2	23.0	11.8	**11.2**	0.25 %	**AA**
28	Inorganic chemicals	30 152.6	35.7	25.7	**10.0**	0.12 %	**AA**
25	Salt; sulphur; earths and stone etc	12 708.7	21.4	12.5	**8.9**	0.17 %	**AA**
03	Fish, crustaceans, molluscs etc.	23 314.7	41.5	35.6	**5.8**	0.18 %	**AA**
81	Other base metals	4 716.0	6.2	2.1	**4.1**	0.13 %	**AA**
43	Furskins, artificial fur and articles	4 437.2	12.5	8.7	**3.8**	0.28 %	**AA**
65	Headgear	2 310.5	2.8	1.9	**0.9**	0.12 %	**AA**
14	Other vegetable products	240.4	0.4	0.0	**0.4**	0.15 %	**AA**
71	Pearls, precious stones	65 260.2	6.8	6.5	**0.3**	0.01 %	A-
97	Art, collectors' pieces and antiques	6 045.2	0.3	0.0	**0.3**	0.00 %	A-
78	Lead and articles thereof	1 494.8	0.2	0.0	**0.2**	0.02 %	A-
92	Musical instruments	3 707.1	1.7	1.5	**0.2**	0.05 %	A-
29	Organic chemicals	112 375.0	34.5	34.4	**0.1**	0.03 %	A-

*Explanation: **AA** = Positive Trade Balance and a Higher Export Share than the Estonian Average Share of OECD Exports, **A-** = Positive Trade Balance, **-A** = A Higher Export Share than the Estonian Average Share of OECD Exports*

Source: OECD, International Trade by Commodities Statistics ITCS Statistical Office of Estonia, Statistical Yearbook of Estonia 1999

Production and productivity growth

Improvements in productivity are a good indicator of technological development. During the entire last decade, Estonian producers had to improve their productivity. This was a must especially for exporters because wages were rising and, at the same time, the export price level was relatively stable due to the currency peg with the German Mark.

In Table 2.7 we have grouped Estonian industries into different categories according to change in production and employment from 1994 to 1997. In 1994, the production declines due to the collapse of the Soviet system came to an end, and new market economy-based growth strengthened sufficiently. Table 2.7 is based on Table 2.8, which presents more detailed data. The data are not optimal as they do not cover the latest developments, which have occurred particularly in the food industry. We have used gross production as an indicator of production. Gross production is sales plus the net increase in inventories. Value added would have been a more proper measure when calculating productivity, but data on it were not available.

On average, Estonian industries improved their productivity by 9.6 per cent per annum between 1994 and 1997. If we exclude energy production and mining, productivity growth is nearly 11 per cent. The yearly increase in production was 6.3 per cent. At the same time, the size of the labour force decreased at an average annual rate of 3.3 per cent. Average yearly productivity growth in the OECD countries is 2-3 per cent. Therefore, the catching-up model seems to be well in force.

Table 2.7 shows the growth industries of Estonia. Those real booming industries, which can increase both production and employment, are valuable to the nation. Estonia has relatively many of these industries compared to, for example, Finland. On the other hand, there are even more industries that can increase production while decreasing their labour force. Estonian manufacturing as a whole seems to belong to this group, which can be named *jobless growth industries*.

These are preliminary results[2]. Anyhow, they show how profound the importance of productivity improvements has been for most of the industries. Such improvements are a must in international competition, taking into account the Estonian foreign trade deficit. Productivity improvements are derived in part from investment and new technology, but in many case only marginal investments, new market channels, and more professional management could have helped to increase the effectiveness of utilising existing production capacity.

In the long run, technology developments in the form of adopting more and more effective production technologies are not enough. Currently, it has been a profitable strategy in wood manufacturing, for example, because, given its good price competitiveness, Estonia has managed to win more market shares and there have been enough local raw materials. However, there are limits to this strategy. Now is the time to start developing new products and production technologies for these effective industries, if possible. According to Finnish experience, those industries, which have actively developed new products, can also increase their labour force. Those industries, which focus on developing only their production technology, belong in the jobless growth group (see the categories in Table 2.7).

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[2] The possible inaccuracy of statistics should be controlled for. Most important is to use value-added figures instead of gross production figures. Also, absolute and relative changes in prices connected to the transformation process should also be taken into account. They probably explain why some industries managed to survive with decreasing production and increasing employment.

Table 2.7: Decomposition of industries according to change in production and employment and average annual productivity growth during 1994 – 1997

	Production decreasing	**Production increasing**
Employment increasing	-1,1 %, manufacture of wearing apparel -2,5 %, mining and agglomeration of oil-shale -3,9 %, manufacture of beverages -13,4 %, manufacture of bakery products	23,9 %, manufacture of wood 21,4 %, manufacture of paper and paper products 20,7 %, manufacture of rubber and plastic products 16,7 %, manufacture of furniture and other manufactured goods 16,3 %, manufacture of furniture 11,7 %, manufacture of fabricated metal products 4,5 %, manufacture of dairy products -- -0,5 %, **Mining** -17,6 %, manufacture of radio, television and communication equipment and apparatus
Employment decreasing	14,3 %, production of meat and meat products 10,5 %, other manufacturing n.e.c. 6,5 %, manufacture of motor vehicles and other transport equipment 4,3 %, extraction of peat -- -3,4 %, publishing, printing and reproduction of recorded media -5,2 %, manufacture of grain mill products -16,9 %, manufacture of prepared animal feeds	41,4 %, manufacture of textiles 39,2 %, manufacture of glass and glass products 21,7 %, manufacture of electrical machinery and apparatus 19,9 %, production of fish and fish products 18,6 %, manufacture of footwear 17,8 %, manufacture of machinery and equipment 15,8 %, manufacture of other non-metallic mineral products 14,5 %, tanning and dressing of leather and manufacture of footwear 10,9 %, **Manufacturing** 9,6 %, **TOTAL** 7,4 %, Energy supply 6,9 %, manufacture of chemicals and chemical products 6,7 %, manufacture of medical, precision and optical instruments, watches and clocks 4,9 %, manufacture of food products, beverages and tobacco products

Note: Percent figures denote average annual productivity growth in the industry. Average annual production and employment changes can be found in Table 2.8.

Table 2.8: Changes in Industrial Production, Employment and Productivity during 1994–1997

Economic activity	Production 1997	Share of Production 1997	Increase in Production 1997/1994	Employ-ment 1997	Increase in Employment 1997/11994	Productivity growth 1997/1994	Production per Em-ployee
TOTAL	**40 385**	**100.0 %**	**6.3 %**	**148 493**	**-3.3 %**	**9.6 %**	**271 965**
Energy supply	4 627	11.5 %	0.3 %	11 069	-7.0 %	7.4 %	418 030
Mining	1 790	4.4 %	0.2 %	10 634	0.7 %	-0.5 %	168 335
.. mining and agglomeration of oil-shale	1 489	3.7 %	-0.1 %	8 593	2.4 %	-2.5 %	173 276
.. extraction of peat	240	0.6 %	-0.7 %	1 747	-4.9 %	4.3 %	137 360
Manufacturing	33 968	84.1 %	7.6 %	126 831	-3.3 %	10.9 %	267 821
....production of meat and meat products	1 454	3.6 %	-0.9 %	3 121	-15.1 %	14.3 %	465 939
....production of fish..and fish products	2 055	5.1 %	12.5 %	7 801	-7.3 %	19.9 %	263 442
....manufacture of dairy products	2 983	7.4 %	6.4 %	4 076	1.9 %	4.5 %	731 909
....manufacture of grain mill products	87	0.2 %	-7.6 %	314	-2.4 %	-5.2 %	276 970
....manufacture of prepared animal feeds	351	0.9 %	-28.3 %	823	-11.4 %	-16.9 %	426 365
....manufacture of bakery products	984	2.4 %	-3.7 %	4 702	9.7 %	-13.4 %	209 279
....manufacture of beverages	1 806	4.5 %	-0.5 %	2 800	3.4 %	-3.9 %	644 992
.. manufacture of textiles	2 586	6.4 %	27.4 %	8 717	-14.0 %	41.4 %	296 658
.. manufacture of wearing apparel	1 391	3.4 %	-0.7 %	14 042	0.4 %	-1.1 %	99 057
.. tanning and dressing of leather and manufacture of footwear	428	1.1 %	0.4 %	2 798	-14.1 %	14.5 %	152 965
....manufacture of footwear	331	0.8 %	6.2 %	1 846	-12.4 %	18.6 %	179 267
.. manufacture of wood	3 348	8.3 %	32.4 %	14 475	8.4 %	23.9 %	231 300
.. manufacture of paper and paper products	647	1.6 %	32.1 %	1 349	10.6 %	21.4 %	479 681
.. publishing, printing and reproduction of recorded media	1 427	3.5 %	-3.5 %	5 693	-0.1 %	-3.4 %	250 657
.. manufacture of chemicals and chemical products	2 483	6.1 %	2.0 %	6 745	-4.9 %	6.9 %	368 143
.. manufacture of rubber and plastic products	876	2.2 %	26.6 %	2 183	5.9 %	20.7 %	401 344
.. manufacture of other non-metallic mineral products	1 559	3.9 %	5.5 %	5 149	-10.2 %	15.8 %	302 799
....manufacture of glass and glass products	470	1.2 %	29.0 %	624	-10.3 %	39.2 %	753 756
.. manufacture of fabricated metal products	1 935	4.8 %	17.9 %	7 936	6.2 %	11.7 %	243 835
.. manufacture of machinery and equipment	762	1.9 %	2.7 %	5 331	-15.1 %	17.8 %	142 931
.. manufacture of electrical machinery and apparatus	803	2.0 %	6.7 %	3 533	-15.0 %	21.7 %	227 285
.. manufacture of radio, television and communication equipment	449	1.1 %	4.6 %	2 838	22.2 %	-17.6 %	158 234
.. manufacture of medical, precision and optical instruments, watches	407	1.0 %	2.9 %	2 576	-3.8 %	6.7 %	157 977
.. manufacture of motor vehicles and other transport equipment	1 303	3.2 %	-1.6 %	4 923	-8.1 %	6.5 %	264 675
.. manufacture of furniture and other manufactured goods	2 590	6.4 %	17.1 %	12 418	0.4 %	16.7 %	208 560

Source: Statistical Office of Estonia, Statistical Yearbook of Estonia 1999

Patenting activity

Table 2.9 displays the results of the activities of the Estonian Patent Office during the last decade. We focus here on the number of patent applications, which is an internationally used high-tech indicator. The number of Estonian patent applications per year has varied between 12 and 20. One cannot find any growth tendency similar to that visible in foreign applications. Starting from a backlog of 482 applications in 1994, the number of foreign applications started to grow from 82 per year in 1995 to 619 applications in 1999, growing each year during that period. There are no figures available on Estonian patent activity abroad.

Table 2.9: Results of activities of the Estonian Patent Office 1992-1999

	1992	1993	1994	1995	1996	1997	1998	1999	Total
Trademarks									
No. of Applications for trademarks	1 365	11 932	2 733	2 830	2 659	3 101	2 963	4 417	**32 000**
No. of Estonian trademark applic.	384	1 521	543	589	513	666	637	723	**5 576**
No. of trademarks registered	0	299	7 500	3 745	3 726	3 179	2 848	2 064	**23 361**
Patents									
No. of applications for patents	0	0	482	82	213	375	463	619	**2 234**
No. of Estonian patent applications	0	0	16	16	12	15	20	13	**92**
No. of patents registered	0	0	0	0	22	108	82	103	**315**
Utility models									
No. of applications for utility models	0	0	32	52	31	45	47	31	**238**
No. of Estonian utility model applic.	0	0	27	50	30	42	38	25	**212**
No. of utility models registered	0	0	15	55	28	36	51	32	**217**
Industrial Design									
No of Industrial design applications							149	107	**256**
No. of Estonian design applications	0	0	0	0	0	0	33	24	**57**
No. of industrial designs registered	0	0	0	0	0	0	131	78	**209**

Source: Statistical Office of Estonia: Teadus, Science 1998

Table 2.10. Patents/Inventiveness coefficient - resident patent applications per 10,000 persons

	1992	1993	1994	1995	1996	1997	1998	1999
Estonia	***0,00***	***0,00***	***0,11***	***0,11***	***0,08***	***0,10***	***0,14***	***0,09***
EU	**2,39**	**2,43**	**2,49**					
Finland	4,10	4,41	4,68	4,56	4,85	4,82	5,40	
Austria	2,70	2,80	2,50		2,30			
Spain	0,54	0,56	0,55					
Latvia	0,94	1,07	0,70	0,83				
Lithuania			0,30	0,28		0,32	0,34	
Poland	0,80	0,70	0,70					
Czech Republic	2,12	0,85	0,73	0,61	0,60	0,57	0,61	
Slovakia		0,53	0,46	0,50	0,37	0,42		
Hungary	1,45	1,11	1,12	1,03	0,78	0,72	0,68	
Slovenia	2,99	5,32	3,44	1,93	1,87	1,65	1,63	1,45
Romania	0,64	0,62	0,72	0,80				
Bulgaria	1,34	0,72	0,29	0,44				

Source: European Commission: Science … and patent offices of countries (see List of references in p)

The absolute number of local patent applications is very small. It is modest also in a relative sense, which can be seen from Table 2.10. Among the countries studied, the smallest number of patent applications per 10,000 persons is in Estonia, at around 0.1. In European Union countries, the corresponding indicator stands at an average value of 2.5 patents. In Finland, the total number of domestic applications was 2,702 in 1998, which is 5.4 application per 10,000 persons. In order to reach a comparable level, Estonian innovators should produce 780 applications per year. The average European Union level would mean around 350 patent applications per year.

Patent application figures clearly indicate that scientific work and research conducted in the Estonian innovation system are not at all practically directed so that they could produce innovations. There is full reason to study this problem in more depth. The following is a list of potential reasons:

1. There is obvious emphasis on subjects and sciences that have no connection to business, but other sectors of life instead.
2. In those areas of sciences, which could be more tightly linked with business activities, actual research work is oriented towards basic research and that kind of applied research that is far from practical solutions.
3. Even though the number of researchers is comparable to other countries, research organisations are not as productive as they are in other countries.
4. Firms are not used to seeking solutions to their practical problems from researchers, which means that researchers are not getting the necessary inputs for innovations. The personnel working in firms has very limited possibilities to advance their own innovations, because firms do not invest in them and outside financing is very scarce[3].

Firms' technology development needs

There are very few studies that address the technology development needs of Estonian industries. In the National Innovation Programme there are industry by industry lists of potential technology development needs. Another source of information is forthcoming R&D statistics on Estonian industries. To get a picture of firms' ongoing R&D activities and future technology development needs, the evaluator visited 10 firms and interviewed the leadership of the firms. The selected firms are very different in terms of size, R&D intensity, location in the production chain, and line of business. Representatives of the Estonian Confederation of Employers and Industries were also interviewed.

Based on this limited sample and other background information about Estonian industrial firms, the evaluator made the following tentative classification of firms, which helps to understand their technology development needs.

[3] For example, the Science Foundation looks at the number of scientific publications as a criterion for financing. Persons working for firms seldom have enough time for this kind of activity.

Table 2.11: A Tentative Classification of Estonian Firms According to Technology Needs and Sources

Subcontractors: This group is quite big. An important technology source for them is customer firms, which normally give precise product specifications for subcontractors and supervise subcontractors also in quality and standards issues. Important for subcontractors is cost effectiveness, which companies can improve by introducing new production technologies. That is why production technology producers are an important source of technology. Imitation of efficient competitors plays an important role as well. Clear examples of subcontractors in Estonia are the country's many tailor shops. A sample of subcontracting activities includes Tarkon Ltd. and the subsidiary companies of Talleks Ltd. These companies are, however, subcontractors with their own, relatively large R&D potential. Tarkon was a former producer of black boxes. Talleks is a holding company. It develops its subsidiary companies actively: For example, considerable changes in production development, production planning, training of workers and assessment of the market situation have been made in Ferreks TT Ltd.
Customer-oriented end producers: Own product development, which is based on customer needs, is an important technology source for the leading companies. R&D can also concentrate on new raw materials or production technology or their introduction. Other producers often imitate the leading companies. In products were product differentiation is not possible, R&D can simply be market research, the design of packages and the creation of brand names. Interviewed companies belonging to customer-oriented end producers were Norma Ltd, which produces seat belts, Imawere Saeveski Ltd, which is a sawmill, and the Tallinn Piimatööstuse Ltd. dairy. In the latter's case R&D has taken the form of market research, brand-making, designing packages and introducing new products from abroad in Estonia. The competitiveness of the Imawere Saeveski sawmill is based on the transfer of modern production technology and effective organisation of production. Norma Ltd. has 40 to 50 persons working in R&D activities. R&D is made together with car producers, when they plan new models. Actually, R&D is at the same time marketing because in that phase car producers select a seat belt producer for the production models.
Science and knowledge-based firms: The technology source of these firms often originates from leading universities and research institutes. Gradually, of course, their own R&D becomes increasingly important. Nevertheless, mutual co-operation between universities and research units continues. Information flows both ways. Universities are also an important source of high-quality labour. Through practical applications, customers also become catalysts of innovation activities. The demanding orders of the government can open links to customer markets. Of the interviewed companies, Gybernetics Ltd., MicroLink Ltd., and Clifton Electronic Components belong to this group. Gypernetics develops information security and monitoring systems. Most of its personnel, which numbers 102, works in R&D activities. MicroLink is the largest information technology (IT) group in the Baltic States, consisting of 15 enterprises. Micro company Clifton is a start-up company that develops and commercialises innovations made for the former Soviet military complex.
High-skilled firms: In these firms, essential features are skills connected to different work activities or processes. Education is an important base for production or business, but it is not sufficient. After vocational education employees need a lot of learning by doing. A good example of this kind of firm is Pioneer, which produces casting moulds. It takes 5 to 6 years to become real experts in that line of work. Here high-tech machinery is important. Also, Elcoteq could be counted in this group instead of in the subcontractors group. It sells electronic manufacturing services with sophisticated business concepts and uses high-technology in its assembling activities. In this case, its parent company has been an important source of technology, but the situation is now changing (see the special study in Chapter 5).
The bulk of firms: This is the biggest group of firms. Here company managers do not invest in any kind of R&D. The companies use common practices. Cheap labour and/or raw materials and local markets are the base for existence. Lack of product development and improvements in production technology compel managers to continuously struggle for survival. They are in a vicious circle - there isn't a sufficient positive cash flow for development, but without development investments they cannot get a positive cash flow.

These kinds of groupings are operational for technology policy officials, because they help to identify the technology sources or, more generally, sources of development.

For international comparisons, the classification developed by the OECD must be used. They are also good indicators with which to follow the dynamics of technology development.

We also asked about the importance of R&D for the firms as a measure to improve their competitiveness and the use of public RTD funding. The results of the interviews are used later in Chapter 7. The most important conclusions were the following:

- R&D is not the most important factor of competitiveness, but its importance is rising. Very many ranked vocational education, fixed investment for new machinery, and activities to open new markets more important. In the case of machinery investments, standard machinery often brings considerable improvements to quality and productivity.
- The firms knew the Innovation Foundation. Many had checked its financing capacity and terms of financing. In practice, most of the firms viewed the IF as being somehow unsuitable for them. Its financing possibilities were too low for their projects. It was ranked as a helper of poor and small firms, "not suitable for profitable firm like us." During recent years bank financing has also developed a lot (availability and terms) together with the creditworthiness of the companies, which have decreased the relative attractiveness of IF loans. One reason must also be the lack of innovative projects.

For some firms (i.e. science and knowledge-based firms) R&D is extremely important. Specifically, nearly all the activities can be ranked as research and development. They had also used or were going to use financing from the IF in their R&D projects.

Conclusions from the chapter

There is no clear picture about the Estonian innovation pattern. This was a preliminary analysis. More precise analyses are needed later on which to base technology policy planning and implementation. There is a need to make international benchmarking as well as benchmarking between different industries and on the public side between different fields of science. Indicators developed later can form the basis for evaluating the effectiveness of technology policy and its measurements. To make this all possible, improved statistics will be needed.

The following conclusion can be drawn from the presented technology indicators:

- Estonia is investing very modestly in research and technology development compared to other countries. Estonian R&D investments are only 0.5 per cent of GDP. The R&D intensity of the OECD and EU countries is over 2 per cent on average. Public investments are used for basic research and the kind of applied research that does not have very many connections to the product and production technology development of firms.
- There is an internationally comparable number of science and engineering jobs in the country's research units. The total number is 4,000, but, upon limiting the calculation to full-time equivalent researchers only, the figure is much smaller – 2,700 researchers. Many researchers engage in additional activities, which lowers their productivity. There are lags in education from a technology development viewpoint. The number of students and graduates in engineering and computer sciences falls below the number corresponding to the future needs of Estonia.

- Estonia has managed to attract the third highest level of foreign direct investment per capita among Central Eastern European and former Soviet countries. The level of annual FDI is manifold or even tens of times higher than that invested by Estonia in R&D. FDI is probably the most important source of technology development because many technology transfers are linked to it.
- Estonia has revealed a comparative edge in rather traditional industries. It has specialised in wood and furniture industries, textile and clothing industries, food industries and some chemical products. An essential part of technology policy could be, through product and production technology development, to ensure that Estonia maintains and strengthens its position in these industries and benefits from their positive cluster effects. Estonia could be a high-tech producer in these industries that have traditionally been kept as low-tech industries. This policy line does not exclude investments to selective high product areas with promising prospects.
- Productivity growth has been remarkable in Estonian industries, expanding by 9.6 per cent in total industry per annum and 11 per cent in manufacturing during 1994-1997. Productivity growth and the necessary tool in its promotion, production technology development, must continue because salaries will continue to grow in the future. Gradually, firms will have to manage production development as well. Otherwise, the country will have industries wherein production levels increase while the number of workers continuously declines. New products that offset new consumer demands also create new jobs.
- Patenting activity is very weak in Estonia. The number of local patent applications has varied between 12 and 20 during the last decade. If the number of Estonian applications were comparable to the European average figure, then it would mean 350 applications per annum in Estonia. A special investigation should be conducted into the reasons why the internationally comparable number of scientists and engineers engaged in research activities, as well as experts working in firms, are not capable of producing more innovations. This is very much linked to the biases in research resources, but also to the nearly total lack of supporting measures.

3. Mapping the existing technology support structures

The Estonian National Innovation System (NIS) was formed during this decade. The starting point was the regaining of independence. There was a common will in the government and among some university professors[4] that Estonia should have modern structures to support and boost innovation activities in firms, research institutions and universities. This rapidly led to a situation where Estonia, years before other Baltic countries, installed a national innovation system with a legal base in legislation and also bodies for policy decision making and executing the practical supporting activities.

Decision-making bodies

The structure of the current system is described in Figure 3.1. At the top level of the NIS is the parliament, which adopts the necessary laws and accepts, on a yearly basis, the state budget for financing the system. The government prepares the legislation, gives the statutes and makes the budget scheme.

The Research and Development Council is a high-level advisory body. The Prime Minister is the president of the body and many other key ministers are also members of the body (Ministers of Education, Economic Affairs, Finance, Culture and Environment). Other members come from universities and from the Science Academy, Science Foundation and Innovation Foundation as well as from the business community. (See Appendix A.)

Policy preparing and managing bodies

The Ministry of Economic Affairs (MoE) has had de jure a central position in the NIS by the Act of Government. However, only since the establishment of a new division called the Technology and Innovation Division under the Department of Industry in the beginning of 1999, it has de facto started to realise this position. MoE is responsible for planning technology policy, managing technology development and for supervising and controlling the technology development agency, i.e. the Innovation Foundation.

On the science and education side of the NIS, the Ministry of Education is in a key position. The Ministry is assisted by the Estonian Science Academy and the Science Competence Council (SCC). SCC assesses the scientific level of universities and research institutes. Their basic financing is based on this evaluation.

The Estonian Academy of Sciences (EAS) is comprised of distinguished academic scientists. Scientific societies act under it. During Soviet times, research institutes operated under the Academy of Sciences. Now research institutes are connected to different universities and ministries. The current role of the Science Academy is to give room for discussions and to work as a grey eminent advisor.

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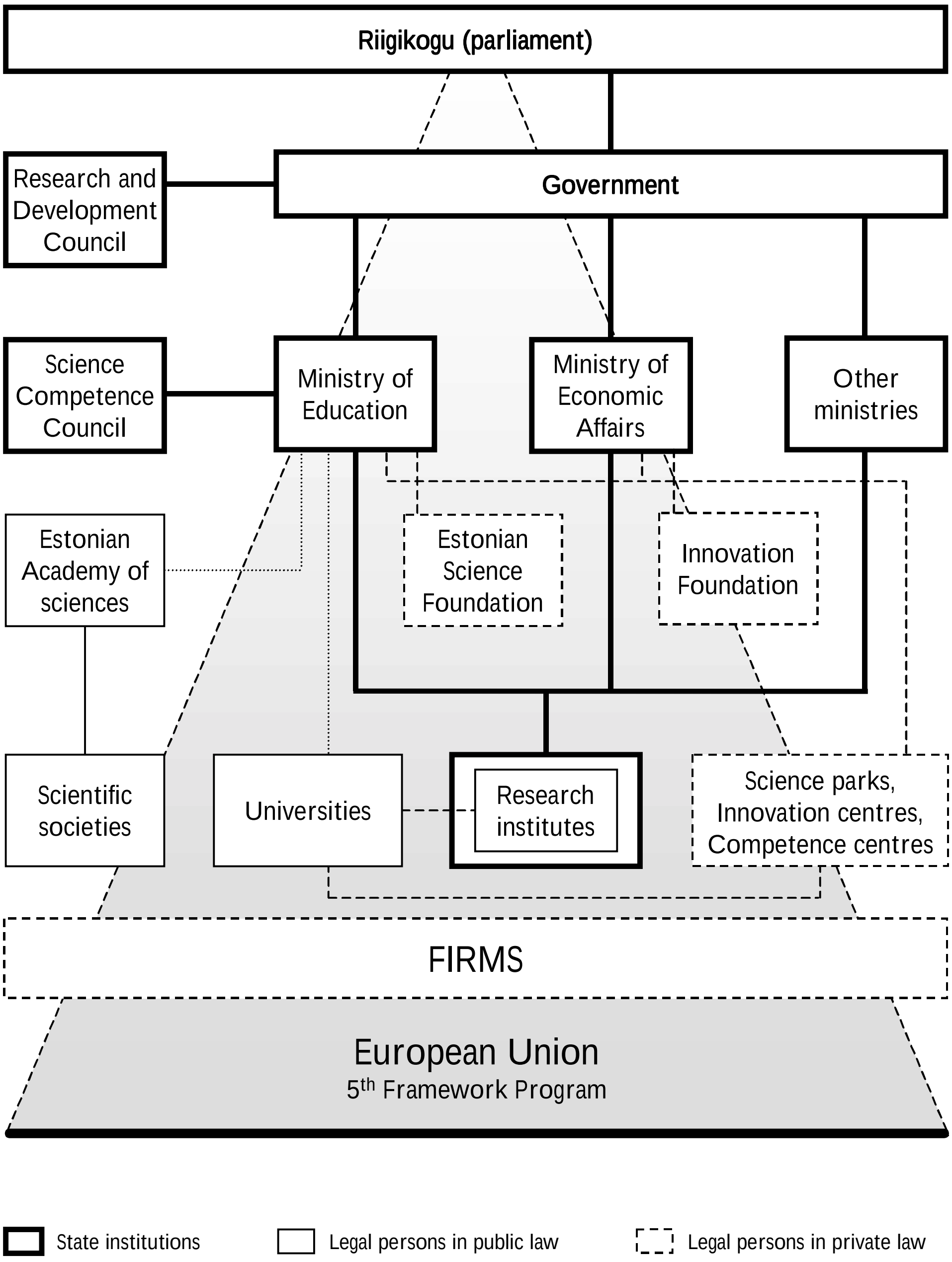
[4] An initiative person was Edgar Savisaari, who was Prime Minister at that time. A key person on the academic side was and still is professor Rein Küttner from Tallinn Technical University.

Figure 3.1: Research and Technological Development Support Structures in Estonia



Executing support institutions

Financier

So far there are two main financing bodies in the Estonian NIS. The Innovation Foundation (IF) and the Estonian Science Foundation (ESF). The Innovation Foundation is responsible for delivering RTD financing on a project basis to the firms, research institutes and research units in universities. It has also given support to the supporting organisation - to science parks, competence centres and innovation centres. The Estonian Science Foundation provides grants to individual academic researchers. Both foundations are legal entities in private law even though they are totally financed by public sources.

There is still no public seed financier in Estonia. In addition, the country lacks domestic public and private venture capitalists. Nevertheless, many foreign venture capitalists are actively present through their local representatives, which offsets this lack. Nor is there a special foundation to support and assist private individuals and entrepreneurs to develop and exploit proposed inventions.

In practice, a very important financier is the European Union. Estonia has been very successful at participating in projects, such as the Copernicus project, given the size of the country. Also, initial results from the 5th framework programme of the EU tell the same story. Phare has also supplied continuous financing possibilities.

Bridging organisations

The main bridging organisations are listed in Table 3.1. They are centred in Tartu and Tallinn, the scientific centres of Estonia. The Tartu Science Park successfully houses over 30 enterprises and current premises are full. Activities are just starting in Tallinn. Science park activities are also being spread to the Ida-Virunmaa and Pärnu districts. The University of Tartu and Tallinn Technical University both have innovation centres for commercialising their scientific potential and to increase the number of spin-offs and entrepreneurship among university researchers and graduates. In 1996, Centres for Strategic Competence were established at the University of Tartu and Tallinn Technical University in the fields of biotechnology, information technology, materials science and environmental technology. They bridge together the intellectual capital and the most competent research labs in these fields. The EU Innovation Centre (FERMIC), which acts within the Archimedes foundation in Tartu, distributes information and consults different actors regarding participation in EU projects.

Universities and research institutes

There are four main universities: University of Tartu, Tallinn Technical University, Estonian Agricultural University and Tallinn Pedagogical University. The majority of scientific research is conducted in the first three universities mentioned above. The Estonian Academy of Arts and the Estonian Academy of Music are also supported by the state. There are also private universities that focus on higher professional education. State universities are legal entities in public law, which means that they have a rather great level of independence. They are financed from the state budget through the Ministry of Education.

There are 14 research institutes within the universities: seven within Tallinn Technical University, four within Estonian Agriculture University, two within Tallinn Pedagogical University and one under Tartu University (see Table 3.2). A total of 20 research institutes work under different ministries: seven under the Ministry of Education, five under the Ministry of Agriculture, four under the Ministry of Environment, and two under the Ministry of Social Affairs. There is one institute operating under each of the Ministry of Economic Affairs and the Ministry of Culture. Research institutes operating under the ministries are state institutions, and research institutes connected to universities are legal entities in public law.

Table 3.1: Summary of Goals and Activities of the Most Important Bridging Institutions of Estonian National Innovation System

Institution	Status	Strategic goal	Fields of activity and Target groups
Tallinn Technical University's Development Centre EAK Akadeemia tee 19,12618 Tallinn jtymanok@online.ee ***Employees*: 60** ***Area:*** 10 622 m² and 260 m² in Vormsi	***Legal form****:* R&D institution of TTU, ***Established:*** In 1997, before the Academy of Science's Development and research bureau, founded in 1963 ***Owner*:** Tallinn Technical University	Promotion of innovation activities and knowledge intensive entrepreneurship (statutory objective). In reality: production and distribution of knowledge intensive products.	Environmental technology Hydromechanics ***Target groups:*** Purchasers of instruments and labs
Innovation Centre of TTU (TIC) Ehitajate tee 5 19086 Tallinn http://www.tuic.ee ***Employees*:** 2,25 ***Area:*** 15 m^2	***Legal form:*** Foundation ***Established:*** 1998 ***Founders****:* Tallinn Technical University, Ministry of Economic Affairs of the Republic of Estonia, City of Tallinn, Estonian Confederation of Employers and Industry, Helsingin Yliopiston Holding Oy	Binding industrial and business activities with scientific and development work: • Marketing of the R&D projects results of TTU • Assistance and consulting for TTU specialists for developing co-operation with industry; • Implementation of spin-off-programs for starting enterprises and incubation systems for companies; • Organising co-operation between domestic and foreign innovation, technology transfer institutions and relevant financial institutions and networks.	Marketing of R&D and services of testing and measuring: Introduction of project packages with TTU innovative resources and business potential. Contractual R&D and testing/measuring services: consulting of scientists, organising of assistance and training in areas related to enterpreneurship; initiative and involvement in protecting TTU interests while compiling, negotiating or implementing contracts on R&D and testing/measuring works. Commercialising the results of R&D: involvement of academic staff in TTU policy on private enterpreneurship; record R&D projects and analyse commercial potential; execute a spin-off-program as a consulting, training and tutoring system for starting enterprises; develop a spin-off and other incubation services (consultations, search for starting capital, etc.) for starting enterprises. International and domestic co-operation of R&D and technology transition: Active membership in international innovation organisations and networks, partnership and joint-ventures with foreign parks/centres /universities; joint projects with Tartu Scientific Park and other Estonian partners; including innovative enterprises in international and domestic TIC channels for technology transfer, marketing, etc. (through TIC association contracts concluded with the companies). ***Target groups:*** Academic personnel interested in commercialising research results; starting and small firms with high science and technology; enterprises interested in services resulting from R&D; development org. in Estonia and abroad.

Tartu University's Centre of Strategic Competence Jakobi St 2 51014 Tartu tk@ut.ee ***Employees*: 39** ***Area:*** Ca 700 m^2	***Legal form:*** Tartu University's R&D institution ***Established**:* 1996 ***Founders:*** Tartu University	Targeted allying of science potential related with Tartu University, cumulating the resources and reasoned utilisation for solving the issues facing education and economy of Estonia in the area of priority technology, including material study, gene technology, information technology, and environment technology.	Information technology, environment technology, biotechnology, material studies • Co-ordination and effecting of scientific research and innovation or development activities in the area of relevant technology; • Initiate and execute national and intl. joint projects in relevant technology area; • transfer of technol. based know-how to the economy, education and other areas; • Participation in technology transfer of relevant area of technology into the economy of the Republic of Estonia and other areas; • Consultations in the area of relevant technology; • Conduct personnel training in the relevant area of technology ***Target groups:*** Entrepreneurship based on different technologies, Public institutions (consultations), University faculties and other institutions
EU Innovation Centre, NGO Archimedes Kompanii St 2 51007 Tartu femirc@femirc.ee ***Employees*:** Archimedes 30, EU 8 ***Area:*** Archimedes 600 m^2, EU 100 m^2	***Legal form****:* Foundation, ***Established:*** 1997 ***Founders:*** Founded with the Government of the Republic Decision in the administration of the Ministry of Education	To accelerate the movement of Estonia to the knowledge-centred society by supporting new innovative initiatives in education, science and development activities and by deepening synergetical co-operation between people, institutions, and regions	Information distribution and consulting for possibly successful participation of Estonia within the EU Fifth Framework Program; Support of international technology transfer; Innovation research and analysis. ***Target groups****:* Scientists, Enterprises, Ministries, County Governments, Local Governments
Foundation Tartu Science Park Riia St 185 51014 Tartu www.park.tartu.ee ***Employees*:** 11 ***Area:*** 3.400 m^2	***Legal form****:* Foundation, ***Established:*** 1996 (before it was the municipal enterprise Tartu Science Park, 1992) ***Founders:*** City of Tartu, Tartu County, Estonian Government, Tartu University, Estonian Agricultural University, Institute of Physics	Development of entrepreneurship with a large volume of science and technology with establishment/development of relevant infrastructure and services network and promotion of co-operation between enterprises and science or development institutions. ***Target groups:*** Starting and existing enterprises with a large volume of science/technology, innovative projects for active companies	Establish favourable environment for development of entrepreneurship with large volume of science/technology (infrastructure, services). Services: • rent of rooms, common utility, incubation discount for beginners; • services of communication, computer network, multiplication, security, etc; • consulting and services of secretary, personnel and accounting work; • assist in finding info., partners or market, investors or financial opportunities; • participation in international networks, presentations at exhibitions and fairs, publishing of an information brochure, information databases and publishing • organise workshops and info. days, communicate with science institutions • radar projection (CAD/CAM), training courses and consulting • services provided by specialised companies (business consulting, etc.) • Companies and entrepreneurs starting science/technology enterprises. Establish innovative projects and development units for active companies

Table 3.2: Estonian Public Owned Research Institutes

Institute	Administrator	Main location	Per-sonnel	Re-searcher
Institute of Physics	University of Tartu	Tartu	171	77
Estonian Institute of Economics	Tallinn Technical University	Tallinn	46	28
Institute of Geology	Tallinn Technical University	Tallinn	94	46
Institute of Chemistry	Tallinn Technical University	Tallinn	119	54
Institute of Cybernetics	Tallinn Technical University	Tallinn	75	32
Institute for Islands Development	Tallinn Technical University	Kuressaare	4	1
Institute of Oil Shale	Tallinn Technical University	Kohtla-Järve	55	15
Institute of Intern. and Social Studies	Tallinn Pedagogical Institute	Tallinn	36	21
Institute of Ecology	Tallinn Pedagogical Institute	Tallinn	49	24
Estonian Plant Biotechnical Research Centre EVIKA	Estonian Agricultural Univers.	Saku	27	6
Forest Research Institute	Estonian Agricultural Univers.	Tartu	5	14
Institute of Animal Science	Estonian Agricultural Univers.	Tartu	153	55
Institute of Experimental Biology	Estonian Agricultural Univers.	Harku	103	38
Institute of Zoology and Botany	Estonian Agricultural Univers.	Tartu	114	53
Institute of History	Ministry of Education	Tallinn	62	31
Estonian Biocentre	Ministry of Education	Tartu	71	53
Institute of Estonian Language	Ministry of Education	Tallinn	103	58
Estonian Literatury Museum	Ministry of Education	Tartu	59	16
National Institute of Chemical Physics and Biophysics	Ministry of Education	Tallinn	176	104
Tartu Observatory	Ministry of Education	Tartumaa	68	41
Under and Tuglas Literature Centre	Ministry of Education	Tallinn	17	11
Estonian Marine Institute	Ministry of Environment	Tallinn	86	52
LLC Building Research Institute	Ministry of Environment	Tallinn	21	12
Geological Survey of Estonia	Ministry of Environment	Tallinn	115	-
Estonian Meteorological and Hydro-logical Institute	Ministry of Environment	Tallinn	462	22
Võru Institute	Ministry of Culture	Võru	5	3
Estonian Energy Research Institute	Ministry of Economic Affairs	Tallinn	54	25
Estonian Institute of Agrarian Eco-nomics	Ministry of Agriculture	Saku	21	15
Estonian Agrobiocentre	Ministry of Agriculture	Tartu	39	
Estonian Research Institute of Agri-culture	Ministry of Agriculture	Saku	69	34
Estonian Institute of Agriculturel En-gineering	Ministry of Agriculture	Saku	20	10
Jõgeva Plant Breeding Institute	Ministry of Agriculture	Jõgeva	117	22
Estonian Institute of Cardiology	Ministry of Social Affairs	Tallinn	32	23
Estonian Institute of Experimental & Clinical Medicine	Ministry of Social Affairs	Tallinn	129	61
34 Institutes	**10 administrators**	**9 location**	**2 777**	**1 057**

The 34 Estonian public research institutes employ together almost 2,800 persons. One third of them are researchers. High researcher concentrations are observed in the fields of agriculture, with 670 employees, and environment, with 680. A total of 560 persons work in research institutes under the Ministry of Education. Research institutes at the Tallinn Technical University employ a total of 400 persons, and the Institute of Physics at the University of Tartu 170 persons.

4. Evaluation of technology policy and its implementation

The Estonian national innovation system has a legal base and it also comprises many relevant actors that are needed in the system. The most concrete parts of the legal basis are the Organisation of Research and Development Act and the Estonian Science Foundation's Articles of Association. The most important actors are shown in Figure 3.1. In principle, the existing base is a good point to start from for developing the national innovation system. There is a lot of accumulated experience. It is on this base that the necessary reforms and corrections can and have to be done. Despite its legal base and relevant bodies, the national innovation system is not working properly. Here we assess the current state of the innovation system using a SWOT analysis framework. This analysis is based on the conclusions of the evaluator. Thereafter, we look at technology policy as a process - different activities in a process and the actors performing them. We also use more materials in this analysis, collected through interviews and the questionnaire. Some suggestions for improving the Estonian innovation system are suggested already here, but more detailed recommendations for improvements are presented in Chapter 7.

Current state of the Estonian innovation system

Weaknesses

The weaknesses can be grouped into four main groups:

1) low awareness, which can be seen as a lack of realised technology development needs in firms and an unwillingness among politicians to invest in technology development,
2) the low RTD funding level and serious deficiencies in practical funding,
3) over allocation towards basic research and sciences not related to technology and unsubstantial contact between research units and firms, and
4) poor functioning of technology policy management and non existing contacts to firms.

The recent history of Estonia still has strong effects on the Estonian innovation system. Estonian industries, educational and scientific systems, as well as the whole economy were built according to a Soviet planned economy. Soviet-era basic research and theoretical sciences in universities and institutes were very well developed. Most of the R&D activities were done in big institutes, not in enterprises, which were simply producers. Emphasis was placed in extensive theoretical work. Experimental R&D activities like testing, redesigning, demonstration with both producer and user, and continuous development based on customer feedback were not commonly employed practises.

Moving from the old innovation system to a new one is a slow process.

- Until now, many enterprises have not realised the importance of research and development. The number of research and development staff is modest even in the biggest firms. Representatives of the confederation of industries and employers emphasise that the word *innovation* may still have a bad reputation among the older generation of industrialists. During Soviet times they were determined outside the company or even outside the country and often implementation caused many negative side effects.

- The educational and scientific system - universities and research institutes - was well maintained in relative terms and respected. Transforming this to offset the needs of a market economy is an extremely slow process. Universities and research institutes maintain their positions through their lobbying activities and, in practice, function very autonomously.

To conclude, there is still a shadow of Soviet-era practises. The NIS places emphasis on the basic science side. Firms are still producers, not innovators. In addition to this, there are still quite weak connections between firms and universities, on the one hand, and research institutes, on the other hand.

The current situation of Estonian industries also diminishes the need for their own R&D work. There are a lot of firms doing subcontracting work for foreign firms. They produce products developed by their principal firms. Often, subcontractors manufacture products belonging to older product generations. This is why firms' personnel do not need to become familiar with the most modern R&D results. What subcontractors need, however, is to improve their production technology and productivity, because the main competitive factor is cost effectiveness. As a result of this, productivity has increased a lot in many branches of industry, which was verified in Chapter 2.

Another reason for the modest product development efforts is the production change occurring in product variants, where production is shifting from advanced products to less value-added products. Firms, which earlier produced electronics to meet the needs of the Soviet military sector, for example, or which imitated western consumer electronics, now are likely to produce metal parts and perform construction work. Former products are no longer able to compete, and the competence gap with respect to new products is too wide. In this case, producing low value-added products is one way to avoid bankruptcy or at least maintain employment levels.

New markets have opened up for many sectors, such as the wood industry. The strategy has simply been to utilise more actively the domestic raw-material base and enhance cost competitiveness by employing, for example, a cheap labour force. There has been no need to invent new products, but firms have raised quality levels by investing in new production technology.

In the future, the role of R&D in firms will rise. Subcontractors will want to develop their own products. There is a need to develop production technology further, and introduction of the newest production technology requires investment in R&D. Science-based firms and knowledge-based services are growing from their infant stages. This development greatly depends on public technology support.

Low technology development funding is one of the main weaknesses in Estonian NIS. In Chapter 7 we show this though international comparisons. We also suggest further development of funding. Low funding is a sign of politicians' low awareness about technology development as one of the major growth factors. This is perfectly understandable. There is no pressure from the industry side to encourage politicians to channel financing towards TD. The NIS, itself, has not supplied relevant information about the importance of TD for growth. As such, TD has been one of the easiest targets for budget cuts.

In company interviews some difficulties due to low financing emerged. Bigger firms with developed products think that the Innovation Foundation is so small that their single production development project would eat the whole budget. The Innovation Foundation might also have a reputation as being some kind of social worker for unprofitable firms, one that is not meant for profitable firms. Because of the low level of funding and the aim to help as many applicants as possible, requested financing is normally cut. Applicants cannot run their projects without additional financing. Often the decision process lasts too long. Thus, there might be a compulsory pause in a project lasting half a year. The results can even be opposite from those targeted. The public promise to fund technology development harms or slows down the technology development. Also, the collateral requirements of the IF loans was criticised. They tie up scarce collateral of start-up firms. Later, there is no collateral left for bank loans, which is needed for commercialising the innovation. There is an obvious need to also develop the technology financing products, not only to raise the amount of financing.

The basic research bias of the Estonian innovation system is obvious (see Chapters 2 and 6). In some potentially promising areas there must also be profound basic research in order to get internationally comparable results. Estonia has estimated that it has possibilities in the fields of biotechnology, information technology, materials science and environmental technology. In 1996 Centres for Strategic Competence were established for these fields. Many other countries also invest in these promising areas. Especially in the case of biotechnology, amounts invested are huge and industrial applications are employed only in the distant future and are uncertain. A more practical strategy for a small country with scarce resources might be to emphasise very practical scientific applications and try to solve the problems that arise from the technology development of industries. Along with the success of firms, there is also growing demand for basic research and theoretical scientific work, because without them further improvements are no longer possible. Existing demand and industrial customers as partners can also boost science.[5]

Looking at a list of research institutes and the number of their personnel and researchers (see Table 3.2), one might argue that there are good possibilities to develop a network of state research institutions, which can strongly support the development of industries. Institutes themselves could become or form science-based firms like Cybernetica Ltd. They could also sell their publicly subsidised services to the firms. There is a remarkable research institute concentration in the field of agriculture, for example, which could serve farming, food industry, and forestry and forest industry technologies. Similarly, environmental institutes could provide their services to several industrial sectors. This could be an element of cluster building, if developing industrial clusters suits Estonian industrial and competition policy. We estimate that in the longer run there is room for a state technical research centre or a network of technical institutions selling partially subsidised services, employing around 800 - 1000 persons, most of whom are researchers[6].

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[5] This has happened in many industries and sciences with respect to their products in Finland. The best examples are in mobile phones and telecommunication technologies, generally Nokia, which leads scientific development, and in forest industry technologies Metso corporation. In these areas Finland has the strongest patenting activities as well.

[6] The estimation is based on a comparison with Finland. The State Research Centre of Finland (VTT) employs 3000 persons.

Strengths

Institution building in Estonia is far more advanced than in the other Baltic countries. As mentioned earlier, a legal background exists as well as many necessary bodies. There are also many people within the system who are very familiar with technology policy issues and who have followed developments in the EU, OECD and their member countries. Nevertheless, if there is to be a notable rise in RTD investments, many new experts will be needed. Recent experts have come directly from universities or are working for them. Successful fulfilment of all the tasks also necessitates persons with an engineering background and experience from different industries. Persons working for technology leaders, in particular, could benefit the system a lot by working as a public officials.

In some areas of science there are serious ambitions to reach top international levels of education and research. An indicator of this is that the quality of graduated students and researchers has been so high that they have had the opportunity to continue their work abroad. Another sign is the relatively high level of participation in EU projects and financing through them. A third indicator is that they provide foreign companies and institutes subcontract services, such as research and testing. Biotechnology is one of these fields. Professor Williams and his team have managed to invest in new facilities and the most modern equipment thanks to foreign donators and customers who conduct their testing at Estonian Biocentre. To a certain extent, this centre is, in many ways, like an outstanding science-based company on an Estonian scale. Another promising area is information technology. Good solutions exist despite the relatively modest number of graduates. Information technology, especially Gybernetia Ltd., has benefited from state orders, when the state has invested in registers, identity cards and security systems. In fact, this is, again, an example of the importance of a customer who demands technology specifications, which in turn provides big challenges to the researchers and product developers.

A relatively more important strength thus far has been Estonia’s ability to attract foreign direct investments (see Chapter 2). Estonia has secured many new production technologies through these investments. Gradually, Estonian units will also be selected to perform product development and testing tasks. Here Elcoteq is a good example (see the case study below). So far, the main reason to invest in Estonia has been the cost-attractive business environment. This has also been the argument used by the Estonian Investment Agency. In order to attract high-tech firms, more tailored labour is needed and perhaps also more advanced premises. The Estonian Investment Agency plans to set up industrial parks. The EIA has also expressed that Estonia should establish a special institute for providing vocational education in computer sciences. The lack of experts has been a bottleneck.

Productivity improvements have been much more rapid in most Estonian industries than in developed western countries. This development is partly due to the introduction of new technology but also better organisation of work and higher capacity utilisation because of new markets. Productivity growth is also one of Estonia's future opportunities. Estonia's industrial policy options are illustrated in Table 4.1. Here it is important that productivity growth leads to salary increases. This is a way that allows for the possibility of conquering new markets and increase capacity at the same time. In the long run, better production technologies as well as new products give a competitive edge, which also makes it possible to raise salaries to the level of developed countries without a loss in world market shares.

Table 4.1: Favourable labour cost and technology combinations for Estonia

	Low tech		High tech
Expensive labour costs			Estonian long term target position
			↑
Cheep labour cost	Estonia's position in the beginning of transformation period	→	Estonian target position in medium term perspective

Case study

Elcoteq as technology transfer process

Elcoteq made its first green field investment in Estonia in 1993. Nowadays, Elcoteq Tallinn is the biggest production unit in the company's network with 2,400 employees. At first, the factory compiled electronic components. Today it also produces end products, packs them and sends them to customers. As a part of these activities it has to test products as well, which is a step towards R&D activities. Elcoteq Estonia has also started to repair broken products, which will raise its knowledge about the products. Because of their Russian language skills, experts at the Estonian factory were responsible for establishing a new factory in St. Petersburg, Russia. It was actually a technology transfer project from Estonian to Russia and meant a totally new kind activity for the company itself. So far, the Finnish Lohja unit of Elcoteq provides instructions on how to assemble new products. Clearly, it is only a question of time before Elcoteq Estonia enjoys a more independent and flexible role. Positive externalities will gradually emerge, such as subcontracting work for other companies. Perhaps several experienced persons, who currently work for Elcoteq, can start their own companies. Elcoteq Estonia has been very self-sufficient. It hasn't co-operated actively with the Estonian NIS, except to the extent that they have contacts to the Tallinn Technical University. Elcoteq Estonia is now interested in participating in the 5th framework program and in developing its functions together with other electronics contract manufacturers of the EU.

Threats

In small countries, the phenomenon of efficiency is often apparent because of good personal relationships. People know each other very well. Often they have studied in the same institutions and have later co-operated much in working life. Unfortunately, positive externalities can be easily offset by negative side effects. This can happen, for example, if a person acts as a high-level technology policy decision maker or an advisor, making concurrent RTD financing decisions, and at the same time holds a position in the firm, institute or university that is applying for financing. In less extreme cases, an organisation can have representatives at every level of the innovation system, but different people hold these positions.

In this evaluation we do not provide any detailed charts of these relationship and memberships of different persons. At any rate, it is obvious that certain concentrations have to break up. Otherwise, there is a danger that technology policy is kept in the hands of a closed circle and some degree of pie-sharing becomes a reality when it comes to financing.

- There is couple of good solutions for preventing this from occurring:
- Educate and recruit new experts to the system
- Ensure, at a personal level, that there are no concentrations of memberships
- Extend the right of financing decisions only to those persons who are state officials
- Have public audits and evaluations from time to time.

Increasing the number of wider-based company representatives in advisory positions could make the system more efficient in the long run. Finally, it is companies who are the most important customers and beneficiaries of the system and through whom also social benefits come from. Their views are important, and at the same time information networks are created through them.

Another threat of the innovation system is a paradoxical one. There is a TD financing system, which promises support for innovation activities and technology development. In practice, there is a very modest amount of financing available, and the Innovation Foundation works slowly and normally cuts funding amounts that applicants view as necessary in order to give something for everybody. As a result, there are time delays in projects and much work must be done later to organise the missing amount of financing. Gradually, the support system will no longer be regarded as a real option. The risky components of innovations, which could bring in the highest return, are not implemented, and in many cases innovators sell their innovations directly to foreign firms. This implies a waste of human capital and a deterioration of domestic growth potential.

A third obvious threat is that scarce money is invested in excessively ambitious projects in high-tech fashionable industries. In particular, this is a risk if it means neglecting the needs of nationally important "traditional" industries (see Chapter 2). A safe strategy could be to invest in practically oriented niches in high-tech industries and create connections between high-tech and traditional industries. Strong domestic industries – comprising close demanding customers -- could benefit a lot from research in high-tech areas. In the long run, lost investments can be recognised by looking at what happens to graduates and researchers. Are they gradually establishing firms or settling themselves in local firms in the field, or is the country continuously raising researchers and scientists for other countries?

Opportunities

The opportunities of the Estonian innovation system are very much connected to industrial policy. It is clear that technology policy has to be in line with industrial policy. Estonian industrial policy is taking shape from competitiveness policy, which is focused on the creation of favourable conditions in factor markets. By supporting framework conditions and advanced factors of production (i.e. R&D, innovation, education and technical infrastructure), the aim will be to create comparative advantages for the development of competitive industry sectors.

What are those competitive industry sectors? There are at least several possibilities to redirect research and technological development, which are listed below:

RTD investments could focus on strengthening those industries that are already apparently successful, such as the textile and clothing industries, wood industries and industries based on wood, like furniture production, food industry and chemical industries. Opportunities lie in the development of these so-called low-tech industries, high-tech niches and also in boosting cluster building, i.e. to develop supporting and related industries.

Many Estonian experts are of the opinion that Estonia is too small to provide a home base for industrial clusters, but share the opinion that it could be part of the strong industrial clusters of neighbouring countries, such as being part of the Swedish and Finnish telecommunications clusters. In fact, this is what is happening. The task of technology policy could be to help firms climb up the chain as subcontractors, producers and technology developers.

A third line could be that of Ireland and Israel, both of which started practically from the bottom. Both countries have managed to build up and attract a remarkable amount of high-tech production. Prime Minister's Advisor Linnar Viik suggested that Estonia learn from these countries' example. A good starting point is the existing knowledge-based firms and spin offs within and around leading universities. This policy requires that there are functioning support structures. Currently, the problem of innovation centres and science parks are that they cannot hire permanent experts because their basic financing is mostly on project bases.

Of course, in practice, demand is what has to steer a lot of technology financing. The Technology Agency must continuously supply information to technology policy officials based on applications: which branches they come from, what is the general content of applications, etc.

During their interviews, Finnish technology policy officials pointed out the importance of technology programmes. Estonia should start yearly one to three technology programmes, which concentrate on solving some problems or develop some areas of technology important to Estonia. The state and communities, with their demanding specifications, could be direct customers in some programmes. There are already good examples of single projects, like the lighthouse project of Gybernetica Ltd.

Fast productivity improvements provide an opportunity for Estonia. Here, the problem may rest in small and medium-sized companies. They lack investment capital, and leadership is struggling with day-to-day survival problems. There is room for a technology programme focusing on improving their production technology.

In the future there will be more cross-border technology development projects. So far, national technology agencies do not finance firms in other countries. A remarkable source of international financing is already possible through the EU. Currently, the Ministry of Education is responsible for most of the EU activities, for example the 5th framework programme. It would be reasonable to give responsibility for technology policy issues to the Ministry of Economy and advisory tasks and duties of promoting Estonian participation to the new Technology Agency. They will have more connections to firms, which must improve the efficiency of this financing.

Table 4.2: SWOT analysis of the Estonian innovation system

Strengths • Legal background exists • Many necessary bodies exist • NIS goes a step ahead of the other Baltic countries • In some areas of science serious ambitions to reach top international levels of education and research • Rapid technology transformation has started through FDI • Rapid productivity growth • Human resources with a comparative edge in quality/price ratio • Small-country efficiency in personal relationships	**Weakness** • NIS does not know enough about real customer needs • Politicians are not aware of the importance of RTD as tool for competitiveness • Total RTD financing is at a too low level and is even shrinking • Allocation between science and technology development is distorted • There are serious deficiencies in the TD financing: imperfect functioning of IF and lack of seed financing • Universities and research institutes don't work with companies •
Opportunities • Possibilities to co-operate with and acquire expertise and/or resources from the OECD, EU and neighbouring countries • Possibilities to keep up productivity and production technology improvements in firms • Join the strong industrial clusters of neighbouring countries with a chain “subcontractor, producer, technology developer” • Increase the practicality of RTD in co-operation between firms and universities and research institutes • Establishing research and knowledge based, intangible intensive firms • Government and communities boosting new technology as customers	**Threats** • Invest scarce money in too ambitious projects in "high tech fashionable" industries • Neglecting the needs of nationally important "traditional" industries • Going on with pie-sharing policy and preventing the old structure (universities and institutes) to change • Waste of human capital and deterioration of firms' growth potential because of the imperfect functioning of the NIS (poor TD financing and paralysed support structures) • Raise good researchers and scientist for other countries • Technology policy is kept in the hands of and as a hobby of a closed circle

Estonian Innovation Programme

The main policy document of the Estonian national innovation system is "Estonian State Innovation programme". It should form the base for the technology policy, i.e. it should give strategic policy targets and main guidelines for policy implementation.

The initiative of the programme was approved by the RDC already in October 1995. After two years of preparation, the programme was approved at the RDC session in May 1998. Finally, the Estonian State Innovation Programme for the years 1998 - 2000 was sent to the Government of the Republic, which approved it in June 1998.

The innovation programme was prepared by a prominent working group, which was headed by Prof. Rein Küttner. There were representatives from the Ministries of Economic Affairs, Finance, Agriculture and Transport and Communication, from Tallinn Technical University and the University of Tartu, Estonian Academy of Sciences and Estonian Chamber of Commerce and Industry. Representatives of the main branches of industry and many experts from two main universities and research institutes contributed to preparing the programme.

After reading carefully the programme and based on the interviews, the evaluation of the programme is the following:

1. In some respects, the programme is an impressive document. It can be seen that those who drew up the programme have gathered profound information about indicators describing the Estonian innovation system, about studies, resolutions and programmes made in the EU and forming relevant framework and support possibilities for Estonia, and evaluation of the situation of different industries.
2. There has been a lack of proper analysis, especially in regard to the real "customer needs" and capacity and performance of the supply side of the national innovation system. The basic material is presented in the programme, but probably a more fruitful approach would have been to provide the analysis and the programme itself in different documents. One could even say that there is a continuous need for this kind of analysis, which then could be used as a reference in political programmes like the Innovation Programme. This would have given more room and emphasis for the strategic part of the document.
3. Very unclear is what the real strategic targets are and the objectives needed to reach them. The problem is that there are huge lists of possible targets and objectives. No real priorities are set or they remain unclear to the reader. Selectivity and priority setting are essential in this kind of strategic document, especially taking into account the limited budgetary resources available for financing and implementation. Selectivity in target and objective setting would have also made the programme more valuable in the eyes of politicians. In its current format, it is more a list of optimistic hopes than a strategic document with clear essential targets based on strict analyses about the situation and well reasoned objectives to reach them.
4. The targets to increase and reallocate financing are very important elements of the programme. Planned technology development financing, in real terms, was 20 Mill. EEK in 1997, 30 in 1998, 50 in 1999, 100 in 2000, 140 in 2001 and 180 Mill. EEK in 2002. By the year 2002, real state budget appropriations for technological experimental development should be comparable to research finance in real terms (approximately 0,5% of gross domestic product). The real needs are

very good grounds for these financial targets and actually the targets are rather modest in international comparison.

5. A weak aspect of the programme regards its implementation. Politicians are not really tied to implementing the program. The management of the programme is also very weak. Politicians are obviously nonchalant. Even though the programme was approved at the government level, the financial backbone of the programme was broken by the Government's budget cutting in 1999. Politicians have not really committed themselves to managing technology development. This is partly because the recent management system has not delivered relevant information to them. According to the programme: "The management of the programme is organised by the Council of the Estonian Innovation Foundation that acts also as The Management Committee of the Programme. The Ministry of Economic Affairs is the managing ministry". It is obvious that the Innovation Foundation is an important link to implementing the programme, but it cannot bear the whole responsibility. It does not have the necessary authority for this nor does it link all the relevant officials and other players, and its financial and human capacity to manage the programme is too modest.

What are lessons to be learned from the programme, its' compiling and use?

First, there is not enough research on technology issues (technology needs, dissemination, transfer, technology anticipation, technology policy etc.). This is necessary for successful policy planning.

Secondly, there are still no functional planning and management systems. Ad hoc organisation resulted in the compilation of the programme and also its management, not the bodies actually meant to handle these duties (i.e. the RDC and its secretariat and the relevant ministries and their special bodies).

Thirdly, there is still no clear division between the different actors. The power of decision and planning and executive power is totally mixed. A sociologist might argue that there is a grapevine organisation beside and within the official organisation. This might be because of the small size of the country and the small number of experts available. More education on innovation system management is needed.

Fourth, politicians lack the commitment to advance technology development. Commitment can be established only by showing the importance of technology development to value added, increased exports, and job creation. Another necessary condition is that the most important targets including real funding, are set by the politicians themselves.

Finally, it seems obvious, if not certain by what was shown, that there is not enough knowledge and understanding about real customer needs in the Estonian national innovation system. A comprehensive inventory should be made on the competitiveness of different industries, the role of R&D in their competitiveness and the need to improve their R&D activities. More knowledge is also needed about the national innovation pattern. An examination is also needed of the areas in which basic and applied research is really conducted at the European or world level, and of the possibilities to commercialise their innovations.

While drawing up the Innovation Programme, strategic targets should have been set by Ministers (belonging to the RDC) and the Government, and discussed in parliament.[7] In phases where strategies are formed, it is politicians who are responsible for setting strategic goals. Of course, they should use the experts and relevant bodies of the Ministries as reinforcements.

Functioning of technology policy organisations

The functioning of policy organisations was studied through a formal questionnaire, which was later fulfilled by several interviews. Seven important organisations of the innovation system responded. Six of them are so-called bridging institutes and one is a knowledge-based company. All respondents are very familiar with the functioning of the national innovation system and have faced the problems of the system in their practical work. Here we have summarised the answers to how the Estonian technology policy organisations function and how the expert would like to improve the system.

Question: ***What would be the state's function in developing the innovation system (incl. supporting structures)?***

Answers were directed to the government, which clearly shows who has final responsibility for development. Here are some important points of view:

"Development of the national innovation system is absolutely presumed for raising Estonian competitive capacity and economic growth in a long-term perspective. Its development and strengthening should be one of the major priorities in Estonia."

"The Government should take a clear and direct political opinion (in a way that would not allow for amendments when the government changes) that supporting innovation and technology transfer, including relevant support systems, is one of the *long-term priorities.* The *specified action plan* should be compiled on the basis of actual priority activities and create a favourable background for them."

Respondents also presented practical tasks for the state, to be performed by different actors of the national innovation system. Later we will discuss more details about the tasks. Below is only a summary of them:

- To create favourable development conditions for science and knowledge-based companies
- To develop a network of support structures, especially infrastructure (scientific/technology parks, centres of innovation, incubation, entrepreneurship, technology, etc.)
- To raise the importance of applied and development activities while financing universities and science institutions

Low public financing of technology development as well as modest investments in companies and lack of private risk capital were identified as problems which the state should solve.

[7] At that time politicians were outsiders. Since the change of the cabinet there has been a strong opinion that this actually is the program of the former cabinet. That is why it is important to approve this kind of master plan either when the new government starts it work or discuss it openly and try to form widespread unity over party lines in parliament.

Question: ***Which institution's work should be improved? Is there any need for some specific institution not yet in existence?***

Most answers were concentrated on funding, directing of funding and functioning of funding organisations. Here are, again, some important viewpoints:

"At the present moment, the public financing rate for basic and applied research or development activities is 4:1. It should be the other way around - 1:4. The Science Competence Council and the Estonian Science Foundation are completely ignoring the necessary applied research and development work for Estonia; therefore, only basic research has been targeted for finance and given grants.

"Historically (conditions of SU), there is a very weak support structure for product development and technology transfer in Estonia. At the present moment, the universities and a few scientific and development institutions are not able to meet the relevant social demand. Therefore, development and public support for relevant support structures is extremely important."

The importance of the Innovation Foundation was acknowledged, because it is the only source of risk financing for technology development. At the same time its resources and functioning were severely criticised: "The state must increase IF financing by 4-8 times." "The Estonian Innovation Fund should work more efficiently. The establishment of the Estonian Innovation Agency is suggested." "Establishment of a public institution (for example TEKES) on technology development is necessary." "The Innovation Fund should function as a fund, not as a commercial bank." We will come back to the Innovation Foundation later in more detail.

Seed financing for start up companies, soft loans for small companies and support for patenting and other related costs were recognised as missing functions. Many also stress that there is no private risk financing. Here the evaluator has a different opinion. There are several foreign venture capital foundations for Estonia and the Baltic countries. The problem seems to be that they are not obtaining enough reliable information about Estonian high-tech companies and projects. In practice, venture capitalists are then investing their funds in traditional industries, which can actually guarantee rather high returns with low risk.

There was also a suggestion to use technology development to solve social problems. "Targets for the latter would be, in addition to supporting technology development, also applying the innovation system to solve socio-economic problems, which is important for Estonia (for example, the structural unemployment problem in Eastern Virumaa, unstable development of the regions, decreasing pollution in the environment). We should look up to the action principles of EU structural funds, where innovation is considered to be a very important measure for solving regional and structural problems."

Question: ***Your evaluation of the effectiveness of the following line and of the different parts of it: Research and Development Council – Ministry of Economic Affairs – National Innovation Program – Estonian Innovation Fund – target groups (enterprises, supporting structures, R&D institutions)***.

The general statement was that the links of the chain do not function together. "It does not seem to be exactly a chain." "Co-operation between the links of the chain is hard to describe. The chain is long and the feedback from the target groups to the Ministry of Economic Affairs and to the R&D Council is extremely insufficient." "The efficiency of links is low and their action, as a chain, is not provided." There was also a lack of information:" As a bystander, it is difficult to evaluate the efficiency of relationships between the RDC and the Ministry of Economic Affairs.

In what follows, we have collected respondents' opinions about different links of the RTD chain:

<u>Research and Development Council</u>

"The Research and Development Council is mainly an extension of the Ministry of Education. The Chairman of the RDC is the Prime Minister. Both vice-chairmen should not be the rectors of the two universities – TU and TTU. One of them should be a representative of enterprises. RDC does not deal with essential tasks, so efficiency is low."

"Probably the RDC has had its own role in recently reorganising Estonian scientific management, but development activities (and more specifically – innovation generally) have been under the attention of the RDC very episodically without involving people related to it and without considerable influence on everyday life."

"The main problem for the RDC is limited authority. This is the case of an advising body, where no one has an obligation to obey." However, the opposite view was also presented: “The Research and Development Council has been relatively effective."

<u>Ministry of Economic Affairs</u>

"The Ministry of Economic Affairs was more passive before, now it is effective." In interviews this change was connected to the establishment of a technology and innovation division and the activities run by it.

"There is no reason to criticise the attitude and the activities of the MoE. Some instability has probably proceeded from the recent change of Government, but now contacts are good and stable." On the other hand, a respondent complained: "There is almost no contact with the Ministry of Economic Affairs. It is difficult to give an evaluation.”

In the beginning of the year 2000 only three persons were working in the Technology and Innovation division. "The problem for the Ministry of Economic Affairs are the limited human resources in the given area."

<u>Innovation Foundation</u>

According to the respondents, the Innovation Foundation is fulfilling an important social task, but its resources are too small for accomplishing that: "The Innovation Foundation has been dealing with essential issues for years. It has been the only source for financing applied work. The financing volume of the fund has been disgracefully small; therefore, efficiency is low." "The Innovation Fund has limited fiscal and human resources."

There were several definitions of the tasks of the Innovation Foundation, hinting that this is a problem in practice. Here is one clear definition of the tasks of the Innovation Foundation:

- Support should mainly be used for the pre-production phase of product/technology development projects.

- Separate direction for development projects of other support institutions on stable and planned bases.
- Via the IF, the establishment of co-operation with private capital for risk capital funds is necessary.

Respondents were from the bridging or supporting organisations. Therefore, much stress was put on the relationship between the IF and supporting organisations: "Co-operation between the Innovation Foundation and the target group is inefficient due to the fact that the tasks of the Innovation Foundation and the target group and their functions are not clearly defined."

Respondents were from support organisations. They are dependent on the Innovation Foundation’s financing. They hoped for more stable support: "The state does not follow the financing plan of the Innovation Foundation. Supporting structures make their own plans on the basis of the planned means. If finances are suddenly cut, a big amount of the previous work that had been financed gradually acquires a value close to zero".

The Innovation Foundation has favoured loans when financing companies' projects. They also suggested many practical improvements to the terms of the loans. For start-up and small companies loans are problematic: "The Foundation gives loans. It considerably decreases possibilities to get additional loans from private enterprises because then the financial input of the company would get too high. Starting companies do not have the possibility to provide so much of their net worth as many of them are not ready to take on excessively high risks in the first stage. Considering the fact that IF demands 50 % of own financing, then it can be said that such a situation creates an offside situation in the company." "The Innovation Foundation must provide more subsidies than loans, because subsidies decrease the risks related with entrepreneurship and enable co-financing of private enterprises with a normal risk." "The requirement of 50 % co-financing should be dropped and a more flexible requirement should be established."

One respondent also had an idea of how to reorganise labour in financing: "Both the Science Competence Council (SCC) and the Estonian Science Foundation are completely ignoring the necessary applied research and development. Only the basic research has been target for finance and given grants." He suggests that the Ministry of Education and the SCC should manage the financing of science. The Innovation Foundation and Science Foundation could be integrated under the Ministry of Economy, and they could handle the financing of applied research and technology development.

One other proposition was made to increase public-private partnership in financing. "While the projects are approaching the commercialising stage, the sources of soft loans and capital investments (especially speed capital) should be made accessible to innovators. These are the sources that the IF should provide in co-operation with private capital (not pretending to be a bank or risk capital institution itself) on the principle of lending larger money with the help of smaller money. The Government should contribute to ensuring infrastructure (personnel training, equipment, etc.) of such financial instruments acting together with private capital."

Target groups: enterprises and bridging organisations

The state of R&D in enterprises was already described earlier. The results of the questionnaire confirm the conclusions. "The main problems for Estonian enterprises are the absence of innovative experience and limited fiscal resources." "The level of development work in enterprises is extremely low." "The problem for Estonia is not only a low budget for innovation development but also a percentage of private capital that is only 20-30%. It should be 60-70%." One respondent suggested: "There is a need for serious research on why companies do not invest in their development."

The limited resources of the Innovation Foundation prevent the extension of risk financing for companies. Also, individual experts working in firms seem to have similar difficulties. According to an interviewee, the Science Foundation provides grants only on the ground of articles published in international journals. Firms' experts seldom have time to prepare scientific articles, so their applications are ignored.

Respondents point out that it is extremely important to develop a public conception for financing the innovation support structures:

"The mentioned conception should be legalised at the highest public levels (Government, Parliament); and on this basis, a complete and functioning system of support structures for innovation should be created:

1) To compile a public innovation strategy and development program for innovation support structures.
2) To develop public measures for the innovation process support chain: science, bridge structures of innovation and entrepreneurship."

"After the determination of specific necessary support units, the Government should ensure a minimum amount to cover their upkeep costs in the case of centres without real estate and rent returns or a few larger investments to develop the entrepreneurial environment in cases when scientific/technology parks are based on real estate." This could be done directly from the public budget or through the IF on the grounds of competition."

"State and local governments must take the initiative in building the technology park. They are creators of social requests, and they have to take the risk related to starting and developing the technology park during the first five years. Later on, the technology park may be privatised. In innovation, the state should take the above average risk, meaning that the state should finance a part of the innovation activity related costs. In that case, private companies shall be ready to invest the rest of the necessary amount. In other words, the state must make the risk acceptable for private companies."

It was also hoped that "the government should especially look for a joint contribution with some potential financier. Such financiers could be "the EU and other international sources, local governments, private entrepreneurs."

There is also healthy self-criticism among support institutes. "A large number of models have been developed for the functions and support structures of innovation and technology transfer, institutions with quite abstract schemes and definitions. It seems like this complicated and multidiscipline area often gives an impression that there is no everyday activities requiring a professional approach beneath those abstract constructions. People seem to forget that the binding of science and entrepreneurship is happening here in actual time by determined people."

It is also very necessary to organise education and training for the personnel of support and bridging institutes. There is a very limited number of real experts, who manage enormous tasks. New experts, who also have business experience, are needed. One respondent suggested "public grants for training specialists of innovation support structures abroad."

Other suggestions

A couple of important suggestions on how to improve the Estonian innovation system, which have not yet been mentioned, were laid out in the answers to the questionnaire:

A lot of criticism was expressed about the National Innovation Programme (NIP), because there were no clear targets and priorities and the implementation part was, in practice, missing. Many respondents shared the opinion that the NIP should be inter-ministerial. There was a suggestion to develop new procedures for compiling national (between ministries) programs and management systems for them. The evaluator is of the opinion that it is the task of the Research and Development Council, wherein several ministries have representatives, as well as business and science expertise. This master plan should be discussed and approved in government, and finally in parliament, so that its financial background is also guaranteed.

Respondents also suggested round table meetings or working groups to discuss and solve practical questions. Here the Ministry of Economy, as a management ministry, has the leading role.

"The Ministry of Economy" should initiate a kind of a round-table meeting (regular or for topical discussions) for the representatives of those structures and relevant public officials, representatives of local governments and entrepreneurship organisations, etc. Such meetings could give an opportunity to clarify mutual duties, ideas and co-operation opportunities and get information or make proposals on subjects actually at the Government level (for example, the future of the Innovation Foundation and other funds, formation of public budget, EU programs, etc.).

5. Evaluation on Innovation Foundation

The Estonian Innovation Fund was originally established in 1991. The Estonian Innovation Foundation (articles of association) was approved with the Order of the Government of Republic No 725, 30 September 1997. The foundation is the legal successor of the Estonian Innovation Fund. According to the articles of the association, the tasks of the Innovation Foundation are the following:

Table 5.1: The Tasks of the Estonian Innovation Foundation

Tasks of the innovation Foundation are:

1) to organise competitions for development projects to increase competitiveness in the field of technology and production, to finance projects selected in such competitions, and to supervise the performance and analyse the results of such projects;
2) to plan and finance development programmes and projects in the field of production and technology;
3) to support the transfer of foreign and domestic know-how and technologies to the economy of Estonia;
4) to prepare draft laws (acts) and resolutions of the Government of the Republic concerning technological development and innovation, and to make proposals for the drawing up of the state budget as regards development activities;
5) to analyse and compile regular reviews concerning the technological competitiveness of the economy and the possibilities for its increasing;
6) to procure and disseminate information on international organisations and programmes pertaining to technology ;
7) to support the development of an infrastructure (support system) to support innovation;
8) to advise undertakings that launch projects in the field of technology;
9) to collect technical and technological information in conformity with the highest world standards, to prepare regular reviews on the basis thereof, and to make recommendations to undertakings for the development of new products and for the implementation of technologies.

Legal status of the Foundation

Legally, the foundation was and still is a private entity in law. The idea behind the privacy was to get private investors to join as co-financiers. In practice, however, the total funding comes from the state budget.

In interviews some interviewees expressed serious criticisms about the legal form of the Innovation Foundation. As a private entity it need not supply information about its activities. It is also out of the range of public evaluation and auditing practises. In practice, there has been a lack of transparency and the Innovation Foundation has not given very much information about itself, though nowadays it has become more open.

Privacy was also argued in order to attract private financing. This has not happened. It is unlikely also in the future, because no commercial investor is investing in this kind of function by definition. As part of the reform, it is sensible to establish the Technology Agency, which is a state institution or an organ, of which the state has full rights to control and from which to obtain necessary information on a regular basis.

Tasks of the foundation

Among the tasks of the innovation foundation (see Table 5.1) is to prepare draft laws (acts) and resolutions of the Government of the Republic concerning technical development and innovation, and to make proposals for the drawing up of the state budget as regards development activities

The above mentioned tasks cannot be tasks of the private foundation. They belong to relevant ministries, in this case to the Ministry of Economic Affairs, the Ministry of Education and the Ministry of Justice and in a certain degree to the Research and Development Council. It is partially understandable that these kinds of tasks were given to the Innovation fund, because state management was not so developed in the beginning of this decade. Currently, ministries are ready and far more capable to handle these tasks. In these tasks, they nevertheless need information, which the Innovation Foundation can collect through its own activities. This is one crucial reason why more transparency is needed.

Management of the foundation

The Innovation Foundation is led by the board. The board members are from the ministries, universities and business community. All the financing decisions are made in board meetings. Applications are also mostly and finally evaluated by the board members although the foundation has the right to hire experts for this purpose.

The main criticism against the recent practice is that some board members have conflicts of interests. On the other hand, they are decision-makers. Moreover, they come from the institutes and universities that are also active applicants. In these circumstances, it is questionable whether the financing is focused on the best projects and allocated according to some set strategic priorities. Many interviewees share the opinion that "the pie is divided between members", because this is a channel to acquire additional financing when budget limits are tight. For these reasons, it is absolutely necessary that those members of the board who have potentially conflicting interests do not take part at all in the evaluation of applications and in making the financing decisions.

The other question of principle is confidentiality. From the applicants' point of view, the contents of applications should absolutely be kept in secrecy, unless agreed otherwise. Otherwise, the foundation will never get the most promising projects, which in the worst case will remain without any financing. None of the interviewees, however, suspected that there have been information leakages so far. In the future, confidentiality rules should be included into the act of the Innovation Foundation. It is also reasonable to exclude other members than state officials from the funding decision making. Confidentiality is another reason why those members of the board who represent applicants or firms should not take part in the financing decision.

Administrative capacity of the Foundation

There are only three permanent officials in the Innovation Foundation: the chief executive, secretary and a specialist who prepares and evaluates the applications. Additional experts are also used for this purpose. In practice, the personnel carry out the following tasks: application process (collecting, preparing and partly evaluating the applications), implementing the financing decision including making agreements and following the progress of the projects via reports and back payments of loans. Part of the work is ad hoc in order to provide the information asked by state officials and board members. The foundation also maintains some contacts with the European Union and with corresponding organisations in some other countries.

What would be the optimum number and the quality of the personnel? The number of personnel and the human skills needed are the outcome of many factors:

- the volume of applications (number of applications and the sum of money requested) ,
- the quality of applications
- the dispersion of industries and sciences covered,
- size of risks of the projects,
- deliverable financing,
- number of and feature of financing products, and
- finally, what tasks the foundation really carries out.

We are ready to say that the number of personnel as well as the quality of the personnel should be higher if the necessary increase (see page x) of R&D financing is implemented. Taking into account the information needs and skills needed in this kind of risk financing the administrative costs could be 15 to 25 % of the total financing.

Financial instruments

Table 5.2: Funds of the Estonian Innovation Foundation and the Financing of the Projects (in Mill. EEK)

	Raised from the state	Loan repayments + interests	Total no. of financed projects	No. of new projects	Paid out as loans	Paid out as grants	Total
1991	0.7		29	29	0.2	0.3	0.5
1992	9.9	0.2	70	63	7.0	1.5	8.5
1993	25.0	1.0	38	33	25.9	1.3	27.2
1994	13.3	6.7	19	19	18.0	1.1	19.1
1995	13.3	10.4	43	42	18.3	3.8	22.1
1996	9.0	8.9	32	28	10.3	4.1	14.4
1997	20.0	10.4	51	43	4.8	15.7	20.4
1998	30.0	11.2	60	53	17.7	28.0	45.8
1999	15.1	3.4	31	24	6.8	13.2	20.0

In earlier years (1991-1995), loans were mostly given. Loans were very attractive as an instrument because general interest rates on bank loans were very high. Nowadays, the banking system is functioning rather well and the interest rate level has declined to near that of the innovation foundation. In 1996 and 1997, loan extensions were cut radically and the amount of grants started to increase. In the years 1998 and 1999, the innovation foundation has again started to prefer extending loans.

Concerning public technology risk financing, there are four major problems, which Estonia has to solve:

1) Low level of financing
2) Undeveloped financial instruments
3) Unpractical terms of financing
4) Problems connecting to funding decisions.

6. Evaluation of current Estonian RTD funding and a suggestion for further funding

Level of current funding

What is the optimal size of R&D funding for the nation? There is a clear positive correlation between per capita GDP and the share of research and development expenditure in GDP. Normally it is thought that causality goes from R&D investment to growth in GDP per capita. Of course, several preconditions and favourable environmental factors must exist before this will be reality. Often the results of R&D investments are visible only after years or even after tens of years. Nevertheless, the R&D share of GDP is an important parameter for the government to use to boost economic growth.

An other important issue is the content of R&D investments. One dimension is the distribution between public and private funding. Actually, the level of public funding is the parameter the government has at its disposal. The government can directly effect the size of total R&D spending. By employing different measures, the government can also activate and promote private funding and thus influence the level of private funding.

The growth point of view is that private R&D funding is essential because growth is finally realised through product and process development, sophisticated service concepts and technology transfer, which are often connected to fixed investments. R&D investment helps firms to make more value added products and to use production resources more effectively.

On the other hand, the pay-back time of business investment is very short and projects are very practical oriented. Also, firms normally cannot finance very risky projects. So, there is a clear task for public R&D investments. The government has to invest in long-term technology development projects, where also basic research is needed, and share the risks of most risky projects. Of course, the government has to take into account the possibilities of the private sector to later utilise the investments made. Public investment has to prepare and/or be in co-ordination with private investment.

There is also an argument that the size of the country, size of its market and production possibilities, has to be taken into account. Some say that it is not profitable for a small country to make big R&D investments because the benefits can easily flow abroad. According to another opinion regarding small export-oriented countries with small inner markets and poor natural resources or other inherited production factor, R&D investments are among the most necessary way to maintain the GDP growth. These opinions might represent the other side of the coin. For a small country it is of crucial importance to invest in technology development, but at the same time make sure that R&D investments are in line with the utilisation possibilities of the domestic firms. Technology transfer is normally the most profitable form of R&D investment for a small country.

The total R&D intensity in Estonia has declined slightly during the 1990s, being under 0,6 percent of GDP nowadays (Table 6.1). A noteworthy feature is very modest private R&D investment activity. In reality, its share is somewhat bigger. Investments made by business enterprises cover only those R&D investments made by companies whose main line of business is R&D activity.

In an international comparison, R&D intensity in Estonia lags considerably behind the respective indicator for developed European Union countries, whose weighted average of R&D investments were 2,1 per cent of GDP in 1995. Estonian R&D investments are also less than the average figures of the so-called EU cohesion countries (Ireland, Spain, Portugal and Greece). Their weighted average of R&D investment was 0,85 per cent of GNP. The OECD average was 2,17 %.

Table 6.1: Estonian Research and Development (R&D) financing by source of funds, % of the GDP

	1922	**1993**	**1994**	**1995**	**1995**	**1997**	**1998**
State	0,67	0,45	0,54	0,44	0,41	0,4	
Business Enterprises	0,02	0,09	0,07	0,08	0,06	0,05	
Foreign Capital	0,07	0,02	0,05	0,06	0,06	0,08	
Other Sources	0,00	0,05	0,05	0,04	0,05	0,06	
Total, % of the GDP	**0,76**	**0,59**	**0,72**	**0,62**	**0,57**	**0,58**	

Table 6.3 clearly shows the Estonian position compared to other countries. The only countries to experience R&D investments as low as those of Estonia are Portugal, Greece, Turkey, Mexico, and the other Baltic States of Latvia and Lithuania. The share of public R&D in Estonia is the highest among the listed countries. Correspondingly, the share of private R&D is the lowest.

The Table 6.3 also presents calculated unweighted averages of the different country groups. These figures are smaller than the weighted averages. This shows that big countries with high levels of GDP are investing relatively more in R&D than small countries. Within developed EU countries, some small countries like Sweden and Finland are also trusting in technology development as a source of economic growth.

An interesting result in Table 6.3 is that in country groups EU10, EU4 and Other OECD countries there seems to be nearly the same average ratio between public and private R&D investments. The public sector takes care of 38-40 percent of investments and the private sector 62-60 per cent. There has to be some optimum combination of financing, which gives the best return on total financing.

In Finland, technology policy officials are of the opinion that the government should take care of at least 30 per cent of total financing, since it is able to run longer term projects and also take relatively bigger risks in unknown technology areas. These are necessary preparations for more business-oriented R&D later on. Without this kind of patient and risk-loving public R&D financing, future R&D utilisation possibilities would be smaller.

It is not only the size of private and public financing and their ratio that matter. Just as relevant are the investment targets. Estonian R&D financing is oriented strongly toward basic research. Applied research and especially experimental development is in an infant stage of development (Table 6.2). The development is, however, towards more practical business-oriented research.

Table 6.2: R&D expenditures by kind of R&D activity in 1992 - 1997, % of total expenditures

	1992	1993	1994	1995	1996	1997	1998
Basic research	79,4	61,7	56,0	52,7	56,3	49,5	
Applied Research	18,8	29,8	39,5	35,5	30,2	37,2	
Experimental Development	1,8	8,5	7,5	11,8	13,5	13,3	

Table 6.3: Research and Development Funding in Different Countries and Country Groups in 1995

	Total R&D % of GDP	Public R&D % of GDP	Private R&D % of GDP	Share of Public Funding	Share of Private Funding	Current R&D % ofGDP	Year
Sweden	3.6	1.0	2.6	28 %	72 %	3.6	1997
Germany	2.3	0.8	1.5	35 %	65 %	2.4	1998
France	2.3	1.0	1.3	43 %	57 %	2.3	1997
Finland	2.3	0.9	1.4	39 %	61 %	3.0	1998
United Kingdom	2.1	0.7	1.4	33 %	67 %	1.9	1997
Netherlands	2	0.9	1.1	45 %	55 %		
Denmark	1.8	0.7	1.1	39 %	61 %	2.1	1998
Belgium	1.6	0.5	1.1	31 %	69 %		
Austria	1.5	0.8	0.7	53 %	47 %	1.6	1998
Italy	1.1	0.5	0.6	45 %	55 %		
EU10	**2.06**	**0.78**	**1.28**	**37.9 %**	**62.1 %**		
Ireland	1.4	0.3	1.1	21 %	79 %		
Spain	0.9	0.4	0.5	44 %	56 %		
Portugal	0.6	0.4	0.2	67 %	33 %		
Greece	0.5	0.2	0.3	40 %	60 %		
EU4	**0.85**	**0.33**	**0.53**	**38.2 %**	**61.8 %**		
EU	**1.71**	**0.65**	**1.06**	**37.9 %**	**62.1 %**		
Japan	2.8	0.6	2.2	21 %	79 %	2.9	1997
Switzerland	2.7	0.8	1.9	30 %	70 %		
Korea	2.7	..	..	..	..		
USA	2.6	0.9	1.7	35 %	65 %	2.6	1997
Norway	1.7	0.8	0.9	47 %	53 %	1.6	1997
Canada	1.7	0.6	1.1	35 %	65 %	1.6	1998
Australia	1.6	0.8	0.8	50 %	50 %		
Iceland	1.5	0.9	0.6	60 %	40 %		
New Zealand	1.0	0.6	0.4	60 %	40 %		
Turkey	0.4	0.2	0.2	50 %	50 %		
Mexico	0.3	0.2	0.2	67 %	33 %		
Other OECD	**1.63**	**0.64**	**1.00**	**39.02 %**	**60.98 %**		
Slovenia	1.6	0.8	0.9	47 %	53 %		
Czech Republic	1.2	0.4	0.8	33 %	67 %		
Slovakia	1.0	0.4	0.6	39 %	61 %		
Hungary	0.9	0.4	0.5	48 %	52 %		
Poland	0.7	0.4	0.3	61 %	39 %		
Romania	0.7	0.4	0.2	63 %	37 %		
Estonia	***0.6***	***0.4***	***0.2***	***71 %***	***29 %***	***0.6***	***1997***
Latvia	0.5	0.3	0.2	53 %	47 %		
Lithuania	0.5	0.3	0.2	69 %	31 %		
CEEC	**0.86**	**0.43**	**0.43**	**50.24 %**	**49.76 %**		

An obvious reason for the basic research orientation is that most of the financing still goes to universities and research institutes, which still do not have very clear links with firms. There is a need to channel more financing through the business sector to these institutes and to make a bigger part of their financing on a competitive basis so that a criterion for financing projects is the usefulness of the results.

A Target for Further Estonian R&D Financing

Table 6.4 presents Estonian R&D financing and its share of GDP in dynamic terms. Estonian research and development expenditure has increased remarkably at current prices. At constant prices, real expenditure has decreased rather than increase during this decade. Especially purchasing power has decreased a lot, taking into account the rise in living costs, which creates pressure to raise the salary level of the personnel.

Table 6.4 displays the target for the GDP share of Estonian total R&D investment. In 2002 the share is set to 1,2 % of GDP, according to the national development strategy. There is a further target to raise the share to 2.2 %, which was the level of developed EU countries in 1995. The idea behind this is that Estonian growth possibilities strongly depend on research and development and upgrading of human skills, because Estonia does not have many other competitiveness factors (big home markets, rich natural resources, strong traditional production chains, etc.)

We have made a reasonable projection that Estonian average annual GDP growth could be 4,5 % during the next decade. According to the targets, there will be a remarkable increase in R&D investments in the early years of the next decade, followed in the latter part by a slowdown in the annual rate of increase to 10 per cent. Of most importance is to reorganise technology development financing and to set up the Technology Agency. That is the main reason for the big steps in financing growth in the beginning of decade. At the same time, there is also room for a warning - proposed growth in financing demands highly qualified personnel to handle activities in the Technology Agency and well prepared plans for financing. Otherwise, there is a danger of ineffectiveness.

What could be the optimum relationship between private and public R&D investment? Table 6.5 provides a suggestion. According to this suggestion, the government share will first even grow. This is because of the start-up of the Technology Agency and the need to have good catalysts - like technology programs - to activate private sector investments. Later, there is a targeted rapid decrease in government financing to 40 per cent once other forms of financing have started to accelerate, including foreign technology-oriented investments. The grounds for a 40/60 % target for the investment ratio between public and private investments comes from the recent international practice. It could be that a decade is too short of a time to reach that ambitious target. Responsible officials have to be able to innovate financing measures, which have an increasingly stronger catalyst effect on private investments.

A source of needed public R&D financing could be the EU. Would it be reasonable to set up a target for membership negotiations to get support for technology development and even some lump sum for basic capital of the Technology Agency? This target to improve the competitiveness of Estonian industries through technology development could probably get a positive response from the EU side, a response that is more positive than that resulting from direct support to firms and industries in difficulties.

Table 6.4: Estonian R&D Investments and a Target for Future Growth

Year	**GDP at current prices**	**GDP at constant 1998 prices**	**Real GDP Growth**	**R&D % of GDP**	**R&D at current prices**	**R&D at constant 1998 prices**	**Real Annual Growth of R&D**
1992	13 054	65 384	-14.2 %	**0.76 %**	99	***497***	
1993	21 918	59 827	-8.5 %	**0.59 %**	129	***353***	-29.0 %
1994	30 268	58 750	-1.8 %	**0.72 %**	218	***423***	19.8 %
1995	40 705	61 217	4.2 %	**0.62 %**	252	***380***	-10.3 %
1996	52 446	63 612	4.0 %	**0.57 %**	299	***363***	-4.5 %
1997	64 324	70 367	11.4 %	**0.58 %**	373	***408***	12.6 %
1998	73 213	73 213	4.0 %	**0.58 %**	425	***425***	4.0 %
1999		73 213	0.0 %	**0.58 %**		***425***	0.0 %
2000		75 776	3.5 %	**0.58 %**		***440***	3.5 %
2001		79 565	5.0 %	**0.90 %**		***716***	62.9 %
2002		83 145	4.5 %	**1.20 %**		***998***	39.3 %
2003		86 887	4.5 %	**1.40 %**		***1 216***	21.9 %
2004		90 796	4.5 %	**1.60 %**		***1 453***	19.4 %
2005		94 882	4.5 %	**1.70 %**		***1 613***	11.0 %
2006		99 152	4.5 %	**1.80 %**		***1 785***	10.6 %
2007		103 614	4.5 %	**1.90 %**		***1 969***	10.3 %
2008		108 277	4.5 %	**2.00 %**		***2 166***	10.0 %
2009		113 149	4.5 %	**2.10 %**		***2 376***	9.7 %
2010		118 241	4.5 %	**2.20 %**		***2 601***	9.5 %

Table 6.5: Estonian Public and Private R&D Funding and a Suggestion for its Future Development, Mill. EKK

Year	**R&D at constant 1998 prices**	**Share of Govern-ment fi-nancing**	**Share of other fi-nancing**	**Government financing at 1998 prices**	**Other fi-nancing at 1998 prices**	**Govern-ment fi-nancing, % of GDP**	**Other fi-nancing, % of GDP**
1992	497	**88 %**	12 %	***438***	59	0.67 %	0.09 %
1993	353	**76 %**	24 %	***269***	84	0.45 %	0.14 %
1994	423	**75 %**	25 %	***317***	106	0.54 %	0.18 %
1995	380	**71 %**	29 %	***269***	110	0.44 %	0.18 %
1996	363	**72 %**	28 %	***261***	102	0.41 %	0.16 %
1997	408	**69 %**	31 %	***281***	127	0.40 %	0.18 %
1998	425	**69 %**	31 %	***293***	132		
1999	425	**69 %**	31 %	***293***	132		
2000	440	**69 %**	31 %	***303***	136		
2001	716	**80 %**	20 %	***573***	143		
2002	998	**80 %**	20 %	***798***	200		
2003	1 216	**75 %**	25 %	***912***	304		
2004	1 453	**70 %**	30 %	***1017***	436		
2005	1 613	**65 %**	35 %	***1048***	565		
2006	1 785	**60 %**	40 %	***1071***	714		
2007	1 969	**55 %**	45 %	***1083***	886		
2008	2 166	**50 %**	50 %	***1083***	1083		
2009	2 376	**45 %**	55 %	***1069***	1307		
2010	2 601	**40 %**	60 %	***1041***	1561		

7. Recommendations for improvements of the Estonian innovation system

Recommendations for system Improvements

Parliament: The Parliament should be committed to developing the innovation capacity of Estonia and the technological level of its industries. There should be a high level strategic master plan discussed and approved by the parliament for its working period. The plan has to include targets for the R&D financing. The government should give the parliament a yearly special report containing the activities done, the achievements and possible problems and further activities for fulfilling the plan.

Government: The government is in key position in systematic development of innovation system and technology development. The Government has, of course, to take into account all of the relevant factors affecting its decisions - not only the needs of the NIS. It is the task of the RDC and relevant ministries to offer enough and accurate information about the importance and the effects of RTD on the competitiveness of industries and the national welfare. Only by using sustainable reality-based arguments can it be possible for the NIS resource needs be fulfilled. This is the only way to get the government to make positive budget-proposals, which are on line with the development targets, to the parliament.

Research and Development Council: The status of the council is high enough. However, a lot has to be done to improve its activities. Here are the necessary improvements:

- *Better organisation of work:* The council has to make a work plan for the beginning year. In addition to general meetings, the RDC should work in two chambers: the chamber of science (headed by the Minister of Education) and chamber of technology development (headed by the Minister of Economy). This will raise the status of technology development.
- *Preparation work has to strengthen:* There should be a secretary for the science and one for the technology development. The technology secretary should physically work in the Ministry of Economic Affairs but as an independent official under the RDC (Prime Minister's office). This would improve information change and provide the necessary know-how and preparatory help to be used by the RDC. At the same time, the secretary remains as a real secretary of the council, not an "agent" of the Ministry of Economic Affairs.
- *Transparency, regular reporting and more information:* The RDC should give some systematic reports, which guarantee the information flow. A yearly progress report, which the government would then give to parliament, is a minimum. Every three years the RDC could prepare a strategic report about a nationally important theme, which opens new paths and directs future development. RDC decisions should be made public. Better information to responsible ministries and their officials is needed. Key officials from the MoE and the MoEd have to have the right to be present, because the discussions of the RDC gives necessary background for their work and also helps them to supply relevant information to the council.

Ministry of Economic Affairs: One of the main development matters of the Estonian national innovation system is its management. There is a short management tradition, not defined work orders and practices, and still too few personnel. The Ministry of Economy and its Division of Technology and Innovation have to have clearly defined tasks as well as the legal power and the human resources to fulfil them. A general outline of the definition of the tasks of the MoE's Technology and Innovation Division could be the following:

- To anticipate technology development
- To plan and prepare the technology policy
- To manage the technology development including its financing
- Handle international co-operation in the field of technology policy and to prepare the multilateral and bilateral technology programmes.

The Technology Agency is the most important tool of the ministry in its mission. It is also the most important source of information for the ministry. The TA can collect through its day-to-day connections to the applicants - firms, universities, research institutes, science parks – a lot of necessary information, which the ministry cannot obtain by itself but which is important to it for policy planning.

In Estonia as well as in other transforming economies quality issues and standards are seen as a means to achieve the acceptable technological and quality level. In the future, quality requirements and standards will increasingly be the tools of technology development. That is why the Quality and Standards Division should be linked tightly to the work of the Technology and Innovation Division.

In order to develop technology policy – the positive social effects of the innovation system, the functioning of policy processes and structures and effectiveness of technology policy administration – the MoE has to define critical success factors and criteria with which to assess the achievements.

Table 7.1 presents a list of rather universally used success factors for technology policy and their assessment criteria.[8] We suggest that the MoE and their experts further develop these strategic factors and criteria so that they fit the recent Estonian situation. These success factors and criteria are operational policy tools if used systematically.

8 The list was originally developed in the strategy work of the Finnish technology policy officials and later modified by us, but as mentioned, basically, the factors and criteria are rather universally used in developed countries

Table 7.1. Critical Success Factors and Criteria to Assess Technology Policy

Critical success factors	*Criteria with which to assess achievements*
Positive social effects	
The effectiveness of the innovation system	• Number of high competence firms and those that are newly created and dissolved • Number of high competence jobs/expert jobs • The industrial structure: shares of technology intensive industries and knowledge intensive business services • Number of domestic patent applications and domestic/foreign ratio
Public R&D efforts	• The share of R&D in GDP • The share of public R&D in GDP and public/private R&D ratio • R&D by industry, R&D by region
Quality-based competitiveness including quality-enhancement policy	• The average of points received in the Estonian Quality Point (EQP) competition and number of participants in the EQP competition • Client satisfaction in different branches (evaluation model) • Certification, Accreditation
Competence-based competitiveness on an international scale	• The total number of R&D jobs • High-tech exports/total exports, the kilo price of exports • The number of Estonian patent applications made abroad • Exports of competence-intensive services
International competitiveness of technical regulation and safety systems	• Evaluation of the systems • The extent of international standardisation • Corporate emphasis on standards • Safety level: 1) the number of deaths, 2) the number of accidents • The reduction of technical barriers to trade
Favourableness of technology	• Employment, environmental, ethical and other effects
Functional processes and structures	
Allocation of public R&D efforts	• The optimal distribution of R&D efforts • The shares of demanded technologies (computer, information, bio)
The efficiency and compatibility of the innovation system	1. Co-operation and networking 2. The service ability of the public innovation system 3. National technology programs 4. Participants in the technology programs 5. External funding of the research institutes
International co-operation to obtain critical staff and added value	• The number of persons participating in EU research programs • International co-operative projects undertaken by research centres • The share of international co-operative projects in the Technology Agency's funding
International competitiveness of technical regulation and safety systems	• Participation in international contractual agreements • Execution of international regulations and their development • Success in international comparisons
Administrative effectiveness	• Development of indicators • Functionality of administrative practice chosen to get results
Effective resource management	
The allocation of public R&D efforts	• Eliminate bottlenecks • Optimal allocation of own resources • Benefiting from R&D efforts in all industries
Sufficiency and quality of human resources in R&D administration and in R&D activities	• Number of researchers and their education (field, level) • Matching of public R&D resources to technology policy targets • The number of international researchers and research experts • "Quality" of staff in the MoE, TA and bridging institutes
The activating effects of funding	• R&D projects initiated by the private sector • Joint projects and programs with other funding institutions

Technology Agency: The TA should be the body offering technology risk financing for product development and improvement of production technology (including technology transfer) and the applied research necessary for them. The main target groups should be the firms and research institutes and facility and knowledge suppliers (science parks and technology centres etc.).

The TA has to be the public body working under the management of the Ministry of Economy. The level of yearly financing must be raised remarkably. The amount of personnel should be bigger and their quality high by international standards, and facilities should be better.

The TA should have the following strategic targets:

- There should be real-based priorities like strengthening the important recent and rising future industries of Estonia by improving their production technologies, developing their products and promoting their positive effects to the supporting and related branches (cluster building).
- Annually, there should be initiated from one to three technology programs in nationally important and promising areas. Technology programmes can open new areas for business. The government and public bodies can also, as an early customer, boost the emerging businesses in these areas.
- Financing should be a way to build ties between firms and, on the other hand, between firms and universities and research institutes. This can be done by requiring, for example, big firms to have a small company as a partner or that universities and research institutes also have firms as paying customers, who will handle part of the financing.
- Financing is one link in the chain of RDDC (Research, Development, Demonstration and Commercialisation). All the links should support each other. Also, demonstration financing is needed, for example, the state can carry part of the risks of first customers. The Export Agency can provide assistance in opening international markets for the products.
- Public R&D financing should act as a catalyst, which attracts firms to invest more and more of their own money in R&D activities. In the long run, the private sector should pay 60 – 70 per cent of the costs. However public financing is needed because demands for short reimbursement times prohibits firms from starting long-term projects. State money spawns new areas for later business.
- There is also a need to increase the competitive part of <u>RTD</u> financing instead of delivering guaranteed financing to the very same institutions each year. Competition improves the efficiency and flexibility of the whole system and also provides more innovations. Financing criteria are practical tools with which to manage the system. This is for example the way to increase co-operation between the state institutions (universities, research institutions) and the firms.

The TA should have solid processes:

- *Information process*: Promotion of products and services, presentation of the results (effects and examples), information collection, processing and dissemination for the purpose of NIS management and statistics are an essential part of the work of the TA.

- *Application process:* Application forms should be standardised and computerised. It is also necessary to provide help for applicants in the application process and sometimes even in project management. Even additional experts from special areas could be used for project evaluation. The TA, itself, should have a good expertise in this. This is to ensure the objectivity of financing and because of maximum confidentially. There have to be quick response times and fast handling time targets. Otherwise, the TA will harm the projects in practice.

- *Transparent management and fair financing decision making:* Smaller financial decisions could be made by delegated managers only, while decisions concerning principle and big projects should go to those members of the board who don't have conflicts of interest and who have the legally prescribed responsibility to maintain confidentiality. There should be published criteria for the financing. (Criteria can be, for example, that the project improves the profitability of the company, and that it represents new technology or at least the advanced technology compared to the recent one used in the industry etc.). Clear criteria are also good guidelines to the applicants.

- *Regular evaluation process:* From time to time, there has to be an evaluation of the TA: What is the effectiveness and expertise of the TA management and personnel? What are the effects of TA financing on the competitiveness of firms (growth, export success etc.) and the quality and the number of employed persons (high-tech jobs)? How well is the TA offsetting the needs of demand?

- *The confidentiality of the TA:* The Technology Agency should maintain absolute confidentiality. It is the partner for applicants in their high technology projects. If there is no guarantee about confidentiality, then there is a danger that, in the worst case, the best project remains without financing or the idea is sold abroad.

Seed financing for start-ups: In Estonia, there are no institutions and instruments for financing new start-ups. There is a clear social need for a new body for seed financing or an additional task for the TA has to be given. In the Estonian case, seed financing could be part of the TA in order to avoid extra administrative costs and to utilise the scare expert resources better. Both also produce valuable information for each other, which can be used if there are no confidentiality barriers.

Venture capital: According to interviewees, there is enough venture capital available from abroad. So there is no need to invest scarce state resources in that. Unfortunately, foreign venture capital financing is now channelled into traditional "low-tech" industries. More information about firms and their new technology projects are needed for managed risk taking. This could be an additional task for the Investment Agency.

Implementation plan

We are suggesting that if the recommendations are put into practice, the implementation plan contain at least the following issues:

- The Parliament’s master plan for Research and Technology Development
- The RTD financial scheme
- Forming the Technology Agency

- First act to start the real TD finance: pro-technology program etc.
- Education of personnel

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8. Concluding remarks

Estonia has a very liberal economic policy. Firms have had a rather high level of freedom to operate within an environment of fair competition. Labour costs have been low compared to education and skills. Actually, very many other types of costs have also remained at reasonable levels compared to those in high-cost northern countries or CIS countries, where unit costs are low but general inefficiency raises total costs remarkably. A liberal and cost effective business environment, and the proximity of CIS markets, has attracted a lot of foreign capital.

However, success based on low costs cannot last long. The salary level has risen and will rise rapidly in the future. As part of the European Union integration process, there will also be some kind of catching-up process in salaries because of free labour movements. Estonia finds itself at a crossroad. The country really has to start to invest in research and technological development that will benefit firms.

There are three preconditions that will make it possible to implement bigger and more effective investments in research and technological development in Estonia:

1. Politics have to realise the importance of RTD investments and the key role of the government in boosting these investments. The government is a superior risk taker while developing the new technology and technology-based firms. Initially, large public investment is needed. Later, when private R&D investments start to grow, public sector investments will be more catalyst in nature.
2. Extensive education of officials and experts is needed. The whole system needs them: Firms need experts to run R&D projects. More experts are needed for preparing and implementing technology policy. In particular, new staff is necessary for fulfilling the new and increasing tasks of the Technology Agency. Also, there is a lot unfinished work in support structures. The education program should start immediately, along with co-operation with policy officials, main universities and the European Union.
3. Awareness that R&D is one of the most important growth factors has to rise among business leaders and in entrepreneurial organisations. High-profile public technology policy, pioneering technology programs with proven results, and publicity attributed to the successful product development of firms are good first-hand measures. In the long run, there should be more stress on R&D issues in vocational and higher education.

In the National Development Plan, the Ministry of Economic Affairs has set a target to increase Estonian RTD financing to 1.2 per cent of GDP in year 2002. The most important reform is to set up a Technology Agency, with modern financing instruments and clear strategic targets to follow. It should have enough high-qualified personnel, appropriate premises and a good network. On a principal level it is the technical development that needs more financing not the science. There is even need to re-orient scientists from basic research to practical applied research and even for them to participate in the technical development. This can be made possible by increasing the level of competitive-based financing and with financing of joint projects between firms and public research units.

Science parks and innovation centres are important incubators for science and knowledge-based firms. It is high time to start giving them permanent financing to cover salary costs instead of project financing.

Resources tied to state research institutes are a huge, but very difficult to utilise, potential for Estonia. There is reason to conduct a good evaluation about the strengths of institutes and their optimal placement in the Estonian innovation system. Probably no simple solutions exist, but, rather, there will be different solutions depending on the institution. Some institutions could still be part of universities, if they mainly conduct basic research, or work under the ministries, if they have a clear social mission. Some could be private units or even companies, or their personnel could become part of firms R&D departments. Some could form a new state technical research centre that sells partly subsidised R&D services to companies.

Estonia is going to join the European Union along with two other Baltic states. They all have similarities with respect to their competitive edge. In this situation, it is their own policy measures, which can make them different and more competitive than the others. One measure, which is highly respected within the member states of the European Union, is investment in research and technological development. It could even be possible to get essential extra financing for this purpose to offset the possible negative impact of membership and to improve the competitiveness of Estonian industries for new common markets.

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Appendix A. Council and Board Members of Estonian NIS Organisations

Members of R&D Council

Mart Laar, Chairman	Prime Minister
Tõnis Lukas	Minister of Education
Mihkel Pärnoja	Minister of Economic Affair
Siim Kallas	Minister of Finance
Signe Kivi	Minister of Culture
Heiki Kranich	Minister of Environment
Aino Lepik von Wiren	State Secretary
Olav Aarna	Vice Chairman, Rector of the Tallinn Technical University
Jaak Aaviksoo	Vice Chairman, Rector of the University of Tartu
Mait Arvisto	Rector of the Tallinn University of Educational Sciences
Enn Helmet	Rector of the Estonian Agricultural University
Jüri Engelbrecht	President of Estonian Academy of Science
Ene Ergma	Chairman of the Council of the Estonian Science Foundation
Mati Heidmets	Professor of the Tallinn University of Pedagogical Science
Ülo Jaaksoo	Chairman of Cybernetica Ltd, private R&D company
Ain-Elmar Kaasik	Professor of the University of Tartu
Jüri Käo	Chairman of Estonian Central Union of the Employers and Industry
Olav Kärt	Director of the Institute on Animal Husbandry of the Estonian Agricultural University
Rein Küttner	Vice Chairman of the Innovation Foundation
Peeter Lõhmus	Vice President of Bank of Estonia
Mart Meri	Chairman of Parliament's Cultural Affairs Committee
Ilmar Petersen	General Director of Elcoteq Tallinn
Richard Villems	Director of Estonian Biocentre

Members of Innovation Foundation Board

Arvi Hamburg	Ministry of Economic Affairs; Chancellor
Rein Küttner	Tallinn Technical University, prorector
Ants Laansalu	Development Advisor, Ministry of Agriculture
Margus Leivo	Ministry of Economic Affairs
Ele Evaraus	R&D prorector, Tartu University
Meelis Pihel	
Rein Ratas	Ministry of Environments, Chancellor
Oleg Epner	Ministry of Economic Affairs
Andres Sarri	President of Eesti Talleks Ltd
Boris Tamm	Professor, Cybernetica Ltd
Eero Vaarmann	Ministry of Defence, Chancellor

Members of Council of the Estonian Science Foundation

Olav Aarna	Rector of the Tallinn Technical University
Ene Ergma	Professor of University of Tartu, Chairman of Expert Commission for Exact Sciences
Hele Everaus	Prorector of University of Tartu
Andres Koppel	Prorector of the Estonian Agricultural University
Ilmar Koppel	Professor of University of Tartu, Chairman of Expert Commission for Chemistry and Molecular Biology
Arvo Krikmann	Senior Research Scientist of the Institute of Estonian Language, Chairman of Expert Commission for Humanities
Olevi Kull	Head of Department of the Institute of Ecology, at Tallinn Pedagogical University, Chairman of Expert Commission for Geo- and Biosciences
Väino Puura	Professor of University of Tartu, representative of the Estonian Association of Scientists
Boris Tamm	Professor, Cybernetica Ltd., Chairman of Expert Commission for Engineering
Arvo Tikk	Professor emeritus of University of Tartu, Chairman of Expert Commission for Medical Sciences
Harald Tikk	Professor of the Estonian Agricultural University, Chairman of Expert Commission for Agricultural Sciences
Maie Toimet	Representative of Ministry of Education
Mihkel Veiderma	Vice President of the Estonian Academy of Sciences
Vello Vensel	Professor of the Tallinn Technical University, Chairman of Expert Commission for Social Sciences

Appendix B: Universities and Research Institutions Under Universities and Ministries

Public universities and their research institutes

University of Tartu
- TU Institute of Physics

Tallinn Technical University
- TTU Estonian Institute of Economics
- TTU Institute of Geology
- TTU Institute of Chemistry
- TTU Institute of Cybernetics
- TTU Institute of Islands Development
- TTU Oil Shale Research Institute

Tallinn Pedagogical University
- TPU Institute of International and Social Studies
- TPU Institute of Ecology

Estonian Academy of Arts

Estonian Academy of Music

Estonian Agricultural University
- EAU Estonian Plant Biotechnical Research Centre EVIKA
- EAU Forest Research Institute
- EAU Institute of Experimental Biology
- EAU Institute of Zoology and Botany

Research institutes under ministries

Ministry of Education
- Institute of History
- Estonian Biocentre
- Institute of Estonian Language
- Estonian Literary Museum
- National Institute of Chemical Physics and Biophysics
- Tartu Observatory
- Under and Tuglas Literature Centre of the Estonian Academy of Sciences

Ministry of Environment
- Estonian Marine Institute
- LLC Building Research Institute
- Geological Survey of Estonia

- Estonian Meteorological and Hydrological Institute

Ministry of Culture
- Voru Institute

Ministry of Economic Affairs
- Estonian Energy Research Institute

Ministry of Agriculture
- Estonian Institute of Agrarian Economics
- Estonian Agrobiocentre
- Estonian Research Institute of Agriculture
- Estonian Institute of Agricultural Engineering
- Jogeva Plant Breeding Institute

Ministry of Social Affairs
- Estonian Institute of Cardiology
- Estonian Institute of Experimental & Clinical Medicine

Private universities

Concordia International University Estonia
Estonian Institute of Humanities
Estonian Business School
Tartu Theological Seminary

Other science-related institutions

Estonian Educational and Research Network-EENet
Estonian Institute for Market Research
Estonian Inter-university Population Research Centre
Estonian National Defence and Public Service Academy
Estonian Institute for Futures Studies
Cybernetica
Pärnu Institute of Health Resort Treatment and Medical Rehabilitation
Stockholm Environment Institute - Tallinn Office

Societies
Estonian Geographical Society
Estonian Society for Research of Native Place
Estonian Naturalists' Society
Estonian Mother Tongue Society
Estonian Union of the History and Philosophy of Science