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Keskusteluaiheita - Discussion papers

No. 622

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COMPARATIVE EVALUATION OF SCIENCE & TECHNOLOGY POLICIES IN LITHUANIA, LATVIA AND ESTONIA

ISSN 0781-6847

08.12.1997

Berg-Andersson, Birgitta, **Comparative evaluation of science & technology policies in Lithuania, Latvia and Estonia.** Helsinki, ETLA, The Research Institute of the Finnish Economy, 76 p. (Discussion Papers, Keskusteluaiheita, ISSN 0781-6847; No. 622)

ABSTRACT: In this study the institutional infrastructure, which determines the science & technology system in Estonia, Latvia and Lithuania, is investigated. The changes in R&D and innovation activities in the three Baltic countries are compared and evaluated on the basis of available science and technology indicators. The aim of the research is to identify deficiencies in the current science and technology systems of the Baltic countries that might become a bottleneck for economic growth. The former S&T-system of the Baltic countries was "destroyed" as a result of the independence. Estonia, Latvia and Lithuania are now building up a new S&T-system in accordance with the Western model. This study has been prepared as base material for the Phare ACE research programme "Infrastructure Policies for Sustained Growth in the Baltic Countries - An analysis of physical and institutional infrastructure development in the Lithuania, Latvia and Estonia". Some parts of the texts on science and technology indicators and on the Estonian S&T-system have previously been published in ETLA's research reports C73 (Berg-Kilvits-Tombak) and C75 (Berg (ed.)).

KEY WORDS: Estonia, Latvia, Lithuania, technology policy, science and technology indicators, innovation system, S&T-system

Berg-Andersson, Birgitta, **Liettuan, Latvian ja Viron tiede- ja teknologiapolitiikan vertailu.** Helsinki, ETLA, Elinkeinoelämän Tutkimuslaitos, 76 s. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; Nro 622)

TIIVISTELMÄ: Tässä tutkimuksessa tarkastellaan Viron, Latvian ja Liettuan tiede- ja tutkimusjärjestelmän institutionaalista infrastruktuuria. Kolmen Baltian maan T&K-toiminnan tasoa verrataan käytettävissä olevien tiede- ja teknologiaindikaattoreiden avulla. Tutkimuksen tavoitteena on tunnistaa kaikki sellaiset puutteet Baltian maiden nykyisissä tiede- ja teknologiajärjestelmissä, jotka voivat olla esteenä talouden kasvulle. Baltian maiden entinen tiede- ja teknologiajärjestelmä "tuhoutui" itsenäistymisen seurauksena. Viro, Latvia ja Liettua ovat nyt rakentamassa uutta tiede- ja teknologiajärjestelmää Länsi-Eurooppalaisen mallin mukaisesti. Tutkimus on tehty käytettäväksi perusmateriaalina Phare ACE tutkimusohjelmassa "Infrastructure Policies for Sustained Growth in the Baltic Countries - An analysis of physical and institutional infrastructure development in the Lithuania, Latvia and Estonia". Osa teksteistä, jotka koskevat tiede- ja teknologia-indikaattoreita sekä Viron innovaatiojärjestelmää on aikaisemmin julkaistu ETLAn tutkimusraporteissa C73 (Berg-Kilvits-Tombak) ja C75 (Berg (toim.)).

AVAINSANAT: Viro, Latvia, Liettua, teknologiapolitiikka, tiede- ja teknologia-indikaattorit, innovaatiojärjestelmä, tiede- ja teknologiajärjestelmä

Yhteenveto

Vuosien 1945 ja 1990 välisenä aikana Baltian maiden tiede- ja tutkimusjärjestelmä oli integroitunut osa entisen Neuvostoliiton tiedejärjestelmää. Poliittisen ja taloudellisen järjestelmän muuttuessa vuosina 1990-1991 Liettuan, Latvian ja Viron itsenäistymisen myötä, myös maiden tiedejärjestelmät olivat suuren rakenteellisen muutoksen edessä. Alussa poliittiset ja taloudelliset tapahtumat määräsivät tutkimusinfrastruktuurin muutosprosessin kulkua, mutta nyt määrätietoiset toimenpiteet tiedejärjestelmän kehittämiseksi Länsi-Eurooppalaisen mallin mukaisesti ovat välttämättömiä.

Tutkimuksessa selvitetään Baltian maiden tämänhetkisen tiede- ja tutkimusjärjestelmän institutionaalisia pääpiirteitä ja kuvataan, miten nykyiset resurssit jakautuvat eri tieteen alojen ja tiedeorganisaatioiden välillä. Viron, Latvian ja Liettuan tutkimus- ja kehitystoiminnan tasoa verrataan käytettävissä olevien tiede- ja teknologiaindikaattoreiden avulla. Tavoitteena on tunnistaa kaikki sellaiset puutteet Baltian maiden nykyisissä tiede- ja teknologiajärjestelmissä, jotka voivat olla esteenä talouden kasvulle.

Kaikkien kolmen Baltian maan pyrkimyksenä on ottaa käyttöön OECD:n kehittämät standardit tieteen ja teknologian mittaamiseksi. Tämä vaatii paljon työtä ja koska harmonisointiprosessi etenee eri vauhtia Virossa, Latviassa ja Liettuassa tilastot eivät vielä ole täysin vertailukelpoisia.

Teknologian nykyaikaistamista edistävät muun muassa ulkomaiset suorat sijoitukset sekä privatisointiprosessi. Ulkomaalaisia sijoittajia auttavilla investointitoimistoilla on erittäin tärkeä asema tässä suhteessa. Latviassa tähän toimintaan ei toistaiseksi ole panostettu tarpeeksi. Uutta teknologiaa maahan tuovat ulkomaiset suorat sijoitukset pääsivät nopeasti käyntiin Virossa suotuisten investointiolosuhteiden ja investointitoimiston hyvän neuvonannon ansiosta.

Itsenäistymisen jälkeen T&K-menot ja -henkilökunta on jatkuvasti vähentynyt Baltian maissa. T&K-menot suhteessa BKT:hen ovat huomattavasti alhaisemmat kuin länsimaissa. Tutkimusrahojen puute on Baltian maille yhteinen ongelma. Perusedellytykset tieteen harjoittamiselle ja tutkimustoiminnalle ovat kuitenkin hyvät, koska koulutustaso Baltiassa on korkea.

Baltian maiden tiede- ja tutkimusjärjestelmä on siirtymässä samantyyppiseen sektorijakoon kuin läntisissä markkinatalousmaissa, joissa tutkimusjärjestelmä muodostuu kolmesta erillisestä sektorista, eli valtio, teollisuus ja korkeakoulusektori. Suurin osa T&K-toiminnasta on kuitenkin vielä valtion rahoittamaa. Käytettävissä olleiden tilastojen perusteella voidaan päätellä, että valtion T&K-menot suhteessa BKT:hen sekä Virossa että Liettuassa ovat normaalitasolla EU-maiden keskiarvoon verrattuna, ja että teollisuuden ja korkeakoulusektorin T&K-panostus on aivan liian alhainen. Tämän johdosta yhteenlasketut T&K-menot suhteessa BKT:hen ovat länsimaita huomattavasti alhaisemmat. Latvian osalta tarkkoja sektorikohtaisia tilastoja ei ollut saatavilla, mutta muun

informaation pohjalta voidaan arvioida että tilanne lienee samankaltainen kuin muissa Baltian maissa.

Nykyaikaisen innovaatiojärjestelmän komponentit ovat jo olemassa Virossa. Sekä Latvian että Liettuan järjestelmä poikkeaa jonkin verran Viron järjestelmästä, joka näyttää olevan lähempänä länsimaisten markkinatalousmaiden järjestelmää. Innovaatiojärjestelmä kaikissa kolmessa Baltian maassa on kuitenkin toimivuudeltaan edelleen erittäin heikko. Muun muassa teknologiakyliä ja muita tukitoimia on jatkossakin kehitettävä. Ainakin Virossa ja Latviassa laatujärjestelmien ja standardien tärkeys on jo tiedostettu, mutta paljon työtä on vielä tehtävä tällä alueella. Tiede- ja teknologiapolitiikan suhteen Viro, Latvia ja Liettua kohtaavat melko samankaltaisia ongelmia. Yhteistä näille maille on, että valtiolla ei ole virallista innovaatiopolitiikkaa. Teknologiapolitiikan tärkeimpiin tehtäviin kuuluu nostaa T&K-toimintaa harjoittavien yritysten osuutta. Näin ollen teknologiapolitiikan kehittäminen ja sen tavoitteiden julkistaminen on tärkeää Baltian maiden teknologisen tason ja kilpailukyvyn kohentamiseksi.

Contents

1. INTRODUCTION

1.1. BACKGROUND

From 1945 to 1990, science in the Baltic countries was an integral part of the science of the Soviet Union. In other words, the organisation and research structure of science, which was established in the Baltic countries after World War II, was developed under control of the organisational bodies of USSR science. During the years 1940-90 when the research infrastructure of the Baltic countries was incorporated into the research system of the former USSR, the Baltic science was in constant interaction with the science of the rest of the USSR. Science was also strongly influenced by the interests of the military-industrial complex of the Soviet Union. As a result, physical and chemical sciences were more developed, especially in Latvia, while less attention was paid to life sciences (Kristapsons & Tjunina, 1995a & 1995b).

In the USSR publication of original scientific results in international research journals was strongly prohibited. The development of science in Latvia and the other Baltic countries naturally suffered from this. In 1988-89 the general transformation of the research systems started to occur in all post-socialist countries of East and Central Europe, including the newly independent states of the former Soviet Union. These changes were linked to the changes in the political and economic system of the state, as well as the internal organisation of the science system in Latvia, Lithuania, Estonia and the rest of the Soviet Union. In other words, the scientific community of the Baltic countries was ready for drastic structural changes in their system of science (Kristapsons & Tjunina, 1995a & 1995b).

Now, after regaining independence in 1990-1991, Latvian, Lithuanian and Estonian science has suddenly become the science of a small country. Kristapsons & Tjunina (1995a) emphasizes that the research infrastructure of the small Baltic countries, however, differ from both small developed countries and small developing countries. In the Baltic countries and the small developed countries, the research infrastructure has already been taking shape over the last 100 years, whereas it is only just starting to develop in the small developing countries.

The radical transformation of the research infrastructure that has been taking place in the Baltic countries since 1990, has so far been driven by political and economic events, but now it is necessary to take further steps in order to direct the transformation process towards some pre-established science model (Kristapsons & Tjunina, 1995a).

As we will also make some comparisons of the level of science and technology in the Baltic countries with that of the Nordic countries, we here present as background information the GDP structure in the Baltic countries and Denmark, Sweden and Finland. From table 1 we can see that the share of industry is approximately about 30 per cent in both Denmark, Finland, Latvia and Lithuania, whereas the share of industry is noticeably higher in Sweden (36 %) and very much lower in Estonia (23 %). The share of services is around 60 % in all countries, except for Lithuania where it is only 53 %. From this data we can conclude that the differences in GDP-structure between these countries after all are not too big. Keeping these differences in mind we can compare science and technology statistics of the Baltic countries with data for the Nordic countries. It should be noticed that the share of industry is the most relevant, when comparing technology data. The larger share of primary production in the Baltic countries, is only in Estonia accompanied by a smaller share of industry, whereas in Latvia the larger share of primary production is at the expense of construction, and in Lithuania at the expense of a smaller service sector.

Table 1. Structure of GDP by Kind of Economic Activity in the Baltic Countries and in some Nordic Countries.

	DENMARK	SWEDEN	FINLAND	ESTONIA	LATVIA	LITHUANIA
	1996 shares at current prices, %	1995 shares at current prices, %	1996 shares at 1990 prices, %	1996 shares at 1993 prices, %	1996 shares at current prices, %	1996 shares at current prices, %
Agriculture and hunting	3.7 [1)]	0.9	3.1[2)]	7.1	8.7 [3)]	11.4 [1)]
Forestry		2.1	2.9	1.7		
Fishing		0.1		0.8	0.4	
Industry	30.0	35.5	31.2	23.1	27.8	28.3
Construction	7.2	6.9	6.6	6.9	4.9	7.1
Services	59.1	59.7	59.5	60.4	58.2	53.2
Bank service charges		-5.4	-3.3			
Statistical discrepancy		0.2				
GDP in basic values	100.0	100.0	100.0	100.0	100.0	100.0

1) Including forestry and fishing.

2) Including fishing.

3) Including forestry.

Sources: The quarterly national accounts, Statistics Denmark; Statistical Yearbook of Sweden '97; The Finnish Economy 1/1997, ETLA; Monthly No 4, Statistical Office of Estonia 1997; Monthly Bulletin of Latvian Statistics No.3/1997; Economic and Social Development in Lithuania, Monthly Bulletin No.3/1997.

1.2. OBJECTIVES OF THE STUDY

The objective of this study is to identify the institutional infrastructure determining the science&technology system in Estonia, Latvia and Lithuania and to derive policy conclusions for science and technology policies. The aim of this research is thus to identify deficiencies in the current science and technology systems of the Baltic countries that might become a bottleneck for economic growth.

The changes in R&D and innovation activities in the three Baltic countries will be compared and evaluated on the basis of available science and technology indicators, which have been defined by the OECD. In addition, country specific data which is not compiled according to international standards will be used to analyse the present S&T-system, especially R&D financing and institutions engaged in research and development.

1.3. CONCEPTS

A **national system of innovation** refers to all parts and aspects of the economic structure and the institutional set-up of a nation which affect the innovation process. This definition which is used by Lundvall (1992b) is explained in detail in chapter 4.

A distinction can be made between a system of innovation in a narrow sense and in a broad sense (Lundvall, 1992b, p. 12). The broad definition of a system of innovation includes all parts of the economic structure and the institutional set-up which affect learning as well as searching and exploring. The narrow definition of a national system of innovation includes organisations and institutions which are involved in searching and exploring, i.e. that set of institutions which are more directly concerned with scientific and technical activities.

Technological systems is a more limited concept than national systems of innovation. Technological systems can be defined as networks of agents which interact in each specific technology area under a particular institutional infrastructure aiming at generating, diffusing, and utilizing technology (Carlsson, 1994, p. 172).

The **science & technology system** can be defined as the institutional framework linking education, R&D, and the system of innovation. The concept of science & technology system goes beyond the concept of R&D system or of national systems of innovation (Radosevic, 1996; Schneider, 1995). The S&T-system can be regarded as the institutional bridge between the knowledge-base of an economy, and its technological development.

Science and technology policy is related to the process of science and technological change. Technology policy can be defined as a set of policies, which involve such government intervention in the economy that intends to affect the process of technological innovation in the firms but also decisions of other actors and institutions that affect the innovation process. Technology policy is often also called innovation policy (Loikkanen, 1996, p. 69).

Research and experimental development, i.e. **R&D-activity**, can be defined as creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this knowledge to find new applications (European Commission, 1994, Methodological Note B). R&D-activity covers 3 activities: basic research, applied research and experimental development.

Research and/or development institutions (R&DI) are defined as:
1. Public financed institutions (Universities, academies,...)
2. Private financed institutions (private research institutes, consulting enterprises...)
3. R&D institutions inside of enterprises (R&D departments..)

1.4. STRUCTURE OF THE STUDY

The objective of science and technology policy is discussed in chapter 2. Technological change and technology policy can be based on two different approaches, i.e. standard economic analysis and evolutionary economics. Some research results on the impact of technological change on economic growth are presented. It is concluded that the importance of technology policy will grow in the future.

Chapter 3 gives an overview of different science and technology indicators used by the OECD. The main features of the indicators are described and compared to the types of data which have been collected in the former socialist countries. This kind of comparison is necessary in order to be able to compare data for OECD-countries with data of the countries in transition. Data for the Baltic countries has been collected from different sources and on the basis of these figures the level of science and technology in the three Baltic countries is analysed and compared to each other. Comparisons are also to some extent made between the Baltic and the Nordic countries, as well as some Central and Eastern European countries.

In chapter 4 the concept of national systems of innovation will be described, as it has been adopted as the basis for science and technology policy in many industrialized countries. The discussion is based on the definitions used by Lundvall (1992b). According to his narrow definition the system of innovation includes institutions, which are directly concerned with scientific and technical activities, that is the innovation system can be identified with the R&D system.

In chapter 5 we try to figure out how the S&T-system in the three Baltic countries currently is organised. The aim of the chapter is to describe the present science and technology policy. Estonia already has all the institutions that are necessary for a market-oriented national innovation system. Both the Latvian and the Lithuanian S&T-system somewhat differs from the Estonian one. In Estonia there are some more institutions than in Latvia and Lithuania which are directly involved in the funding of R&D. In Estonia the Estonian Research and Development Council is the supervisor of the Estonian Innovation Foundation, the Estonian Science Foundation and the Estonian Informatics Foundation. In both Latvia and Lithuania the core of the new research system is the Council of Science. It seems that the Estonian S&T-system is a little bit closer to the system in the western market economies. The problem in all three countries is that their present national innovation system is not a well-functioning system. For example, technological parks and other centres and organizations that support high-technology entrepreneurship need to be further developed.

The conclusions are finally drawn in chapter 6. It seems that Estonia, Latvia and Lithuania still faces the same kinds of problems as regards their science and technology policies. Non of the countries has officially declared any state innovation policy. It is important that the S&T-systems are further developed so that the competitiveness of the Baltic countries can be improved.

2. THE IMPORTANCE OF SCIENCE AND TECHNOLOGY POLICY

The economics of technology policy deals with economic, social and ecological problems such as globalized techno-economic competition, unemployment, ecological damages, and de-materialization of production. According to Loikkanen (1996, p.68), the economics of technology policy is, however, still in its infancy. Technological change and the related technology policy is today based on two different approaches, that is, standard economic analysis and evolutionary economics.

Innovation is regarded as being of crucial importance for industrial efficiency and competitiveness, to economic growth and to the benefit of the whole society at least in the long-term. In the standard economic analysis, the objective of technology policy is to maximize or increase welfare. Evolutionary economics regards technology policy-making as an evolutionary process in which the organizational and institutional structures are critical for the process. In the evolutionary approach some of the main tasks of technology policy are thus the generation of variety and the promotion of selective mechanisms of innovation processes as well as making the interaction of the actors participating in the innovation process more efficient. According to the evolutionary context, the key concept in the innovation process is learning, both on the level of individuals and organizations (Loikkanen, 1996).

In general we can say that the main actors of the innovation process are the firms with their innovation activities. Other important institutions are public R&D centers, universities, banks which are financing innovation activities, and the authorities which are in charge of the promotion of technology transfer and the coordination of technology policy. Technology policy making with all its policy measures and instruments is aiming at influencing the innovation process. Regardless of which economic approach one wants to use, the ultimate target of technology policy is to contribute to social welfare (Loikkanen, 1996).

Traditional welfare economics assumes that there is a socially optimal level of R&D. This matter as well as hypotheses of under- or over-investment in R&D are mostly discussed on a highly theoretical level. So far, no succesful empirical analysis have been made. Researchers, however, think that under-allocation to industrial R&D seems to be more relevant than over-allocation, when compared to the socially necessary level of R&D. Furthermore, it seems that under-investment in R&D emerges unless the governments takes any action (Loikkanen, 1996).

Tombak (1996) emphasizes that fast progress in science and technology gives economic growth, so it is important for policy makers to pay attention to policies which affect technological development. Technology policies consist of the public policies which affect both the supply and demand for technological innovations. Overall technology policy encompasses a wide array of policies ranging from educational, informational, demand stimulating, to general business environment policies. These policies all interact to provide incentives and opportunities to the inventor to innovate.

In his article Tombak (1996) gives an overview of theoretical work on the relation between technological progress and economic growth. He refers to Robert Solow (1956) who estimated the impact of technological change on economic growth. The result of the study was that about 90 % of the increase in per capita output was attributable to technological change. Tombak also discusses more recent studies that have examined the relation between capital, labour and technological progress which attribute even more of the growth to technological advance. Romer (1989) for example has found a positive correlation between the number of scientists and engineers employed in R&D and the growth rate of output. On the basis of both theoretical and empirical research, technological change seems to be one of the most important factors responsible for economic growth.

Tombak (1996) wants to emphasize that all empirical studies have used gross national product or national income as the dependent variable, which can introduce bias against technological development as a factor for economic growth. This means that the impact of technological development probably is underestimated in those empirical studies of economic growth.

Why has technology progress been more rapid and/or more effective in western Europe than in China, India or eastern Europe ? This question is raised by Tombak (1996), who refers to Rosenberg and Birdzell (1990) who have suggested the following five possible explanations: 1) there were institutions which facilitated the diffusion of information between the business and scientific communities, 2) R&D activities were better organized, 3) the scientific method was developed and its use became widespread, 4) technologies were transferred and adapted for local use, 5) market economies resulted in decentralized decision making.

As regards the scientific method it can be noticed that the balance in Soviet science was more towards the theoretical and less of the empirical in many fields. In order to avoid this kind of imbalance in the former socialist economies the first step is to create reliable databases, which are needed for empirical work. It is also of utmost importance that the countries in transition possess the ability to adapt production technology to the local environment. Otherwise transferred technologies do not have any impact on economic growth. A country is able to adapt new technology only if it fully understands how it works. In addition, technology transfer is successful only if one understands the environment in which that technology will be used, i.e. one must know how the technology should be changed in order to function in the local environment (Tombak, 1996, p. 14-15).

One of the most important tasks of technology policy is to raise the percentage of companies performing innovation activities and utilizing the results of science. The general opinion is that the importance of technology policy will grow in the future. Vuori and Vuorinen (1993) emphasizes that especially in the case of countries in fast change, technology policy may be crucial in the creation of a sound technological basis for a new growth path.

3. AN OVERVIEW OF DIFFERENT SCIENCE AND TECHNOLOGY INDICATORS

This chapter will give an overview of the various science and technology indicators which are widely used all over the world. As we will see, the data in statistical publications are usually prepared according to the OECD recommendations. First of all, however, we will present the main reasons for the need of science and technology indicator systems. The main features of the science and technology indicators are also described. In order to show how these indicators are used data on some of the most important science and technology indicators will be presented for the Nordic countries, the Baltic countries and a few Central and Eastern European countries.

3.1. SCIENCE AND TECHNOLOGY INDICATOR SYSTEMS

A science and technology indicator system is a collection of possible quantitative indicators on science and technology. It also includes information sources to generate the indicators (Åkerblom & Virtaharju, 1987, p.6). Science and technology indicators are series of data which are designed to answer a specific question about the development of science and technology. The main reason for the need of these indicators is that science and technology is becoming more and more important for the industry, because it influences the international competitiveness. Many indicators have to be studied simultaneously in order to be able to draw any reliable conclusions about the trend of technology. Science and technology indicators can be divided into four main categories: 1) indicators on general prerequisites for science and technology, 2) indicators on resources for R&D activity, 3) indicators on application of technology, 4) indicators on the economic impact of science and technology.

Who are the users of science and technology indicators ? The users can broadly be divided into two categories, that is researchers and planners, and science and technology policy decision makers at various levels. Science and technology indicators are used for several purposes. Industrial firms for example need these indicators to get information on the impact of science and technology on competitiveness, productivity and employment. Policy decision makers are using the indicators for identifying trends that require science and technology policy measures. They are also used for setting policy goals and following them through, and for policy planning and studying. Researchers need information on interdependency of science, technology and the economy. The indicators can also be used as background information for appropriation of resources for R&D activity, and for discussions on science and technology (Åkerblom & Virtaharju, 1987, p. 6).

The OECD has been collecting R&D data since the early 1960s. The OECD has a coordinating role for the collection of data in databases as well as for the analysis of new indicators. During the last fifteen years the OECD has arranged several meetings where different technology indicators and guidelines for collecting these, have been discussed (Vitenskaps- og teknologi-indikatorer for Norden, 1992, p. 9). Also the statistics for the Baltic countries should be presented in accordance with the OECD recommendations in order to facilitate international comparisons, etc.

The work done by the OECD to expand research statistics into science and technology indicators has stimulated the development of new information systems in many countries. The

OECD databases have been expanded by addition of indicators which are reflecting the output of R&D-activity. Such indicators are information on patents, the foreign trade of high-tech products, and the technological balance of payments (Tiede ja teknologia 1989, p. 9).

In Finland for example, the central statistical office, Statistics Finland, has produced statistics on R&D-activity since 1971. The statistics includes data on R&D-personnel, -expenditure and -financing (Tiede ja teknologia, 1989, p. 9). The data contents have later been expanded to include indicators on general prerequisities of science and technology, application of technology and economic impact of science and technology. A proposal for a science and technology indicator system was prepared in cooperation with the Technology Development Center, Confederation of Finnish Industries, The Research Center for Technology in Finland, and The Academy of Finland which are users of science and technology indicators. The official statistics are based on this proposal (Åkerblom & Virtaharju, 1987, p. 1). International experiences were widely utilized and this should be the case also in the Baltic countries when developing the science and technology statistics. It is highly recommended that the Statistical Offices of the Baltic countries should use foreign experts in the developing work.

The Nordic countries have a relatively good basis for comparable R&D statistics. The collaboration in this area started about twenty-five years ago. A few years ago this work was expanded to the development of other indicators of science and technology (Vitenskaps- og teknologi-indikatorer for Norden, 1992, p. 9).

We have already pointed out that the productivity and the competitiveness of the firms can be raised by a higher standard of science and technology. R&D-activity is however not the only way to increase the technological level. That is why many countries, especially the United States, Canada and the Netherlands regularly publish science and technology indicator reports that contains extensive quantities of parameters on prerequisites for science and technology, resources directed toward it, as well as economic and social impact of science and technology (Åkerblom & Virtaharju, 1987, p. 5).

3.2. SCIENCE AND TECHNOLOGY INDICATORS IN THE BALTIC COUNTRIES

Auriol & Radosevic (1996) emphasises that the economic transition of Central and Eastern European countries (CEECs) has had important impacts on both the level of the research effort and the re-organisation of the science sector in these countries. This statement also concerns the Baltic countries. R&D expenditures and personnel have steadily decreased since regaining independence in the Baltics. Many R&D institutes have to diversify their activities, find new sources of funds, privatise etc. Governments need to revise their S&T policies while their ability to implement them is not always up to the required levels. This developing process and the new patterns of scientific and technological activities emerging in Central and Eastern Europe and in the Baltic countries need to be analysed. Such an analysis has to be based on reliable S&T indicators as internationally comparable statistics are necessary for countries in order to be able to position themselves among others in the globalised economy.

Analysing changes in R&D and innovation activities in the economies in transition are, however, faced with two main problems, that is, with the lack of data and difficulties in their comparability. The reason is that not only the organisation of the economy and of science was different in the former centralised economies, but also the organisation of the whole statistical system. One problem is now the changes in statistical indicators which have to be made in order to adjust the statistical systems to OECD recommendations, while another problem is the considerable changes in R&D and innovation activities. Some statistics and indicators are totally new for the economies in transition. Some other indicators were, however, already existing but their interpretation and features are changing, which makes analysis of R&D and innovation much more difficult when compared to other countries. Auriol & Radosevic (1996) furthermore points out that one cannot use only one type of statistics to analyse the transition process, which is gradual and not yet completed, but rather a combination of statistics describing the patterns of the former system, and of new indicators allowing comparisons with market economies.

There are three main structural differences between systems of S&T indicators in socialist countries and OECD-based systems of S&T (Auriol & Radosevic,1996). First, in the socialist system the R&D and innovation activities were considered as activities specific to one separate sector ("science and scientific services"). Production by itself was not considered as a source of technological change but merely as an application area of "R&D results ready for implementation". In market-based economies, R&D and innovation activities are considered as multisectoral activities, where patterns of innovation vary, and the institutional basis and function of R&D also differ between sectors. In addition, R&D and innovation activities are viewed as more closely linked to economic competitiveness. Second, in centrally planned economies, the lack of market based innovation incentives and the treatment of technology and innovation as basically non-market goods, implied that patents and innovation could not be used as indications of competition and technological competence. Third, according to the opinion of Auriol & Radosevic (1996) much of R&D and innovation was of the "reinvention of the wheel" type in the system of socialist countries. This was basically the result of the isolation from the international science and R&D community and led to outputs in the form of patents, innovations and publications which could not be meaningfully compared in international terms.

While the methodologies of the OECD and statistics which measure scientific and technological activities may be used to describe situations in developed market economies, the corresponding information is not yet fully available for CEECs. Efforts are, however, now being carried out by most CEECs to adopt OECD standards for the measurement of science and technology (Auriol & Radosevic, 1996). Also the Baltic countries have to some extent adopted OECD standards, but it seems that the CEECs have made more progress in this area. These efforts are a pre-requisite for the countries in transition in order to be able to compare their R&D effort with that of developed market economies.

The first steps in revising the statistical systems consist in making adjustments to existing methodologies until finally new national R&D surveys based on the Frascati manual will be launched in all countries. The very first data based on these surveys are becoming available for 1994 or 1995 as reference years for Poland, the Czech and Slovak Republics, Hungary and Russia (Auriol & Radosevic,1996). Since the harmonisation process is going at different speeds in the different formerly centrally planned economies, the availability and quality of data will thus still vary between countries, which means that statistics are not yet fully comparable. Auriol & Radosevic (1996) concludes that reforming statistical systems does not only mean changing statistical definitions and data collection but also implies a change in the underlying conceptual understanding of the role and function of R&D and innovation activities.

Auriol & Radosevic (1997) points out that the available data for the period 1990 (or 1991) to 1994 in CEECs represent a minimum length for making an evaluation on some of the emerging trends in R&D and innovation. As comes to the Baltic countries, data of various quality is available for a similar length of period as in the CEECs. Kristapsons & Tjunina (1995a) wants to emphasize that the use of science and technology indicators in Latvia and the other Baltic countries is difficult as applied methods of both science and technology indicators are well developed only for big and medium-sized developed countries. Accordingly, one has to keep in mind that these indicators must be used with caution for small countries, where the values of indicators are low.

In the following sections we will in addition to general prerequisites for science and technology analyse inputs of R&D, i.e. R&D investments as measured by R&D expenditures and R&D employment, institutional structures of R&D funding and outputs of R&D as measured by patents.

3.2.1. GENERAL PREREQUISITES FOR SCIENCE AND TECHNOLOGY

3.2.1.1. Indicators on Population with Higher Education

Economic growth is highly dependent on knowledge as well as know-how. The generation of new knowledge which is required for innovations and scientific and technical development is, however, possible only if there is enough people with higher education and professionalism (Åkerblom & Virtaharju, 1987, p. 7). Population with higher education is defined as those which have a Master's, Doctoral or Licentiates degree from universities, and college engineers. Internationally the term "scientists and engineers" is used.

Data on the level of education in Estonia, Latvia and Lithuania are given in tables 2 and 3. The study system which includes a Master's degree is relatively new in Estonia, so the majority of the students at university level are studying for a lower degree. Almost a third of the total enrolment of universities is at Tallinn Technical University. The total number of students at Tallinn Technical University is in relation to the population about the same as the number of students in technical sciences in Finland. This proofs that there is a lot of technological knowledge in Estonia. The problem is how to use this potential effectively. The total enrolment of universities in relation to the population is more or less the same in Lithuania as in Estonia. The total number of doctorates and students for a Master's degree are only slightly higher in Lithuania than in Estonia. One can thus conclude on the basis of the numbers in table 2 that the general prerequisites for science and technology are approximately on the same level in Estonia and Lithuania. The total enrolment of universities in Latvia is somewhat higher than in the other two Baltic countries, which indicates that the educational level would be the highest in Latvia. Detailed information on students at university level are unfortunately not available for Latvia. If one compares the numbers on students in Finland to the Baltic countries one can see that there are considerably more students in Finland. This may, however, not be a very good comparison, as the educational level is unusually high in Finland in international comparison.

Table 2. Students at university level per 10.000 inhabitants in Estonia, Latvia and Lithuania compared with Finland.

	ESTONIA				LATVIA				LITHUANIA			FINLAND	
	at the beginning of the academic year				at the beginning of the academic year				at the beginning of the academic year			at the end of the year	
	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1995	
Total number of doctorates												**licentiate**	**doctor**
- in all fields of sciences	2.0	2.6	4.2	5.0	*	*	*	3.0	2.3	2.9	3.6	20.4	10.7
- engineering	0.3	0.3	0.5	0.5					0.6	0.7	0.8	6.0	2.2
- natural sciences	0.5	0.7	1.0	1.3					0.4	0.5	0.7	2.7	1.8
Total number of students for a Master's degree													
- in all fields of sciences	10.3	12.9	17.5	19.2	*	*	*	*	10.1	14.0	*		215.4
- engineering	1.7	2.2	2.5	2.6									44.4
- natural sciences	1.3	1.3	1.4	1.5									32.1
Total enrolment of universities	141.9	135.1	141.6	149.3	146.1	148.6	173.9	204.0	141.9	138.5	*		260.6
- technical sciences						18.4	*	17.5					52.6
- natural sciences						3.0	3.9	4.3					36.6

*) not available

Sources: Statistical Yearbook 1994, 1995, 1996 and 1997, Statistical Office of Estonia; Eesti Pank Bulletin No. 2/1995; Monthly Bulletin of Latvian Statistics No.3/1997; Statistical Yearbook of Latvia 1995; Educational Institutions in Latvia at the beginning of school year 1996/97 Statistical Bulletin, Riga 1997; Statistical Yearbook of Lithuania 1994-1995 and 1996; Statistics Finland, Education 1996:12 ; Statistics Finland, Bulletin of Statistics 1997:II.

Compared to Finland there are only a few persons which have received a doctor's degree in the Baltic countries in the nineties. This is, however, a temporary phenomenon. In Estonia the old system was abolished and only after some interval the new system was organized. When we add the number of graduates awarded a Master's degree to those who have been awarded a bachelor degree, we can notice that the number of graduates in relation to the population is about the same in Estonia compared with Finland. This indicates that the educational level is very high in Estonia. In Lithuania most of the graduates have been awarded a higher professional education diploma, which means that the educational structure is different from that in Estonia. Because of the lack of data for Latvia it is difficult to make any general conclusions about the number of university graduates. Anyway, both the government and the universities should encourage the young graduates to continue with postgraduate studies and research work in the Baltic countries. There should be a possibility to get some kind of scholarships for postgraduate studies. Research grants should be made available also for more progressed researchers.

Table 3. Number of higher educational institution graduates per 10.000 inhabitants in Estonia, Latvia and Lithuania compared with Finland.

	ESTONIA				LATVIA		LITHUANIA			FINLAND	
	at the beginning of the academic year						at the beginning of the academic year			at the end of the year	
	1993	1994	1995	1996	1995	1996	1993	1994	1995	1995	
Number of receivers of doctor's degree										**licen-tiate degree**	**doctor's degree**
- in all fields of sciences	0.01	0.1	0.2	0.3	*	0.1	0.2	0.1	*	1.5	1.5
- engineering	-	0.01	0.02	0.04						0.3	0.2
- natural sciences	0.01	0.03	-	0.04						0.3	0.3
Graduates awarded a Master's degree											
- in all fields of sciences	0.7	1.1	2.2	2.8	*	*	0.3	1.2	*		19.2
- engineering	0.04	0.1	0.1	0.1							3.7
- natural sciences	0.1	0.2	0.3	0.3							2.0
Graduates awarded a university degree or diploma (bachelor)											
- in all fields of sciences	26.4	18.6	17.2	14.4	32.5	*	8.5	14.6	*		2.8
- engineering	5.8	3.9	2.5	1.6							-
- natural sciences	0.7	0.6	0.7	0.7							0.2
Graduates awarded a higher professional education diploma											
- in all fields of sciences	0.8	2.1	3.1	5.1	*	*	23.2	19.6	*		
- engineering	-	-	0.1	0.4							
- natural sciences	-	-	-	0.2							

Note: The figure for Latvia in 1995 is the total number of graduates from institutions of higher education.

*) not available

Sources: Statistical Yearbook 1994, 1995, 1996 and 1997, Statistical Office of Estonia; Eesti Pank Bulletin No. 2/1995; Monthly Bulletin of Latvian Statistics No.3/1997; Statistical Yearbook of Latvia 1995 and 1996; Educational Institutions in Latvia at the beginning of school year 1996/97 Statistical Bulletin, Riga 1997: Statistical Yearbook of Lithuania 1994-1995; Statistics Finland, Education 1996:12 ; Statistics Finland, Bulletin of Statistics 1997:II.

3.2.1.2. Indicators on Scientific and Technical Information Service

Transfer of knowledge is necessary in order to make progress in science and technology. Printed publications is the ordinary channel for the spreading of research results. Access to knowledge through publications can be measured by information on scientific library and information service activity (Åkerblom & Virtaharju, 1987, p. 10). The statistics on scientific libraries are often compiled in accordance with the Unesco recommendation.

Bibliometrics means quantitative research of publication activity, i.e. data about publications (Tiede ja teknologia 1989, p. 25). There are no official international recommendations for the collection of this kind of data or for their use as science and technology indicators. Common bibliometric indicators are numbers of scientific articles and publications, classified by authors and/or by institutions, fields of science, country etc. Also models and indicators which are based on citations in articles are used as productivity indicators for academic research (OECD, 1992, TEP, p. 299).

The use of bibliometric indicators has become more common as the Science Citation Index (SCI) was created in 1963. Citations made in scientific publications are used as a base in construction of the citation indexes. The citation indexes and co-citation analyses gives more sensitive measures of research quality, and of the development of fields of sciences and of networks. Today there are several international bibliometric databases (Tiede ja teknologia 1989, p. 25-26).

International publications are in general a good macro-indicator of the international performance of a country's scientific community. For centrally planned economies which were closed, the international communication in science was rather limited and hence the usefulness of assessing the science performance based on international publications is somewhat limited. Furthermore, when it comes to national publications, much of the production was in the form of "grey literature" and not in standard journal formats (Auriol & Radosevic, 1996).

Also the use of citations as indicators of scientific "productivity" is limited. The average level of performance, as measured by citation statistics, was very low in socialist economies and below that of most countries of the EU. An explanation for the low citation rate is that scientists from centrally planned economies had different research traditions where their intellectual work was not located in the mainstream of the science networks. This may be the result of the closeness of their science systems and inability to participate in international scientific networks (Auriol, & Radosevic, 1996).

In the post-socialist period we now have for the first time the opportunity to evaluate the real performance of science systems in post-socialist economies through international publications. However, Auriol & Radosevic (1996) points out that different national publication rates after 1989 will have to be explained by taking into account also the national histories of science systems.

By comparing the distribution of Latvian articles published in the journals covered by the Science Citation Index (SCI), i.e. SCI publications, in different fields of science with that of the other Baltic countries and the whole world, Kristapsons & Tjunina (1995a) have drawn conclusions about the general character and trends of Latvian science. The study by Kristapsons & Tjunina (1995a) focused on two dependent variables: changes in the number of SCI publications over the years and changes in the distribution of SCI publications among the fields of science (Table 4). The latter variable describes the changes in the science structure that has occured between 1986 and 1994. It was assumed that the transformation processes influenced the number of publications in 1991 and 1992, as the work for those publications had basically already taken place in 1990 and 1991.

It can be seen from table 4 that for many years the number of publications from the Baltic countries has remained practically the same, at an average of 250 per year. It is a small number compared with other developed countries with a similar population. It might be expected that the number of SCI publications would decrease in the course of the transformation of science, because of the reduction in funding and number of scientists, but this has not happened so far. One explanation is that the results which have accumulated during the previous years now are being published. The second explanation is that in general the authors of the SCI publications, for instance in 1995, are the same as in 1986-1990. Many of them have already had articles published in the SCI journals of the former Soviet Union, so they are experienced in publishing their papers in quite high-ranking journals. Although most scientists aim for the western journals today, there are very few new authors (Kristapsons & Tjunina, 1995a).

Table 4. SCI publications of Baltic countries by science fields

	ESTONIA			LATVIA			LITHUANIA		
Year	**1986**	**1990**	**1994**	**1986**	**1990**	**1994**	**1986**	**1990**	**1994**
All science fields	226	239	305	246	237	241	229	250	269
Life sciences	87	79	129	86	82	50	85	87	71
Agriculture	4	2	5	0	0	1	1	0	0
Biological sciences	19	24	28	20	10	8	13	12	9
Biochemistry & mol biology	12	14	23	30	32	7	26	22	16
Medicine	52	39	73	36	40	34	45	53	46
Physical sciences	63	88	107	55	56	80	95	92	103
Phys cond matter	22	18	23	22	30	27	55	46	34
Earth sciences	3	7	10	2	1	2	1	2	0
Chemistry	55	42	47	79	70	83	38	39	54
Organic chemistry	18	15	5	41	40	41	11	5	1
Engineering	10	14	16	17	17	24	16	22	34
Mathem & comp sciences	1	8	3	1	3	4	1	7	5

Source: Kristapsons, J. & Tjunina, E. (1995a)

Kristapsons & Tjunina (1995a) found out that in 1986-90 the structure of Latvia's as well as Estonia's, Lithuania's, ex-USSR's and Central and Eastern European scientific publications was characterised by a prevalence of physical and chemical sciences over the life sciences, while world science is characterised by exactly the opposite pattern. Of the three Baltic states, the structure of Estonia's science is closest to the world average. The share of life sciences there has increased from 35 to 40 % in recent years. Agricultural sciences provide 3.5 % of the total number of publications in Estonia, while this share in Latvia and Lithuania is only 0.6 and 0.8 % respectively. Furthermore, Kristapsons & Tjunina (1995a) noticed that the share of individual fields and subfields of science in Estonia is relatively constant, whereas a considerable decrease in the life sciences is observed in Latvia and Lithuania, which has happened mainly at the expense of medical sciences. Three subfields of chemistry are highly developed in Latvia: biochemistry, pharmacy and pharmacology. In Latvia, the number of publications related to biochemistry has, however, decreased radically. The share of physical sciences, as a percentage of the total number of the SCI publications, has grown considerably both in Latvia and Lithuania.

Table 5. Citation of SCI publications of Baltic states

	1990					1994				
	Share of cited publ (%)	Total IF 1988+ 1989	Number of observed citations		RCR (relative citation rates)	Share of cited publ (%)	Total IF 1992+ 1993	Number of observed citations		RCR (relative citation rates)
			total	per publ				total	per publ	
Estonia	28	453	284	0.64	0.63	41	732	585	1.16	0.80
Latvia	19	376	185	0.35	0.49	31	528	301	0.57	0.57
Lithuania	15	356	145	0.25	0.41	33	639	475	0.96	0.74

Source: Kristapsons, J. & Tjunina, E. (1995a)

Kristapsons & Tjunina (1995a) have also studied the impact factor (IF), which characterises the citation probability. The IF values for Latvian and Lithuanian publications were relatively constant during the period 1986-1990. This can be explained by the stable tradition of publication and relatively constant group of authors who publish their papers in SCI journals. In the case of Estonia there is a slight increase in the IF value during the period 1986-1990. The IF started to grow considerably in Lithuania and Estonia after 1990 and in Latvia after 1992. Kristapsons & Tjunina mean that this growth is the result of the re-orientation of scientists to publishing their papers in western journals (higher IF values), instead of mainly in journals of the former USSR (low IF values). The changes in the years 1990-92 coincide with the restoration of Latvia's political independence and elimination of restrictions on publication of papers abroad (as was the case in the former USSR). Since Latvian publications have lower IF values than those of Estonia and Lithuania after 1990 (Table 5), scientists in Latvia were slower than in the two other Baltic states to start publishing their papers in western journals.

Kristapsons & Tjunina (1995a) counted citations of SCI publications of 1988-89 in 1990 and of 1992-93 in 1994, as well as the relative citation rates (RCR). From table 5 one can see that between 1990 and 1994 the citation of publications from the Baltic countries has increased 1.5 times for Latvia, 2 times for Estonia, 3 times for Lithuania. Also the RCR values have grown. This can be explained by the recognition of scientists from the Baltic States and their growing contribution in the world. Participation of Baltic scientists in publications of international collaboration has increased and these are cited more often. In 1990, 92 out of 185 citations were in western journals, whereas in 1994, 222 out of 301 citations were in western journals.

Prior to 1990 Latvia's authors had 16 joint publications a year with foreign authors beyond the USSR. In 1991 this figure rose to 43, and in 1995 to 107. Two indicators were used to describe international collaboration: the number of joint publications with scientists of other countries and the number of papers delivered at international conferences. The most dramatic increase of Latvian papers can be observed immediately after 1990 as international contacts with western scientists grew rapidly, including participation in conferences. In order to analyse joint research papers, Kristapsons & Tjunina (1995a) compared fields and subfields in the period 1986-90 with those in 1993-94. The number of papers produced jointly with foreign authors has grown from 6 % to 32 %, while collaborations with authors of other regions of the former USSR have decreased from 20% to 15%.

According to Kristapsons & Tjunina (1995a) Estonian scientists currently have the strongest international contacts. The number of papers delivered at important conferences has increased between 1986 and 1993 almost 4 times. The number of papers from Estonia and Lithuania at international conferences has grown especially during the last few years, which correlates well with the increase in the total number of publications and particularly in the case of Estonia with the increase in the number of SCI publications in general.

3.2.1.3 Indicators on Research Salaries

Earnings of research personnel influences the availability of competent personnel for R&D work (Tiede ja teknologia 1989, p. 15). Progress of science and technology will suffer in the long run if salary indices for research personnel increases less than the average. This indicator can, however, not be analysed here because of lack of data.

3.2.2. INDICATORS ON RESOURCES FOR R&D ACTIVITY

Research and experimental development, i.e. R&D-activity, can be defined as creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this knowledge to find new applications (European Commission, 1994, Methodological Note B). R&D-activity covers basic research, applied research and experimental development.

In all OECD-countries the statistics on R&D expenditure are based on the methodology developed by the OECD. These recommendations are published in the so called Frascati Manual. It was first issued in 1963 and it is the generally acknowledged international standard for surveys of research and experimental development (OECD, 1992, TEP, p. 296). The fifth edition was published in 1993 (Åkerblom & Virtaharju, 1987, p. 12).

The OECD is maintaining a substantial data base of R&D statistics. Very detailed information is collected biannually on the R&D-activity of the member countries. OECD publishes both summary statistics and analytical reports. Time series back to the late 1960's are available from the database (OECD, 1992, TEP, p. 296). The different measures of resources devoted to R&D which are used by OECD can be divided into four categories: 1) Total national resources devoted to R&D, 2) R&D in the business enterprise sector, 3) R&D in the higher education sector, and 4) Government R&D appropriations or outlays. These four categories of R&D measures will be described in detail in chapters 3.2.2.1.-3.2.2.4.

The statistics on resources for R&D activity are based on questionnaires which are sent to the units doing R&D work, i.e. firms, the public sector and the universities. There are, however, some problems associated with the data collection. The definition for R&D activity may be differently interpreted in the units supplying the information. Despite the existing instructions for separating R&D activity from other functions, it is possible to give only general guidelines to respondents. The definitions are international, so in practice the application of the definition has to be decided by the respondent (Åkerblom & Virtaharju, 1987, p. 12). The occurence of disparate survey methods and the present pecularities of national R&D systems also result in that the data are not always totally comparable between different countries (European Commission, 1994, Methodological Note B).

There are some disadvantages connected with the use of R&D data. The statistics on resources of R&D activity doesn't say anything about the results of the research activity or its economic impact, it only indicates the scope and trend of the research activity. For many years, however, R&D data was treated as a good proxy of the overall technological level of an industry or country, because R&D was usually considered as the only significant technology development activity. Later on one has been aware of the gap between the uncertain R&D process and the economic application of the resulting new technology. R&D data measure only "inputs", i.e. the resources put into developing new technology. A separate measure of its "output" is needed, because not all R&D activity leads to new technology. Output indicators such as patents, the technological balance of payments and bibliometrics have been developed. Most of them give only partial measures of R&D output (OECD, 1992, TEP, p. 291).

Another problem with R&D statistics is that they measure only organised activities which are undertaken in established laboratories. New technology can for example also be generated by "shop floor engineering" in the machine tool industry. Experts have concluded that despite these deficiences organised R&D remains a necessary indicator and its definition should not be changed (OECD, 1992, TEP, p. 291).

The basic approach of the Frascati Manual is to separate R&D from other S&T activities and to measure R&D in all sectors of the national economy through R&D expenditures and personnel as input indicators. Countries of Central and Eastern Europe and of the former Soviet-Union (FSU) had based their statistics on the concept of S&T activities. This concept did not separate R&D from related scientific activities. The R&D systems were dominated by independent R&D institutes involved in several kinds of activities ranging from basic and applied research to design development, engineering, testing, S&T information services and micro-production. These R&D institutes, which were servicing industry, were grouped together with other scientific organisations in one sector of activity. However, R&D activities performed outside the R&D institutes in higher education institutions were not always taken into account in statistics (Auriol, & Radosevic, 1996).

As a result of the transition process there are structural changes within the national R&D systems. Most of the old independent industrial institutes are transformed into manufacturing or service enterprises, while academic institutes and universities remain purely research oriented. In the future R&D activities will mainly be performed in the business enterprise sector (Auriol, & Radosevic, 1996).

It should also be noticed that OECD countries include defence R&D in their data according to Frascati recommendations. This is not yet the case for Central and Eastern European countries, except for Romania. Countries like Hungary and Poland still only include defence R&D being conducted in the civil sector (Auriol, & Radosevic, 1996).

3.2.2.1. General Development of Resources for R&D activity

The standard measure of the general development of resources for R&D activity is the **"Gross domestic expenditure on R&D (GERD)"**. It is the total intramural expenditure on the R&D carried out on a national territory during a given period. R&D can be performed in the business enterprise, higher education, government or private non-profit sectors.

Intramural expenditure includes all funds used for the performance of R&D, whatever the source of finance. It includes current expenditure, such as employment costs and expenditure on materials, as well as capital expenditure on buildings and equipment (European Commission, 1994, Methodological Note B).

The share of R&D expenditure in the GDP (GERD/GDP) is the most widely used key figure for expressing the research input of the national economy. It is referred to both in the technologypolitical discussions and in comparisons between different countries (Tiede ja teknologia 1989, p. 18). Data on GERD/GDP in the Baltic countries as well as in the Nordic countries and some CEECs are given in table 6.

Table 6. Gross domestic expenditure on R&D as a percentage of GDP (GERD/GDP)

	1981	1985	1989	1990	1991	1992	1993	1994	1995	1996
European Union	1.71	1.89	1.97	1.99	1.96	1.94	1.94	1.88	1.84	*
Denmark	1.1	1.25	1.55	1.63	1.7	1.74	1.79	*	1.82	*
Iceland	0.63	0.74	1.02	0.99	1.16	1.33	1.34	1.39	1.46	1.49
Norway	1.17	1.48	1.69	*	1.65	*	1.73	*	1.59	*
Sweden	2.29	2.88	2.94	*	2.89	*	3.28	*	3.02	*
Finland	1.2	1.58	1.83	1.91	2.07	2.18	2.21	2.34	2.32	*
ESTONIA	*	*	*	*	*	0.76	0.59	0.72	0.61	*
LATVIA	*	*	1.6	1.6	*	0.3	0.35	*	0.38	*
LITHUANIA	*	*	*	*	*	*	0.43	0.51	0.48	*
Czech Republic	*	*	*	*	2.12	1.83	1.35	1.25	1.15	*
Hungary	*	*	*	*	1.07	1.05	0.98	0.89	0.75	*
Poland	*	*	*	*	*	*	*	0.82	0.74	*

*) not available

Sources: OECD: Main Science and Technology Indicators. Science 1995, Statistical Office of Estonia. For Latvia: Kristapsons, J. & Tjunina, E. (1995b) and Karnite & Gulans (1996). For Lithuania: Statistical Yearbook of Lithuania 1996.

With post-socialism the R&D funding decreased sharply. Radosevic (1996) points out that this was not only the result of the worse budgetary conditions but also of a natural decrease in the previously overexpanded and non-competitive R&D. According to Auriol and Radosevic (1996) the GERD/GDP ratios in socialist economies were, due to their closed character and weak incentives, far above the relative levels of comparable medium-income economies. R&D was predominantly funded from the State budget. In the post-socialist period there is a strong absolute decrease of military R&D, which means that military R&D spending is levelling off to normal levels (Radosevic, 1996).

Of the three Baltic countries the value of GERD/GDP is the largest in **Estonia**, although the business enterprise sector is not covered by the R&D survey. GERD/GDP was 0.61 in 1995. In **Lithuania** GERD/GDP was 0.48 in 1995. Naturally, this is far below the level in all Nordic countries. The R&D expenditures have been relatively stable in both Estonia and Lithuania during the recent years. Unfortunately data for the socialist period is not available so we cannot make any statement here about the changes in R&D expenditure after regaining independence.

Science in **Latvia** receives very little funding from the state (Kristapsons & Tjunina, 1995a). From table 6 we can see that gross domestic expenditure on R&D has decreased from about 1.6 % of GDP in 1990 to 0.38 % in 1995. From 1992 to 1994, the transformation in the national economy of Latvia from the centrally planned system to a free market was quite radical. This process was followed by a sharp decrease in funding for science and an increase in energy and maintenance costs. Kristapsons & Tjunina (1995b) underlines that when the former links between the national economy and science were broken, the state budget remained the only domestic source for funding science. The percentage of GDP allocated to science decreased about five-fold. This lack of funding was the main reason for the sharp decline in the number of people employed in science. At the same time the new Latvian state was expected to allocate additional funds for scientific research.

Central and Eastern European countries are still "overinvesting" in R&D despite drastic cuts in GERD. CEECs are, however, now converging in terms of R&D expenditures to relatively similar GERD/GDP levels after the considerable differences they showed during the process of downsizing their R&D systems between 1990-1993. Despite the drastic reductions in relative spending, their R&D investment still remain above investments of comparative groups of countries. It should be noticed that the percentage for the Czech Republic is still overestimated, since it refers to total expenditure of the "R&D base" which also includes some non-R&D expenditure (Auriol & Radosevic, 1997). As comes to Poland, data on capital expenditure of enterprises and of higher education institutions was not reported before 1993.

One should also keep in mind that the indicator previously used in CEECs was the so-called "value of S&T" or "value of R&D", which represented the total amount of contracted projects in S&T/R&D organisations and/or total revenues of S&T/R&D institutions rather than expenditures on R&D actually performed. It included all S&T or R&D projects or contracts, whether completed or not. Situations varied between countries (Auriol, & Radosevic,1996).

Resources devoted to R&D can also be measured in labour terms. **Total R&D personnel** includes both researchers and technicians, who are directly employed on R&D, and managers, administrative staff and office staff, who are supplying direct services to R&D. Sometimes a more limited concept is used. It is focussing on the number of **research scientists and engineers (RSE)** employed in R&D. Personnel data are always expressed in full-time equivalent (FTE) on R&D. This means that a person who is working half-time on R&D is counted as 0.5 person year (European Commission, 1994, Methodological Note B).

In the former socialist countries total employment of R&D institutions was reported in head-counts. This means that data is not directly comparable with data of OECD countries. Furthermore, categories of staff such as supporting staff or auxiliary personnel were included which are not considered as R&D personnel in the Frascati manual. The definition of other categories of personnel - i.e. researchers, scientists and engineers (RSE) and technicians - were closer to OECD definitions, although they were often based on qualification criteria rather than on occupation. For most socialist countries only full-time R&D personnel was taken into account in the higher education sector, which meant that R&D activities of teaching personnel were excluded (Auriol, & Radosevic, 1996).

Data on research personnel are not available for the business enterprise sector in **Estonia** (tables 7-10). This is a very serious lack in the collection of statistics. The Statistical Office of Estonia is now aware of the problem. It is important to compile data on research personnel as well as R&D expenditures for the business enterprise sector and of course also for the higher education and government sectors.

Table 7. Total R&D personnel per thousand labour force, FTE

	1981	1985	1990	1991	1992	1993	1994	1995	1996
European Union	8.6	9	9.4	9.4	9.3	9.4	*	*	*
Denmark	6.2	7.2	8.6	8.8	9.1	9.5	*	*	*
Iceland	6.7	6.8	9.3	8.5	8.7	9.5	9.7	*	*
Norway	7.5	9.1	*	9.5	*	10.4	*	*	*
Sweden	9.7	11.2	*	11.9	*	12	*	*	*
Finland	7.2	9.1	*	11.6	*	12.2	12.9	*	*
ESTONIA	*	*	*	*	(11.1)	(11.6)	(12.1)	(8.8)	*
LATVIA	*	*	(21.7)	*	*	4.9	4.0	4.1	*
LITHUANIA	*	*	*	*	*	4.5	4.3	4.6	*
Czech Republic	*	*	*	*	11.5	7.9	7.2	4.5	*
Hungary	*	*	*	*	5.4	5.3	5.3	4.8	*
Poland	*	*	*	*	*	*	4.6	4.9	*

Note: Figures in parentheses are expressed as the number of physical persons per thousand labour force, not in terms of FTE. In consequence R&D personnel data are overestimated by international standards. The business enterprise sector is not covered by the data in Estonia. In Lithuania workers directly engaged in research are classified into scientists, assistants, specialists with higher education and others.

*) not available

Sources: OECD: Main Science and Technology Indicators. The figures for Estonia are based on data from the Statistical Yearbook 1995, 1996 and 1997, and Science 1995, Statistical Office of Estonia. The figures for Latvia are based on data from Statistical Yearbooks of Latvia. The figures for Lithuania are based on data from the Statistical Yearbook of Lithuania 1994-1995 and 1996.

Data on total R&D personnel per thousand labour force is given in table 7. Although the figures for Latvia and Lithuania are in full-time-equivalent and at least the numbers for Latvia covers all sectors, the data is not necessarily fully internationally comparable. As was stated above, staff such as auxiliary personnel may be included although this is not correct. Despite these deficiencies we can see that total R&D personnel per thousand labour force has been between 4 and 5 in both Latvia and Lithuania during the years 1993-95. This is about half of the R&D personnel in the Nordic countries. In 1995 the number of R&D personnel in Latvia and Lithuania was approximately on the same level as in the Czech Republic, Hungary and Poland. As the numbers for Estonia are not in FTE they are not fully comparable, as they are overestimated by international standards. On the other hand, they are also underestimated as the business enterprise sector is not included. It seems that total R&D personnel may be somewhat higher than in the other two Baltic countries.

Auriol & Radosevic (1997) have noticed that the reduction has been stronger for personnel than for R&D expenditures in CEECs. They found that the levels of R&D personnel and researchers per thousand labour force in CEECs are around the EU average, which is 9.4 and 4.7 respectively in 1993. Differences in terms of total R&D personnel and RSE in the R&D systems of CEECs are to a greater extent the result of different restructuring patterns or total lack of restructuring than of differences in GDP levels. When the possible absorption of R&D manpower outflows into other sectors of the economy is taken into account, the currently still high levels of R&D employment in some CEECs should probably not be considered as the final ones. Further reductions in terms of R&D employment can thus be expected. The high correlation between reductions in total personnel and RSE, which holds for countries in transition, indicates a more general downsizing of the R&D system, which has affected equally both researchers and technical personnel within R&D.

Table 8. Total RSE (or Univ. Graduates) per thousand labour force (RSE= research scientists and engineers), FTE

	1980	1981	1985	1990	1991	1992	1993	1994	1995	1996
European Union	*	3.3	3.7	*	4.5	4.5	4.7	*	*	*
Denmark	2.4	2.5	3.1	4	4.1	4.4	4.7	*	*	*
Iceland	*	3.1	3.8	5.3	4.9	5	5.7	5.8	*	*
Norway	3.8	3.8	4.7	*	6.3	*	6.9	*	*	*
Sweden	*	4.1	5	*	5.9	*	6.8	*	*	*
Finland	*	*	*	*	5.5	*	6.1	*	*	*
ESTONIA	(8.5)	*	*	(8.6)	(8.8)	4.9	5.0	4.3	4.3	(6.1)
LATVIA	*	*	*	(12.5)	*	*	3.0	2.3	2.4	*
LITHUANIA	*	*	*	*	*	2.5	2.4	2.4	2.4	*
Czech Republic	*	*	*	*	*	3.8	2.6	2.6	2.4	*
Hungary	*	*	*	*	*	2.8	2.8	2.8	2.6	*
Poland	*	*	*	*	*	*	*	2.8	2.9	*

Note: Figures in parentheses are expressed as the number of physical persons per thousand labour force, not in terms of FTE. In consequence RSE personnel data are overestimated by international standards. The business enterprise sector is not covered by the data in Estonia.

*) not available

Sources: OECD: Main Science and Technology Indicators. The figures for Estonia are based on data from the Statistical Yearbook 1995, 1996 and 1997, and Science 1995, Statistical Office of Estonia. The figures for Latvia are based on data from Statistical Yearbooks of Latvia. The figures for Lithuania are based on data from Science 1995, Statistical Office of Estonia and the Statistical Yearbook of Lithuania 1994-1995 and 1996.

In table 8 the data on total research scientists and engineers is given in FTE for all three Baltic countries. We can thus see that total RSE personnel is higher in Estonia than in both Latvia and Lithuania. In fact, total RSE per thousand labour force is above the average of the European Union. This may indicate that RSE employment is still oversized in Estonia. The number of research scientists and engineers per thousand labour force is both in Latvia and Lithuania on approximately the same level as in the Czech Republic, Hungary and Poland.

As a consequence of the radical reduction of financial resources and industrial output the number of people employed in science has decreased in **Latvia**. According to Kristapsons & Tjunina (1995a) more than 75 % of the employees have left the science system since 1989. This concerns especially auxiliary workers who started to look for other jobs earlier than professional scientists. Employees with academic degrees have thus left science in smaller numbers. The former institutes of the Academy of Sciences have only half the employees they had in 1990. Before and during the 1980s most of the Latvian researchers were employed in

R&D for industrial science. During the transition period the number of researchers has decreased most of all in engineering sciences.

From table 9 we can see that also in Estonia the number of scientists and engineers has decreased much more in engineering than in natural sciences. Still in 1980 the number of RSE per thousand labour force was bigger in engineering than in natural sciences, but today it is in the opposite direction. However, the number of technicians in relation to the labour force has not changed during the nineties, neither in engineering nor in natural sciences. In Lithuania the proportion of RSE was the same in engineering as in natural sciences in 1992. Later data was unfortunately not available.

Table 9. Personnel engaged in R&D per thousand labour force in Estonia, Latvia and Lithuania.

	ESTONIA Full-time + Part-time excl. business enterprise sector						LATVIA FTE, all sectors			LITHUANIA FTE, excl. business enterprise sector (?)			
	1980	1992	1993	1994	1995	1996	1993	1994	1995	1992	1993	1994	1995
R&D personnel, total	*	11.1	11.6	12.1	8.8	*	4.9	4.0	4.1	*	4.5	4.3	4.6
Scientists and engineers (RSE)													
- all fields of sciences	8.5	6.4	6.6	6.8	6.2	6.1	3.0	2.3	2.4	2.5	2.4	2.4	2.4
- engineering	2.2	1.0	1.3	1.2	1.2	1.2	*	*	*	0.7	*	*	*
- natural sciences	2.0	1.9	1.9	2.0	1.8	1.9	*	*	*	0.7	*	*	*
Technicians													
- all fields of sciences	*	0.7	0.9	1.1	1.0	0.8	0.8	0.7	0.8	*	*	*	*
- engineering	*	0.1	0.1	0.2	0.1	0.1	*	*	*	*	*	*	*
- natural sciences	*	0.2	0.2	0.3	0.3	0.2	*	*	*	*	*	*	*
Auxiliary personnel (Technical personnel)	*	4.0	4.1	4.2	1.6	*	1.1	1.0	0.9	*	*	*	*

Note: The business enterprise sector in Estonia is not covered by the data.

*) not available

Sources: Statistical Yearbook 1995, 1996 and 1997, Estonian Statistics 1996 Monthly No 12 (60), Science 1995, Statistical Office of Estonia; Estonian Economy 1994-1995, Ministry of Economic Affairs of the Republic of Estonia; Eesti Pank Bulletin No. 1/1996; Monthly Bulletin of Latvian Statistics No. 3/1997; Kristapsons, J. & Tjunina, E. (1995a): Statistical Yearbook of Latvia 1993, 1995 and 1996; Statistical Yearbook of Lithuania 1994-1995 and 1996: Economic and Social Development in Lithuania Monthly Bulletin 5/1997.

The number of doctors (including candidates of sciences) engaged in R&D has decreased only slightly in Estonia during the nineties, from 3.1 per thousand labour force in 1992 to 2.8 in 1996 (table 10). At the same time the number of masters engaged in R&D has steadily been increasing, although the changes are not big. However, in Latvia the number of doctors per thousand labour force engaged in research has dramatically decreased between 1990 and 1994. It is now far below the level of the two other Baltic countries. This may, however, only reflect the fact that the downsizing of the R&D system probably has been faster in Latvia than in the other two countries. That remains to be seen when new data becomes available in the next few years. The number of doctors engaged in R&D in relation to the labour force has been stable in Lithuania during the last few years and in fact exceeds the level in Finland. This either implies that there has been no downsizing of R&D employment in Lithuania, or that the number of R&D personnel with doctoral education really is exceptionally high.

Table 10. Number of doctors, candidates of sciences and masters engaged in R&D per thousand labour force in Estonia, Latvia and Lithuania compared with Finland.

	ESTONIA					LATVIA			LITHUANIA			FINLAND
	at the end of the year											
	1992	1993	1994	1995	1996	1990	1993	1994	1993	1994	1995	1995
Postgraduates	**doctors**					**doctors**			**doctors habilis + doctors**			**licentiates + doctors**
- in all fields of sciences	0.5	0.5	0.6	0.6	2.8	2.6	1.5	1.1	3.3	3.2	3.3	3.1
- technical sciences	0.05	0.1	0.1	0.1	0.6	*	*	*	*	*	*	
- natural sciences	0.2	0.2	0.2	0.2	1.0	*	*	*	*	*	*	
Masters												
- in all fields of sciences	0.2	0.2	0.4	0.5	0.6	*	*	*	*	*	*	6.7
- technical sciences	0.1	0.04	0.1	0.1	0.1	*	*	*	*	*	*	
- natural sciences	0.02	0.1	0.1	0.1	0.2	*	*	*	*	*	*	
Candidates of sciences *) (= Ph.D.)												
- in all fields of sciences	2.6	2.5	2.5	2.3	1)	-	-	-	-	-	-	-
- technical sciences	0.5	0.5	0.5	0.5	1)							
- natural sciences	0.8	0.8	0.8	0.7	1)							

Note: The business enterprise sector is not covered by the research and development survey in Estonia.

*) In the old system in Estonia there was only candidates and doctors. Candidate, which corresponds to a Ph.D. degree, was the first university degree and doctor was the higher degree.

1) The degree of the candidate of science is considered equal to doctor's degree.

Sources: Statistical Yearbook 1994, 1995 and 1997, Estonian Statistics 1996 Monthly No 12 (60), Statistical Office of Estonia; Eesti Pank Bulletin No. 1/1996; Statistical Yearbooks of Latvia; Monthly Bulletin of Latvian Statistics No. 3/1997; Statistical Yearbook of Lithuania 1994-1995 and 1996; Economic and Social Development in Lithuania Monthly Bulletin 5/1997; Statistics Finland, Tiede ja teknologia 1997:1 ; Statitics Finland, Bulletin of Statistics 1997:11.

Although there are no numbers available yet on research personnel in the business enterprise sector in Estonia, one can conclude on the basis of other information that there are relatively few researchers in the companies. In the long run the number of researchers has to be increased in the business enterprise sector. It is important that the government supports a development in this direction. It is very important for all three Baltic countries that expenditures on research and development, including research personnel, in the business sector will be increased in order to improve the absorptive capacity of the firms. Without a higher absorptive capacity it is difficult to increase the technological base of the country.

3.2.2.2. Universities/Higher Education

Universities play a central role in promoting science in general, and in basic research. Consequently it is of interest to collect data on the characteristics and trends of **R&D in the higher education sector**. In Finland at least, the evaluation of information on R&D activity in universities is very complicated. Statistics Finland sends inquiries about the use of time to university research personnel, and inquiries are sent to institutes. Also administrative data sources are the basis for assessments (Åkerblom & Virtaharju, 1987, p. 12).

Besides universities the higher education sector comprises colleges of technology and other institutes of post-secondary education, research institutes, experimental stations and clinics which in some way are associated with higher education establishments. The OECD uses a classification in the six major fields of science and technology, according to the UNESCO Recommendation Concerning the International Standardisation of Statistics on Science and Technology. The major fields of sciences are natural sciences, engineering, medical sciences, agricultural sciences, social sciences and humanities (OECD, 1993, Basic science and technology statistics, p. 331).

Universities in the former socialist countries were primarily teaching institutions. This is still the case for most of the countries in transition. Auriol & Radosevic (1997) found that in CEECs the share of R&D expenditure performed in the higher education sector (HERD) is ranging between 2.2 % (Romania) and 5.9 % (Russia). When looking at GERD performed by the higher education sector only Hungary (26.4 %) and Poland (20.7 %) was at the same level as Western European countries. The result was the same when looking at the share of researchers in the higher education sector.

Our data on R&D expenditure in the higher education sector in Estonia will be presented later in chapter 5.1, as it is not compiled according to international standards. Some data on scientific personnel in institutions of higher education in Latvia are presented in chapter 5.2. Also some data which is not internationally comparable will be presented for Lithuania in chapter 5.3.

3.2.2.3. Government R&D Appropriations

Government R&D appropriations or outlays means all expenditure by federal or central government allocated to R&D by the budget. The data are assembled by national authorities. All the budget items involving R&D has to be identified and their R&D content has to be measured or estimated. Data on government R&D appropriations thus refer to budget provisions and not to actual expenditure (OECD, 1993, Basic science and technology statistics, p. 331).

In market economies R&D is financed and performed within three institutionally separate sectors: government, industry and the higher education sector. In the former socialist countries the following sectors could be discerned: industrial institutes, the enterprise sector, academies and higher education R&D. However, if OECD recommendations are taken as a point of departure then these countries had only one or two sectors, i.e. government funded and industry oriented R&D which were part of the same structure. Enterprises were only production units, while industry oriented R&D was performed in separate industrial institutes. The share of R&D performed in the higher education sector was low under the socialist system, as basic research was performed within Academies of Science institutes and other institutes which were part of the government sector (Auriol & Radosevic, 1997).

The institutional restructuring of R&D systems in countries in transition is now shifting towards a system where three distinctive institutional sectors are emerging, i.e. government, industry and higher education sector, as in other market economies. The institutional differentiation between government and business R&D is, however, still unclear in some countries in transition due to the existence of old independent industrial institutes, which still lie somewhere in between government and private industry. In addition, in-house R&D capacities are still weak. Shares of R&D performed in the higher education sector are still very low, but the increasing importance of university based R&D is a sign of clear institutional convergence with the market-based economy model (Auriol & Radosevic, 1997).

Table 11. Percentage of gross domestic expenditure on R&D (GERD) performed by the government sector

	1981	1985	1990	1991	1992	1993	1994	1995	1996
European Union	18.9	18	16.4	16.9	16.4	16.6	16.4	16.3	*
Denmark	22.7	19.5	18.3	17.7	17.8	17.8	*	*	*
Iceland	60.7	48.3	49.2	44.5	43.4	40.9	40.9	40.9	40.9
Norway	17.7	14.4	*	18.8	*	19.2	*	*	*
Sweden	6.1	4.4	*	4.1	*	4.2	*	*	*
Finland	22.5	19.9	18.8	20.2	20.6	20.5	18.9	18.4	*
ESTONIA	*	*	*	*	88.1	74.9	76.2	71.4	*
LATVIA	*	*	*	*	*	*	*	*	*
LITHUANIA	*	*	*	*	*	*	*	68.7	*
Czech Republic	*	*	*	29	24	23.6	28.5	26.4	*
Hungary	*	*	19.5	24.5	25.3	25.7	27.2	25.6	*
Poland	*	*	*	*	*	*	35.1	35.3	*

*) not available

Sources: OECD: Main Science and Technology Indicators. Science 1995, Statistical Office of Estonia.
The figure for Lithuania is based on data from the Statistical Yearbook of Lithuania 1996.

According to Auriol & Radosevic (1997) the Czech and Slovak Republics have already managed to reduce the role of the government in R&D. This is to some extent also the case in Hungary. In Poland there is a gradual shift from state to industry funding. In Russia and Romania, the shares of government funding are still high. This is only a sign of a very low demand for R&D from industry.

The fact that Academies of Science were part of the government structure can also be seen in the figures in table 11. The share of R&D expenditure performed in the government sector (GOVERD) in 1995 was 25.6 % for Hungary, 26.4 % for the Czech Republic, and 35.3 % for Poland, which is higher than the EU average (16.3 %). The same pattern appeared when Auriol & Radosevic (1997) were looking at the share of researchers in this sector. The percentage of gross domestic expenditure on R&D performed by the government sector is even higher in Estonia and Lithuania (about 70 %), than in the just mentioned countries. Also in Latvia most of R&D is financed by the government sector. This indicates that the process of restructuring the R&D system is very much slower in the Baltic countries than in CEECs.

Table 12. Government Intramural Expenditure on R&D as a percentage of GDP (GOVERD/GDP)

	1981	1985	1990	1991	1992	1993	1994	1995	1996
European Union	0.32	0.34	0.33	0.33	0.32	0.32	0.31	0.3	*
Denmark	0.25	0.24	0.3	0.3	0.31	0.32	*	*	*
Iceland	0.38	0.36	0.49	0.52	0.58	0.55	0.57	0.6	0.61
Norway	0.21	0.21	*	0.31	*	0.33	*	*	*
Sweden	0.14	0.13	*	0.12	*	0.14	*	*	*
Finland	0.27	0.31	0.36	0.42	0.45	0.45	0.44	0.43	*
ESTONIA	*	*	*	*	0.67	0.44	0.55	0.44	*
LATVIA	*	*	*	*	*	*	*	*	*
LITHUANIA	*	*	*	*	*	*	*	0.36	*
Czech Republic	*	*	*	0.62	0.44	0.32	0.36	0.31	*
Hungary	*	*	*	0.26	0.27	0.25	0.24	0.19	*
Poland	*	*	*	*	*	*	0.29	0.26	*

*) not available

Sources: OECD: Main Science and Technology Indicators. The figure for Estonia is based on data from Science 1995, Statistical Office of Estonia. The figure for Lithuania is based on data from the Statistical Yearbook of Lithuania 1996.

Surprisingly, government expenditure on R&D as a percentage of GDP is only slightly higher in Estonia (0.44 %) and Lithuania (0.36 %) than in the European Union (0.30 %) on average (see table 12). On the basis of the figures in tables 11 and 12 we can thus conclude that government spending on R&D is on a quite normal level both in Estonia and Lithuania, but that the R&D expenditures are too low in the other sectors of the economy, that is, in the higher education sector and in the business enterprise sector. Also the figures in table 6 in section 3.2.2.1 supports this conclusion, as GERD/GDP in the Baltic countries are far below the level of the European Union countries.

3.2.2.4. Industrial R&D

As the technology is getting more advanced the success of the firms is more and more based on knowledge and the ability to change. It has been shown in many studies that the development of the production technic and the products, increases the profitability of the firm more than just an increase of the input factors would do (Tiede ja teknologia 1989, p. 17).

Data on **R&D in the business enterprise sector** is needed to get internationally comparable indicators of resources for R&D activity and trends at industry level. The business enterprise sector covers both private and public enterprises, as well as institutes serving such enterprises. The OECD uses the International Standard Industrial Classification (ISIC, rev.2). In some countries it is possible to break down the R&D data for multi-product enterprises between their main lines of business, but usually the breakdown between industries is made at the level of the enterprise (OECD: Basic science and technology statitistics 1993 edition). It is difficult to get precise numbers on industrial R&D, because usually R&D expenditures are not followed up in the accounts of the firms. Especially the information given by small firms for the research statistics may be only approximate (Tiede ja teknologia 1989, p. 17).

In most Western countries there has been a shift from public to private financing of R&D since the beginning of the 1970's. Usually government research centres, university laboratories and non-profit organisations are only marginally responsible for commercial innovation. The expenditures on R&D by the business-enterprise sector reflects the role of industrial innovation in competitiveness and growth (OECD, 1992, TEP, p. 30).

To measure the resources spent on R&D by industry is the least controversial and most common tool used by governments to examine industrial innovation, in spite of the fact that industrial R&D is not the only innovation-related activity in firms. In the first place, the **industrial expenditure on R&D in relation to gross domestic product** reflects the propensity of firms to spend money on R&D, compared to the average of other countries. In the second place, it reflects the industrial structure of the country, both with respect to industrial profiles and size profiles. Average R&D intensity will be low, if there are few high technology industries. Large firms do proportionately more R&D than small ones, because they can take better advantage of scale economies. However, the numbers do not reflect technology which is acquired through the purchase of foreign machinery. Despite such shortcomings, governments will still pay attention to this indicator (OECD, 1992, TEP, p. 42).

Auriol & Radosevic (1997) have found that the share of business enterprise R&D expenditure (BERD) in total GERD is significantly lower in CEECs than in OECD countries on average. R&D institutional systems in OECD economies make a relatively clear distinction between in-house and government R&D. In market economies R&D is performed mainly by industrial enterprises. The nature of industry funding and R&D performed in the business sector is different in countries in transition, where business R&D is not R&D in industry but R&D for industry. In socialist economies R&D activities were dominantly oriented towards industry, but were separated from enterprises as they were located in industrial R&D institutes. Industry R&D thus involved all independent R&D institutes which were oriented towards industry.

The distinction between government and business R&D will become more and more important for the former socialist countries. However, in the transition period industry R&D has not yet become integrated as in-house R&D. The independent R&D institutes are business oriented organisations but in terms of sources of funding are neither "in-house" R&D units nor entirely government dependent. The existence of independent R&D institutes are in the transition to OECD classification treated as business R&D but are in fact non-integrated R&D. In those cases where all industrial institutes are counted to the business enterprise sector they accordingly overestimate the share of real business R&D (Auriol & Radosevic, 1996).

Industrial R&D expenditures below 1 per cent is usually taken as a sign of a weak national system of innovation. If they fall below 0.2 per cent, an exceptional and concerted effort is required from both firms and the government (OECD, 1992, TEP, p. 42). Business enterprises expenditures on R&D as a percentage of GDP (BERD/GDP) are however not directly available for the **Baltic countries**, but an approximate number can be derived for Estonia and Lithuania.

The gross domestic expenditure on R&D as a percentage of GDP (GERD/GDP) was 0.61 per cent in 1995 for **Estonia** (see table 6). In the same year the percentage of gross domestic expenditures on R&D (GERD) performed by the government sector was 71.4 % (table 11), that is, government expenditure on R&D as a percentage of GDP (GOVERD/GDP) was 0.44 % for Estonia in 1995 (table 12). Higher education expenditures on R&D are mostly financed by the government. This means that the business enterprises expenditures on R&D plus private non-profit sector expenditures totals about 0.17 % of GDP in Estonia in 1995 (0.17 % also in 1994). In the same way an approximate number for **Lithuania** can be calculated. The result is that the business enterprises expenditures on R&D plus private non-profit sector expenditures totals about 0.12 % of GDP in Lithuania in 1995. From these numbers one can conclude that the industrial R&D expenditures in the private sector in Estonia and Lithuania surely lies below 0.2 per cent, that is, both countries have a very weak innovation system. Some of the companies are still state-owned so their R&D expenditures are included in the numbers for the government sector, but this fact does not alter the conclusion that the innovation system is weak in Estonia and Lithuania. The large state-owned firms still produced 41 % of the industrial production in Estonia in 1995, but in 1997 the share of the state-owned firms is very low.

The R&D intensity in the manufacturing of different products can be measured by the share of the R&D expenditures in the value added of the products. **The ratio of R&D expenditures to gross output or value added of the industry** is the traditional measure of the technological level of an industry (Virtaharju & Åkerblom, 1993, p. 25). This is also called the research intensity in industry. Other measures on industrial R&D which have been used are **the ratio of R&D investment to traditional fixed investment**, **the number of enterprises engaged in research**, **public support of R&D activity**, and **research man years**.

Table 13. Research intensity in manufacturing industries in Finland and the Baltic countries.

	Research intensity based on value added, %	Research intensity based on gross output, %
	1994	1994
Finland	5.6	1.95
ESTONIA	0.68	0.24
LATVIA	*	*
LITHUANIA	*	*

Sources: Statistics Finland, for Estonia: The Ministry of Economic Affairs, not official data

*) not available

As was mentioned above the technological level of an industry can be measured by the research intensity in industry. In international comparisons research intensity is the most commonly used and a widely accepted measure of the technological level. Other measures of the technological level in an industry are usually too complicated to use, because a lof of factors should be included which are very difficult to measure as for example embodied technology. From table 13 we can see that the research intensity based on value added was only 0.68 % for total manufacturing in Estonia in the year 1994. The corresponding figure was 5.6 % for Finland. Usually the calculations of research intensity are based on value added, but research intensity based on gross output can also be used. If we use the research intensity based on gross output, the research intensity for total manufacturing was 0.24 % in Estonia and 1.95 % in Finland in the year 1994. This comparison of the Estonian figures to the Finnish figures, confirms the common view that the technological level of Estonian manufacturing industries is very low. The reader should, however, pay attention to the fact that quite a lot of new embodied technology has been taken into use during the years 1995 and 1996. As a result of increased import of new technology, foreign investments and increased know-how the technological level of the Estonian industries seems to be improving rather fast at the moment. It is also important to notice that the low research intensity for Estonia reflects the fact that there are no high technology industries in Estonia. Furthermore, in branches were the technological level is above the average level the industrial firms are very small and accordingly they do very little R&D of their own. Unfortunately there are no data available on R&D expenditures for manufacturing industries in Latvia and Lithuania so no comparison between the different Baltic countries can be made here.

There are different opinions concerning whether a strong R&D activity is optimal for a small country or not. Accordingly there's no consensus in this matter, so one cannot definitely say what's right or wrong for the Baltic countries. Japan for example has never been a leader in basic research. In spite of this, Japan has gained a leading position in the product markets of many high-tech commodities thanks to applications of modern technology. Also the Finnish strategy has been based on diffusion and imports of technology, rather than on innovation activity (Kanniainen, 1994, p. 91). In this context it is however very important to notice, that although a strong R&D activity is not always optimal for a country, some level of R&D activity is always necessary so that the absorptive capacity of the firms will stay on a sufficiently high level. The relevant question is consequently, what is this "minimum" level of own R&D activity which is required in a country. Cohen & Levinthal (1990, p. 150) among others points out that if a firm wants to exploit a new technology, which is not similar to its present technology, it first has to invest in the corresponding absorptive capacity.

3.2.3. INDICATORS ON APPLICATION OF TECHNOLOGY

In section 3.2.2 it was concluded that R&D activity measures only inputs in the technology development process, and that separate output measures are needed. The OECD has, however, only proxy indicators on the output of scientific and technological (S&T) activities. One is the "technology balance of payments" which is extracted from the national balance of payments. The technology balance of payments consists of money paid or received for the use of patents, licences, know-how, marks, models, designs, technical services and for industrial R&D carried out abroad. In other words it registers all commercial transactions which are related to international transfers of technology and know-how. This means that the technological balance of payments (TBP) shows the degree of technological openness of the economy either in terms of import or export of technological knowledge.

The exchange of patents and licences constitutes an important channel of technology transfer. A licence is a permission that a manufacturer purchases from the owner of a particular technology in order to benefit commercially from the owner's production method, trade mark and other associated rights. A licence gives the recipient of a technology an opportunity to utilise a production process that has been well developed and tested in practice. In the cases of patents and licences, technology is transferred from one country to another in the form of written documents and blueprints of devices. The exchange is especially lively between highly industrialised countries (Myllyntaus, 1992, p. 232, p. 237).

In market economies, most of the licences are transferred within foreign direct investments (FDI) and multi-national enterprises. In the socialist period FDI were, however, extremely limited which reduced the potential role of disembodied technology in the form of licences. The opening of former socialist countries and the fast growth of FDI will thus increase the importance of this indicator for assessing their S&T (Auriol, & Radosevic, 1996).

The use of foreign licences in Estonia was the most common mode of production before 1987, as foreign ownership of production facilities was not permitted in Estonia. The licensing agreements generally included foreign companies' supply of trademarks, quality control, basic material and packaging material. Those few foreign companies, which were operating by licensing closely controlled both the raw materials and the manufactured products in order to make sure that the products fulfilled the quality requirements (Hyvärinen & Borsos 1994, p. 100).

Data on patent applications gives information on inventions and can thus be seen as a partial proxy of the output of R&D. Together with patent data the technology balance of payments may indicate something about a countries' technological performance. Patenting will be discussed in more detail in section 3.2.3.1. Two other indicators on application of technology, i.e. investments and robots, will be described in the following sections.

3.2.3.1. Patenting activity

A patent is a sole right granted by a government to an inventor to utilize the invention for an agreed period. The patent grant requires novelty, usefulness and adaptability of the invention. Patenting increases the willingness of firms to invest in R&D because the patent system keeps competitors away. The common opinion is that the patent system accelerates technological progress although the temporary technological monopoly it gives has a slowing down effect. A patented invention is not always industrially utilized, because the technology may not be suitable for large scale production, or because the marketing of the product is difficult. The types of inventions which can be protected by the patent right vary a great deal in different countries (Åkerblom & Virtaharju, 1987, p. 22).

Patent data cover both applications and grants. They are usually classified by field of technology. International data series of patent applications are divided into four sub-categories: 1) the number of resident applications, i.e. applications in a given country A by citizens or residents of country A, irrespective of nationality, 2) the number of non-resident applications, i.e. applications in country A from abroad, 3) the number of national applications in country A, i.e. the sum of resident and non-resident patent applications registered in that country, 4) the number of external applications, i.e. applications by citizens or residents of country A in other countries (OECD: Basic science and technology statistics, 1993 edition). Data on patents granted is only divided into patents awarded to residents and to non-residents. The raw data can be obtained from national and international patent offices.

Patenting activity can also be described by key ratios. The share of domestic applications in national applications describes the technological independence in patenting as well as the relative level of innovation in a country. Foreign applications/domestic applications describes the openness in a country to foreign technology. External applications/foreign applications describes the balance of patent applications, i.e. how much patents are applied for from a country in relation to received applications. The applications are in balance if the key ratio is near one. External applications/domestic applications in the previous year, describes for how large share of the innovations a patent right is applied for also abroad. The indicator shows the spreading abroad of the technology which has been developed in a country (Tiede ja teknologia 1989, p. 35-37).

Patent statistics as technology indicators have the benefit that time series usually are available for long time periods. There's information on a lot of different qualities of the invention and inventor which makes it possible to study the nature of technological progress. The patent statistics gives information on transfer of science and technology between countries. Comparisons between various countries are possible, but they are complicated by different criteria for granting patents (Åkerblom & Virtaharju, 1987, p. 22). It is in fact very difficult to measure the true innovative capacity as different national patent legislations seriously distort the comparability of patent indicators.

There are, however, also some other problems connected with patent statistics. All inventions cannot be patented and patents are not applied for all inventions, so the statistics give an imperfect picture of inventions. Another problem is the evaluation. For example, patented products can be only small improvements to existing ones. Also the economic importance of patents varies. If patents granted are studied instead of patent applications, the time delay has to be considered (Åkerblom & Virtaharju, 1987, p. 22).

The different systems of patent protection in the socialist and market-based economies imply that the national patent statistics in the former socialist countries should be interpreted with caution. The patent protection systems in former socialist countries were based on Soviet-type regulations, the so-called "inventor's system" or "authors certificates". This system had little to do with intellectual property in the market economy sense, even if the "technical" aspects of patent procedure were similar. It can therefore be expected that patents underestimate the innovative capacity since the system of property rights was weak in the past. Auriol & Radosevic (1996) explains the authors certificate in the following way: "An author certificate certifies the recognition of an application as an invention, its priority and authorship, the exclusive rights of the state to use and take charge of the invention, as well as securing the rights and privileges of the author as specified by the legislation. As a distinction from the author certificate, a patent certifies the exclusive rights of the author (the patent owner) to the invention."

The former socialist economies have been collecting innovation data for quite a long time. These product innovations were defined as being developed in the country for the first time and being essentially different from the previously manufactured ones. The counting of product and process innovations did, however, not reveal the true innovation capacity of these economies (Auriol & Radosevic, 1996).

Innovation incentives are strongly dependent on the prevailing incentives in product markets. In market economies innovation is stimulated through a large variety of innovation incentive mechanisms such as patents, secrecy, lead times, learning curve advantages, etc. Under the socialist system, innovation was essentially a non-competitive process, mostly dependent on political will and individual decisions. As innovation incentive mechanisms now have been created, patent activity in the post-socialist period should better reflect innovative capacities. Competition policy, especially foreign trade liberalisation, is important in post-socialism as these countries have inherited a very high degree of industrial concentration and vertical integration (Radosevic, 1996).

Table 14. Inventiveness coefficient, i.e. resident patent applications per 10 000 population

	1981	1985	1990	1991	1992	1993	1994	1995	1996
European Union	2.25	2.33	2.26	2.16	2.4	2.44	2.48	*	*
Denmark	2.12	1.67	2.51	2.11	2.36	2.26	2.49	*	*
Iceland	0.61	0.87	0.67	1.32	1.07	1.28	0.82	*	*
Norway	1.74	2.22	2.12	2.19	2.23	2.34	2.41	*	*
Sweden	4.75	4.65	3.74	3.72	3.89	4.37	4.58	*	*
Finland	2.96	3.52	4.13	4.26	4.1	4.31	4.55	*	*
ESTONIA	*	*	*	*	*	*	0.11	0.10	*
LATVIA	3.98	3.86	3.75	*	*	*	0.79	*	*
LITHUANIA	*	*	*	*	*	0.25	0.30	0.29	*
Czech Republic	*	*	*	*	2.11	0.87	0.73	*	*
Hungary	*	*	*	*	1.45	1.11	1.13	*	*
Poland	*	*	*	*	*	0.69	0.69	*	*

Sources: OECD: Main Science and Technology Indicators. The figures for Estonia in the years 1994-1995 are based on data from the Estonian Patent Office and the Statistical Yearbook 1995 and 1996, Statistical Office of Estonia. The figures for Latvia are based on data from Kristapsons, J. & Tjunina, E. (1995a) and the Statistical Yearbook of Latvia 1995. The figures for Lithuania are based on data from the Statistical Yearbook of Lithuania 1996.

*) not available

Resident patent applications per 10 000 population in the Baltics and some other countries are presented in table 14. As we can see from the table the inventiveness coefficient for **Estonia** is very low, only 0.10 in 1995. There are very few domestic invention applications in Estonia, only 15 in 1995. The total number of applications in Estonia is not large either, 482 in 1994 and 82 in 1995. However, the Patent Office in Estonia is relatively new so the patenting activity can be expected to increase in the future. The number of trade mark applications (2830 in 1995) has been much bigger than the number of invention applications. Most of the trade mark applications have been made by foreigners, but there are also relatively many Estonian applicants (589 in 1995).[1]

[1] Estonian Economy 1995-1996. Ministry of Economic Affairs of the Republic of Estonia.

According to data provided by the State Bureau of Patents in **Lithuania** the number of patent applications by Lithuanian applicants was 111 in 1994 and 106 in 1995. In the same years, the number of patent applications by foreign applicants was 180 and 27, respectively. The number of domestic patent applications is thus larger in Lithuania than in Estonia, which is also reflected in a larger inventiveness coefficient for Lithuania, 0.29 in 1995. Estonia has, on the other hand, attracted more foreign patent applicants than Lithuania. This can probably be explained by larger foreign direct investments into Estonia, as foreign firms so far have shown more interest in Estonia than in Lithuania.

Latvia is the one of the Baltic countries that shows the highest level of resident patent applications. By patents Kristapsons & Tjunina (1995a) mean both Latvia's patents, which have been granted since 1992, and the author's certificates of the former USSR. The number of patents in Latvia has dropped radically, from about 1000 per year until 1990 to approximately 200 in 1994, which also can be seen from the inventiveness coefficient in table 14. This is of course connected with changing the patent system in Latvia, but the main reasons are the collapse of industrial science and lack of industrial demand for inventions, as the number of patents to a large extent reflects the level of R&D in a country and the degree of development of science. The inventiveness coefficient for Latvia was 0.79 in 1994. Accordingly, it is somewhat higher than the coefficient for the Czech Republic and Poland.

Before 1990, Latvia was in fact famous for its high level of patenting of inventions among other regions of former USSR. Such fields as pharmacy, cosmetics, aerotechnics, heterocyclic compounds, enzymes and gene engineering were highly developed. In these branches the number of patent documents filed by Latvia's inventors was at least 1.5 times higher than the world average indices. This is confirmed by the data in table 14, where we can see that the inventiveness coefficient of Latvia in the years 1981-1990 clearly exceeds the average of the European Union countries with a large margin. During 1980-1991 there were at least 100 inventors in Latvia who received more than 30 USSR author's certificates each; 20 % of them were from the institutes of the Academy of Sciences, 50 % from technical universities and 30 % from industrial enterprises (Kristapsons & Tjunina, 1995a).

The reduction of the number of patents as early as 1991 was a reaction to the political events of 1988-1989. When the issuing of Latvian patents started in 1992 the intensity of the process was low, compared with the number of USSR authors' certificates in previous years. Still in 1993 and 1994, Russian patents were being given to Latvian applicants to a small degree, as the majority of applications were dated 1991 and 1992 (Kristapsons & Tjunina, 1995b). Now the number of applications practically coincides with the number of patents received in Latvia. There are not many firms, research institutes or inventors among Latvia's patent applications that were previously granted a large number of USSR author's certificates (Kristapsons & Tjunina, 1995a).

Surprisingly, in terms of R&D expenditures and personnel, there is a totally opposite pattern of the level of science in the Baltics, i.e. Estonia shows the highest level of science while Latvia has the lowest. We can thus conclude that data on GERD/GDP (as well as R&D personnel) and resident patent applications do not support each other in the case of the Baltic countries.

Auriol & Radosevic (1997) on the contrary found that resident patenting in CEECs follows the same downward trend as for R&D expenditures and employment. Relative 'over investment' in R&D of CEECs in the transition period is thus reflected in patents, as significantly downsized R&D systems still produce numbers of patents above those of comparable economies. Even after a sharp decrease in resident patenting throughout the 1980's and 1990s, in terms of inventiveness coefficient resident patenting in CEECs is still far above Greece, Mexico, Portugal and Turkey.

This result may, however, be misleading because of still widespread problems in intellectual property rights legislation in some CEECs. Looking at external patent applications should give better insights, as the limits of patent indicators are less crucial then. External patenting indicates the degree of technological competitiveness. In all CEECs there is a strong rising tendency of the numbers of external patents. Despite this, the degree of outward orientation of patent activity, when analysed through the rates of diffusion (external/residential patent applications of preceding year), is comparable to or below less developed EU economies except for Hungary (Auriol & Radosevic, 1997). Unfortunately we have no data on external patent applications for the Baltic countries.

Non-residential applications indicate the technological integration of countries in transition, i.e. the degree to which they have become important as technological markets. Auriol & Radosevic (1997) found that patent activity in CEECs is driven by foreign patenting which has increased by two or three times. Despite big differences in population size, the absolute levels of non-resident patent applications in CEECs are very similar. This indicates that foreign companies in similar degrees have been interested in all CEECs, and that natural country differences in terms of growth and imitative capability cannot yet be seen.

3.2.3.2. Investments and New Technology

The quantity of new technology in an industry is very difficult to measure and therefore no such data series exists. Investments in machinery and equipment can, however, be used as an indirect measure of new technology, because investments reflects the introduction of new or at least more up-to-date technology (Tiede ja teknologia 1989, p. 37). The value of total fixed investments in industry, i.e. investments in buildings plus investments in machinery and equipment gives an overall picture of the investment situation. The use of new technology can be described by the value of investments in machinery and equipment in industry. A good measure is also the value of investments in machinery and equipment per employee in industry. We have, however, chosen not to present any data on investments in this report, as our objective is not to describe the general development of any industrial branches.

3.2.3.3. Robots, the Age of Fixed Capital Stock, and the Technological Level

A good measure of the technological level of production machinery would be the age of fixed capital stock and its development. Unfortunately reliable information on this does not exist in every country. This is the case for example in Finland where information on the number of industrial robots is used instead. It is, of course, a more limited indicator, but the number of robots nevertheless is a rough estimate of the technological level of production machinery in the industrial branches where they are used. Besides statistics on robots, information on NC machine tools and flexible production systems, could be useful (Åkerblom & Virtaharju, 1987, p. 28).

Table 15. The use of industrial robots in selected countries.

	Industrial robots						Industrial robots per million indust. employees [1]	
	1982	1985	1988	1989	1991	1995	1989	1995
Estonia					58	80	240	620
Latvia	*	*	*	*	*	*	*	*
Lithuania	*	*	*	*	*	*	*	*
Finland	70	250	545	670			1260	
Sweden	1300	3400		3460			4340	
Belgium	350	1000		1400			1730	
France	950	5900		7060			1490	
Germany	3500	8800		22400			2900	
Italy	700	4000		10000			2470	
UK	1150	3200		5910			1110	
[1] Rounded to nearest 10.								

Sources:
George F. Ray: The Diffusion of selected technologies in Finnish Industry, p. 310., in Vuori, S.& Ylä-Anttila, P. (1992) Mastering the technology Diffusion - The Finnish Experience. Tiede ja teknologia 1989, Statistics Finland, Education and research 1989:24. For Estonia: data from the Ministry of Economic Affairs, not official.

*) not available

Table 15 shows the use of industrial robots in selected countries. The number of robots per million industrial employees can be used as a rough estimate of the technological level of the production machinery. Also these figures confirm the conclusion above that the technological level of Estonian industry is far below the level in the western countries. However, as a result of the rapid development of the Estonian electronics industry in recent times, the number of industrial robots is rising. No comparison between the Baltic countries can be made here, as we have not found any data on industrial robots for Latvia and Lithuania.

3.2.4. INDICATORS ON THE ECONOMIC IMPACT OF SCIENCE AND TECHNOLOGY

New technology, which is a result of research and development activity, is reflected also in production and foreign trade. The economic impact of science and technology is described by indicators on the production and foreign trade of high technology products (Tiede ja teknologia 1989, p. 40).

Several studies have shown that the contribution of new technology to total factor productivity is considerable. Total factor productivity is that part of the growth in production which is not due to changes in labour resources or capital investments. Growth in production thus depends more and more on technology (Åkerblom & Virtaharju, 1987, p. 37).

3.2.4.1 Production of High Technology Products

There are no official international standards for classifying high-tech industries and products. One approach is the industry approach which is used by the OECD, and the other is the product approach (OECD, 1992, TEP, p. 300).

The OECD has declared that high technology products are products for which R&D activity is of utmost importance and that they are strategically important to the government. High tech products are also characterized by large capital investments which are subject to risk, and by strong international cooperation and competition. In addition products and processes are rapidly going out of date (Åkerblom & Virtaharju, 1987, p. 30). These qualities are usually associated with computers and electronics, space research, medicines, highly developed systems of arms, equipment for nuclear power production or the like (Teknologian soveltaminen ja siirto 1993, p. 13).

The OECD has defined high technology products according to industries where the research intensity is relatively high, using the R&D intensity of industries in eleven main OECD countries. First of all the research intensity has been calculated, i.e. R&D expenditures as a percentage of the production, turnover or value added, in each country and industry. Then the intensities per industry were calculated, weighing the research intensity of a particular country and industry with a parameter that represents the share of the industry of that particular country in the total production in the industry. Finally industries were divided into "high", "medium" and "low" research intensity groups by the OECD as follows: industries with a research intensity over 4% were defined as high tech industries, branches with a research intensity over 1% were classified as medium tech industries, and branches with a research intensity of 1% or less were classified as low tech industries (Åkerblom & Virtaharju, 1987, p. 30).

There are, however, some methodological problems associated with the OECD classification of high technology products, especially in the case of small countries. The research intensities have been calculated with a fairly rough industry classification. There are subbranches which are classified as medium or low tech industries, although they include products or parts which require a high technological knowledge and an advanced mechanical equipment. The OECD also assumes that products with a high technology intensity are produced in industrial branches which have a high R&D activity of their own. Technological progress in certain branches is however based on the purchase of technology, such as patents, licences, and investments on production machinery. Despite these deficiences the OECD classification is the most commonly used (Vitenskaps- og teknologi-indikatorer for Norden, 1992, p. 93).

The product approach requires the use of detailed R&D data by product field. It has the advantage that it allows for more detailed analyses and identification of the technology content of products. For a very detailed analysis of technology intensities there are methods based on input-output-calculations.[2] Industries can be divided up according to their "technology content", taking into consideration both direct investment in R&D as well as the indirect acquisition of its domestic results incorporated in intermediate consumption, capital

[2] See for example Virtaharju, M. & Åkerblom, M. (1993): Technology intensity of Finnish manufacturing industries, Science and technology 1993:3, Helsinki.

goods, and results of foreign R&D-incorporated in imported goods. The technology inputs are estimated econometrically using input-output matrices (OECD, 1992, TEP, p. 300).

Indicators on the production of high technology products are for example the value of production of high technology products by product group, and the share of high-technology products in industrial production.

3.2.4.2 Foreign Trade of High Technology Products

Indicators on the foreign trade of high technology products are for example the share of high-technology products within total exports, the share of high tech in total trade, the value of high-technology exports and the value of high-technology imports. Transfer of technology in the form of goods can also be studied by looking at the export of investment goods.

In table 16 the value of high-technology exports and imports between Finland and Estonia is given. The year 1991 is the first one for which data is available. From the figures we can see that the value of foreign trade of high-tech products has increased considerably during the four years for which data is available. After Estonia regained independence Finland has become the main exporter to Estonia, which explains the fast increase in exports of high-tech products to Estonia. Finland is also the main importer of Estonian products. The relatively large value of imports of high-tech products from Estonia to Finland in 1994, implies that also Estonia to some extent has production of high technology products. This is contrary to the general opinion, that high-tech production is totally lacking in Estonia. However, as the Statistical Office of Estonia does not keep any statistics on neither production nor trade of high-tech products, we cannot make any more analysis than the statements above.

Table 16. Foreign trade of high-tech products between Finland and Estonia 1991-1994.

	1991 mill. FIM	1992 mill. FIM	1993 mill. FIM	1994 mill. FIM
Exports from Finland to Estonia	12.8	87.9	227.6	502.4
Imports from Estonia to Finland	0.6	4.9	8.1	145.9

Note: High-tech products include the following product groups as defined by the OECD: Aerospace, Computers, Electronic components, Telecommunication equipment, Drugs and Medicine, Instruments, Electrical equipment and machinery, Power machines and -motors, Automatic machines for industry, Chemicals.

Source: Tiede ja teknologia 1995, Statistics Finland.

Indicators on trade in high-tech products were originally ment to be measures of the "output" of R&D. They have a wider use, however, in the analysis of competitiveness and globalisation (OECD, 1992, TEP, p. 300). A series of import-export ratios for the main R&D-intensive industries are published twice a year in "Main Science and Technology Indicators" (OECD). Series for trade classified by high, medium and low R&D-intensive industries are analysed in the annual "Review of Industrial Policy in OECD Countries".

4. NATIONAL SYSTEMS OF INNOVATION AS THE BASIS FOR SCIENCE AND TECHNOLOGY POLICY

According to Lundvall (1992b, p. 2), a system of innovation consists of elements and relationships between these elements which interact in the production, diffusion and use of new and economically useful knowledge. Similarly, a national system of innovation encompasses the elements and relationships which are located or rooted inside the borders of a nation state. In other words, a **national system of innovation** refers to all parts and aspects of the economic structure and the institutional set-up of a nation which affect the innovation process.

The definition used by Lundvall (1992b) is explained by Gregersen et al. (1994, p. 116) in the following way: In most parts of the modern economy we can find on-going innovation activities of different kinds. Innovation results from different kinds of learning processes through which new knowledge emerges. Most forms of learning may be regarded as an interactive process in which people combine different pieces of knowledge so that something new is created. That is, innovation is gradual and cumulative. Present innovations are in some respects a continuation of past ones. From this results that the distinction which is made in innovation theory between invention, innovation and diffusion as separate stages becomes blurred. Accordingly, innovations appear not primarily as single events, but more as a process. It follows from this reasoning that innovation is rooted in the institutional set-up of the economy. Lundvall (1992b, p. 9) points out that since learning partly emanates from routine acitivities in economic production, innovation must also be rooted in the prevailing economic structure.

Gregersen et al. (1994, p. 116-117) sums up as follows. Innovation processes can be regarded as a result of interactive learning processes that are affected by both the economic structure and the institutional set-up of the economy. Since both the economic structure and the institutional set-up differ between nations, the concept of national systems of innovation (NSI) can be used.

According to Lundvall (1992b) the main elements of a national innovation system are:
- the internal organisation of firms
- interfirm relationships
- the role of the public sector
- financial institutions
- the organisation of R&D activities
- the intensity of R&D activities
- the national education and training system

Lundvall (1992b, p. 2) strongly emphasizes that **learning** is a central activity in the national system of innovation. Usually the elements of the system of innovation reinforce each other in promoting processes of learning and innovation, but in the opposite case they combine into constellations which are blocking such processes. Cumulative causation is thus characteristic of systems and sub-systems of innovation. As Freeman (1992, p. 180-181) points out it is impossible to consider any major innovation as the work of a single individual or organisation, because there always exists a long range of earlier scientific and technical contributions.

Most innovations are developed by firms, so Lundvall (1992b, p. 14) assumes that the internal organisation of private firms is one important element of the system of innovation. The organisation of the flow of information and of the learning process are important, because they affect the innovative capability of the firm. The interaction between the different departments engaged in sales, production and R&D is an important aspect of the internal organisation.

Also the public sector plays an important part in the process of innovation. First of all, it is involved in direct support of science and development through the connection to the R&D system. Further, the regulations and standards issued by the public sector influence the rate and direction of innovative activities in the economy (Lundvall, 1992b, p. 14).

The national education and training system is an extremely important element of the national system of innovation. The quantitative investment in education, the enrolment in science and engineering, the investment in training of skilled workers, are factors which affect the innovative capabilities of a country. The formal and informal education and training systems differ a lot between countries (Lundvall, 1992b, p. 15).

Lundvall (1992b, p. 12) makes a distinction between a system of innovation in a **narrow sense** and a system of innovation in a **broad sense**. The **broad definition** reflects the importance of interactive learning as a basis for innovation. The broad definition of a system of innovation includes all parts of the economic structure and the institutional set-up which affect learning as well as searching and exploring. This means that all institutions which affect the introduction and diffusion of new products, processes and systems in a national economy are included in this definition. Also Freeman (1992, p. 169) emphasizes that national systems of innovation in the broad sense stresses the importance of the interactions between the production system, the users and innovation. The production system, the marketing system and the system of finance are **subsystems** in which learning takes place.

If technical innovations are assumed to follow mechanically from scientific efforts and from research efforts inside firms (Lundvall 1992b, p. 13), then the system of innovation is much more narrowly defined and it can be identified with the R&D system. The **narrow definition** includes organisations and institutions which are involved in searching and exploring (Lundvall 1992b, p. 12), in other words that set of institutions which are more directly concerned with scientific and technical activities.

Freeman (1992, p. 173) mentions that the national system of innovation in the narrow sense comprises R&D departments, technological institutes and universities, quality control and testing facilities in the industry, national standards institutes, national research institutes and libraries, and a network of national scientific and technical societies and publications.

Besides learning, the **institutional set-up** is the second important dimension of the system of innovation. One of the most important characteristics of institutions is their relative stability over time. Therefore institutions and routines provide the stability which is needed for innovative efforts to take place and to be successful. Agents and organisations also need guidance for action, which is provided by institutions. Economic systems characterised by innovative activities, can survive and act in a changing and uncertain world thanks to institutions (Lundvall, 1992b, p. 10).

The factors in the institutional set-up which affect innovations, can be divided into "formal" and "informal" institutions. **"Formal institutions"** refers to formally organized entities. As examples of formal institutions Gregersen et al. (1994, p. 120) mentions the formal system of education and training, the formal research system, the telecommunication infrastructure, the system for financing innovations, the technical service system, the patent-, trademark and copyright systems. Post offices, labour unions, government agencies, and banks may also be considered to be "formal institutions" under this definition.

"Informal institutions" refer to those habits, routines, rules, norms and laws which affect the character and pattern of communication and consequently also the interactive learning (Gregersen et al., 1994, p. 120). According to Lundvall (1992b, p. 10) institutions may for example be routines, which are guiding everyday actions in production, distribution and consumption. The degree of working place democracy, the degree of trust and the informal cooperation norms in both intra-firm and inter-firm relations, informal network relationships and user-producer relationships can also be mentioned as examples. Gregersen et al. (1994, p. 120) points out that both the formal and the informal parts of the institutional set-up are important elements in the national system of innovation.

The concept of national systems of innovation can, however, be used only if clear national differences in institutions and economic structures can be identified. If this is not the case, it may be better to analyze regional and local systems of innovation or sectorial delimitations, as for instance **"technological systems"**. The different concepts and approaches complement each other, so the choice of concept depends on the empirical context (Gregersen et al., 1994, p. 117).

Technological systems can be defined as networks of agents which interact in each specific technology area under a particular institutional infra-structure aiming at generating, diffusing, and utilizing technology. There are three important differences between technological systems and national systems of innovation. First, technological systems are defined by technology and not by national boundaries. The degree of internationalization vary among technology areas. Second, within any given country the technological systems differ in character from one technology area to another. One technology area may be strong in a country while another may be weak. A third difference concerns the emphasis on diffusion, utilization and creation of new technology (Carlsson, 1994, p.172).

The concept of a national system of innovation has been adopted as the basis for science and technology policy in many industrialized countries. A national innovation system is in fact one of the most important components that influences the competitive advantage of a nation. A prime goal of technology policy is the dissemination of new technology and promotion of innovative activities as well as promotion of the interaction between the researchers and firms, between firms and their customers or suppliers as well as between firms operating in the same field (National Industrial Strategy for Finland, 1993, p. 61-62). Firms must engage in innovative activities because, the long term competitiveness of firms and of national economies, depends on their innovative capability (Lundvall, 1992b, p. 8). Technology policy has been discussed already in chapter 2, so we will not deal with it in this context.

5. THE CURRENT SCIENCE AND TECHNOLOGY POLICY OF THE BALTICS

Estonia and the other countries in transition are now in a situation, in which their task is to restructure their science and technology sector into a market economy oriented innovation system. Without an active technology and research policy of their own, the countries in transition are not capable of achieving the necessary restructuring of the science and technology sector. Paasi (1995, p. 11) emphasizes that the countries in transition should in their technology strategies put the weight on diffusion of foreign technology and on the use of modern technologies of all kind. Paasi (1995, p. 15) also points out that the best way for the EU to promote the technology transfer in the transition phase is to open the EU-markets. For the reform countries this would mean that the amount of potentially available technology would increase.

Without an effective science and technology sector, consisting of public research institutes, universities as well as research and development activity in the firms, the countries in transition are unable to raise their long run growth potential. A well functioning science and technology sector is thus a necessity. Because of the present low efficiency of the science and technology sector both structural and institutional changes are required in this sector (Paasi, 1995, p. 11).

With the changes brought by post-socialism the structure of the R&D and innovation activities has also changed. Under socialism the technological emphasis was mostly on product development. Technological activities are, however, now directed towards non-R&D activities like testing and standards as these have become critical for exports. In post-socialism export requirements have thus increased the emphasis on quality considerations. At the same time cost considerations play a more important role as the countries in transition usually are competing in low cost market segments. Accordingly enterprises are restructuring their technological effort towards process innovations. Now improvements in product quality often is the most important objective of innovations (Radosevic, 1996).

The whole R&D community has shifted towards basic science, because the state support is focused on this area. This has, however, weakened applied and strategic research. Applied research is therefore relatively shrinking, while basic research and the development/testing part of the R&D activities has become relatively more important. In other words, enterprises have moved towards development activities and abandoned applied R&D (Radosevic, 1996).

In this chapter we try to figure out how the S&T-system in the three Baltic countries currently is organised. The aim is to describe the present science and technology policy.

5.1. ESTONIAN S&T-SYSTEM, SCIENCE AND TECHNOLOGY POLICY

The technological level of Estonian industries has improved considerably in recent years thanks to the current innovation policies, foreign direct investments and other forms of technology transfer. The technological level and thus the competitiveness of the Estonian industry can be further increased by adopting an appropriate innovation policy. In this section those parts of the national innovation system that are related to the public sector will be discussed. Especially, the Estonian Research and Development Council, the Estonian Science Foundation, the Estonian Innovation Foundation and the Estonian Informatics Foundation play an important role in financing of technology transfer and innovation in Estonia.

A system of innovation consists of elements and relationships between these elements which interact in the production, diffusion and use of new and economically useful knowledge. A national system of innovation encompasses the elements and relationships which are located or rooted inside the borders of a nation state. Theoretically, the main classical elements of a national innovation system are: the internal organization of firms; interfirm relationships; the role of the public sector; financial institutions; the organization of R&D activities; the intensity of R&D activities; the national education and training system. The national system of innovation thus means a whole set of factors influencing the development and utilization of new knowledge and know-how to the benefit of science, economy and social development.

The present S&T-system in Estonia is sketched up in figure 1. As can be seen from the figure Estonia already has all the institutions that are necessary for a market-oriented national innovation system. The Ministry of Economic Affairs and the Ministry of Education promotes technology development through supportive programs and funds. A Science and Technology Policy Council was founded in the year 1995. It is the supervisor of The Estonian Innovation Foundation, The Estonian Science Foundation and The Estonian Informatics Foundation. Other special funds are The Export Crediting and Guaranteeing Fund and The Small Business Promotion Foundation.

The Privatization Agency and The Foreign Investment Agency are important institutions during the transition period. Also the Patent Office is relatively new. Estonia has a well developed education system, including universities, state professional higher schools and vocational education institutions. The Science Park in Tartu and the Technological Park in Tallinn are still in the incubator state. Consequently they are in the need of further development. Estonia also has a Technology Development Center.

The Confederation of Estonian Industry and Employers is the head-organization of several member associations. Furthermore there are 15 commercial banks in Estonia, two branch banks of foreign banks and six agencies of foreign banks. The Tallinn Stock Exchange was founded in April 1995. The Exchange started its performance in the first half of 1996. The problem in Estonia is, however, that the present national innovation system is not a well-functioning system.

The Republic of Estonia has not officially adopted and proclaimed its innovation policy. The **Estonian Ministry of Economic Affairs** in its activity in the field of financing technology transfer and innovation has tried to be guided by the following standpoints. In shaping its innovation policy, Estonia cannot take into consideration only examples of the respective systems of the developed countries, but must additionally take into account the local conditions and requirements. The general objective of innovation policy can be formulated as optimization of the legal, organizational, individual, and financial conditions of the technological development of the economy. The objectives of the innovation policy must fit naturally into the purpose and tasks of the transformation process of the economy. Therefore, the current purpose of the innovation policy is the transformation and qualitative development of the interrelated systems of higher education, scientific research and technological development of the economy (Berg (ed.), 1997, p. 82-83).

It is, however, necessary to introduce formal procedures for setting technology and innovation policy priorities. It must be accompanied by the creation of mechanisms designed specifically to forecast trends in research and technology and supporting mechanisms (Berg (ed.), 1997, p. 83-84).

FIGURE 1. THE INSTITUTIONAL SET-UP OF THE PRESENT SCIENCE AND TECHNOLOGY SYSTEM IN ESTONIA

Ministry of Economic Affairs	Ministry of Education	Ministry of Finances	Ministry of Foreign Affairs

Estonian Research and Development Council		
Estonian Innovation Foundation	Estonian Science Foundation	Estonian Informatics Foundation

Privatization Agency	Foreign Investment Agency	Export Crediting and Guaranteeing Fund	Small Business Promotion Foundation

Statistical Office of Estonia	Estonian National Library	Patent Office	Estonian Association of Quality	Standards Board of Estonia	Phare Office

Academy of Sciences of Estonia	Tallinn Technical University	Tartu University	Other Universities	Estonian Business School
State professional higher schools	Vocational Education Institutions	Centre for continuing education	Estonian institute of future studies	Institute of Economies

Science Park in Tartu	Technological Park in Tallinn	Technology Development Centre

Confederation of Estonian Industry and employers CEIE				
Federation of Estonian Engineering Industry	Association of Electronics and Instrument Industry Enterprises	Federation of Estonian Chemical Industry	Estonian Woodworking Federation	Union of Estonian Paper Manufacturers
Estonian Clothing Manufacturers Association	Association of Estonian Leather Manufacturers	Association of construction material producers of Estonia	Association "Estonian forest"	Union of Estonian Food Industry
Association of Estonian Local Industry		Unions associated with CEIE	Unions co-operating with CEIE	
ESTONIAN COMPANIES		Estonian Small Business Association (EVEA)		

As the innovation policy may be divided into two large groups (development of the infrastructure of the innovation system; special subprogrammes and activity connected with them) the financing and activity in general are directed at two main fields. These are:

A. Promotion of innovation-supporting infrastructure

1. Development of the state supporting system (state funds to support innovation, laws to regulate innovation, statistics).

2. Development of technological parks and other centres and organizations that support high-technology entrepreneurship.

3. State orders to educational institutions, co-operation and division of roles in education between various organizations and institutions, upgrading and defining the tasks of these institutions. Preparation of development plans for upgrading and retraining.

4. Promotion and guiding of international scientific-technical cooperation (FRAMEWORK IV, EUREKA, COST, PHARE, ESA, CERN, ESF, EMBL etc. European Union and world-wide research, technological and innovation programmes).

B. Special subprogrammes/projects

The financing of both innovation-supporting infrastructure and special programmes/projects comes as a rule from several sources and is based on the so-called co-financing by participating enterprises, the Estonian Innovation Foundation and other funds. Programmes are financed from the state budget, interests on loans, own assets of participating enterprises and organizations (Berg & Kilvits & Tombak, 1996, p. 177).

As mentioned already in chapter 3 the data on R&D expenditures collected by the Statistical Office of Estonia covers only a part of the R&D system, as the business sector has not been questioned. In other words, in the research statistics of Estonia the development organizations, spin-off companies, industrial R&D units etc. are fully absent. Hence, we have no idea about the total amount of R&D allocations in Estonia during the recent years. For the other sectors of the economy (i.e. other than the business sector) there are, however, data available on science financing and the sources of financing in the period of the Estonian kroon, i.e. for the years from 1992 onwards.

Table 17. R&D financing in Estonia by source of funds.

	1992 mill. EEK	1993 mill. EEK	1994 mill. EEK	1995 mill. EEK	1990 %	1992 %	1993 %	1994 %	1995 %
Government funds	89.1	100.0	165.3	180.6	48.6	88.1	74.9	76.2	71.4
Business enterprises' funds	1.7	19.1	20.8	32.7	51.4	1.7	14.3	9.6	12.9
Non-profit organizations' funds	-	5.8	6.8	6.1		-	4.4	3.1	2.4
R&D institution' s own funds	0.4	4.3	8.7	9.4		0.4	3.2	4.0	3.7
Foreign funds	9.9	4.3	15.1	24.2		9.8	3.2	7.0	9.6
Total funds	101.1	133.5	216.8	253.0	100.0	100.0	100.0	100.0	100.0

Sources: Martinson, H. The reform of R & D system in Estonia,Tallinn, 1995, p. 37; Science 1995, Statistical Office of Estonia.

Total R&D financing in Estonia has more than doubled during the years 1992-1995. From table 17 we can see that most of the R&D financing in Estonia comes from government funds. Although total government financing is increasing, a decreasing trend in the percentage share can be seen. In 1992 the share of government financing was as high as 88 %. In 1995, however, still over 70 % of R&D was financed by government funds. The share of business enterprises funds has increased from about 2 % in 1992 to 13 % in 1995. When looking at percentage shares, financing by foreign funds has varied a lot, i.e. between 3 and 10 per cent in recent years. The absolute amount of foreign funds, however, seems to be increasing after 1994. While the main source of R&D financing has been the state budget, the share of the business sector is obviously too low. It is also important to notice that the absolute growth of the state budget appropriations does not compensate for the inflation rate. The data above therefore indicates that the situation with R&D financing in Estonia during the past 4-5 years has been absolutely unsatisfactory.

Table 18. R&D expenditure in Estonia by kind of R&D activity.

	1992	1993	1994	1995	1992	1993	1994	1995
	mill. EEK	mill. EEK	mill. EEK	mill. EEK	%	%	%	%
Basic research	79.5	80.3	121.3	132.0	79.4	61.7	56.0	52.7
Applied research	18.8	38.7	78.9	89.0	18.8	29.8	36.5	35.5
Experimental development	1.8	11.1	16.2	29.5	1.8	8.5	7.5	11.8
Total expenditures	100.1	130.2	216.5	250.6	100.0	100.0	100.0	100.0

Source: Science 1995, Statistical Office of Estonia.

During the years 1992-1995 the share of R&D expenditure on basic research has decreased from 79 % to 53 %, whereas the share of applied research has increased from 19 % to 36 % (table 18). This is a sound tendency, as there has been too little applied research in the transition countries during the socialist period. The share of experimental development has also been increasing, from 2 % to 12 %.

Table 19. R&D expenditures in Estonia by fields of science.

Field of science	1992 mill. EEK	1993 mill. EEK	1994 mill. EEK	1995 mill. EEK	1992 %	1993 %	1994 %	1995 %
Natural sciences	26.1	43.4	81.9	87.3	26	33	38	35
Engineering	10.4	26.3	37.4	61.5	10	20	17	25
Medical sciences	10.2	12.8	19.7	26.2	10	10	9	10
Agricultural sciences	9.0	13.2	22.2	31.5	9	10	10	13
Social sciences	11.0	9.0	17.1	17.8	11	7	8	7
Humanities	11.8	25.4	38.2	26.3	12	20	18	10
Other sciences	21.7	-	-	-	22	-	-	-
TOTAL	100.1	130.2	216.5	250.6	100	100	100	100

Source: Science 1995, Statistical Office of Estonia.

Data on R&D expenditures by fields of science are given in table 19. In the year 1995 the majority of R&D expenditures was spent on natural sciences and engineering, the shares were 35 % and 25 % respectively. The importance of natural sciences and engineering has increased on the expense of humanities, the share of which has decreased from 20 % in 1993 to 10 % in 1995. However, the shares of medical sciences, agricultural sciences and social sciences have remained more or less unchanged.

Table 20. R&D financing in Estonia by source of funds and field of science in 1995.

Field of science	Total funds Thous. EEK	Government funds %	Business enterprises' funds %	Non-profit organizations' funds %	R&D institution's own funds %	Foreign funds %
Natural sciences	87612	37.9	14.7	39.5	24.9	39.6
Engineering	62781	15.9	66.4	6.9	35.3	35.8
Medical sciences	26289	11.5	4.1	29.7	5.9	7.7
Agricultural sciences	31406	14.4	7.1	7.9	19.3	3.0
Social sciences	17868	7.4	6.9	6.1	8.5	4.6
Humanities	27089	12.9	0.8	10.0	6.2	9.3
TOTAL	253045	100.0	100.0	100.0	100.0	100.0

Source: Science 1995, Statistical Office of Estonia.

The majority of the government funds, almost 40 %, was allocated to natural sciences in 1995 (table 20). Engineering and agricultural sciences both received around 15 % and the other fields of sciences slightly less than that. As could be expected, two thirds of the business enterprises' funds are directed to engineering. Non-profit organizations' funds have mostly supported natural sciences and medical sciences. One should, however, keep in mind that these funds are very small. The same concerns R&D institutions' own funds, most of which are allocated to engineering, natural sciences and agricultural sciences, in the mentioned order. The priority of foreign funds, which are rather small, has been to spend money on natural sciences (40 %) and engineering (36 %). It is quite natural that most part of the funds during the transition period are allocated to natural sciences and engineering, because these are the most important science fields when it comes to developing the technological level of industry. This in turn is very important for the competitiveness of the countries in transition.

Table 21. R&D expenditures in Estonia by kind of R&D activity and type of institution in 1995.

Type of institution	Total expenditures thous. EEK	Basic research thous. EEK	Applied research thous. EEK	Experimental development thous. EEK
Universities	70 707	42 668	22 586	5 453
Academy of Science	105 087	77 298	17 757	10 032
Medicine	12 478	1 895	9 858	725
Agriculture	27 970	3 645	16 501	7 824
Construction and industry	4 033	375	2 508	1 150
Wildlife preserves	5 260	-	2 135	3 125
Museums	4 049	4 049	-	-
Other	21 020	2 084	17 697	1 239
TOTAL	250 604	132 014	89 042	29 548

Source: Science 1995, Statistical Office of Estonia.

According to the international classification the universities form the separate higher education sector, all other listed groups in table 21 are part of the government sector. The R&D survey does not cover the business enterprise sector, but the financial survey of enterprises indicates, that the expenditures in the business enterprise sector in 1995 on research and development were about a half of those in government and university sectors. In earlier years these expenditures were lower, the change is connected with the growth of Estonian GDP and industrial production. The new situation creates the necessity for more detailed surveying of R&D activities also in the business enterprise sector (Science 1995, Statistical Office of Estonia).

As was already mentioned in earlier chapters, most part of the basic research has taken place in the Academy of Science institutions during the socialist period. In 1995 the percentage of R&D expenditures spent on basic research in the Academy of Science was almost 60 %. About a third of the money allocated to basic research was for universities. According to the data in table 21, most of the applied research has been taking place in universities, whereas most of the experimental development has been conducted in the Academy of Science. The research performed in medical and agricultural institutions is mainly applied research.

Table 22. R&D financing at universities and institutions of Academy of Science in Estonia by socio-economic objectives in 1995.

	Universities		Institutions of Academy of Science	
	Total funds, thous. EEK	Total funds, %	Total funds, thous. EEK	Total funds, %
Agriculture, forestry and fishing	5879	8.1	696	0.7
Industry	5365	7.4	792	0.8
Production and rational use of energy	6161	8.5	2238	2.1
Development of infrastructure	6459	8.9	1588	1.5
Control and protection of the environment	4940	6.8	3892	3.7
Public health	11699	16.1	1658	1.6
Social development and services	4514	6.2	80	0.1
Exploitation of the earth and atmosphere	999	1.4	3215	3.1
Civil exploitation of space	-	-	-	-
National defence	-	-	-	-
Advancement of knowledge	26524	36.6	91133	86.6
TOTAL	72540	100.0	105292	100.0

Source: Science 1995, Statistical Office of Estonia.

The majority of R&D financing both at universities and in institutions of Academy of Science is used for advancement of knowledge, 37 % and 87 % respectively (table 22). At universities 16 % of total funds are used for research concerning public health, 9 % for development of infrastructure, 9 % for research promoting production and rational use of energy and about 7 % for research in the field of industry.

The Estonian Ministry of Culture and Education has established the aim that the research expenditures as a percentage of GDP should be 0.9 % by the end of the century. As GERD/GDP has constantly decreased and the resources are very small, achieving this aim is, however, quite problematic. Accordingly, the use of state budget resources for structural-political purposes is extremely limited.

It should also be noted that Estonian scientists have been quite successful in getting grants from many sources, but these grants cannot compensate for the absence of financing from the business sector. Unfortunately, the taxation system does not encourage enterprises to invest in R&D.

Table 23. Distribution of scientists and engineers by field of science in Estonia.

	Number of scientists and engineers, FT+PT									FTE
Field of science	**1960**	**1970**	**1980**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1995**
Natural sciences	402	1144	1466	-	-	1533	1451	1535	1335	1018
Engineering	593	1103	1644	-	-	801	950	863	864	739
Medical sciences	204	315	470	-	-	535	517	545	550	298
Agricultural sciences	189	331	392	-	-	565	395	462	417	292
Social sciences	341	840	1217	-	-	773	741	718	658	367
Humanities	480	949	897	-	-	827	942	956	679	395
Other sciences	18	25	159	-	-	70	-	-	-	-
TOTAL	2227	4707	6245	7150	7227	5104	4996	5079	4503	3109

Source: Science 1995, Statistical Office of Estonia.

From table 23 we can see that the number of scientists and engineers increased during the period 1960-1990, but after that the number has been decreasing. As these numbers include both full-time and part-time employees, they are however difficult to interprete. In the 1960's and 1980's most of the scientists and engineers were employed in engineering, but in the 1990's the number of scientists and engineers in natural sciences clearly exceeds that of engineering. This is also the case when looking at full-time-equivalent numbers in 1995. Throughout the whole period from 1960-1995 social sciences and humanities have employed more researchers than both medical and agricultural sciences.

Table 24. Scientists and engineers in Estonia by type of institution in 1995.

Type of institution	**1995, Full-time-equivalent**
Universities	1626
Academy of Science	822
Medicine	121
Agriculture	262
Construction and industry	73
Wildlife preserves	25
Museums	28
Other	152
TOTAL	**3109**

Source: Science 1995, Statistical Office of Estonia.

In 1995 more than half of all scientists and engineers were employed by universities, counted in full-time-equivalent (table 24). Surprisingly, the number of scientists and engineers is much higher in universities than in the Academy of Science, despite the fact that the latter institution receives more money for R&D than universities. As the figures are in full-time-equivalent, this discrepancy cannot be explained by teaching work engaging scientists at universities. Labour costs in both types of institutions slightly exceed 50 %. The only reasonable explanation seems to be that wages paid at universities are lower than in the institutions of the Academy of Science. However, we have no data available that could verify this assumption.

A very important role in the financing of technology transfer and innovation in Estonia is played by three special funds - the Science Foundation, the Innovation Foundation and the Informatics Foundation. These funds were established in 1990 to cover the financing of all stages of R&D. Despite the small amount of resources available the work of the Estonian Research and Development Council, the Estonian Science Foundation, the Estonian Innovation Foundation and the Estonian Informatics Foundation has been satisfactory in general. As an "umbrella" above these foundations is the **Estonian Research and Development Council**, a collective advisory body to the Government of the Republic of Estonia. Since May 1995 it has 20 members, including 6 ministers, a member of *Riigikogu*, the Rectors of the universities, the President and some members of the Academy of Sciences, the Chairman of the Estonian Science Foundation Council, the Chairman of the Estonian Innovation Foundation Council, the Chairman of the Estonian Informatics Foundation Council and some representatives of the business sphere. The Chairman of the Estonian Research and Development Council is the Prime Minister (Berg (ed.), 1997, p. 84).

From 1991 till December 1993 the main decision-making body for R&D policy was the Estonian Science Council. From the moment of reorganization in December 1993 the Research and Development Council became actively involved in advising the Government on matters of science, technology and development, and higher education. The Research and Development Council decides the principles of distribution of resources between the research areas, participates in the formulation of the state budget on R&D, and represents Estonia's interests in the matters of R&D at an international level. All ministries and other governmental bodies are accountable to the Research and Development Council on matters of R&D. In opening, restructuring and closing of research institutions the Government proceeds from the suggestions made by the Research and Development Council. The first and most concrete undertaking of the Research and Development Council was a thorough inventory of the whole research establishment of Estonia. In this process the results of the Swedish evaluation of Estonian science as well as the knowledge and impressions of experts of the Estonian Science Foundation were taken into account. On the basis of this inventory a number of cardinal institutional changes were proposed in December 1994 (Berg (ed.), 1997, p. 84-85).

The **Estonian Science Foundation** was established on July 16, 1990 to support basic and strategic research. At the end of 1990, the Estonian Science Foundation Council (15-17 members) was appointed by the Government and the Foundation began to work. The budget for 1995 was 166.9 million kroons and 931 grants were handed out. As compared with the Research and Development Council the Estonian Science Foundation Council is another level of decision-making on the matters of research development. It makes the main decisions on distribution of the research funds. The main principle for the Estonian Science Foundation Council has been the demand for original, high quality research that would meet international quality criteria, to be carried out in Estonia, and consequently, to make every effort to help sound research survive during the transition period (Berg (ed.), 1997, p. 85).

The first principle question to be solved concerned balancing of the basic financing of research institutions and the grant money. In the first two years the percentage of grant money was low: less than 5%. Since 1993, the share of money distributed by the Science Foundation as grants has grown every year (20.0% in 1993; 24.0% in 1994; 28.0% in 1995) (Berg & Kilvits & Tombak, 1996, p. 169).

The distribution of grants (total number of grants was 695 in 1994 and 931 in 1995) by fields of science was as follows:

Natural sciences	36.0%;	
- exact sciences		14.3%;
- chemistry and molecular biology		10.3%;
- geo- & biosciences		11.4%;
Engineering	16.7%	
Medical sciences	16.5%;	
Agricultural sciences	11.4%;	
Social sciences	9.8%;	
Humanities	9.6%.	

The state budget financing of research in Estonia in 1992-1995 allocated to Estonian Science Foundation was as follows:

1992 - 60.8	mill. EEK
1993 - 93.0	mill. EEK
1994 - 125.9	mill. EEK
1995 - 166.9	mill. EEK

A comparison of the data in table 17 and the state budget financing of research in Estonia in 1992-1995, which is allocated to the Estonian Science Foundation, reveals that of the total government funds 68 % in 1992, 93 % in 1993, 76 % in 1994 and 92 % in 1995 was allocated to the Estonian Science Foundation. This means that the Estonian Science Foundation has a very important role in R&D financing in Estonia. For example, research at the Academy of Science is financed through the Estonian Science Foundation.

The **Estonian Innovation Foundation** is a non-profit fund under the Ministry of Economic Affairs. It was founded by the Government of the Republic of Estonia in July 1991 to finance the technological progress of the Estonian economy. According to the revised Charter the Innovation Foundation should assist the Government in developing national innovation policy and preparing of relevant guidelines and programmes. The main financial source of this foundation was designed to be a certain percentage of state property income. The foundation got some starting capital (5 mill. roubles) from the state. But already by 1992 it was clear that the state property income was in reality much less than expected. In 1992, the foundation got from the state budget about 10 million kroons only. From 1993, the foundation is a state-financed organization. The foundation renders grants for applied research and technology development projects, supports technology development programmes, supports creating of infrastructure of science/technology parks. The Innovation Foundation can provide grants for applied research projects up to 50 % of the project cost or loans for preindustrial production projects up to 75 % of the project cost at interest rates generally lower than those at commercial banks. Priority is given to innovation projects in the area of energy saving, improvement of production technology, use of local know-how and raw materials, medical and veterinary technology, plant protection, transportation technology, environmental technology (Berg & Kilvits & Tombak, 1996, p. 171).

The operation of the Estonian Innovation Foundation is co-ordinated with the activities of the Estonian Science Foundation and the Estonian Informatics Foundation in a way that the boards of all the three foundations are represented in the Estonian Research and Development Council. Every project is weighed by expert groups and by the Board of Foundations. Every project is subjected to a technical-economic survey. The decision is made proceeding from the innovativeness of the project, from its economic indicators and according to the priorities of the economic development. The Innovation Foundation resources are rather small. In 1991-1995, the Foundation financed 186 projects with a total of 77.4 million EEK. In 1995, 42 projects were financed with a total of 22.1 million EEK. The Foundation has supported the organization of manufacturing of analytical equipment (lasers, chromatographs etc.) at the Academy of Sciences spin-off companies: production of vaccines and other biotechnological products; projects on energy saving and other projects. The Foundation supported the creation of the Science Park in Tallinn. There are, however, not enough resources to fund high-risk technical projects (Berg (ed.), 1997, p. 85-86).

The Estonian Informatics Council, an advisory body acting under the auspices of the State Chancellery, was formed by the Estonian Government in 1989. The **Estonian Informatics Foundation** started its activities in December 1990, when Estonia had not yet regained full independence. Its main goal has been the development of national informatics policy, that is to work out the state policy for promoting the informatics sphere and support research in this field. The Foundation is a nonprofit organization which promotes and supports the development of information technology and state information systems. Basic funding is provided by the national budget. The income from commercial activities - publishing, exhibitions, etc. is used to finance the foundation's basic activities. The Foundation gives out an illustrated monthly "Arvutimaailm" (in Estonian), has published several books on various information technology issues, such as open systems design, EN/EDIFACT, Internet, etc. (Berg & Kilvits & Tombak, 1996, p. 170).

In late 1993, a regulation for information technology public procurement was issued by the Government. The Informatics Foundation has been issuing certificates to companies interested in participating in the procurement tenders as well as organizing the tenders. About one hundred computer companies have been certified and more than 30 tenders carried out at a total volume of 4 million USD. The Foundation has concluded agreements with software giants Microsoft, WordPerfect and Oracle about bulk purchase of software licenses for central and local government agencies. Purchase of almost a thousand licenses has markedly reduced the use of non-licenced copies of software packages. By agreement with the Standards Board of Estonia, the Foundation bears responsibility for information technology standardization, co-ordinating the development of draft standards, publishing and distributing Estonian standards and representing Estonia in international standards organizations (Berg & Kilvits & Tombak, 1996, p. 170-171).

The national system of innovation is also supported by the development of the **banking system** and the **capital market**, as well as that of the **export crediting fund, small business promotion foundation, Small Business Association (EVEA) and the associated bank,** the **Estonian Chamber of Commerce and Industry**, and a number of **territorial and branch alliances** etc. The state budget for 1996 allocated 11.5 million kroons for export development, including direct aid to enterprises, for exhibitions and fairs to be held on behalf of the Estonian state and support to the Estonian Export Council for implementing export promotion programmes (Berg (ed.), 1997, p. 87).

The industrial policy of the Republic of Estonia promotes in every possible way small and medium-sized private firms. In recent years the importance of foreign projects in promoting the growth of small business has increased. Several projects have been initiated and realized by the **Estonian Small Business Association (EVEA)**, which has co-operated with the USA, Nordic countries and several other European countries. Short courses for entrepreneurs have been conducted, development plans completed, draft laws supporting small business prepared and questionnaires arranged to find problems facing small and medium-sized enterprises. The Ministry of Economic Affairs worked out and the Government approved in 1995 two programmes for promotion of small and medium-sized enterprises: 1) Programme for promotion of small and medium-sized enterprises - 20 million EEK, and 2) Programme for advising small and medium-sized enterprises - 1.92 million EEK from the regional development programmes (Berg (ed.), 1997, p. 87).

Small subsidies in the form of start-up capital have been allocated through the National Labour Market Board. It accounted for only 5 %, however, of the total expenditure on labour market policies. Four business advisory boards have been set up within the PHARE programme in Tallinn, Tartu, Narva and Pärnu. They attempt to promote the development of Estonian small- and medium-sized enterprises and advise them on access to the European market. In 1995 they rendered services (subsidized by PHARE) to 91 enterprises for a total of 320,000 EEK. The principle services are: preparation of business plans, drawing up of loan applications, searching for business partners and management and accounting consultations. Entrepreneurship centres have been created in co-operation with Sweden. The Swedish-Estonian Circulation Fund at the Ministry of Economic Affairs issued in 1995 three loans for a total of 2.8 million SEK. There are plans for 1996 to form on the basis of business advisory boards and entrepreneurship centres an entrepreneurship promotion system. The state support would mean that an entrepreneur who turns to this centre gets the service below the average market price. The British Know-How Fund promotes the financial, energy, environmental, administrative and small business sectors. For using Danish financial aid there have been concluded social agreements between various Estonian and Danish ministries. The Estonian economy and its development programmes have also been assisted by Finland, Italy, Switzerland, USA, etc. The Ministry of Economic Affairs plans to continue in cooperation with the PHARE programme the development of the entrepreneurship supporting system. A new service to be introduced will be technological advice. The PHARE credit line will be opened for Estonian small- and medium-sized enterprises in the amount of 10 million EEK in 1996 (Berg & Kilvits & Tombak, 1996, pp. 185-186).

The technology and innovation policy priorities of the Estonian Innovation Foundation were discussed above. The Estonian Research and Development Council appointed the following priority areas in the field of engineering sciences: information technology and system engineering; production engineering; power (energy) engineering. The list of priorities in the Ministry of Economic Affairs is as follows: power engineering equipment, incl. technologies and equipment for introducing resource-saving technologies and local fuels; information equipment; production equipment (by branches); biological and medical equipment;

modernization of the technical base of transport, promotion of economical modes of transport and trunk-line transport; projects based on elaborations by Estonian research institutions. The final decision upon the priorities of technological development for 5-10 years must be taken into consideration and the corresponding support measures implemented (Berg (ed.), 1997, p. 87-88).

One of the main objectives of the state innovation policy is the promotion of high technology production. One reason for this is the fact that the high technology industries are economically extremely profitable. These areas of production use less material and energetic production inputs per unit of output, i.e. they are effective from the aspect of value added production. With the purpose of increasing the share of high technology industries in the national economy many advanced industrial countries spend over 2 % of their GDP on R&D annually. In 1994 and in 1995 Estonia spent only 0.7 % of its GDP on R&D. While the share of R&D in the state budget is similar with other small and poor European countries, the enterprises' spending for this purpose are quite insignificant (in most Western countries expenditure on R&D is divided between the state budget and private sector almost equally). R&D spending is usually carried out mainly by large firms which have a well-known trademark and produce finished products. In Estonia such enterprises are almost missing and it would be unrealistic to expect considerable spending on R&D from small firms oriented to subcontracting. It is prevalent in the modern world that (large) firms with a well-known trademark produce finished products, and that they are surrounded by small firms who fulfil subcontracts. This situation is quite natural as this kind of organization of production satisfies both parties. R&D costs, creation of co-operative relations, marketing, the whole market risk in general is taken by the large enterprises (Berg (ed.), 1997, p. 88).

In creating high technology production Estonia cannot rely on the help of state institutions of Western countries either. The developed industrial countries protect their priority to operate in profitable high technology industries with both economic and political instruments. The same policy is pursued by international economic and monetary organizations under the supervision of developed industrial countries. Still the industrial production is becoming rapidly internationalized. The industrial policies are increasingly less determined by states and increasingly more by international corporations. This is the fact that the Estonian innovation policy should be based on. Estonia has chosen the fastest way to upgrade its technological level, that is, largely through foreign direct investments from Western countries, which brings advanced technology to Estonia. It is necessary to promote in every way the establishment of subsidiaries of international corporations in Estonia, the inflow of know-how and foreign capital with market relations in general. This enables the raising of the technological level of the Estonian economy, provides local enterprises with both single orders and subcontracts in the future to "start" the whole Estonian economy (Berg (ed.), 1997, p. 89).

Given the above it may be said that the most important element of the Estonian technological development and innovation infrastructure is the **Foreign Investment Agency**. It promotes Estonia as a favourable place for investment. It is possible to get information on investment opportunities there any time - from laws to concrete projects. The agency also offers possible co-operation partners both from amongst state and private enterprises. Feedback about investments and suggestions to the government are of great importance for improving the investment climate (Berg (ed.), 1997, p. 89).

5.2. LATVIAN S&T-SYSTEM, SCIENCE AND TECHNOLOGY POLICY

The Latvian research system has changed radically since 1989. As a consequence of the fast transformation of the national economy, the changes in the Latvian research system have also been very rapid. The problems connected with this radical change were already discussed in section 3.2.2.1. The main aim of the Latvian science policy is to change it in accordance with the western model. The integration into western science also means changing the "language of science" from Russian to English (Kristapsons & Tjunina, 1995a & 1995b).

The Latvian scientists themselves have taken the initiative to the reforms in the research system. At the end of 1988, when the Latvian Union of Scientists was founded, it was an influential power in Latvia's science. Among the countries of Eastern and Central Europe there are two rather radical reforms that were undertaken only in Latvia. Excluding former East Germany, whose Academy has been closed, the transformation of science in Latvia is thus the most radical (Kristapsons & Tjunina, 1995b).

The reform of the system of funding for science from the state budget was the most important one. This policy decision meant formation of a new system of funding for science, in which the whole state science budget is divided into separate grants given to particular research projects. None of the other post-socialist countries have chosen a similar science-funding model. This reform was drafted in 1989-90 by a working group consisting of representatives from the Union of Scientists, the Academy of Sciences, and the Board of Rectors of the Latvian higher educational institutions. The decision about this reform was taken by the Government of the Republic of Latvia only two months after the declaration of independence. The second reform was the transformation of the Academy of Sciences during 1989-1993 from the Soviet-type of academy which was supervising research institutes, into a classical type of academy without subordinated institutes. This reform was drafted by the Statutes Commission of the Academy of Sciences in 1990-1992. A similar model was chosen by Lithuania. Now the Academy of Sciences is an autonomous state-subsidised non-profit scientific institution, while institutes, specialised design offices and pilot plants are independent state organisations (Kristapsons & Tjunina, 1995b).

There were several attempts to speed up the process of transition to the western model of science organisation, where science and university education are closely connected, but there seem to be many conflicting interests. University professors do not want to start doing active research work, and scientists want to continue doing research work only. Furthermore, as a consequence of the economic reform in Latvia and rapid reduction of industrial production the former industrial science has more or less ceased to exist. As a result, several research institutes have been merged and many of them have been shut down (Kristapsons & Tjunina, 1995b).

Between 1985 and 1990, there were plans to establish a special Ministry of Science and Technology of Latvia, but the idea was never realised. Later, in 1992 the Department of Science and Higher Education of the Ministry of Education and Science was, however, founded (Kristapsons & Tjunina, 1995b).

The present S&T-system in Latvia is sketched up in figure 2. The most important institutions and features of the system will be discussed below.

FIGURE 2. THE INSTITUTIONAL SET-UP OF THE PRESENT SCIENCE AND TECHNOLOGY SYSTEM IN LATVIA

Ministry of Economy	Ministry of Education and Science - Department of Higher Education and Science	The Ministry of Environment and Regional Development

Latvian Council of Science (20 members)		
Expert commission (14 members)	Representative of the Cabinet	Repr. of the Latvian Academy of Sciences
Repr. of the Board of Rectors of the higher education institutions	Repr. of the Association of Latvian Scientists	Repr. of the Latvian Academy of Agricultural and Forestry Sciences

Latvian Privatization Agency	Latvian Development Agency	Latvian Investment Bank

Central Statistical Bureau	National Center of Standardization and Metrology of Latvia	Latvian National Accreditation Office (LATAK)

Secondary schools, Higher Education and Science Institutions				
Latvian Academy of Sciences	Latvian Academy of Agricultural and Forestry Sciences	University of Latvia	Riga Technical University	Other Universities
Riga International College of Economics and Business Administration		Vocational schools	Institutions of secondary specialized education	

Latvian Association of Technological Parks, Centers and Business Incubators - LTICA (1996)		
Radioelectronic Technology Center - RTC (1993)	Latvian Technological Center - LTC (1993)	Salaspils Technological Center - STC (1994)
Latvian Technology Park at the Riga Technical University - LTP (1996)		Business Incubator in Liepaja (1997)

Latvian Electrical and Electronics Industry Association	Other Industry Associations
Latvian Small Business Association	LATVIAN COMPANIES

The core of the new research system is the Latvian Council of Science, which was founded in July 1990 in accordance with the decision of the Latvian government to change the science funding system and management of science. The Council of Science started its activities, which are determined by the Law on Scientific Activity, in the autumn of 1990. The main task of the Council is the distribution of the state budget for science and research. Since 1 January 1991, the previous direct funding of scientific research institutes from the state budget has been replaced by the financing of selected projects by grants. The Latvian Council of Science prepares the draft of the Republic's science budget for each year together with the Council of Ministers of Latvia and prepares laws aimed at development and organization of science in Latvia (Kristapsons & Tjunina, 1995b). The Council also promotes co-operation between research institutes and higher education institutions in the area of education and science.

The main characteristics of the new funding system are that scientists from each field of science elect an expert commission, making 14 expert commissions in all. The Council consists of 20 members. One representative from each commission is elected, i.e. 14 Council members are elected from 14 branches of science. Additionally the Latvian Council of Science includes 6 members in accordance with their positions: a representative of the

Cabinet, Latvian Academy of Sciences (LAS), Board of Rectors of the higher education institutions, Association of Latvian Scientists and Latvian Academy of Agricultural and Forestry Sciences.

The 14 expert commissions from each branch of science are elected by ballot for 3 years. Each commission consists of 5-13 scientists, who carry out the examination of the proposed scientific projects and research programs. Based on the recommendations of the expert commissions, the state science budget is distributed by the Council of Science for different grants among the different fields of sciences. The Latvian Council of Science and the expert commissions together consist of 133 scientists, of which 37 are representatives from the independent state research institutes, 73 from higher education institutions and 23 from other scientific institutions.

The difference between the Latvian system and that of other countries is that these commissions and the Council of Science are elected and not appointed. As the elected members of the Council represent a particular field of science or research organisation they are obliged to make decisions which satisfies their electors. The opinion of Kristapsons & Tjunina (1995b) is that this results in a situation where the Council of Science is not capable of distributing money effectively between the different scientific fields.

Table 25. Number of grants by the Latvian Council of Science and total funding among branches in 1996-1997.

Branch	Number of grants				Funding			
	1996	1997	1996 %	1997 %	1996 (Ls)	1997 (Ls)	1996 %	1997 %
1. Computer science	50	49	6.3	7.5	271520	184807	6.8	5.6
2. Mechanics, machine engineering and energetics	62	56	7.8	8.6	336940	248732	8.4	7.6
3. Physics, mathematics and astronomy	102	96	12.9	14.8	468521	433286	11.6	13.2
4. Chemistry	62	58	7.8	8.9	411835	337777	10.2	10.3
5. Scientific principles of technology: materials, chemistry, pharmacy	47	21	5.9	3.2	284456	154326	7.1	4.7
6. Biology, ecology, geography and geology	72	76	9.1	11.7	308342	322472	7.7	9.8
7. Molecular biology, microbiology and biotechnology	34	27	4.3	4.2	285666	239138	7.1	7.3
8. Medical sciences	85	71	10.8	10.9	415124	343605	10.3	10.5
9. Agricultural sciences	101	58	12.8	8.9	468552	360803	11.7	11.0
10. History (including history of culture)	23	16	2.9	2.5	125392	100392	3.1	3.0
11. Linguistics, history of literature and arts sciences	45	38	5.7	5.9	173061	130262	4.3	4.0
12. Philosophy, sociology psychology and pedagogics	55	45	7.0	6.9	196218	172838	4.9	5.3
13. Economics and law	27	21	3.4	3.2	210335	193815	5.2	5.9
14. Wood sciences	26	18	3.3	2.8	62696	60000	1.6	1.8
Total	791	650	100	100	4018626	3282253	100	100
Programms funding					292500	1482644		
Total					4311126	4764897		

Source: Latvian Council of Science 1997.

In 1997 the Latvian Council of Science decided to give grants to 650 scientific projects according to their scientific level. The total sum of funding amounted to Ls 3.282.253. From table 25 we can see that in 1996 and 1997 most of the funding was allocated to the fields of physics, mathematics and astronomy, agricultural sciences, medical sciences and chemistry. According to Kristapsons & Tjunina (1995b) the distribution of funds among different fields of science has changed little since the new science funding system was started.

In 1990 the Government adopted a proposal about the introduction of scientific degrees in Latvia. In October 1991 the Latvian academic degrees were introduced and the complicated procedure of receiving the new degrees on the basis of the former Soviet scientific degrees started. The Latvian scientific degrees were not received automatically, but for each person evaluation and secret ballot were required. Lithuania is following a similar procedure of receiving new scientific degrees, but Estonia transformed the former USSR degrees into Estonian ones automatically (Kristapsons & Tjunina, 1995b).

In the Republic of Latvia the qualification of scientists is confirmed by promotion. The highest scientific qualification is confirmed by awarding the degree of Dr. habil for important contributions in development of science. The Latvian Council of Science gives the rights of habilitations and promotions to scientific research institutes and higher education institutions. As of January 1, 1997, 750 habil. doctors and more than 5100 doctors have received their new academic degrees.

The Council of Science has officially declared that when distributing the research grants, higher scores are given to the projects, if the authors have publications in the SCI journals. In addition, the Council has recommended that the degree of doctor habilitatus should be given only to those scientists who have publications in the SCI journals (Kristapsons & Tjunina, 1995a).

According to Kristapsons & Tjunina (1995a & 1995b) it is difficult to draw any conlusions about the future of science in Latvia, as it is not clear which scientific fields Latvia should concentrate on. One possibility is to preserve all the existing research fields on a smaller scale. Another possibility is to focuse on a few selected branches in order to ensure a high scientific level in those areas. The question is, however, which branches of science should be supported. At least some of the physics and chemistry branches should be advanced, where the number of articles published in the SCI journals is on the same level as in some of the European countries.

The development of technological centers in Latvia started in 1992 in order to develop innovative business support structures in Latvia. The initiative was taken by the Department of Higher Education and Science of the Ministry of Education and Science. The reason for this was the decreased financing of research grants which has taken place since 1991. The main goal of the technological/innovation centers and science/technology parks is to fill the gap between the system of higher educational establishments and scientific institutions, and industry, as well as to promote economic development by foundation of small and medium-sized enterprises (SMEs). It is also very important to promote international economic and scientific collaboration in designing high-quality products and to create new jobs for the highly-qualified specialists and researchers who lost their jobs because of the reorganization of science and the higher education system in Latvia. The technological parks and centers can promote restructuring of mutual cooperation among scientific research institutions, industrial and trade enterprises. In this way they can meet the demands of the market economy and the formation of new small technologically-oriented private enterprises is facilitated (Stabulnieks, 1997).

The first technology oriented business support structures were established in Latvia in 1993. Today there are already four innovative business support institutions. These business support structures have a great impact on the foundation of new companies, as they have offered considerable support to the new knowledge-based and technology-oriented enterprises (Stabulnieks, 1997).

The Radioelectronic Technology Center was established in 1993 in order to promote the development of small enterprises, which are oriented in the production of electronic equipment and instrument-making. The main objective is to transfer technology by offering technological support to newly formed small companies and to significantly facilitate collaboration with the existing technical laboratories and industry. The Radioelectronic Technology Center promotes the modernization of the Latvian industry through cooperation with western technological firms, as well as looking for new partners in such technical directions as energy saving, telecommunications, medical and biotechnological instrument-making, microelectronics and sensor-technology, environmental protection, conservation of surroundings, etc. This activity is financed by the state and by enterprise subsidies, as well as payments from services from firms and project groups (Stabulnieks, 1997).

The Latvian Technological Center was also established in 1993. It is a technological or business and innovation center in the classic form. The activity is financed by the Ministry of Education and Science from the resources for the market oriented research in the state budget. The main directions of the activities of the 34 new small enterprises in LTC are electrical engineering, telecommunications, laser technology, multimedia systems including computer networks and software, bioreactors and equipment for biotechnology and medicine, environmental protection, technology of high-quality latex rubber catheter production for medicine, instrument making for medicine, hygienic and medical products on the base of natural substances and medical herbs, production and testing of new veterinary pharmaceutical preparations, etc. (Stabulnieks, 1997). The state financing of the Latvian Technological Center has increased systematically, but it has not been very extensive. In 1995 the state financing amounted to LVL 82500, which is approximately USD 147000. This sum provided 88.3 % of the center's income. The majority of expenditures (56.5 %) was used for renovation and the center's facilities (Karnite & Gulans, 1996).

The structure and status of the Salaspils Technological Center, which was established in 1994, is similar to the well-known innovation or technological centers in Europe. The activity was financed by the Ministry of Education and Science from the state budget and partly from the budget of the local government. The activities of the Salaspils Technological Center have, however, stopped for some time as a result of the still ongoing reorganization of the system of higher education and science, as well as privatization of state property (Stabulnieks, 1997).

The Latvian Technology Park was established at the Riga Technical University in 1996. Its main goal is to reorganize about 8 ha of available land and former barracks of the Russian army in Riga into a technologically developed area. The Technology Park has a business incubator with 8 tenant companies and 110 employees (Stabulnieks, 1997).

The development of technological centers in Latvia has since the end of 1993 been supported by the Technological Center Warnemunde in Germany. Now the establishment of a Science park in Riga is under consideration. It would be located in the area of the "Academy campus" with 5 research institutes of the Academy of Sciences and the Latvian Technological Center (Stabulnieks, 1997).

In 1996 the Latvian Association of Technological Parks, Centers and Business Incubators (LTICA) was established. Its first activities were to create contacts with particular government bodies, such as the Ministry of Education and Science, the Ministry of Economy, the Ministry of Environment and Regional Development, the Latvian Development Agency and the Agency of Privatization. In the same year the Baltic Association of Science/Technology Parks and Innovation Centers (BASTIC) was established. The Latvian Technological Center and the Latvian Technology Park are also members of the International Association of Science Parks (IASP) since 1997 (Stabulnieks, 1997).

The Latvian Ministry of Economy has taken the initiative in 1997 to work out the National Program for the development of small and medium-sized enterprises (SMEs). This program includes a special chapter about the innovative business support structures. In the operational plan for the time period 1997-1998 it is for example proposed to improve the national quality management system and to make more efficient collaboration between the Ministry of Education and Science and the Ministry of Economy in support of the technology-oriented business (Stabulnieks, 1997).

The objective of the National Program of Quality Assurance in Latvia is to create an infrastructure in the quality ensuring area, including special training of all level personnel on quality management. The work to create an informative, consultative and training center of quality assessment of goods and services is proceeding. In the data base of this center there is information on the available EU standards in Latvia and on standards themselves (approximately 3000 EU standards). This data base is coordinated with the data base of the European Standard Committee CEN and it also contains information on the recognized certificates, etc. information that is linked with quality assessments and assurance (Ministry of Economy, Republic of Latvia, 1997).

Within the framework of the National Program of Quality Assurance work was continued in 1997 at draft standards and their interpretations, training programs and materials to introduce in Latvia environment quality management systems corresponding to EU basic principles and standards of EN/ISO 14000. The review of drafts of Latvian national standards and coordination of terminology is now going on. The relevant EU standards and directives are taken into consideration in the development of legislation in the field of quality assurance. The National Program of Development of Standardization has been devised which envisages to accept European standards in order to harmonize Latvian legislation with EU legislation in technical areas. It is planned to start massive acceptance of EU standards without their translation into Latvian where it is not indispensable. It is estimated that Latvia could follow adaptation of "new" EU standards and adapt at least 500 "old" EU standards per year. This means that all EU standards would be adapted in Latvia by the year 2004 (Ministry of Economy, Republic of Latvia, 1997).

The main tasks of the National Center of Standardization and Metrology are the organization of the development of national standards and adaption of international standards, creation and maintenance of an information base of standardization documents, maintenance of national physical measurement standards, as well as verification and calibration of metering equipment. Within the framework of the National Program of Quality Assurance, the Program of the Development of National Standardization of Latvia has been developed with the objective to promote the adoption of European standards. Latvia has joined the activities of International Standardization Organization (ISO), European Standardization Committee (CEN), International Electro-Technical Commission (IEC) and International Organization of Regulated Metrology (OIML) (Ministry of Economy, Republic of Latvia, 1997).

Legislation of Latvia is now modelled to meet the requirements of the European Union and international rules in the area of accreditation and the necessary European standards in the area of conformity assessment have been adapted. Until May 1997 the Latvian National Accreditation Office has accredited in conformity with the EU standards 7 laboratories, 1 certification institution and has done supervision procedures in 8 laboratories. In addition, there are 87 laboratories, 5 certification institutions and 11 inspections undergoing the process of accreditation. A system of assessment corresponding to the EU requirements which consists of 44 accredited laboratories and accredited certification institutions in 19 biggest Latvian cities has been established during the period August 1994 - May 1997 (Ministry of Economy, Republic of Latvia, 1997).

The International Standard Classification of Education (ISCED) has not yet been adopted in Latvia, but the existing educational system generally speaking conforms to this classification. The system of higher education is currently in rapid transformation. The institutions of higher education provide professional education via bachelor's and master's degree programs. In the old system there were 10 institutions of higher education, now the number of state financed institutions have increased to 17. At the same time, several institutions that are private or that work under the auspices of various public organizations have been established. However, these institutions have no right to award state-recognized documents about the completion of higher education. Curricula in the state-financed schools have been changed, so that they now are closer to the standards of European countries. Furthermore, the number of research units at the universities has increased, as some of the institutes of the Latvian Academy of Sciences now operate under the auspices of educational institutions (Karnite & Gulans, 1996).

Table 26. Institutions engaged in research and development in Latvia in 1990-1994.

	Number of institutions			Number of scientific personnel		
					full-time-equivalent	
	1990	1993	1994	1990	1993	1994
Self-dependent R&D institutions	56	50	38	9649	2451	1656
Self-dependent design institutions	36	13	10	3898	225	155
Institutions of higher education	8	11	11	1528	994	960
Total	171	122	**81**	18970	3999	**3010**

Source: Statistical Yearbook of Latvia 1993, Statistical Yearbook of Latvia 1995.

The number of applied research institutions in Latvia has declined radically (Karnite & Gulans, 1996). From table 26 we can see that both the number of self-dependent R&D institutions and design institutions have decreased drastically between 1990 and 1994. However, there are a few more institutions of higher education, as already mentioned before in this section. It is also evident that the number of scientific personnel has radically decreased, although the numbers for the year 1990 are not directly comparable with those of the years 1993-1994, since only the latter are expressed as full-time-equivalent.

Table 27. Institutions engaged in research and development in Latvia in 1994-1995.

	Number of institutions		Number of scientific personnel			
			full-time-equivalent		full-time-equivalent, %	
	1994	1995	1994	1995	1994	1995
Institution of higher education	17	18	1289	1374	42.8	44.7
Public sector	42	49	1344	1349	44.7	43.9
Manufacturing enterprises	22	23	377	347	12.5	11.3
Private sector	-	2	-	2	-	0.1
Total	**81**	**92**	**3010**	**3072**	**100.0**	**100.0**

Source: Statistical Yearbook of Latvia 1996.

From the year 1994 onwards the Latvian science statistics has been changed so that the division of institutions engaged in R&D is more in conformity with the OECD classification (table 27). In 1995 there were in fact already 18 institutions of higher education. The number of institutions belonging to the public sector was 49. There was 23 manufacturing enterprises engaged in R&D and two private sector institutions. The majority of the scientific personnel was employed in the institutions of higher education and the public sector, 45 % and 44 % respectively. The share of scientific personnel in manufacturing enterprises was accordingly only 11 %. The absolute number of scientific personnel increased slightly from 1994 to 1995. The increase was largest in the higher education sector, whereas there was a minor decrease in the manufacturing enterprises.

Table 28. Research workers by performance sector in Latvia, full-time-equivalent employment.

	Institutions of higher education			Other non-profit institutions		Public sector	Industry (Manufacturing enterprises in 1995)			Research workers - Total, FTE		
	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995
Scientific personnel	1278	1289	1374	1589	1344	1349	1132	377	347	3999	3010	3072
Technicians and laboratory assistants	325	482	585	520	386	303	221	76	120	1066	944	1008
Technical personnel	168	254	210	731	651	631	588	380	316	1487	1285	1158
Total	1771	2025	2169	2840	2381	2283	1941	833	783	6552	5239	5238

Source: Statistical Yearbook of Latvia 1993, 1995 and 1996.

From table 28 we can see that the total number of research workers has been stable in the years 1994-1995. However, there was a sharp decline from the level of 1993. In the higher education sector the total number of research workers has steadily been increasing during the three year period 1993-1995. This concerns both scientific personnel as well as technicians and laboratory assistants. At the same time the number of research personnel has decreased in the public sector and in the industrial sector. Especially in the latter sector, the decrease has been substantial.

Table 29. Number of researchers by fields in Latvia.

	Year	
	1990	**1993 full-time equivalent**
Natural	3455	1672
Engineering	10038	1338
Medicine	424	184
Agriculture	472	283
Social	1652	299
Humanities	938	223
Total	16979	3999

Source: Kristapsons, J. & Tjunina, E. (1995a)

In Latvia more than half of all researchers were employed in natural sciences in 1993. The second largest field of sciences was engineering (table 29). This is contrary to the statistics for 1990, but one should notice that those numbers are not in full-time-equivalent so they are not fully comparable. In addition to discrepancies which are due to the different statistical measures there seems to be a very sharp decrease in engineering, which can be explained by the collapse of industrial research. The field of medicine employed the smallest number of researchers both in 1990 and in 1993.

It is important to further develop the Latvian S&T-system in order to improve the competitiveness of Latvia's economy. Karnite (1997) underlines that there are two main ways to increase the competitiveness of the country. First, new technologies and science-intensive sectors must be developed on a scientific basis. Second, foreign investments must be attracted to the country. As comes to the first strategy Kapenieks & Stabulnieks & Viesturs (1996) points out that Latvia has considerable scientific potential. Two changes, which have a direct impact on science and technology policy, have recently been undertaken by the Latvian Government. It was recognized that it is necessary to work out a long-term economic development strategy. The taxation policy should stimulate the accumulation of national capital and increase investment. This is important in order to facilitate the recovery of different branches of the national economy and the creation of modern production and technological base. The state is particularly interested in supporting small companies and technological centers for the creation and implementation of new technologies. Starting from the year 1993 about 10 % of the budget is earmarked for science. This was about 1.3 millions USD in 1995. In the framework of a PHARE project a network of Enterprise Support Centers with offices in six industrial Latvian towns has been established.

No clear policies, however, exist on how to facilitate the adaptation of industrial enterprises to the new market system. Only speeding up the privatization process has been emphasized.

Since the establishment of the Latvian Privatization Agency, the privatization of state-owned properties has proceeded very quickly. It is expected that the privatization process will be finished by 1998. The privatization program, however, began relatively late. As a consequence, many companies had already suspended production. In some cases privatization has therefore occured through liquidation. Renewal of production in these enterprises is not possible without radical reconstruction (Karnite & Gulans, 1996).

Karnite (1997) emphasizes that the main way to increase the competitiveness of the industrial sector is to modernize it technologically, to make scientific achievements in the sector, and to integrate higher education, science and industry. New competitive technologies and science-intensive sectors can be developed through the restructuring of existing enterprises or the establishment of new ones. A pre-requisite for this is a developed scientific system, as scientific efforts strengthens competitiveness. The establishment of new and competitive production methods and the restructuring of traditional industries, cannot be done without an ongoing process of innovation. So far the development of high tech sectors in Latvia has, however, been slow, and currently they are mostly represented by small trade enterprises.

For most companies in Latvia, maintaining of existing or previous output profiles is no longer possible. These enterprises have been producing specialized goods, which have no market demand in the European economic area. Accordingly, it is highly recommended to produce something new. Of course, there are Latvian enterprises which can be competitive with their traditional products, but this requires that prices are lowered and that quality standards are improved. In most cases, new technologies will be needed for this, and scientific research is needed in order to support the development of these technologies. It is important that a country does not only focus on the discoveries of its own scientists, but also on research work that has been done elsewhere in the world (Karnite & Gulans, 1996).

This means that also a small country like Latvia needs a well-developed science and technology system. Without a modern S&T-system, there will be "brain drain" when talented young people moves abroad. This in turn reduces the intellectual potential of their home country. In other words, the process of brain drain reduces a country's ability to develop manufacturing and production processes which involve scientific knowledge, as well as the ability to develop a high level of labour productivity which is the economic basis of welfare. In addition, small companies usually lack the necessary resources for research. They can begin new production only when they obtain existing technologies. A science and technology system is needed, which provides small and medium-sized companies with opportunities to start new types of production in order to find their market niche. The development of a well-functioning science and technology system in Latvia is absolutely necessary, if the country wants to survive in the economic environment of the European Union (Karnite & Gulans, 1996).

Although the government of Latvia has announced that facilitation of foreign direct investment is one of the economic development priorities, little has yet been done in this area. In other countries development agencies usually are succesful in leading and organizing the process of attracting foreign direct investment, which is the fastest way to obtain new technologies. Foreign development agencies often participate in the work concerning the development strategies of their countries. Their work is very serious, purposeful and effective. According to Karnite (1997) this is not the case with the Latvian Development Agency. This explains to a great extent why Latvia has not been able to attract foreign investors in any larger scale. In addition, the country's technological and intellectual potential are factors which help to attract foreign investment. Latvia cannot, however, only rely on foreign investors, but must also increase the competitive abilities as discussed above.

In Latvia there's a widely spread view that Latvian science is out-of-date and that it will always be. Some are even of the opinion that the development of local sciences can be totally ignored and that foreign specialists and scientific research can be utilized instead. Latvian enterprises have not yet understood the importance of the innovation process, and even if they had, they have no money to finance scientific research. Scientific institutions are seeking additional resources from the European Union and other international sources, because local scientific resources have been far too low for several years. In Latvia, the investment of science in economic development is thus not particularly large. The main reason for this is that the role of science as a facilitator of economic development has not yet been understood. Without financing, Latvia's scientific potential will slowly waste away. Latvia must therefore understand in the very near future that the development of a national system of science is a national problem which has to be resolved by the national government. Currently there's a tendency in government circles to leave even important strategic development matters in the hands of the market forces (Karnite, 1997).

As Karnite (1997) points out, it is the task of the state to determine economic development strategies and to establish a favourable environment for economic development. For example, in some cases it is impossible to access international and local business resources without the help of the state. Furthermore, in order to facilitate and maintain the process of innovation, the state should establish a well considered technology policy, facilitate technology transfer from abroad, attract financial resources to the development of scientific potential, facilitate exchange of information and experience at the international level, organize education and training, etc. Another problem is that business services in Latvia such as banks, insurance, accounting services, legal assistance, advertising, hotel services and conference centers are still expensive and unstable.

In other words, the state science policy has not been drafted so far. It was already stated above that the main aim is that the scientific system should be similar to that in western countries. Kristapsons & Tjunina (1995b) mentions that there will be a reform of the Council of Science which would bring the Latvian system closer to that of the Scandinavian and other West European countries.

5.3. LITHUANIAN S&T-SYSTEM, SCIENCE AND TECHNOLOGY POLICY

Until the year 1990 the system of research institutions was well developed in Lithuania. Priorities were given to natural, exact and technical sciences. After regaining independence it has become necessary to maintain the science potential in the fields of fundamental sciences, where world level standards have been achieved, and also to develop new research works in such fields as environmental protection, energetics and social sciences. Development of applied research is especially important for Lithuania. The activities in science and higher education in Lithuania are regulated by the Law on Science and Studies, which came into force on February 15, 1991.

The institutional set-up of the present science and technology system in Lithuania is sketched up in figure 3. The main objective of the Department of Science and Higher Education of the Ministry of Education and Science is to form and implement the Lithuanian state policy of research and studies in the field of higher education. The field of responsibility of the Department of Science and Higher Education is very wide. One of its tasks is to prepare proposals for the allocation and use of budget funds to the institutions of research and higher education. Together with higher educational institutions the department determines the conditions of student enrollment in regard to the needs of the state. It also creates and orders state programmes for training and requalification of high skill specialists. Other tasks is to prepare proposals to the Government of the Republic of Lithuania concerning the development of priority branches of research and technologies and to form drafts of state scientific programmes. Preparation of proposals concerning establishment, reorganization and liquidation of research and higher education institutions are also the responsibilities of the Department of Science and Higher Education.

The Science Council of Lithuania supports the development of fundamental science and related research and analyzes the use of the budget funds for science and studies. The Council also maintains the qualification of Lithuanian scientists and the prestige of science in Lithuania, evaluates studies programs, textbooks and determines the qualification requirements for higher schools and research institutes and for scientific degrees and academic titles.

The Lithuanian Centre for Quality Assessment in Higher Education co-ordinates and guides the regular self-analysis process of scientific and pedagogical activity of the State and Non-state research and higher education institutions, organizes expert assessment, publishes information about the quality of that activity and offers suggestions about its improvement. The Centre gives information, consultations and recommendations for research and higher education institutions and for other legal persons on all questions connected with the recognition of higher education acquired abroad.

In 1995 there were 15 State higher education institutions in Lithuania, 29 State research institutes, 19 State research institutions, the Lithuanian Academy of Sciences and other research institutions and scientific groups. The higher education establishments consists of 6 universities, 7 academies and 2 institutes. Subsidies from the state budget are granted to the most active groups of scientists and researchers. Studies and researchers are financed according to the programmes elaborated by the scientists themselves. The greatest degree of sovereignty has been given to the fifteen higher educational establishments.

FIGURE 3. THE INSTITUTIONAL SET-UP OF THE PRESENT SCIENCE AND TECHNOLOGY SYSTEM IN LITHUANIA

Ministry of Economics	Ministry of Industry and Trade	Ministry of Education and Science - Department of Science and Higher Education	Ministry of Finance	Ministry of European Affairs	Ministry of Foreign Affairs
Education, Science and Culture Committee of the Seimas of the Republic of Lithuania					

Science Council of Lithuania	Lithuanian Centre for Quality Assessment in Higher Education	Lithuanian Scientific Society

Lithuanian State Privatization Agency	Lithuanian Investment Agency	Lithuanian Small and Medium Enterprise Development Agency	Lithuanian Export Promotion Agency	International Chamber of Commerce - Lithuania

LITHUANIAN DEPARTMENT OF STATISTICS to the Government of the Republic of Lithuania	State Patent Bureau

Lithuanian Academy of Sciences	Kaunas University of Technology	Vilnius Gediminas Technical University	Vilnius University	Vilnius Pedagogical University
Klaipeda University	Vytautas Magnus University	State professional higher schools	Vocational Education Institutions	
State Research Institutes	State Research Institutions	Economic Research Center	Lithuanian Free Market Institute	

Lithuanian Rectors Conference (LRC)	State Science Institute Directors Conference	The Conference of the Chairmen of the Senates (Councils) of the Lithuanian Higher Education Studies and Science Institutions

Lithuanian Innovation Centre

The Confederation of Lithuanian Industrialists (CLI)		
Lithuanian Furniture Producers' Association "Medė"	Lithuanian Light Industry Enterprises' Association	The Lithuanian Association of Entrepreneurs (LAE)
Lithuanian Commodity Expertise Services' Association		LITHUANIAN COMPANIES

Research institutions are either granted the status of a research institute or a research centre. The research institutes, the number of which is 29, conduct research in the humanities, natural and social sciences as well as certain applied science fields which are of high priority for Lithuania. Examples of such priorities are geology, biotechnology, agriculture, construction and architecture. The state research institutes enjoy the same kind of sovereignty and academic freedom as the institutions of higher education. Research centres, on the contrary, are not autonomous, but their heads are appointed by the founders which usually are ministries, departments or higher educational establishments. The status of research centre is given to institutions which investigate practical problems, are engaged in experimental designing, and which make analyses in the interests of their founders. Research institutes can, however, use state property and enjoy privileges in the same way as the institutions of higher education and the state research institutes.

Table 30. R&D financing in Lithuania in 1995.

	All institutions, thous. litas	of which, % Higher schools	Scientific institutes	Scientific institutions	Other institutions
Assignments from state budget	85631.2	38	49	7	6
Customers' funds	30843.9	34	43	16	7
Participation in international programmes	2672.2	49	34	5	12
Other	5562.8	6	81	8	5
Total funds	**124710.1**	**36**	**49**	**9**	**6**

Source: Statistical Yearbook of Lithuania 1996.

Total R&D financing in Lithuania amounted to 124 710 thousand litas in 1995 (table 30). About half of the assignments from the state budget were allocated to scientific institutes, and almost 40 per cent to higher schools. Also most of customer's funds were distributed to scientific institutes and higher schools. Almost half of the money which comes from participation in international programmes has gone to R&D financing of higher schools. The total sum is, however, very modest. In 1995 about 70 per cent of total R&D financing came from the state budget and 25 per cent from customer's funds. Only 2 per cent came from participation in international programmes (table 31). The proportion of customer's funds from foreign institutions has clearly decreased during the last few years. The R&D financing of higher schools from the state budget has decreased during the three year period 1993-1995, while the share of financing from customers' funds has increased. The state financing of scientific institutes has also decreased somewhat, while the share of other financing sources has slightly increased. However, the state financing of scientific institutions and other institutions shows a clear increasing tendency. The increased state financing of scientific institutions has compensated for the decreased financing from foreign institutions. Financing from national institutions has on the contrary steadily increased.

Table 31. R&D financing sources in Lithuania, in per cent.

	All institutions			Higher schools			Scientific institutes			Scientific institutions			Other institutions		
	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995
Assignments from state budget	75	69	69	86	74	73	76	71	69	30	49	51	55	8	65
Customers' funds	21	26	25	12	23	23	20	23	22	65	48	44	25	84	27
- National institutions	*81*	*89*	*88*	*80*	*89*	*87*	*87*	*90*	*88*	*72*	*85*	*90*	*83*	*87*	*90*
- Foreign institutions	*19*	*11*	*12*	*20*	*11*	*13*	*13*	*10*	*12*	*28*	*15*	*10*	*17*	*13*	*10*
Participation in international programmes	1	1	2	1	2	3	0	0	2	0	-	1	-	-	4
Other	3	4	4	1	1	1	4	6	7	5	3	4	20	8	4
Total funds	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Statistical Yearbook of Lithuania 1994-95 and 1996.

Table 32. Structure of expenditure on R&D in Lithuania in 1995.

	Expenditure, thous. litas	of which, % Wages and salaries	Other current expenditure	Acquisition of fixed capital	Other capital expenditure
Higher schools	43395.9	59	36	4	1
Scientific institutes	52657.3	57	33	7	3
Scientific institutions	11239.8	53	43	4	-
Other institutions	7625.4	48	47	5	0.0
Total	**114918.4**	**56**	**36**	**6**	**2**

Source: Statistical Yearbook of Lithuania 1996.

The structure of expenditure on R&D is shown in table 32. More than half of the expenditure are on wages and salaries. Other current expenditure are around 40 per cent, while acquisition of fixed capital as well as other capital expenditure constitute the smallest item. A little more than fifty per cent of total expenditure on R&D is allocated to fundamental research. In higher schools, science institutions and other organizations the share was almost 60 per cent in 1995. A little less than 40 per cent of total R&D expenditure is allocated to applied research. However, in 1995 the share of applied research was over 70 per cent in science institutions. The share of total expenditure on experimental development is less than 10 per cent. Unlike other institutions, the science institutions, however, spend as much as 25 per cent of their R&D expenditure on experimental development.

Table 33. Expenditure on R&D by kind of R&D activity in Lithuania, in per cent of total expenditure.

	Expenditure on Fundamental research			Applied research			Experimental development		
	1993	1994	1995	1993	1994	1995	1993	1994	1995
Higher schools	68	58	59	30	39	37	2	3	4
Science institutes	54	56	57	37	33	35	9	11	8
Science institutions	8	21	2	54	55	73	38	24	25
Other organizations	23	71	60	77	19	37	0	10	3
Total	55	54	53	36	37	39	9	9	8

Source: Statistical Yearbook of Lithuania 1994-95 and 1996.

Most of the Lithuanian R&D personnel are employed in technical and natural sciences (table 34). The third largest field of science is humanities, which shows a slight increasing trend. The share of medicine has been decreasing, while the share of social sciences has increased. The employment of R&D personnel in the agricultural sciences has been quite stable during the years 1993-1995. One should, however, keep in mind that the data is not in full-time-equivalent. Accordingly the analyses based on these figures are not fully reliable, but they anyway indicate the division of employees between the different science fields.

Table 34. R&D personnel by field of science in Lithuania.

	Personnel directly engaged in R&D, all working day + not all working day			R&D personnel, %		
	1993	**1994**	**1995**	**1993**	**1994**	**1995**
Agrarian	1287	1257	1227	9.0	9.9	9.0
Natural sciences	2854	2555	2841	20.1	20.2	20.8
Humanities	2227	2276	2680	15.7	18.0	19.7
Mathematics	417	461	520	2.9	3.7	3.8
Medicine	2022	1546	1578	14.2	12.2	11.6
Social	1744	1902	1998	12.2	15.0	14.7
Technical	3666	2627	2752	25.8	20.8	20.2
Theology	13	21	36	0.1	0.2	0.2
Total	14230	12645	13632	100.0	100.0	100.0

Source: Statistical Yearbook of Lithuania 1996.

On the basis of the small amount of information which was available it seems that Lithuania has the same problem as Latvia and Estonia, that is, no state innovation policy has been officially declared.

6. CONCLUSIONS

As the Baltic countries regained independence in the beginning of the 1990's these countries began their transition from a planned to a market economy. The former S&T-system was "destroyed" as a result of the independence, that is, the S&T-system no longer existed. In recent years the Baltic countries have begun to build up a new S&T-system for their country. Because of difficulties to get appropriate data for these countries, analyses have to be made on the basis of limited numerical information. A problem in all three countries is that very little resources are spent on R&D-activity in the private sector. The countries are aware of this but the problem has so far been the lack of money.

In general, the role of the private industry in the innovation process and in the competitiveness that follows from innovation, can be measured by the contribution of the private sector to total expenditure on R&D. It is, however, impossible because of lacking data, to exactly establish to what extent innovation is the result of the activities of the private sector in the Baltic countries. We, however, know that the R&D level is exceptionally low. Accordingly, a lot has to be done in order to raise the competitiveness of the Baltic industrial branches. This concerns all three countries.

Estonia has chosen the fastest way to improve its technological level, i.e. largely through foreign direct investments from the Western countries which brings advanced technology to Estonia. Despite the possibility to improve the technological level through technology transfer it is, however, very important for the Baltic countries to invest in the absorptive capacity of firms, that is the R&D activity has to increase in the business enterprise sector. The ongoing privatization process is also a necessary condition for technological change and modernization. Of the Baltic states, Estonia is the one which has attracted most foreign investors. One explanation to this is the well functioning Foreign Investment Agency and the favourable conditions which have been created for foreign direct investment. Especially Latvia has not paid enough attention to the importance of the activities of the Development Agency. Accordingly, Latvia has difficulties in attracting foreign investors.

Quality is a factor that becomes more and more central as competition gets harder as a result of the international markets. The technical framework concerning standards, certification, quality control and insurance is today of crucial importance. It is also important that governments are involved in standardization.

All three Baltic countries are working on the adoption of OECD standards for the measurement of science and technology. The process is, however, slow and requires a lot of efforts. As the harmonisation process is going at different speeds, statistics are not yet fully comparable.

R&D expenditures and personnel have steadily decreased since regaining independence in the Baltics. Gross domestic expenditure on R&D as a percentage of GDP is far below the level in western countries. The R&D expenditures are somewhat larger in Estonia than in Latvia and Lithuania. The lack of funds for scientific research is thus a common problem for the Baltic countries. Total R&D personnel per thousand labour force in Latvia and Lithuania was during the years 1993-1995 about half of the R&D personnel in the Nordic countries. The total number of research scientists and engineers in relation to the labour force is higher in Estonia than in both Latvia and Lithuania. There's some signs that the downsizing of the

R&D system has been faster in Latvia than in the other two countries. The level of education is high in all three Baltic countries, which means that the prerequisites for science and technology are good.

The number of SCI publications from the Baltic countries is small compared with other developed countries with a similar population. There's considerable more scientific publications in physical and chemical sciences than in life sciences, which is contrary to the average in the world. The structure of Estonia's science is closest to the world average. According to some studies Latvian scientists have been slower than in the two other Baltic states to start publishing their papers in western journals. The integration into western science also means changing the "language of science" from Russian to English.

During the Soviet period Latvia was famous for its high level of patenting of inventions among the other regions of former USSR. In certain fields the number of patent documents filed by Latvia's inventors was at least one and a half times higher than the world average indices. Latvia is still the one of the Baltic countries that shows the highest level of resident patent applications. The number of domestic patent applications is larger in Lithuania than in Estonia, whereas Estonia has attracted more foreign patent applicants than Lithuania. A possible explanation to this is the larger foreign investments into Estonia.

The aim of all Baltic countries is to develop their S&T-system in accordance with the Western model. The institutional restructuring of R&D systems in the Baltic countries is now shifting towards a system where three separate institutional sectors are emerging, i.e. government, industry and higher education sector, as in the western market economies. Most of R&D is, however, still financed by the government sector. Surprisingly we found that government expenditure on R&D as a percentage of GDP is only slightly higher in Estonia and Lithuania than in the European Union on average. Data on Latvia was not available. It can thus be concluded that government spending on R&D is on a quite normal level in both Estonia and Lithuania, but that the R&D expenditures are too low in the other sectors of the economy, i.e. in the higher education sector and in the business enterprise sector. On the basis of other kind of information this is the case also in Latvia.

We can conclude that Estonia, Latvia and Lithuania still faces the same kind of problems concerning their science and technology policies. All three countries have a very weak innovation system. Accordingly the S&T-systems have to be further developed in order to increase the competitiveness of the Baltic economies. The governments of all Baltic countries have to create environments which are conducive to innovation, as they have at their disposal various policy instruments. The governments can for example encourage the diffusion of generic technologies and support strategic technologies. Innovation policies include policy measures which influence innovation directly, but they also include other types of policies that are not directly aimed at innovation activity. It is important that the Baltic countries develops and officially declares their state innovation policies. The technological level and thus the competitiveness of the Baltic industries can be increased by adopting an appropriate innovation policy.

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