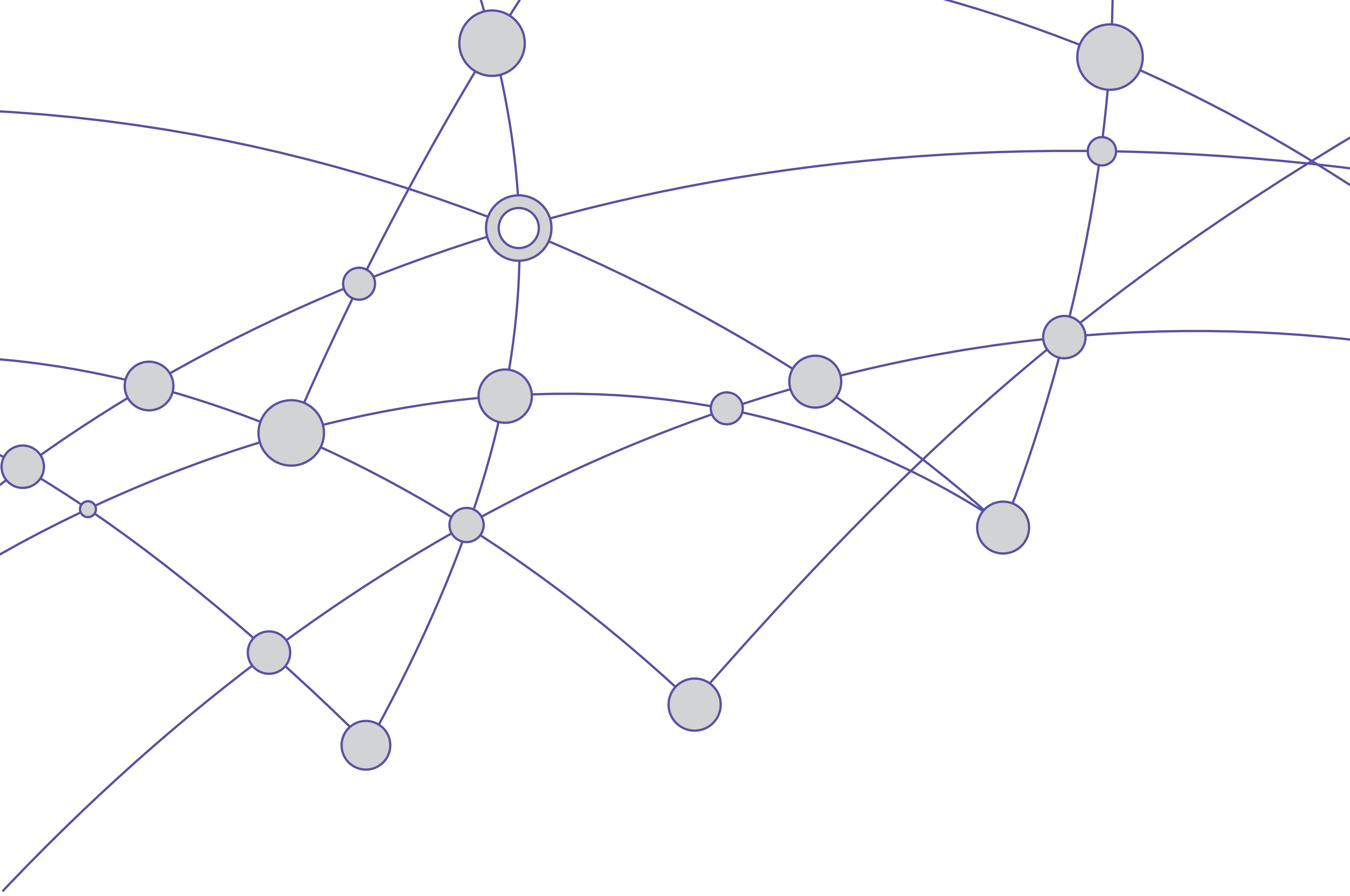
Eesti Teadusagentuur
Estonian Research Council

ESTONIAN RESEARCH 2019



ESTONIAN RESEARCH 2019

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Old karst landscape at Rõstla quarry
Author: Tõnu Pani (Estonian Science Photo Competition 2017).

INTRODUCTION

Andres Koppel
Director General of Estonian Research Council

As a small country with scarce natural resources, Estonia's development relies mainly on knowledgeable and entrepreneurial people. After regaining independence, we have reached a position where simple development factors have been exhausted and it is becoming increasingly clearer that for further socio-economic advancement, the potential of research and development must be used more effectively.

What is this potential, how does Estonian research compare internationally, what are the major persisting and current problems in research and development? In this overview, these questions are discussed based on facts and figures.

The last similar overview *Estonian Research 2016* was well received. The data and analyses on Estonian research and development presented there were widely used in many subsequent analyses and contributed arguments to discussions regarding research policies.

The main structure of the overview is similar to the previous one, consisting of two interrelated parts. The first part includes four comprehensive articles, the first two explore the resources needed for conducting scientific research: monetary resources on the one hand and human resources on the other hand. The next two articles describe the performance of Estonian research. The first focuses on publishing activity and the quality of scientific publications and the second on the socio-economic impact of research and the interrelations of research and society. The articles in the first part are compiled so that the principal data would be comparable to the information presented in the previous overview. This way, it is possible to build time-series in similar overviews in the future. The second part of the overview consists of short articles on the current topical research policy issues.

Estonian Research 2019 and the figures together with data tables are available on the webpage of the Estonian Research Council. An editorial board of professors Ülo Niinemets, Erkki Karo, Rainer Kattel and Richard Villems from the Estonian University of Life Sciences, Tallinn University of Technology, and University of Tartu oversaw the compilation of this publication. Special thanks to Professor Jüri Allik and Kalmer Lauk from the University of Tartu for their willingness to contribute a paper in a very limited time. The staff of the Department of R&D Analysis, Estonian Research Council helped gathering material for the articles, much substantial assistance was provided by Tiina Pärson, Leading Analyst at Statistics Estonia. Many thanks to them and also to the authors of the articles and photographs used in this publication. I would also like to thank the Research Council's Executive Director Karin Jaanson for her numerous recommendations. Kadri Raudvere, the editor of this publication, deserves a special mention for assisting the authors in collecting new data and motivating them in a delicate way when the writing deadlines started to close in.

The overview includes the most recent data that was available at the time of compiling the publication (end of 2018). Since collecting and submitting statistical data at the state level often takes up to a year or sometimes even longer, some statistical data dates back to 2017 or an even earlier time. The data mostly derives from OECD databases, Eurostat, Statistics Estonia, Ministry of Education and Research, Universities Estonia, and Estonian Research Council.

We hope that the content of this overview offers food for thought for researchers, policy makers, and all others interested in research, and that it will provide support for substantiated discussions on research and fact-based policy making.

ESTONIAN RESEARCH SYSTEM

Kadri Raudvere
R&D Analyst, Estonian Research Council

The legal basis for the organisation and functioning of the Estonian research system is the Organisation of Research and Development Act.[1] The different parts of the Estonian research system have the following functions.

- The government together with the parliament shape the policies; the parliament approves the research, development and innovation strategy and state budget for research; once a year the Prime Minister provides the parliament with an overview on the execution of the strategy.[2,3]
- The Research and Development Council, which consists of four ministers and eights members appointed by the government, directs the state's research and innovation policy and advises the government in such matters.
- Different ministries prepare and implement sectoral policies. The Research Policy Committee[4] is an advisory body to the Estonian Ministry of Education and Research. The respective advisory body to the Estonian Ministry of Economic Affairs and Communications is the Innovation Policy Committee.
- State foundations, the Estonian Research Council and the Archimedes Foundation, are the principal institutions organising research within the area of responsibility of the Estonian Ministry of Education and Research, and Enterprise Estonia, which operates under the supervision of the Estonian Ministry of Economic Affairs and Communications, is the principal institution funding innovation.
- Research and development work is carried out by public sector research institutions (primarily universities) and private sector research institutions. Most of Estonia's research personnel are employed by universities, where most of the research is conducted.

The Estonian Academy of Sciences[5] acts under a separate law. It is an independent association of top-level scientists and scholars, with commitment and responsibility to advance scientific research and represent science nationally and internationally.

Estonian research institutions and primary instruments for the state funding of research

Twenty Estonian research and development (R&D) institutions have successfully passed regular evaluation,[6] an assessment carried out by foreign experts on whether the R&D institutions correspond to international criteria. Among these are six public universities: the University of Tartu, Tallinn University of Technology, Tallinn University, the Estonian University of Life Sciences, the Estonian Academy of Music and Theatre, and the Estonian Academy of Arts.

Public research and development institutions acting under the supervision of the Estonian Ministry of Education and Research include the Estonian Literary Museum and the Institute of the Estonian Language; the National Institute for Health Development is within the area of responsibility of the Ministry of Social Affairs; the Estonian National Museum is under the Ministry of Culture, and the Estonian Crop Research Institute is under the Ministry of Rural Affairs.

Only one public research institute operates pursuant to a separate act, the National Institute of Chemical Physics and Biophysics. The Under and Tuglas Literature Centre operates under the Estonian Academy of Sciences.

Six private research institutions have successfully passed evaluation: Cybernetica AS, Protobios OÜ, BioCC OÜ, Tervisetehnoloogiate Arenduskeskus AS (Competence Centre on Health Technologies), AS Toidu- ja Fermentatsioonitehnoloogia Arenduskeskus (Centre of Food and Fermentation Technologies), and Tarkvara Tehnoloogia Arenduskeskus OÜ (Software Technology and Applications Competence Center). Only one private university, Estonian Business School, has passed evaluation.

Compared to non-evaluated institutions, a positive evaluation grants R&D institutions the opportunity to apply for funding from the state budget for their research and development activities.

The primary funding instruments financed from the state budget are institutional **baseline funding** and **research grants**. EU structural funds contribute a substantial share of the public

[1] Organisation of Research and Development Act (Teadus- ja arendustegevuse korralduse seadus - TAKS). (1997). Adopted by the Parliament of Estonia on 1st January 2015. - Riigi Teataja, I osa, 1997, nr. 30, art. 471. https://www.riigiteataja.ee/akt/104122014014 (30.11.2018).

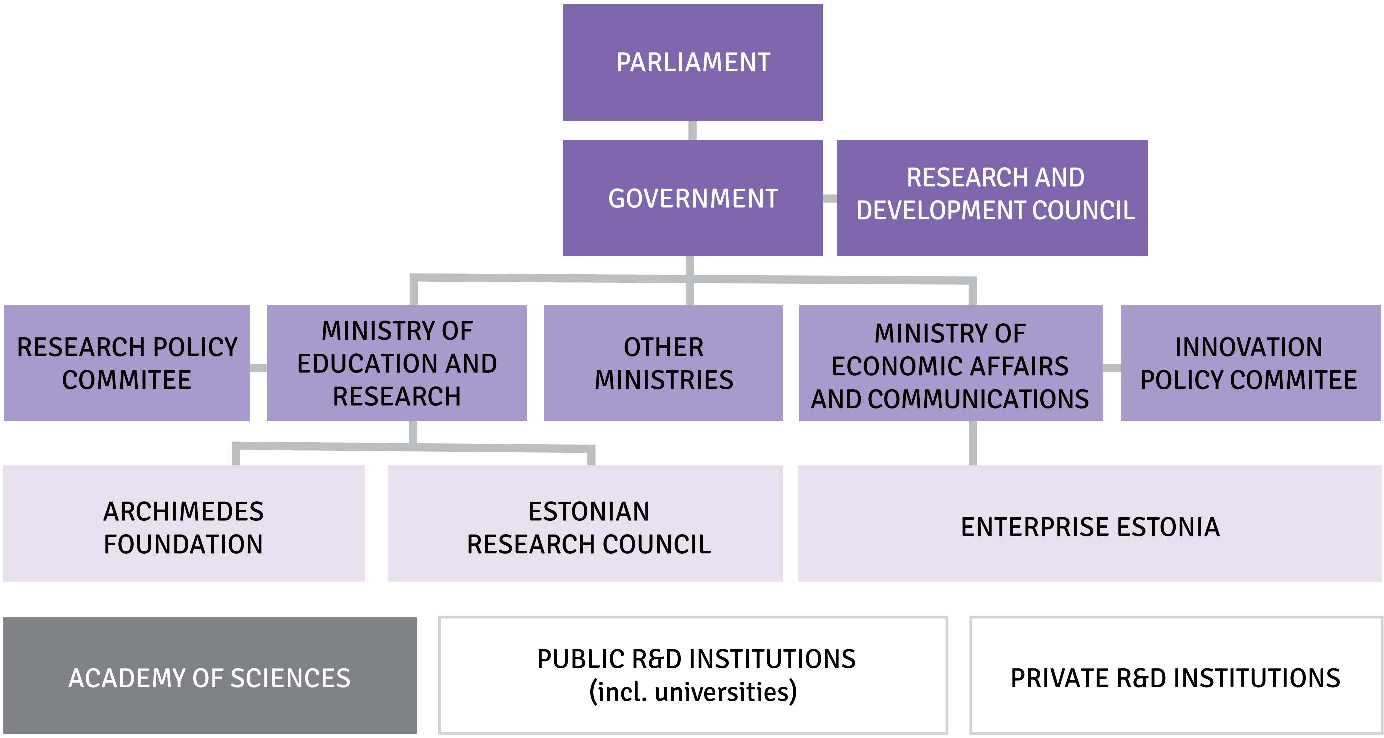
[2] Estonian Research and Development and Innovation Strategy 2014-2020 "Knowledge-based Estonia". (2014). Ministry of Education and Research. https://www.hm.ee/sites/default/files/estonian_rdi_strategy_2014-2020.pdf (24.10.2018).

[3] Stenographic records are available at the webpage of the Government Office of Estonia. https://riigikantselei.ee/et/valitsuse-toetamine/teadus-ja-arendusnoukogu/peaministrite-ettekanded-teadus-ja-arendustegevuse (26.10.2018).

[4] Research Policy Committee (Teaduspoliitika komisjon). (2018). Estonian Ministry of Education and Research. https://www.hm.ee/et/teaduspoliitika-komisjon (26.10.2018).

[5] Estonian Academy of Sciences. (2018). http://www.akadeemia.ee/en/ (26.10.2018).

[6] Regular R&D evaluation. (2019). Estonian Research Council. https://www.etag.ee/en/activities/rd-evaluation/ (22.02.2019).



Estonian research and development organisation structure
Source: Estonian Research Council.

R&D funding, in Estonia these are deemed a part of the state budget. Baseline funding means the financing of research and development for the purpose of attaining the development objectives of a research and development institution, including for co-financing national and foreign projects, opening new research directions, and investing into infrastructure. Baseline funding is allocated under the leadership of the Estonian Ministry of Education and Research to institutions that have received a regular positive evaluation.[7] National research grants are meant for financing activities necessary for the realization of high-level R&D projects. Competitions for national research grants are organised by the Estonian Research Council; applications are assessed and grants awarded by the Estonian Research Council's Evaluation Committee.

Important definitions and methodology

Public sector – for the purposes of this overview, this sector includes higher education sector and government sector.

Private sector – for the purposes of this overview, this sector includes business enterprise sector and private non-profit sector.

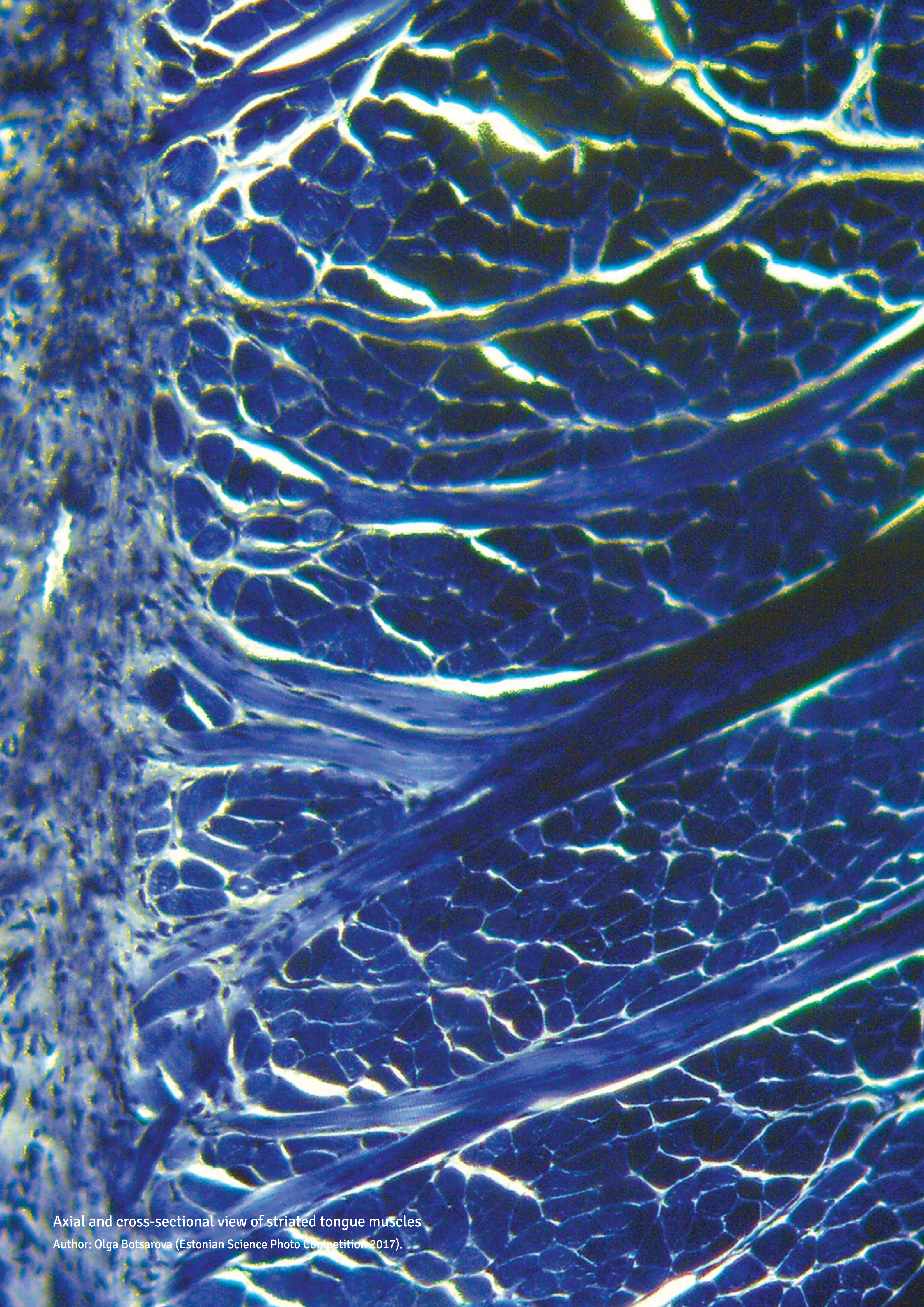
Individual entities within the public and private sectors are understood in accordance with international methodology, where:

- business enterprise sector – includes all enterprises, organisations and institutions whose main activity is the production of goods or the offering of services (other than higher education) at an economically viable price;
- higher education sector – includes universities and other institutions that offer higher education and all institutions under their direct control or associated with universities (research institutes, clinics, science centres, etc.), regardless of their sources of financing or legal status;
- government sector – includes agencies and offices funded by the state or the local government whose main activities are not the production of goods or offering services for sale and which do not belong to the higher education sector. This sector also includes non-profit institutions mainly financed by the state;
- private non-profit sector – includes non-profit organisations, societies, funds, and their research units (excluding those primarily financed from government sources or servicing private enterprises).

The final three sectors are included under the non-profit sector in order to distinguish them from the business enterprise sector.[8]

[7] Base funding and centres of excellence. (2019). Estonian Ministry of Education and Research. https://www.hm.ee/en/activities/research-and-development/base-funding-and-centres-excellence (22.02.2019).

[8] Definitions and Methodology. Statistics Estonia. http://pub.stat.ee/px-web.2001/I_Databas/Economy/28Science._Technology._Innovation/04Research_and_development_activities/02General_data/RD_01.htm (02.22.2019).



Axial and cross-sectional view of striated tongue muscles

Author: Olga Botsarova (Estonian Science Photo Competition 2017).

RESEARCH AND DEVELOPMENT EXPENDITURE: EXPECTATIONS AND REALITY

Andres Koppel
Director General of Estonian Research Council

Introduction. Financing research: an investment, not expenditure

This article is a follow-up to a previous similar overview.[9] The layout of the article and the structure of the principal data presented have been retained. In some cases, the data presented in the previous overview has been also reproduced in an unchanged format, e.g., information on centres of excellence, where no changes have taken place in terms of financing in the past two years. The purpose of this is to provide as comprehensive an overview of Estonian research financing as possible without the need to consult additional sources. The article covers the most important research policy events concerned with financing that have taken place in the last two years and changes in the organisation of research financing. I hereby thank many colleagues at the Estonian Research Council for assistance and critical notes in preparing this article. My special thanks to Kadri Raudvere who ensured that the data presented here is up-to-date.

The decisive role of research and development (R&D) on people's welfare, the development of countries, and tackling potential future issues is common knowledge and most European countries have set the strategic objective to increase R&D expenditure. Moreover, the correlation between public and private sector expenditure is also well-known: the public sector acts as a catalyst and starter in increasing research in business enterprises. Therefore the public sector's research and development expenditure has not been considered so much an expense, which it undoubtedly is according to the logic of accountancy, but rather as a long-term investment into the future of the society. This topic is explored in depth by E. Karo in this publication.[10]

The profitability of R&D investments has been assessed repeatedly. The ex-post evaluation of the 7th EU Framework Programme for research and technological development (2007–2013) has shown that every euro invested into research earns back at least 11 euros, either directly or indirectly.[11]

A report commissioned by Universities Estonia shows that in 2016 Estonian universities contributed 6.4% to the gross domestic product and every euro spent brought back 5 euros of revenue to the Estonian economy.[12] A comparable result was obtained in 2015 from the economic impact assessment of top European universities that belong to the League of European Research Universities.[13]

In recent years it has been repeatedly emphasised that the socio-economic effect and actual value of research on society is much bigger than the direct and short-term impact on economy. Overestimating the direct economic impact may have negative consequences on understanding the full value of scientific research. Science Europe, an association of European research funding and research performing organisations, has given clear recommendations for meaningful research impact assessment to gain a better understanding of the diversity of research impacts.[14]

Tallinn Call for Action: Increase public sector research expenditure, Europe!

Similarly to other European countries, Estonia has set a strategic objective for increasing R&D expenditure. Estonia's R&D expenditure should reach 3% of the GDP by 2020.[15]

However, most European countries struggle with performing those funding objectives (Figure 1.2). Therefore, in 2017 Estonia deemed it important during its Presidency of the EU Council to emphasise the importance of research and innovation and the need for funding research. At the high-level conference European Research Excellence—Impact and Value for Society held on 12 October 2017, Estonian Prime Minister Jüri Ratas symbolically handed over the Tallinn Call for Action to the representatives of the key stakeholders of the research system (policymakers, the academia, research funders, media).[16]

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[9] Koppel. A. (2017). Research and development expenditure: an investment in the future. – Estonian Research 2016 (ed. K. Raudvere), pp. 11–18. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (22.02.2019).

[10] Karo. E. (2019). The Future and Societal Importance of Estonian Research and Development. – Estonian Research 2019 (ed. K. Raudvere). Estonian Research Council, Tartu. http://dx.doi.org/10.15158/DISS/0004

[11] European Commission. (2015). Commitment and Coherence – Ex-post evaluation of the 7th EU Framework Programme (2007–2013). https://ec.europa.eu/research/evaluations/pdf/fp7_final_evaluation_expert_group_report.pdf (24.10.2018).

[12] Biggar Econimics. (2017). Economic Contribution of the Estonian Universities, A Report to Universities Estonia. http://ern.ee/files/Biggar/economicimpact.pdf (24.10.2018).

[13] Biggar Econimics. (2015). The Economic Contribution of LERU Universities 2014. https://www.leru.org/publications/the-economic-contribution-of-leru-universities (24.10.2018).

[14] Science Europe. (2017). On a New Vision for More Meaningful Research Impact Assessment. Science Europe Position Statement, July, 2017. https://www.scienceeurope.org/wp-content/uploads/2017/07/SE_PositionStatement_Impact.pdf (24.10.2018).

[15] According to the operational programme of the strategy "Knowledge-based Estonia", R&D funding from state and local government budgets should have increased to 1% by 2015 and remained at that level from that time. (Estonian Research and Development and Innovation Strategy 2014-2020 "Knowledge-based Estonia". (2014). Ministry of Education and Research. https://www.hm.ee/sites/default/files/estonian_rdi_strategy_2014-2020.pdf (24.10.2018)).

[16] Tallinn Call for Action 2017. Seize the opportunity now: research and innovation matter for the future of Europe. Statement of the Estonian Presidency of the Council of the EU. (2017). https://www.hm.ee/sites/default/files/tallinn_call_for_action_2017.pdf (24.10.2018).

Once again, the document stresses the importance of research and innovation. To ensure the prosperity of European citizens also in the future and to be able to handle new and unexpected global problems, all stakeholders of the research and innovation system are called on to act collectively to increase research and innovation funding, the impact of those investments, and the mutual trust between the research community, society and the representatives of the research system.

Tallinn Call for Action: research and innovation are important for Europe's future

Upon handing over the Tallinn Call for Action, the Prime Minister said: "Investing in research and innovation is not a luxury, but a necessity. Wisdom, creativity, and the will to act are the main sources for Europe's strength and prosperity. Europe will not become a leader if investments are cut or stagnate."

Estonia's research expenditure—the gap with advanced research countries is not decreasing

The earlier trend of stagnation in R&D expenditure has continued in recent years (Figure 1.1). The decline of public sector expenditure in 2016 to 0.59% of the GDP, which is the lowest percentage in the last decade, has been especially drastic.[17] This can be explained by the concurrence of two factors. First, government R&D funding is still largely based on EU Structural Funds (see also Figure 1.5). Since the transitioning from one structural funding period to the next creates a nearly inevitable time-loss due to the launching of measures, R&D expenditure financed from that source decline significantly. At the same time, the proportion of R&D expenditure financed from government tax revenue has not kept pace with economic growth. Due to these two factors, public R&D funding declined to a very low level in 2016. The commendable growth of baseline funding in 2016 and 2017 could not improve the big picture considerably. In 2017, public sector expenditure is growing for the first time after a three-year decline, but the volume has not surpassed the 2008 level.

Upon analysing the R&D expenditure figures, the role of EU Structural Funds needs to be underlined. The great proportion of EU Structural Funds in government-funded research causes a significant disparity between the planned and actual research expenditure since launching the funding programmes takes several years. Thus, the percentage of R&D expenditure calculated on the basis of the government budget usually approved at the end of the year is more optimistic than what is indicated as the actual expenditure by Statistics Estonia two years later. Hence, the volume of public sector research expenditure in individual years remains fluctuating and growth in spending is to be expected for the coming years even if the expenditure funded from tax revenue does not change significantly. The sudden flooding of EU Structural Funds will cause an automatic increase in R&D expenditure in the coming years.

Estonia's position in the international R&D funding comparison has not improved in the last two years. We still remain in the lower section of the countries monitored by the OECD (Figure 1.2). We are more than three times behind Israel and South Korea, the countries taking up the first two places, and two and a half times behind the Scandinavian countries. The two available years of comparison (2014 and 2016) seem to reveal a general trend that the countries at the top of the table (e.g., Israel, Sweden, Austria, Switzerland, Germany) have managed to increase their expenditure a little, while the countries at the bottom (including Estonia and Hungary) have rather dropped even further. Still, two years is too brief a period for long-term trends to emerge.

Private sector R&D funding exceeds the public sector's share several times for most of the compared countries: approximately six times in Israel, almost four times in South Korea, two times in the Scandinavian countries, Switzerland, and Germany. The countries at the bottom of the table are characterised by an especially low private sector involvement in R&D in the context of an overall low general funding level. From 2011 to 2012, the contribution of the Estonian private sector exceeded public sector funding significantly when vast investments were made into the oil industry.

It is interesting to compare how countries vary from from their research spending targets. Regardless of behaving as a spokesperson for increasing research investments, Estonia has not been able to come closer to its own target even during the growth years following the recession and is therefore still falling behind the set target.

[17] The percentages take into account the correction made by Statistics Estonia in Estonia's GDP as at 31.08.2018.

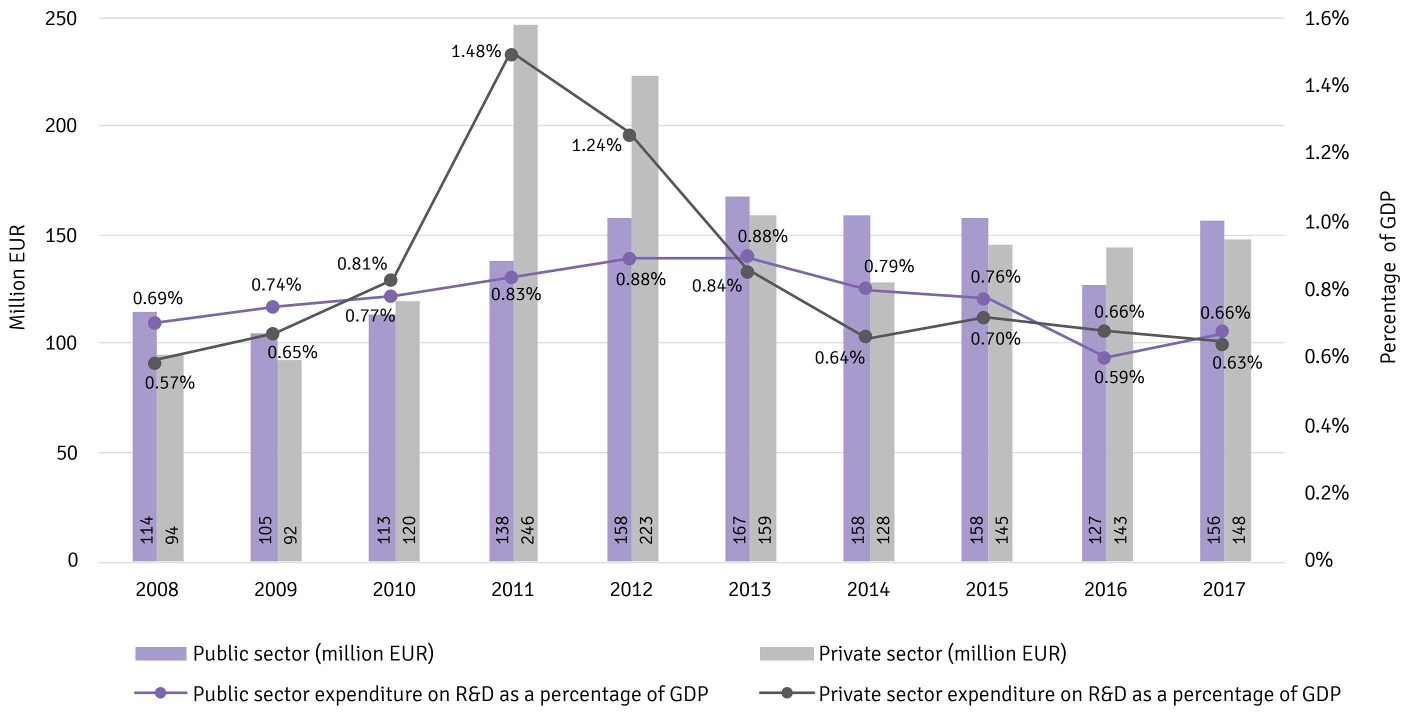

Figure 1.1. Gross domestic expenditure on R&D in Estonia (million EUR and as a percentage of GDP) in 2008 to 2017

Source: Statistics Estonia,[18] calculations by Estonian Research Council.

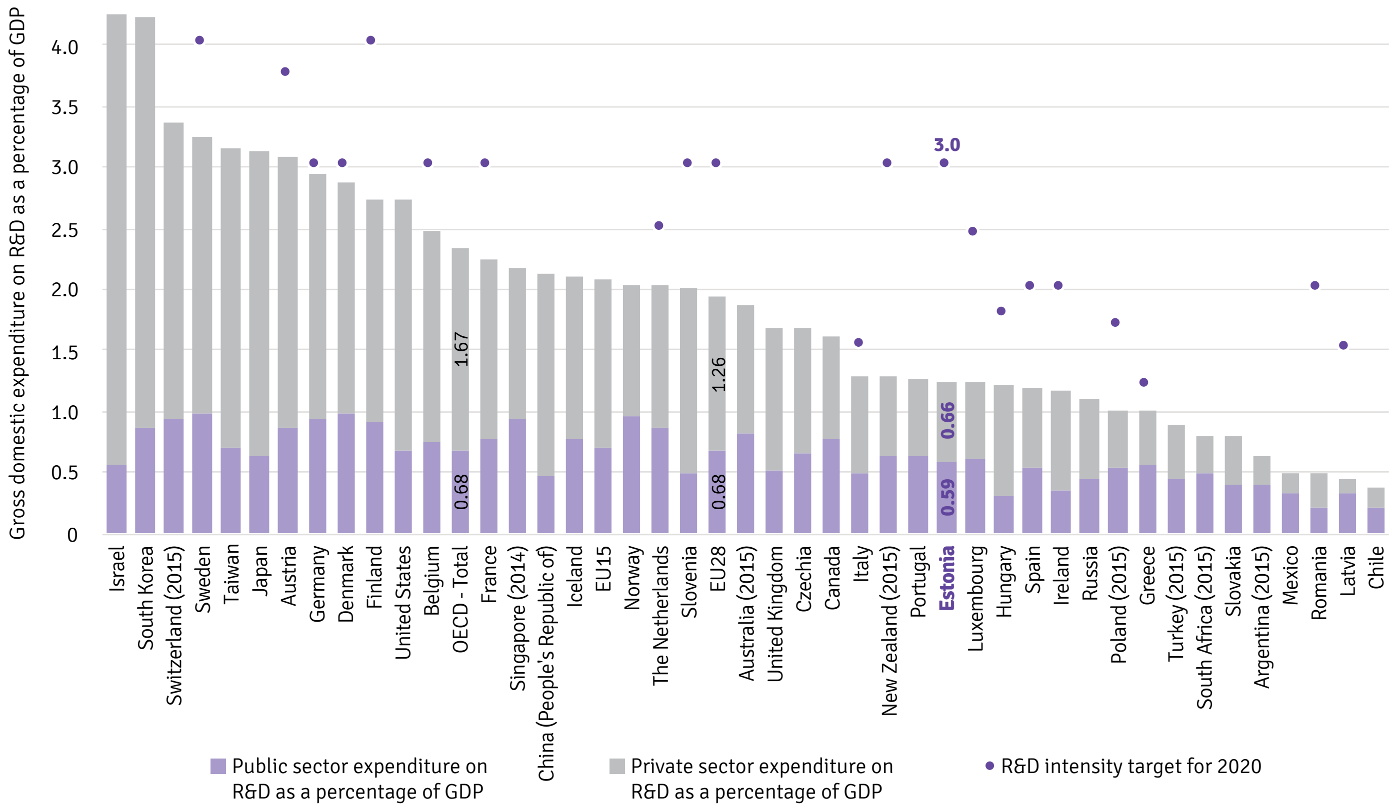

Figure 1.2. Gross domestic expenditure on R&D as a percentage of GDP in 2016

Sources: OECD,[19] Statistics Estonia[20] and European Commission,[21] calculations by Estonian Research Council.

[18] Statistics Estonia. www.stat.ee (29.10.2018).
[19] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (10.04.2018).
[20] Statistics Estonia. www.stat.ee (10.10.2018).
[21] European Commission, Directorate-General for Research and Innovation. (2018). Science, Research and Innovation Performance of the EU 2018. Strengthening the foundations for Europe's future. Figure I.3.-A4. https://ec.europa.eu/info/sites/info/files/rec-17-015-srip-report2018_mep-web-20180228.pdf (19.11.2018).

In terms of the difference between the R&D intensity target set in the strategy and the actual R&D expenditure, Estonia held the first place among European countries in 2016, right ahead of Romania. If one would deem the negative difference between the 2020 target and the reality in 2016 ironically as the "rate of ambition", it would be 1.75 percentage points for Estonia and 1.52 for Romania. In comparison, Sweden is 0.75 percentage points away from their 4% goal, Germany 0.06 from its 3% objective.

Upon comparing the research expenditure of different countries, it must be noted that these proportions indicate the rate at which countries are making contributions to R&D. The capability of countries and research institutions to compete for talents at a global and open market does not only depend on the proportion of the research expenditure, but primarily on the actual ability to offer competitive salaries and modern research infrastructure. It must be emphasised that if the Estonian research system does not become more attractive, our outlook in the global talent competition seems bleak.[22]

Long-term discussions over trying to achieve a political consensus about increasing public R&D spending and fixing it at the minimum level of 1% of the GDP concluded successfully at the end of 2018. On 19 December 2018 the chairpersons of Estonian political parties, representatives of Estonian research institutions, the academia and the largest business organisations signed the Estonian Research Agreement, a social agreement to ensure the further development of Estonian research and innovation (see pp. 78-79).

Funding sources of research and where is it spent?

Commonly, analysis on research financing present data on spendings in public and private sector, as in Figures 1.1 and 1.2. However, such a simplified approach does not enable understanding relations between funders and research performers in sufficient detail. Therefore, it pays to examine the relations between the flows of funding between sectors. By dividing R&D funding sources into three (public sector, i.e., mainly the government; private sector; foreign funders) and R&D performers into two groups (public sector institutions, mainly universities and governmental research institutions; private sector institutions, enterprises performing research and private research institutions), a network of funders and performers emerges, providing much more information (Figure 1.3).

There are clear changes compared to 2014 data.[23] Private sector R&D funding increased more than it is indicated in the expenditure statistics, and the decline of public sector funding was equally greater. In three years public sector R&D funding declined from 0.72% in 2014 to 0.53% of GDP.[24] Private R&D funding increased a little, from 0.53% to 0.56%. Mutual transfers, contributing public sector funds to private sector R&D, and vice versa, private sector research agreements with universities and research institutions, were exactly equal in 2017. Private sector funding to public research institutions increased by approximately 1.5 million euros, while public sector support to the private sector decreased nearly two times. This was caused by the dwindling use of EU Structural Funds, as described above. The volume of foreign sources increased by a quarter, while its division between the private and public sector remained virtually the same compared to three years ago. Two thirds of foreign funds transferred to Estonia are used by research institutions, a third by enterprises. The main foreign sources are the EU Framework Programme Horizon 2020 and institutions' R&D contracts with foreign partners.

The proportions between three principal sources of R&D funding have been very variable over the years. Surprisingly, the share of foreign funding has turned out to be the most stable during the last three years, remaining at 10–15%. The proportions of public and private sector expenditure have changed remarkably during the years (Figure 1.4). It has been emphasised repeatedly that the yearly fluctuations of public sector funding are caused mainly by the uneven application of structural funds. While the annual fluctuation of funding large infrastructure from structural funds is inevitable, abrupt changes in funding activities related to research positions destabilise the research system and therefore have a very negative impact.

The Ministry of Education and Research is the primary funder of Estonian research

Most of the public sector R&D funding comes from the budget of the Ministry of Education and Research (MER) (Figure 1.5). Compared to two years ago, the MER budget has undergone two considerable and positive changes. The volume of baseline funding has increased by two times and its proportion in the MER research budget has risen from 11% to 18%. Second, the importance of EU Structural Funds has declined by 6 percentage points to 42%. Although the importance of EU Structural Funds in the entire funding volume is still remarkable, the certain decrease in its proportion is a sign that the system is stabilizing. At the same time, the share of research grants has declined by 2%, constituting 27% of the MER research budget in 2018.

[22] Koppel, A., Reimand. I., Raud.T., Jaanson, K. (2016). Eesti teadus ajaperspektiivis. — Riigikogu Toimetised, 33, lk. 64–80.

[23] Koppel. A. (2017). Research and development expenditure: an investment in the future. – Estonian Research 2016 (ed. K. Raudvere), pp. 11–18. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (22.02.2019).

[24] In Estonia, financing from EU Structural Funds is considered to be a part of the state budget and thus accounted similarly to funds derived from tax revenue in public sector R&D funding. On the contrary, funds obtained from Horizon 2020 competitions are considered to be foreign funding sources although both Horizon 2020 and EU Structural Funds are funded by the European Commission.

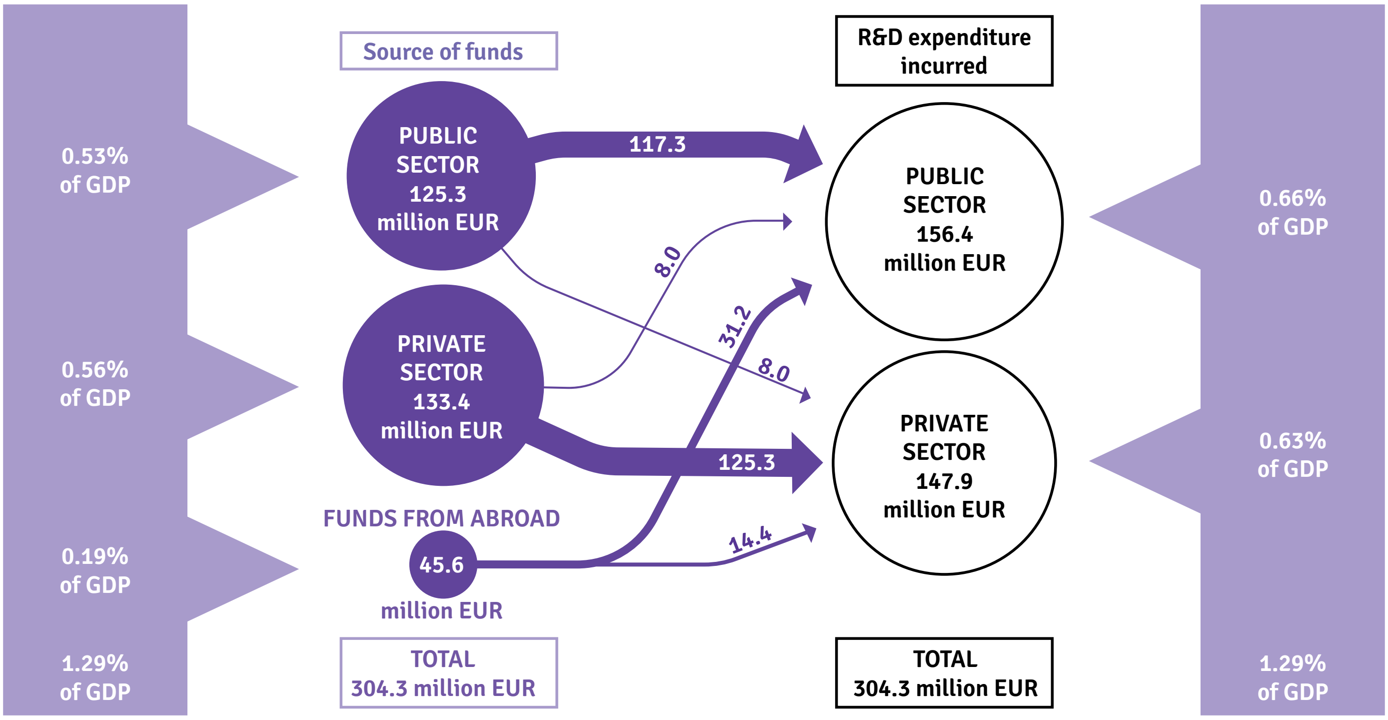

Figure 1.3. Flows of funding and expenditure on R&D between sectors in Estonia in 2017 (million EUR)

Sources: Statistics Estonia[25] and OECD,[26] calculations by Estonian Research Council.

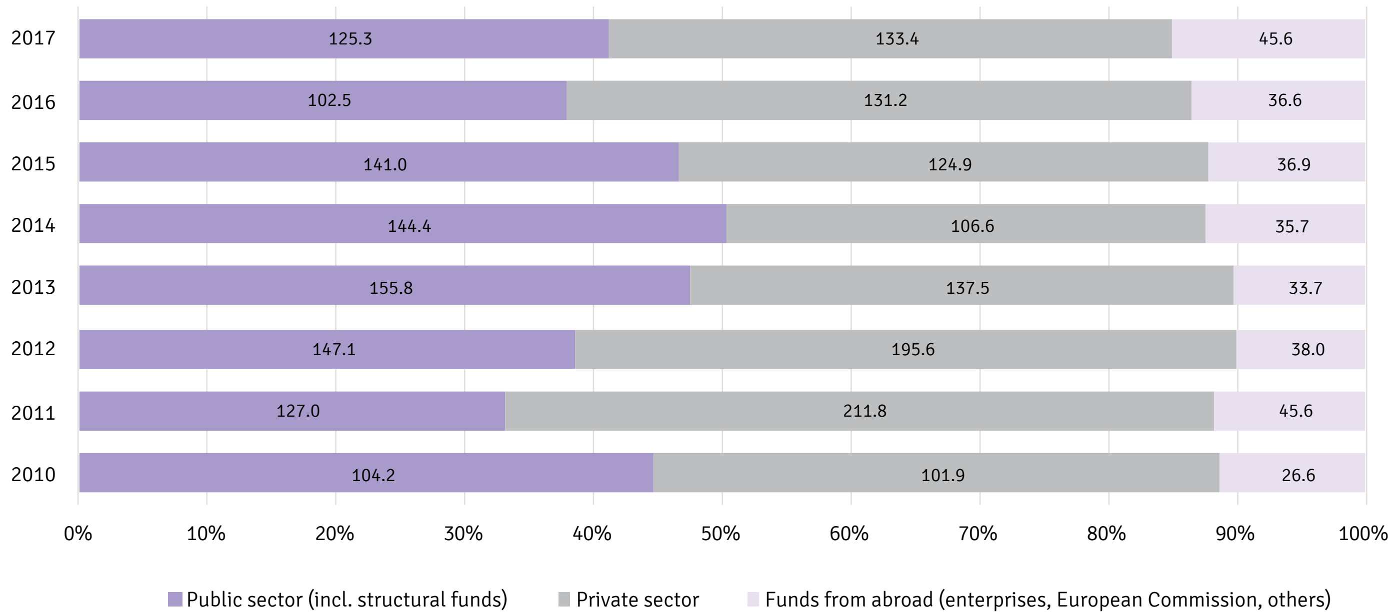

Figure 1.4. Gross domestic expenditure on R&D in Estonia by source of funds in 2010 to 2017. The bars indicate the proportions (%) of R&D funding sources and the figures refer to respective volume of expenditure (million EUR)

Sources: OECD[27] and Statistics Estonia.[28]

[25] Statistics Estonia. www.stat.ee (10.10.2018).
[26] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (10.04.2018).
[27] OECD. Research and Development Statistics. www.oecd.org/sti/rds (24.10.2018).
[28] Statistics Estonia. www.stat.ee (data for 2016 and 2017 requested in January 2018).

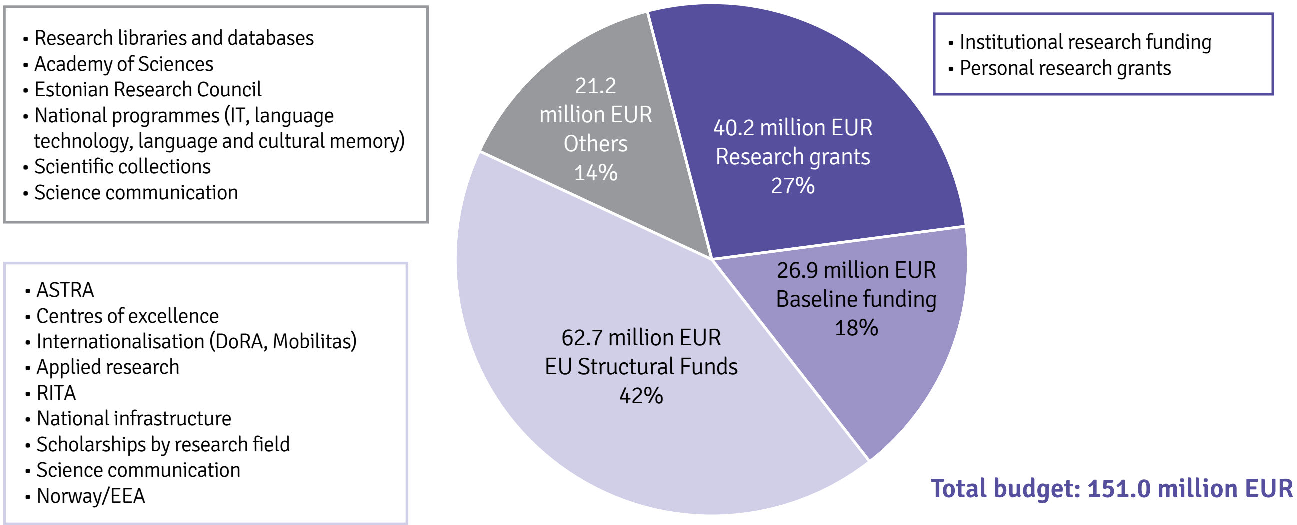

Figure 1.5. The research budget of the Ministry of Education and Research and its main components in 2018 (million EUR)
Source: Ministry of Education and Research.

Continuously improving research funding instruments

The prioritized increase in baseline funding has taken place as planned and in accordance with the Framework of Research Grants and Baseline Funding developed by the Estonian Research Council in 2016, the purpose of which was to develop a logical, coherent, and comprehensive system of basic research funding instruments.[29] One objective of the framework is to clarify the system: to switch from three funding instruments with partly overlapping objectives (personal and institutional research grants, and the baseline funding of institutions) to two instruments with clearly distinguishable objectives (research grants aimed at the different levels of a researcher's career and baseline funding aimed at supporting institutional and strategic research objectives). The second objective is to stabilise the system: increase the share of institutions' baseline funding and equalize the ratio of competition-based research grants and baseline funding by 2020. More stable permanent research funding provides research institutions the opportunity and flexibility for setting strategic research objectives and, thus, for taking greater responsibility.[30] According to the framework, the current baseline funding will be redesigned into a new model that supports research institutions performing clearly defined tasks.

In addition to reforming research grants and baseline funding, the framework sets out a third element: reducing the fragmentation and improving the systematisation of R&D funding instruments. The future directions of the R&D funding model are described more thoroughly in this publication in the paper by K. Pihor and M. Saaliste "On the Development Prospects of the Research and Development Funding Model".[31]

Figure 1.6 indicates that the total volume of research grants and baseline funding started to grow slowly after the recession in 2014 when the 2008 level was surpassed and the growth has continued strongly in subsequent years. The dynamics of gradually closing down the previous grant types and targeted research funding is also clearly outlined. In 2012, personal research grants (PRG) and institutional research funding (IRF) were developed based on Estonian Science Foundation's grants (ESF) and targeted research funding. The transition ended by 2016, when nearly all earlier projects had been completed. Institutional research funding was granted only in three years (2013–2015) and due to the transition to new research funding, IRF grants were not opened anymore in 2016. When pending IRF projects come to an end, they are gradually replaced with research grants issued under the 2016 Framework. The last IRF projects will end in 2020. Baseline funding started growing in 2014 and has more than tripled from then on, reaching 26.9 million euros in 2018. In 2018, growth constituted 10 million euros. While in 2005 when baseline funding was introduced, the ratio of competition-based and stable funding was 90:10, and between 2007 and 2015 it stayed at 80:20 for a very long time, in 2018 the ratio of 60:40 was reached. In 2015 Estonia still had a markedly large share of competition-based funding in comparison with many other countries, but the aforementioned developments will place Estonia among the most common research systems.[32]

[29] A New Framework of Research Grants and Baseline Funding in the Estonian Research and Development Funding System. (2016). Estonian Research Council. https://www.etag.ee/wp-content/uploads/2018/03/New-Framework-of-Grants-and-Baseline-Funding_2016_short-version.pdf (24.10.2018).
[30] The Framework did also set out increasing the total volume of research grants according to inflation and increases in the GDP. However, the volume of state funding has not allowed adhering to that principle.
[31] Please note that in the article by K. Pihor and M. Saaliste the new concept of baseline funding is translated to operational grant.
[32] Koppel. A. (2017). Research and development expenditure: an investment in the future. – Estonian Research 2016 (ed. K. Raudvere), pp. 11–18. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (22.02.2019).

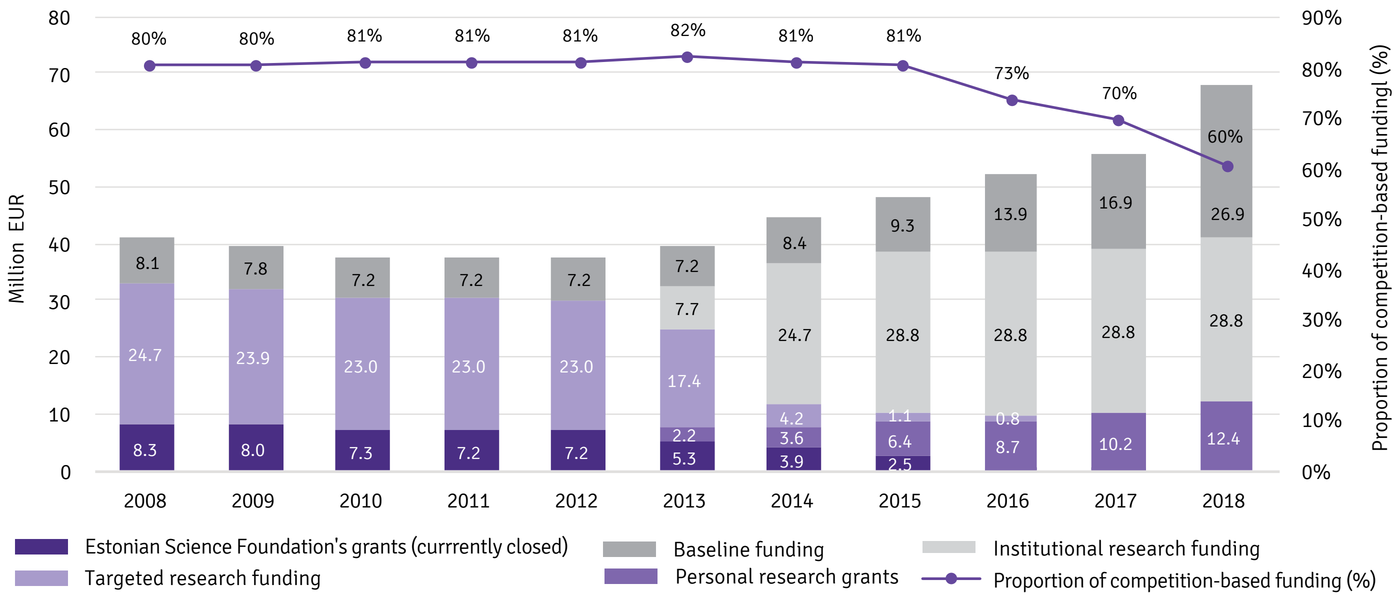

Figure 1.6 The volume of competition-based funding (personal and institutional research funding, targeted research funding, Estonian Science Foundation's grants) and baseline funding of research institutions in the period in 2008 to 2018 (million EUR). The line marks the proportion of competition-based funding (%)

Source: Estonian Research Council.

Differentiating between competition-based and noncompetition-based funding methods is a slightly simplified scheme (researchers must sometimes also participate in in-house competition for funds that have been accrued by the university via baseline funding). Besides research grants and baseline funding, a large share of Estonia's research financing is based on several other instruments, most of which require researchers to compete for them, just like for receiving research grants from the Estonian Research Council. Most of the research and development schemes funded from EU Structural Funds are related to competition, e.g., centres of excellence, the applied research projects of the RITA programme, support for applied research or product development projects under the smart specialisation programme, and the Technology Competence Centres' programme. The EU Framework Programme for Research and Innovation has also been built on competition-based selection processes. For some parts of the Framework Programme, applying for the European Research Council's (ERC) grants, for example, the competition is exceptionally high.

Changes in financing allocations between research fields

Compared to 2010, the funding of natural sciences has increased 1.1 times, engineering 1.6, medical sciences 1.5, social sciences 2.8, and the humanities 1.4 times. The funding of agricultural sciences was at the same level in 2017 as in 2010 (Figure 1.7). In reality, we cannot establish trends by comparing individual years to one another, because unexpectedly large changes may emerge owing to this method. During a period of eight years, research funding in "best" and "worse" years differed several times in some fields (social sciences 2.8 times—2017 vs. 2010, agricultural sciences 2.5 times—2013 vs. 2016, engineering 1.9 times, other fields 1.4–1.5 times). The reasons for the vast scope of these changes have not been analysed.

Since the division of research grants between the Estonian Research Information System's four fields of research (ETIS classification) has stayed relatively similar throughout the years (Figure 1.8), it can be speculated that the significant differences in the overall funding of research fields through the years are caused by the fluctuation of funding originating from structural funds. The Evaluation Committee of the Estonian Research Council whose competence includes deciding over the financing of research grants has not found a reason to amend the current funding proportions for fields of research. In 2018, the Estonian Research Council switched from the ETIS classification to OECD's (so-called Frascati) classification that is based on six research areas. During the classification transition, the divisions of funding for research fields were recalculated so that the formerly established funding proportions remained in effect. Changing the proportions between research fields is an important research policy decision that can be made by a research policy body standing above the Evaluation Committee of the Research Council, if it is necessary and substantiated.

Competition for research funding is growing

The growing competition for research grants is a worldwide trend. The main reasons behind it are the limited research budgets on the one hand, and the improvement of research quality on the other. The number of top level researches is constantly growing. In Estonia, the main factor for the increasing competition in recent years has been the fact that the total funding

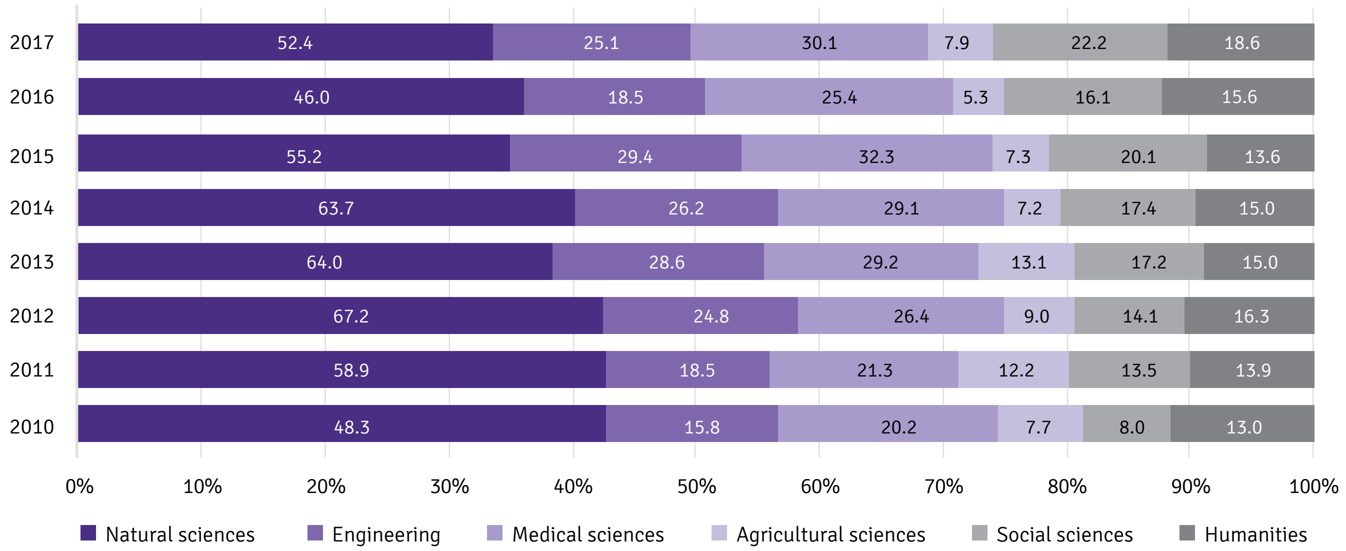

Figure 1.7. Public R&D expenditure by research fields in the period in 2010 to 2017 (length of columns, million EUR)
Source: Statistics Estonia,[33] calculations by Estonian Research Council.

volume of research grants has remained almost constant while the volume of single grants has increased. The Estonian Science Foundation's grants were very small and the number of grants was high. The average size of ESF grant was approximately 12.5 thousand euros for one year in 2010 and the total number of running projects was 548. In 2018, 43 new research grants with an average size of 93 thousand euros for one year (the average size being 38.8 to 145 thousand euros by different grant types) were started.

IRFs emerged from the targeted research funding scheme, with an initial objective to establish a substantial quality control over the baseline funding of institutional research. By the beginning of the 2010s, the evaluation of targeted research funding applications had become increasingly competition-based and the establishment of IRFs in 2012 finally formally concluded the transition from target funding to competition-based grants. Since the applications were institutional, the success rate of IRF applications was relatively high (Table 1.1). In biosciences and environment as well as health the rate was at 50% and more; the success rate of culture and society, which had proportionally more applications for smaller groups, was below 50%, even below 30% in some years. As from 2016, no institutional research funding has been allocated.

The success rate of personal research grants is below that of IRF. The level of competition has been different through the years and depends primarily on the availability of funds. In years when the funds for new grants are scarce, competition is high and the success rate low. In 2018, a new type of research grants was issued that differed from old PRF projects and IRF subjects in terms of fixed grant volumes. Their funding volumes were greater than for previous PRF projects, but slightly smaller than for IRF projects. Since very few research projects ended in 2017, the competition in the 2018 call was very high. The success rate turned out to be 13.6%, i.e., on average only one out of seven submitted grant applications was successful and six applicants did not receive the funding they were hoping for their research. The competition was the tightest in the field of culture and society once again.

The benefits of competition-based research funding are well known—it assures the quality of research. Yet, too high competition has very significant disadvantages: for applicants, the frequent application-writing is time-consuming and frustrating; with too many applications, the monetary and time costs of administration increase considerably. It is a common understanding among the world's research councils that if the success rate falls below 20%, a grant system becomes inefficient and chance will start to play a significant role in selecting the best of the best. The Evaluation Committee of the Estonian Research Council has come to the conclusion that in terms of quality, almost half as many projects deserve funding compared to what it was possible to support in the 2018 call. A reasonable success rate is at least 30%.

EU Structural Funds support centres of excellence and research infrastructure

During the time period observed in this publication, nine centres of excellence continue operation (Table 1.2). Every centre of excellence includes research groups from different research institutions. Because of that, centres of excellence are well-equipped for establishing contacts between institutions and promoting interdisciplinary work. Centres of excellence are financed from EU Structural Funds. Their funding capacity is significant compared to the total volume of research grants (on average ca 6 million euros a year for all centres of excellence, i.e., almost one sixth of the volume of all research grants).

[33] Statistics Estonia. www.stat.ee (10.10.2018).

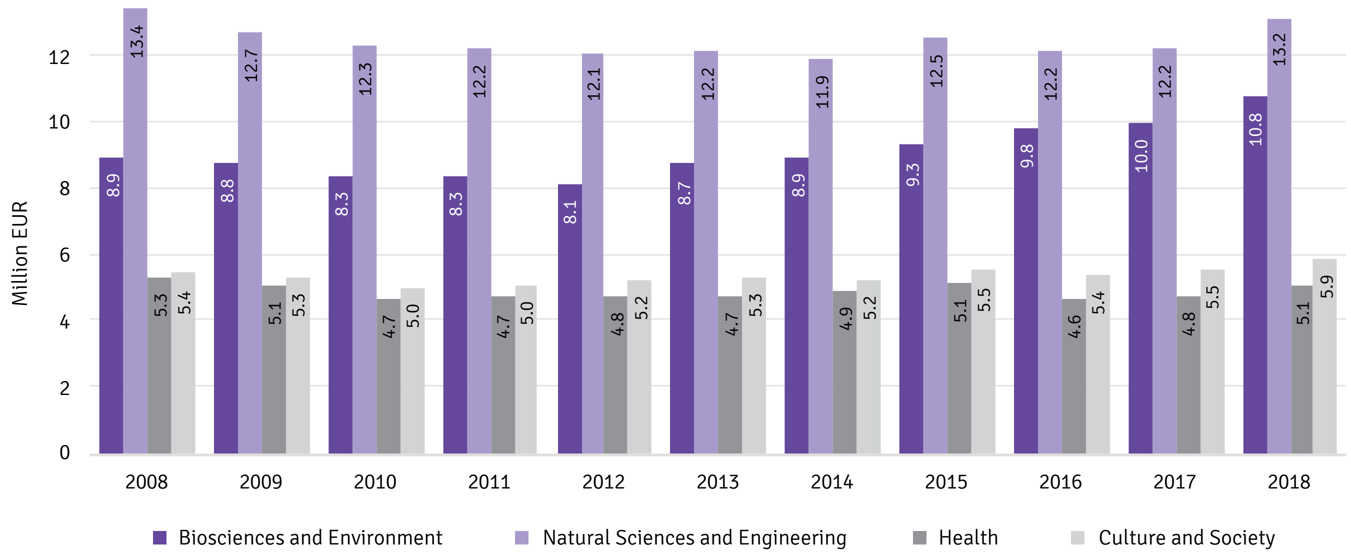

Figure 1.8. Division of competition-based funding by four major research fields from 2008 to 2018. All types of competition-based funding instruments (personal research grants and institutional research funding, targeted research funding, Estonian Science Foundation's grants) are pooled

Source: Estonian Research Council.

Table 1.1. Average success rates for institutional (IRF) and personal research grants (PRF) application rounds from 2013 to 2018 (by project commencement year)

	Share of funded projects among all applications				
	Biosciences and Environment	Natural Sciences and Engineering	Health	Culture and Society	Total
IRF 2013	50.0%	40.0%	77.8%	26.7%	41.3%
IRF 2014	68.6%	59.1%	64.3%	48.5%	59.5%
IRF 2015	50.0%	39.4%	50.0%	30.4%	40.5%
PRG 2013	23.1%	22.2%	26.7%	18.3%	21.6%
PRG 2014	9.8%	14.0%	21.7%	11.1%	13.1%
PRG 2015	28.0%	21.2%	35.3%	18.8%	23.0%
PRG 2016	27.1%	16.8%	27.3%	13.1%	19.0%
PRG 2017	24.1%	24.6%	39.0%	20.6%	25.1%
PRG 2018	15.8%	15.0%	14.3%	8.9%	13.6%

Source: Estonian Research Council.

Table 1.2. Centres of excellence in the period from 2016 to 2022 and the funding volumes (million EUR) for the entire funding period

Centres of excellence from 2016 to 2022	Total budget (million EUR)
Ecology of global change: natural and managed ecosystems	**4.4**
The Dark Side of the Universe	**4.0**
Emerging orders in quantum and nanomaterials	**3.9**
Advanced materials and high-technology devices for sustainable energetics, sensorics and nanoelectronics	**4.7**
Centre of Excellence for Genomics and Translational Medicine	**5.1**
Center of Excellence in Molecular Cell Engineering	**4.8**
Centre of Excellence in Estonian Studies	**4.8**
Zero energy and resource efficient smart buildings and districts	**4.4**
Estonian ICT Centre of Excellence in research (EXCITE)	**5.1**
Total	**41.2**

Source: Estonian Research Information System (ETIS).[34]

[34] Estonian Research Information System. www.etis.ee (22.10.2016).

Table 1.3. The research infrastructure objects that received support in Call 1 of Research Infrastructures of National Importance based on the national research infrastructures roadmap. The funding volume covers the period 2016–2022

Name of research infrastructure object	Total budget (million EUR)
Estonian Centre for Genomics	**1.8**
Center of Estonian Language Resources (CELR)	**0.7**
The Optical Backbone Network of Estonian Research and Education	**0.5**
Infotechnological Mobility Observatory (IMO)	**0.8**
ELIXIR Estonia—A Distributed Infrastructure for Life-Science Information	**1.3**
Smart Industry Centre (SmartIC)	**1.6**
Nanomaterials—research and applications (NAMUR+)	**1.8**
European Spallation Source	**3.0**
National Centre for Translational and Clinical Research	**2.1**
Estonian Scientific Computing Infrastructure (ETAIS)	**2.1**
Estonian Centre of Analytical Chemistry (ECAC)	**1.5**
Natural History Archives and Information Network (NATARC)	**1.6**
Estonia's participation in the European Social Survey	**0.4**
Total	**19.1**

Source: Estonian Research Council.

The support for investments into objects of the Estonian Research Infrastructures Roadmap continued in the examined time period (Table 1.3). The research infrastructure objects received support under Call 1 of the EU Structural Funding measure Research Infrastructures of National Importance based on the national research infrastructures roadmap.[35]

Estonian researchers and entrepreneurs are successful in EU Framework Programmes

Estonian researchers and enterprises have increased their participation in EU research and development programmes constantly over the years (Figure 1.9). Although the intensity of the participation as measured by the amount of funds allocated to Estonia from the EU Framework Programmes has been rather varying from year to year (this is caused by the cyclic nature of the opening of programmes and application calls), the general growth trend is obvious.

It is notable that in addition to research institutions, Estonian entrepreneurs are also successful in the EU Framework Programmes. Data published as at September 2018 reveals that Estonian applicants have performed successfully in Horizon 2020 competitions a total of 426 times and have been awarded 126.3 million euros. Private enterprises have been successful 149 times (in 117 cases small and medium-sized enterprises) and they have been awarded 50.8 million euros (35.4 million euros for SMEs).[36]

Estonia is holding a very good position within the EU in view of its successful participation in Horizon 2020 (Figure 1.10). If we compare the proportion of the awarded funds to a country's GDP, Cyprus has taken a narrow lead in front of Estonia. In this regard, Estonia exceeds the European average 2.6 times. Upon comparing countries on the basis of this indicator, it must be noted that countries with a lower GDP have an advantage. If one eliminates the effect of a lower GDP and considers the success of participation as a ratio to the country's population, Estonia's position is still rather good, exceeding the EU's average 1.45 times. Such success is evidence of the high level and competitiveness of Estonian researchers and entrepreneurs in the European research and innovation market.

Since participation in the EU Framework Programme generally requires co-operation, success also indicates that our researchers and entrepreneurs are valued partners. The share of foreign sources in funding Estonian research is very high (Figure 1.3). The EU Framework Programme holds a significant share among these sources. Therefore, it must be noted it is not very likely that participation in the current and next EU Framework Programme will increase significantly. Estonian researchers and entrepreneurs should set taking more leading roles in future international co-operation projects as their next objective.

[35] The Research Infrastructures Roadmap is a strategic planning instrument that includes a list of new research infrastructure units (infrastructure objects) or units that are in need of modernisation and that are of national importance. The roadmap is updated regularly so as to consider changing needs and opportunities. The previous Estonian Research Infrastructures Roadmap was issued in 2014. In 2018, tasked by the MER, the Estonian Research Council initiated updating process of the roadmap. The updated roadmap will be approved by the Government of the Republic presumably in early 2019.

[36] External Common Research Datawarehouse (eCORDA) data, cut-off date 29.09.2018. https://webgate.ec.europa.eu (25.10.2018).

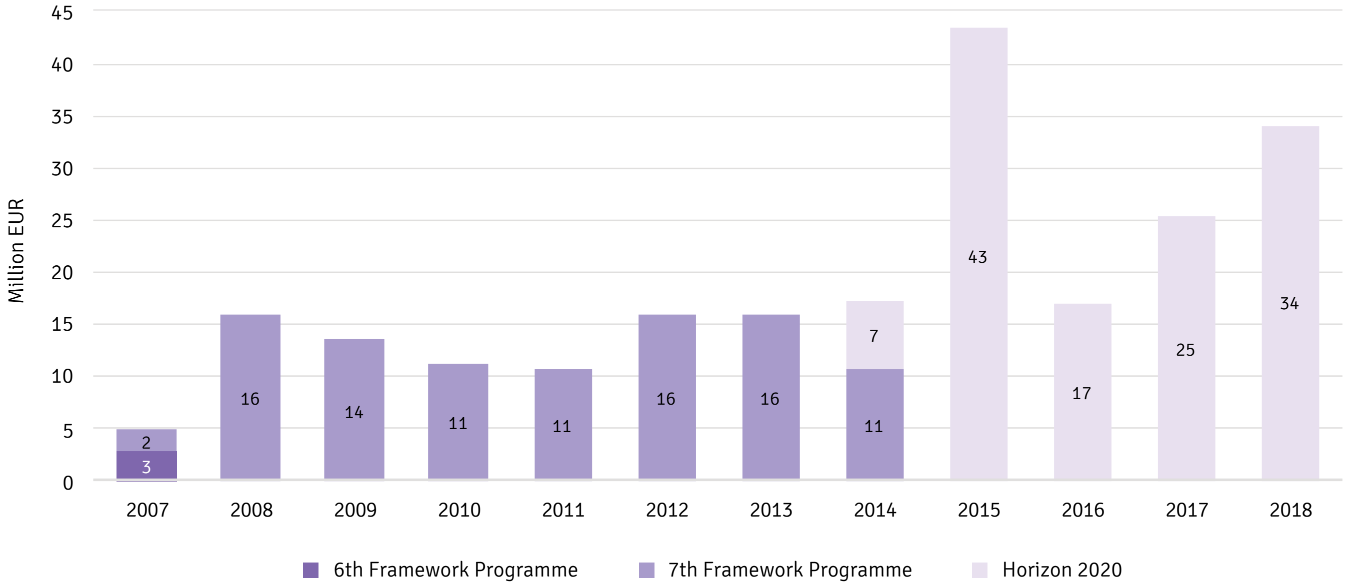

Figure 1.9. Financial contribution to Estonia from EU Framework Programmes for Research and Innovation in 2007 to 2018 (million EUR). The figure features annual amounts that correspond to the monetary value of contracts signed that year. The funding is used throughout the duration of projects during several subsequent years (cut-off date 29.09.2018)

Source: eCORDA.[37]

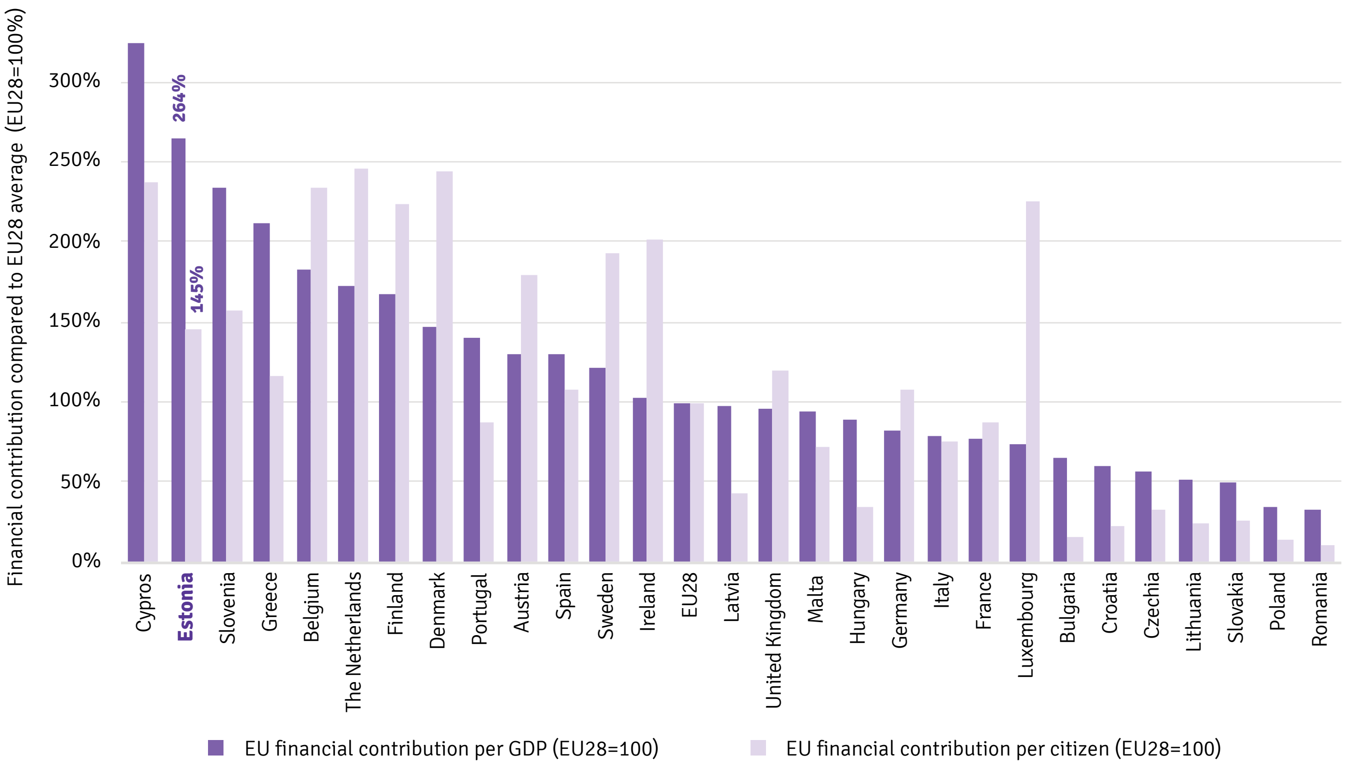

Figure 1.10. EU financial contributions from Horizon 2020 compared in participating EU28 countries per GDP and per citizen in view of the EU28 average (EU28=100) (data cut-off date 13.08.2018)

Sources: eCORDA[38] and Eurostat,[39] calculations by Estonian Research Council.

[37] External Common Research Datawarehouse (eCORDA) data, cut-off date 29.09.2018. https://webgate.ec.europa.eu (25.10.2018). It must be noted that the data in the eCORDA database is sometimes corrected afterwards, thus the data obtained from the database at different times may differ slightly.
[38] External Common Research Datawarehouse (eCORDA) data, cut-off date 29.09.2018. https://webgate.ec.europa.eu (25.10.2018).
[39] Eurostat. https://ec.europa.eu/eurostat/data/database (29.08.2018). (GDP as at 2016, population as at 1 January 2017).

Student Kalev Joab performing plane table measuremen
raphy students' field training trip in June 1990 with his supervisor, associate professor Leo Kullus, in the background
Author: Margus Hendrikson (Estonian Science Photo Competition 2017).

CAREER MODELS AND JOB OPPORTUNITIES FOR THE RESEARCHERS IN ESTONIA: WHERE ARE WE COMING FROM, AND WHERE ARE WE HEADING TO?

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Introduction

Being successful as a country and a society in a globalising world encompasses a multitude of challenges, especially for a small country like Estonia with limited natural and human resources. Predatory labour- and resource-intensive economic growth based on raw materials, non-renewable natural resources and irreversible destruction of environment is non-sustainable. Boosting economy by creation of financial and tax havens attractive for global enterprises has been a successful strategy for several countries, but with greater global efforts to avoid money laundry and tax evasion, such economic model will not be viable for long. In fact, there are plenty of reasons to believe that the future belongs to knowledge-based high value-added economy, and that knowledge becomes even more important in the future. This is because increasingly complex technologies, processes and societal changes require creation of new knowledge at an unprecedented pace. Recognising this, the most economically developed countries with high value-added economic models are prioritising investments in education, and research and development activities. Often these investments are considered, in a highly simplified manner, only as inputs to contribute to creation of new goods and services. However, the environment conducive to the development of highly advanced technologies and coherent and environmentally sustainable development of society are equally important. Therefore, the level of education needs to increase everywhere, both in private and public sectors.

This article analyses the "health" of the Estonian human resources in comparison to other countries, focusing on the highest level of education (doctoral studies), and R&D personnel. The key questions addressed are how the overall situation and trends in Estonian R&D human potential compare to other countries and whether we are closing the gap to the exemplary countries that we have considered our role models. This analysis updates the previous summary by Professor Tiit Tammaru published in Estonian Research 2016,[40] and further extends it by addressing in more detail the age dynamics of doctoral students and researchers, career model of researchers and the gender gap. The new data highlight a number of recent shifts in the age dynamics and graduation rates of doctoral students, and indicate a significant decline in the number of R&D personnel in both public and private sectors. The overall decline is clearly following the stagnation of both state and industry expenditure on research and development in recent years, and confirms the fact that "we get what we pay for". The evidence summarised here shows that the entry of doctorates and R&D personnel into the labour market has slowed down, and instead of closing the gap, we are drifting further away from advanced research countries. Due to lack of funding and transparent career models, it is particularly problematic for young researchers to enter, establish and progress in the research landscape. To increase the transparency of creation and filling of vacancies and to increase job security, it is necessary to establish clear merit-based career models for researchers. The first steps in this direction have already been made, but, as with many things, we tend to get slowed down by seeking for our own unique Estonian way. As the comparisons of country-specific R&D statistics demonstrate, in a globalised world, there are only limited options for outcompeting others, and by trying to "play a different game by different rules" we risk being left behind, as our competitors are moving at a higher pace.

The number of employees with a doctoral degree is directly linked to investments in research and development as well as to economic growth

In modern advanced countries, rapid and sustainable economic growth is achieved, in particular, by increasing the average level of education. In developed countries, both the number of first- (on average 23.8% in OECD countries as of 2016) and second-level (master and other equivalent levels of education, 11.9%) higher education graduates have increased, as well as the number of graduates in the highest level of higher education (doctoral studies, 1.0%).[41] While the two first levels of higher education have become mass education in the modern world (about 45% of 25–35 years old people have higher education in OECD countries)[42] and constitute an indispensable precondition for competing in a multitude of labour market spheres, a doctoral degree is still an elite top-level education, achieved by a relatively small proportion of the population in society. At the same time, the top-notch competence is inevitable to boost the

[40] Tammaru T. (2017). Doctoral degree holders and researchers in the labour market: Estonia compared with other European countries.— Estonian Research 2016 (ed. K. Raudvere), pp. 19-24. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).

[41] OECD. (2017). Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/eag-2017-en

[42] OECD. (2018). Education attainment. Population with tertiary education (indicator). doi:10.1787/0b8f90e9-ne (25.02.2019).

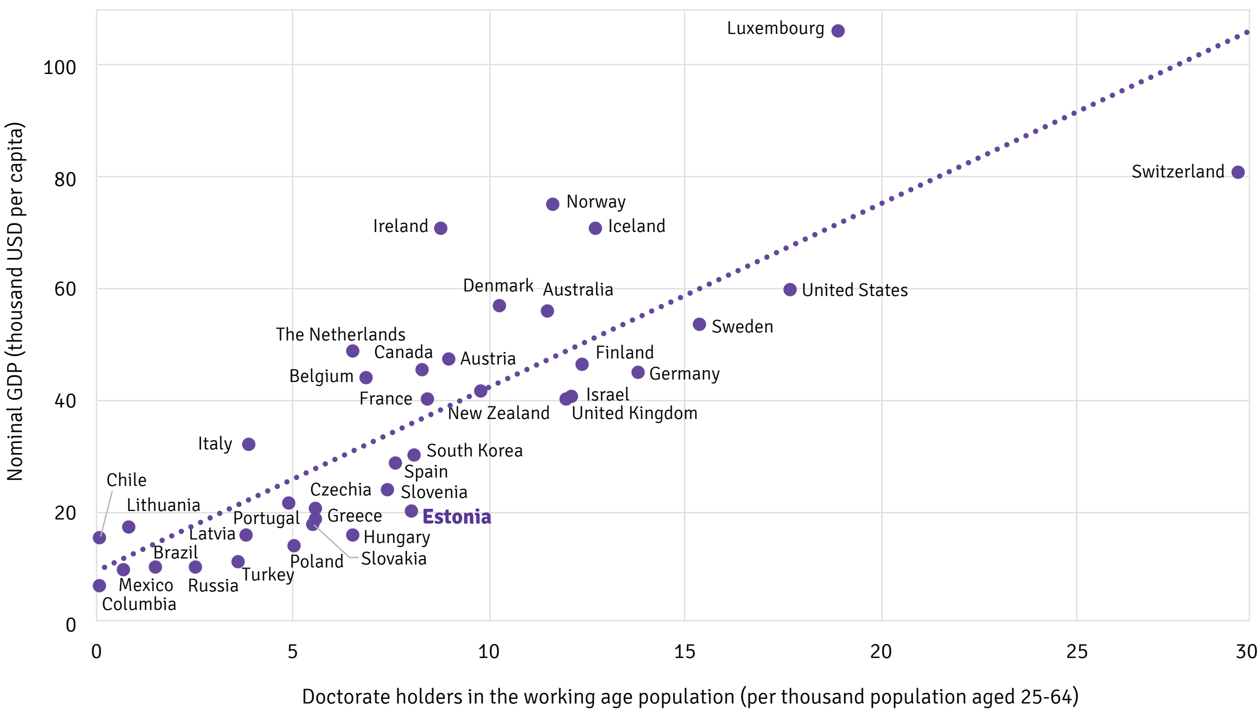


Figure 2.1a.

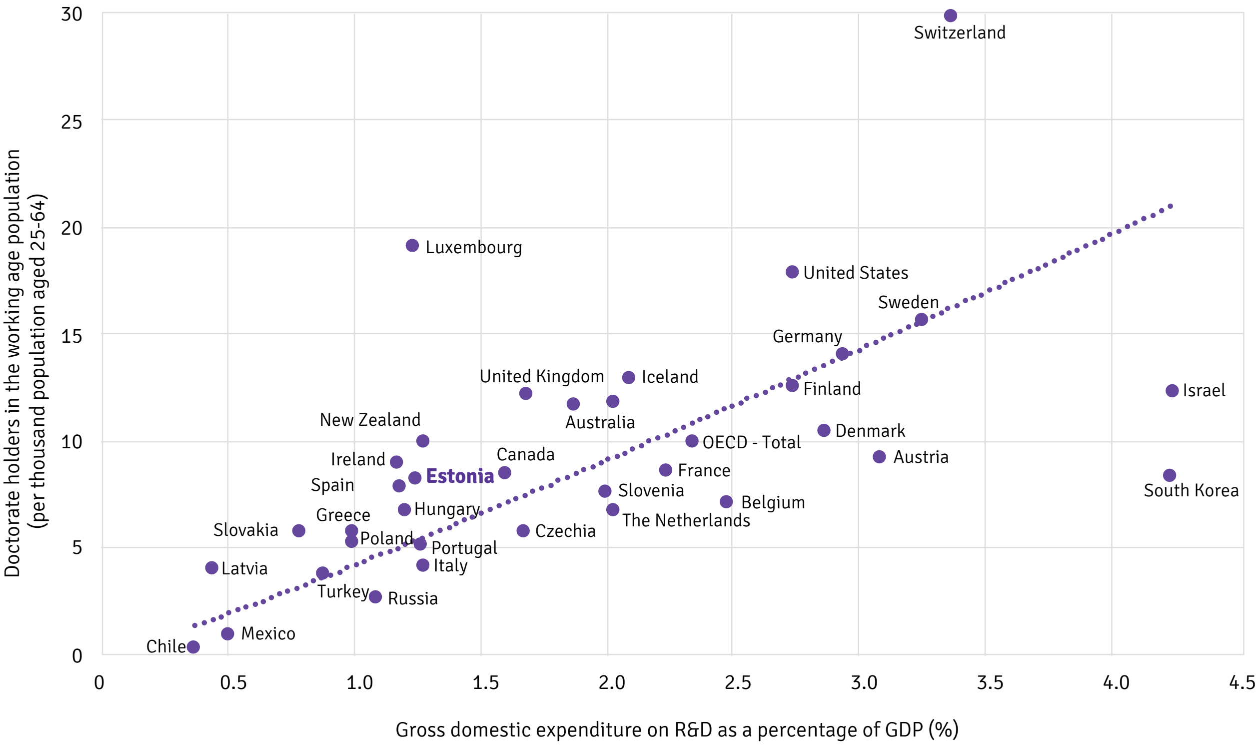


Figure 2.1b.

Figure 2.1. Relationship between the nominal GDP of the country (GDP per capita, thousands USD) and the proportion of people with doctoral degree (a), and the proportion of people with doctoral degree in relation to country's total intramural R&D investment (b). Doctoral degree holders are calculated in relation to working age (25–64 years) population; investments in R&D activities (% of GDP) for 2016 or the last available year and GDP for 2017 or the last available year[43]

Sources: OECD,[44,45] IMF[46] and Statistics Estonia,[47] calculations by Estonian Research Council and the author.

[43] Remark: in figure 2.1a the data were approximated with the function *y=ax+b* and in figure 2.1b with the function *y=ax^b* (determination coefficients r^2=0.67 for (a) and r^2=0.57 for (c)).
[44] OECD. (2017). OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris http://dx.doi.org/10.1787/9789264268821-en.
[45] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (03.09.2018).
[46] IMF. World Economic Outlook Database. https://www.imf.org/external/pubs/ft/weo/2017/02/weodata/index.aspx (10.10.2018).
[47] Statistics Estonia. www.stat.ee (10.10.2018).

country's innovation capacity and innovation readiness. Unlike the first levels of higher education, the share of doctoral graduates within the working age population varies greatly between countries. In 2016, the number of doctorate holders in the working age population (per thousand population aged 25-64) varied among OECD countries from 0.2 (Chile) to 29.8 (Switzerland).[48] This is a significant variation, since the proportion of people with doctoral degrees, with a few exceptions, is directly related to national wealth in terms of gross domestic product (GDP, Figure 2.1a).

Worldwide, the proportion of doctoral holders in labour force also positively correlates with the country's expenditure on research and development (in proportion to gross domestic product, GDP, Figure 2.1b). This positive relationship explicitly underscores the main contention of the European Growth Strategy Europe 2020[49] that investing in research increases the number of "smart" jobs with high added value, and is a key driver for sustainable economic growth. In this relationship, Switzerland appears to be an exception with the incontestably highest ratio of doctorates, followed by Luxembourg, whereas both countries have more doctorates in the working-age population than would be expected from their expenditure on research and development (Figure 2.1b). However, both are wealthy countries that can afford the luxury to "import" educated labour force (Figure 2.1a). In addition, the paradox of Luxembourg can also be explained by the disproportionally large number of European Union institutions, where, in general, the average education level is much higher.

Where is Estonia placed in comparison to the countries having the highest ratio of specialists with highest level of education? In Estonia, in 2016, there were 8.1 doctorate holders per 1,000 people in the working-age population[50] (out of which 3,155 employees with a doctoral degree were involved in research and development[51]). This indicator corresponds well to our wealth and expenditure on research and development, but also places us in the back echelon in comparison to other OECD countries (Figure 2.1b). As for the distribution of doctoral degrees between research fields, Estonia has been relatively successful in natural sciences (31.7% of graduates in 2006–2017,[52,53] and 31% in 2015, according to OECD data[54]). This is higher than the average in the Nordic countries, according to the 2015 data (Denmark 18%, Finland 18%, Sweden 21%, Norway 28%), but similar to other advanced research countries (Germany and Great Britain 29%, Switzerland 31%[55]). On the other hand, the contribution of medical sciences to doctoral studies is small (6%) compared to the above-mentioned seven advanced research countries where the proportion of doctoral graduates in medical sciences varied from 16% (UK) to 29% (Denmark).[56] Clearly, there are far too little people with doctoral degrees in Estonia in all areas of life, especially in certain key areas, and this is directly related to the low expenditure on research and development (Figure 2.1b).

Doctorates in the private sector: to what extent and why do countries differ?

Comparable data on the distribution of doctorate holders between different sectors in different countries—the public sector (higher education and government sectors) and the private sector (profit-seeking business enterprise sector and private non-profit sector) are limited, as the sectoral breakdown varies between countries, and there are gaps in time series for many countries. Current analysis is based on the latest OECD data (published in 2017),[57] and despite some discrepancies, the existing data set allows several important conclusions to be drawn. Importantly, these data demonstrate that the proportion of R&D personnel in private sector (the number of R&D personnel with a doctoral degree working in the private sector relative to the total R&D personnel with doctoral degree in a country) varies widely among the countries, from 2.9% in Poland, 3.8% in Slovakia and 3.9% in Turkey to 32.4 % in Austria and 33.6% in Belgium (Figures 2.2b,c).

What causes large variations in the proportion of doctorates in the private sector between countries? First of all, data show that the relative contribution of the private sector to gross domestic expenditure on R&D is higher in developed countries, which are also spending more on R&D (Figure 2.2a). This is a very important dependence, which clearly shows that a certain minimum level of public sector spending is needed for a significant increase in R&D of the private sector. This extra expenditure is necessary to increase the number of doctorates beyond the level necessary to maintain the supply of doctorates to fill the academic positions that become vacant as the professors retire. Even in the most successful countries that have the greatest expenditure on research and development, most people with a doctoral degree still work in the public sector. This is necessary as the public sector, in particular universities, prepares doctorates for the business sector, but is also responsible for the functioning of the three-level higher education. This implies that no more doctorates can enter the private sector than is necessary to rebuild the corps of academics. In fact, in the private

[48] OECD. (2017). OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264268821-en
[49] European Commission Europe 2020. A strategy for smart, sustainable and inclusive growth. Communication from the Commission. Brussels, 3.3.2020. COM(2010) 2020. http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf (03.09.2018).
[50] OECD. (2017). OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264268821-en
[51] Statistics Estonia. www.stat.ee (28.09.2018).
[52] Statistics Estonia. www.stat.ee (03.09.2018).
[53] Haridussilm. www.haridussilm.ee (10.05.2018).
[54] OECD (2017). Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/eag-2017-en.
[55] OECD (2017). Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/eag-2017-en
[56] OECD (2017). Education at a Glance 2017: OECD Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/eag-2017-en
[57] OECD. Research and Development Statistics. www.oecd.org/sti/rds (04.09.2018).

sector, the proportion of doctorates does not exceed a third of all doctorates in any country. This conclusion is supported by the positive dependencies between the proportion of doctorates working in the private sector and the expenditure of the private sector on research and development (Figure 2.2b) and between the proportion of doctorates working in the private sector and the expenditure of the private sector on research and development and national GDP (Figure 2.2c). In countries with a lower proportion of doctorates in the private sector, there is generally also a lower GDP, lower overall public investment in research and development, and thus, an even smaller proportion of the doctorate holders in the private sector. There are some exceptions to these relationships, for example, Russia has a relatively large number of doctorates in private enterprises (Figure 2.2c), but due to the unevenness of the aforementioned statistical data, a detailed analysis of these exceptions is currently not appropriate.

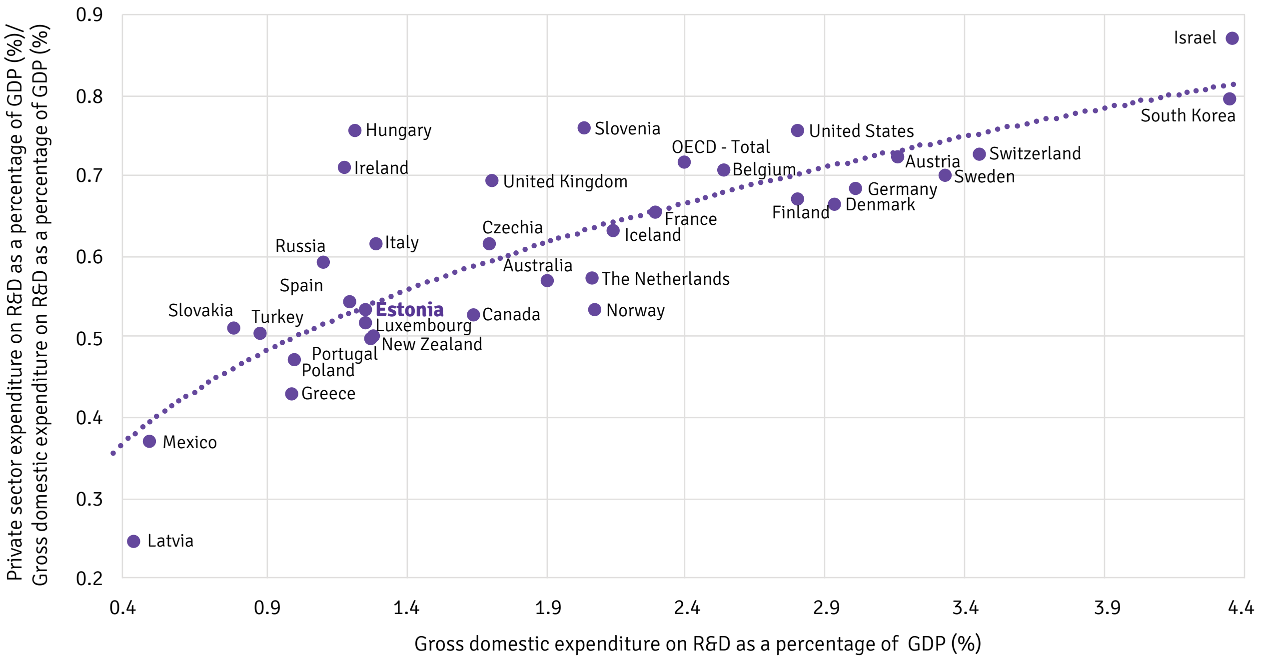


Figure 2.2a.

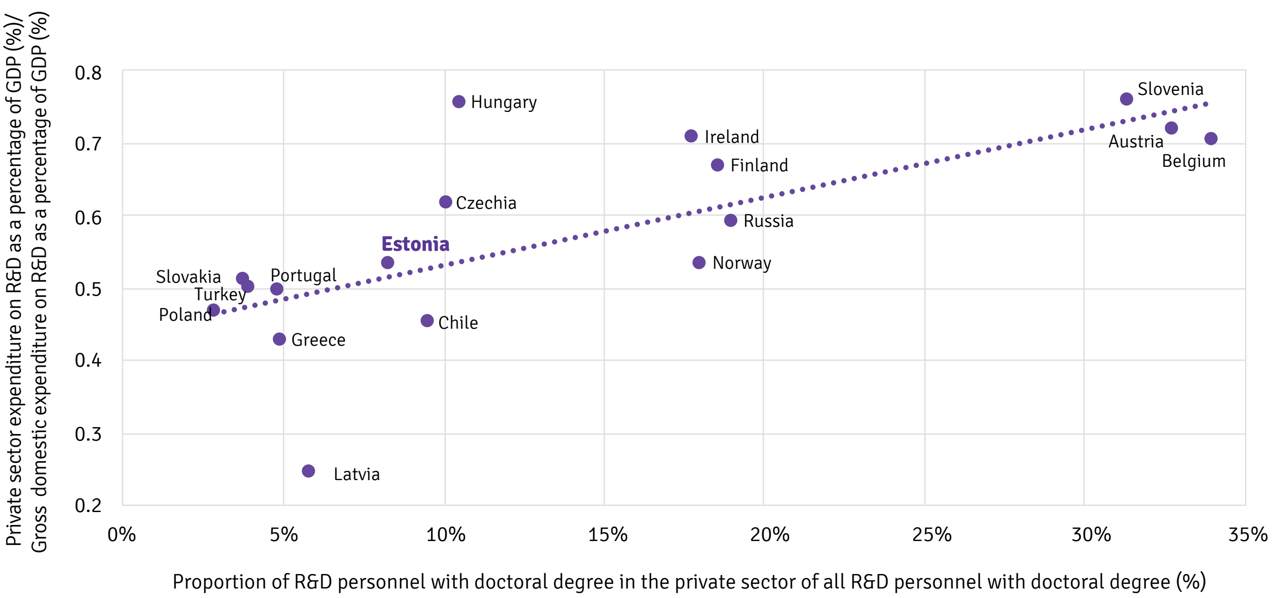


Figure 2.2b.

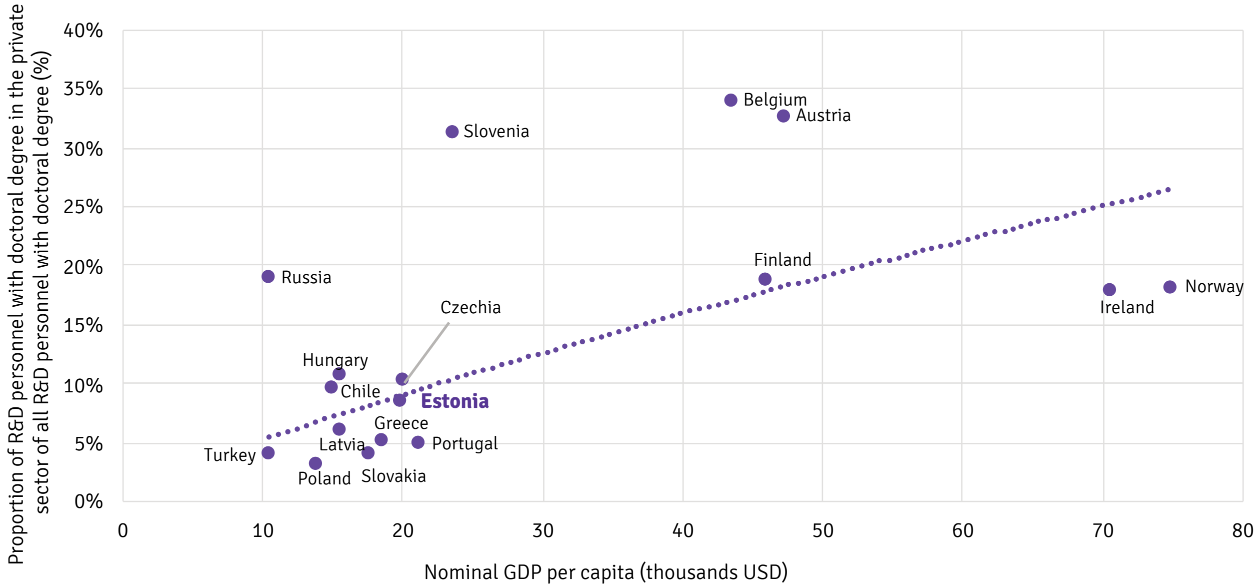


Figure 2.2c.

Figure 2.2. The proportion of private sector R&D expenditure of total gross domestic expenditure on R&D in relation to (a) the total gross domestic expenditure on R&D and in relation to (b) the proportion of R&D personnel with a doctoral degree in the private sector of all R&D personnel with a doctoral degree, and the relationship between the nominal gross domestic product and the proportion of R&D personnel with a doctoral degree in the private sector of all R&D personnel with a doctoral degree (c).[58] The data for private sector R&D expenditure, and total gross domestic expenditure on R&D, are for 2016 or the last available year. The data for the R&D personnel are for 2015 or 2016, and in the absence of data for these years, for 2014. The nominal gross domestic product is for 2017.

Sources: OECD[59,60] and IMF,[61] calculations by the author.

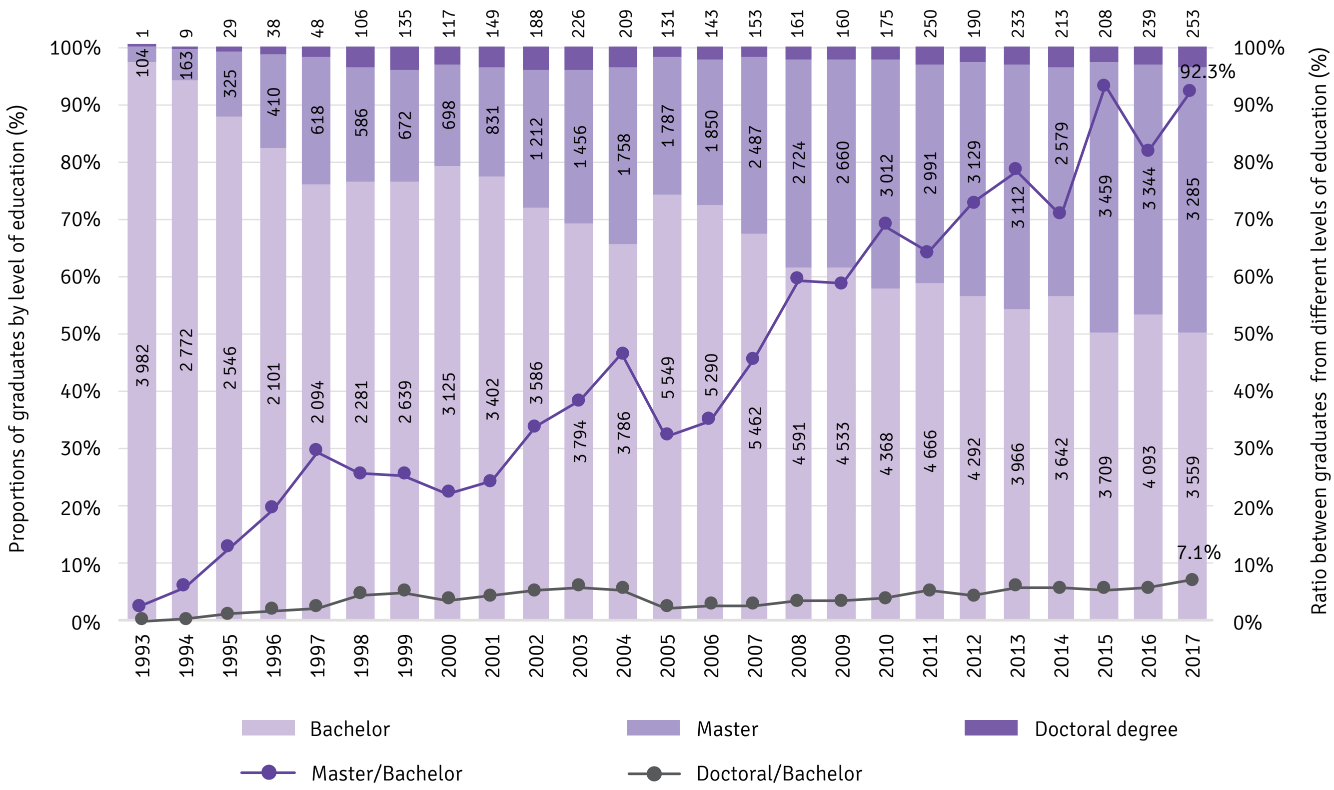


Figure 2.3. Graduates according to the level of education in 1993–2017

Source: Statistics Estonia.[62]

[58] In figures 2.2a and 2.2.c, the data were approximated with the function $y = ax^b$ (determination coefficients r^2=0.67 for (a) and r^2=0.39 for (c)) and in figure 2.2b with the function $y = ax+b$ (determination coefficient r^2=0.51).
[59] OECD. Research and Development Statistics. www.oecd.org/sti/rds (04.09.2018).
[60] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (09.05.2018).
[61] IMF. World Economic Outlook Database. https://www.imf.org/external/pubs/ft/weo/2017/02/weodata/index.aspx (08.10.2018).
[62] Statistics Estonia. www.stat.ee (27.04.2019).

The situation in Estonia is very much in line with the broad relationships across the countries. Due to overall low R&D expenditure, the doctorate graduation is moderate, and Estonian doctorates do not end up in the business enterprise sector.[63] Estonia has only 8.3% of doctorates in the private sector (Figure 2.2b), belonging, thus, to the last third of the observed countries. However, this position is in a very good agreement with the Estonian R&D intensity rate, and private sector expenditure on research (Figure 2.2a, b). It further reiterates the small proportion of doctorates in the Estonian working-age population that cannot be significantly increased at the present R&D intensity rate.

Doctoral studies in Estonia: what should we change?

A goal of preparation of 300 new doctorates every year in Estonian universities had been defined already in late 1990s.[64] This target has been criticised, and it has been questioned whether Estonia indeed needs 300 fresh doctorates each year. Yet, if we had 300 new doctorates every year, we would slowly move towards developed countries, but since regaining our independence, 300 doctorates per year have never entered the labour market (Figure 2.3). There are far too few doctorates in Estonia due to objective reasons, e.g. limited financing. However, is funding the only problem? Are all the possible measures taken in Estonian doctoral studies to make the best use of the limited resources? The analysis of all three levels of higher education in 1993–2017 shows that the proportion of students who, after getting their bachelor's degree, also acquire a master's degree, has consistently increased (Figure 2.3). This trend is well explained by the latest research looking at employers' expectations of the education of job applicants. The evidence showed a growing appreciation of master's degree as an important qualification criterion; similarly, job seekers find that a master's degree is necessary to stand out from the 'mass'.[65,66]

Unfortunately, there is no such positive trend when it comes to recognising the value of the doctoral degree. The proportion of doctoral students among all graduates has remained at 4–5% since 1998, reaching the lowest point in 2005 (2.4%), and then slowly recovering, reaching the highest percentage ever (7.1%) in 2017 (Figure 2.3). It is currently unclear whether this rise marks the change of the trend. However, in addition to the proportion of doctorates, we must also bear in mind that, at the same time, the total number of students has decreased due to demographic reasons. Thus, to meet the target of at least 300 doctorates graduating each year in Estonian universities, the proportion of students entering the doctoral programs should be significantly higher.

Compared to other countries, in terms of doctoral graduates, Estonia with its 3.6% of doctoral graduates in 2016 (taken as percentage of the graduates of the first level of higher education) lags far behind advanced research countries Sweden (9.6%), Austria (7.5%) and Switzerland (6.9%), but also, for example, Slovakia (6.9%) (Figure 2.4). For some reason, in Estonia, the attitude of employers and prospective students is that the doctoral degree is something extraordinary, so a person with a doctoral degree is considered overqualified for most jobs. Although in the modern world, the highest tier of education is needed not only for researchers, but also in public administration and private enterprising, this opinion is hard to change.[67]

Looking at the temporal variation in the number of admissions to doctoral studies and numbers of graduations and dropouts in Estonian universities in 2005–2017 (Figure 2.5), several relevant trends emerge. First, in 2012, the number of admissions to the doctoral programmes dropped sharply due to new regulations for accepting doctoral students outside the state budget (university was required to guarantee a doctoral allowance to non-state funded students in the same way as to state-funded doctoral students). Second, the proportion of doctoral students quitting the studies is very high, and exceeds each year the proportion of graduates during the whole time period. Third, the number of doctoral students studying in each calendar year in 2005–2017 (from 1970 to 3051 persons) exceeds the number of doctoral students admitted in the current calendar year by 4.4–8 times (Figure 2.5).

A large number of doctoral candidates studying at any moment of time means, in turn, that the duration of doctoral studies is far too long. For the doctoral students admitted between 2005–2011 and graduated by 10 November 2017 at the latest, the average duration of studies was more than five years (Table 2.1). The shorter time for graduation of doctoral students admitted from 2012 on arises probably from the circumstance that many of those admitted are still studying and the statistics includes only the faster graduates. For women, it takes somewhat longer to complete the studies than for men, possibly due to parental leave(s) (Table 2.1). In addition to the long time required to graduate, it is striking that the students who ultimately dropped out stayed in the doctoral program essentially as long as the successful graduates (Table 2.1).

[63] Tammaru T. (2017). Doctoral degree holders and researchers in the labour market: Estonia compared with other European countries.— Estonian Research 2016 (ed. K. Raudvere), pp. 19-24. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).

[64] Estonian Higher Education Strategy, 2006–2015. Ministry of Education and Research. https://www.hm.ee/sites/default/files/higher_education_strategy.pdf (07.01.2019).

[65] Oras K. (2014). Tööle värbamisel arvesse võetavad kriteeriumid tööandjate ja vilistlaste pilgu läbi. — Tööturu väljakutsed kõrgharidusele (toim. M. Unt, K. Täht), lk. 150-167, Vali Press OÜ.

[66] Unt M., Saar E., Helemäe J., Täht K. (2014). Kõrghariduse väärtuse langus või sisemise kirjususe tõus? — Tööturu väljakutsed kõrgharidusele (toim. M. Unt, K. Täht), lk. 79-98, Vali Press OÜ.

[67] Niinemets Ü. (2013). Vastukaja: igast doktorist ei pea saama teadlast. – Sirp, 20 October.

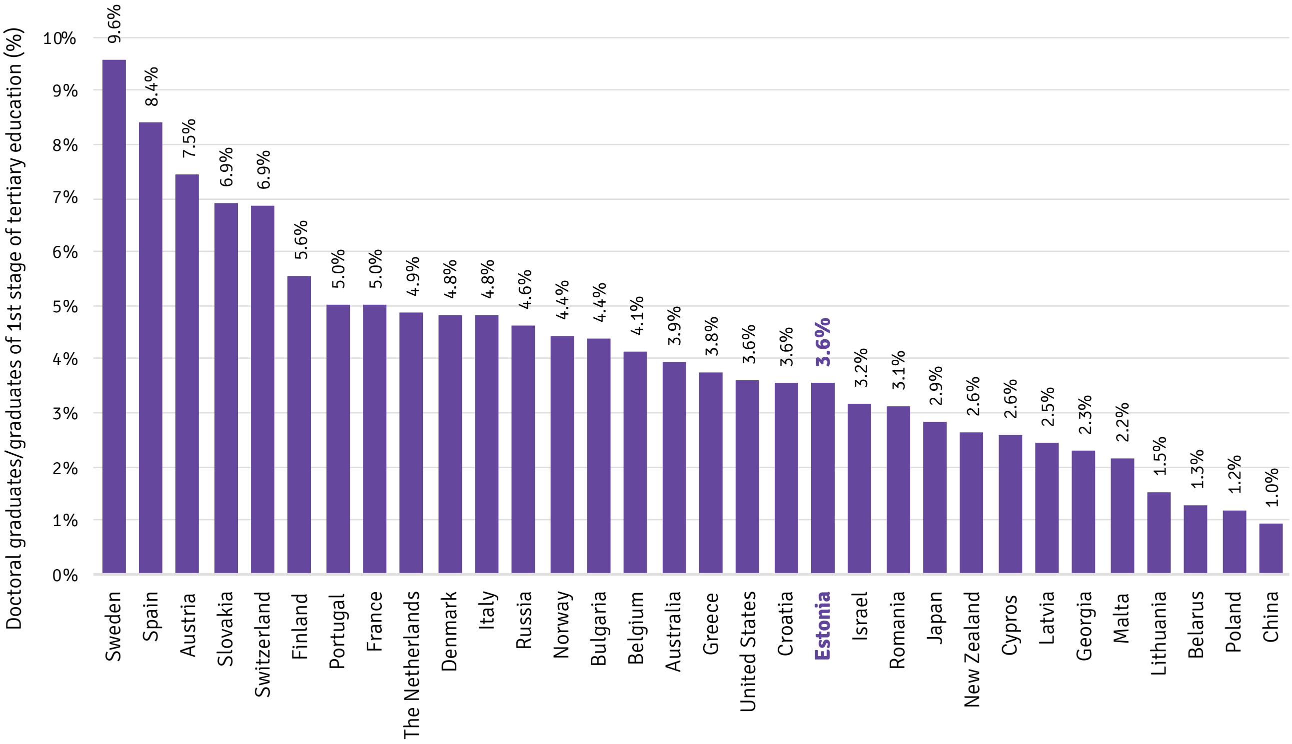


Figure 2.4. Number of doctoral graduates in relation to the graduates of the first stage of tertiary education in different countries in 2016

Source: UNESCO,[68] calculations by Estonian Research Council.

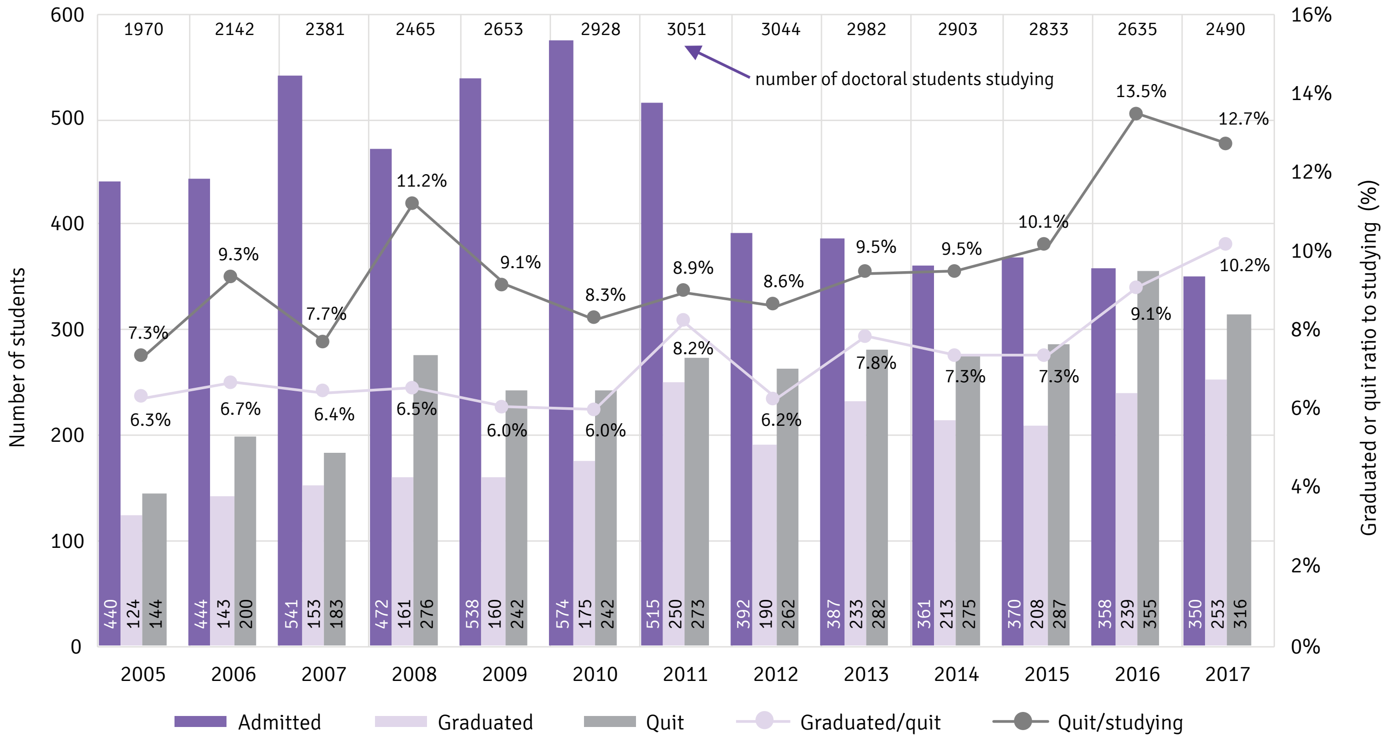


Figure 2.5. The number of students admitted to, graduated from, quit and continuing studies in doctoral programs in 2005–2017

Source: Statistics Estonia.[69]

[68] UNESCO. UIS Stat. http://data.uis.unesco.org/ (01.10.2018).
[69] Statistics Estonia. www.stat.ee (10.05.2018).

Table 2.1. Average time spent on doctoral studies through academic years 2005/06-2013/14[70]

		2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Total number of students admitted to doctoral studies (includes people who obtained the degree as well as those who dropped out)	male	5.2	5.9	5.2	5.1	5.1	5.0	4.9	4.4	3.8
	female	5.9	6.2	6.0	6.3	6.0	5.7	5.2	4.7	3.9
	total	5.5	6.1	5.7	5.7	5.6	5.4	5.0	4.6	3.9
Graduates by 10 November 2017 (only the ones who obtained the doctoral degree)	male	5.3	5.2	5.1	4.9	5.1	5.1	4.7	4.0	3.8
	female	5.8	5.9	6.0	5.5	5.2	5.3	5.0	4.4	3.4
	total	5.6	5.6	5.6	5.2	5.1	5.2	4.8	4.2	3.6

Source: EHIS.

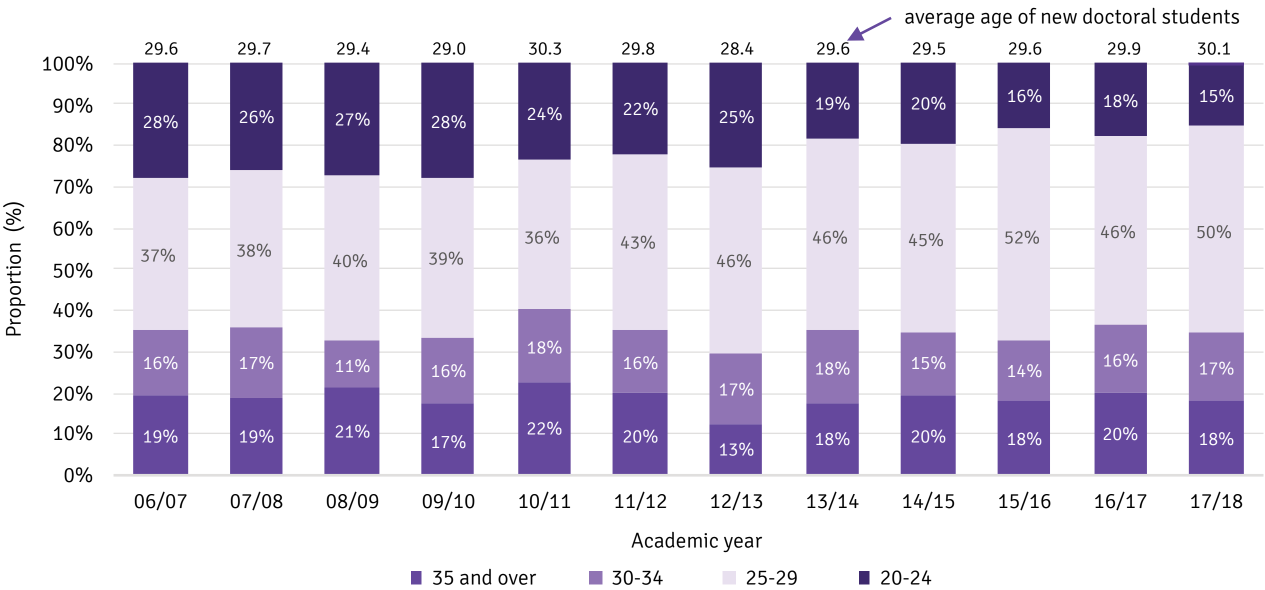


Figure 2.6a. The distribution of students enrolled in the doctoral programs between age groups throughout the academic years 2006/07 to 2017/18[71]

Sources: EHIS, Haridussilm,[72] calculations by Estonian Research Council.

Given the age of high school graduates, typically 18–19 years in Estonia, and the nominal length of the various levels of university studies (3 years for BSc, 2 years for MSc and 3–4 years for PhD), students continuously studying could obtain the PhD on average between the ages of 27 and 28 years. However, Estonian students enter the doctoral program relatively late. The average age of the student at the time of enrolling into doctoral studies has stayed close to 30 throughout the period of reference 2006–2017, except in 2012, when the average age was 28.4 (Figure 2.6a). There has been a significant decline in the number of admissions for doctoral studies in the age group 20–24 years (28% in 2006 and 15% in 2017) and an increase in the age group of 25–29 years (37% in 2006 and 50% in 2017, Figure 2.6a). Given the long time needed for the completion of doctoral studies, the average age of graduates is also relatively high. In the academic years 2006–2017, the proportion of graduates aged 30 years and older was 73–86%, whereas the proportion of those aged 35 and older was 37–46% (Figure 2.6b).

[70] Students studying in the first course/year of higher education curricula as of 10 November, and who started their studies in given calendar year during the period from 1 July to 10 November were considered to be admitted. Doctoral students studying with the TULE program financing and those returned to the ESF are not included among the admitted students. Study period in years: date of graduation/quitting of studies as of 10 November 2017 (for those who were still studying) minus the date of commencement of studies or the starting date at the reorganised institution. The days spent on academic leave are not subtracted. "All students admitted to doctoral studies" includes both those who defended their degree and those who quit their studies. "Graduated by 10 November 2017" included only those who had defended their doctoral degree as of 10 November 2017. www.ehis.ee

[71] The diagram considers only new students, i.e., only those students to whom this was the first PhD curriculum they have been admitted during the year of admission as of 10 November, and who started their studies in given calendar year during the period from 1 July to 10 November. Returning doctoral students (quitted, but re-established their student-status later) whose studies were financed from TULE program and those who returned under the programmes financed by the ESF (European Social Fund programmes e.g. DoRa, PRÕM) are not included among the admitted students.

[72] Haridussilm. www.haridussilm.ee (17.09.2018).

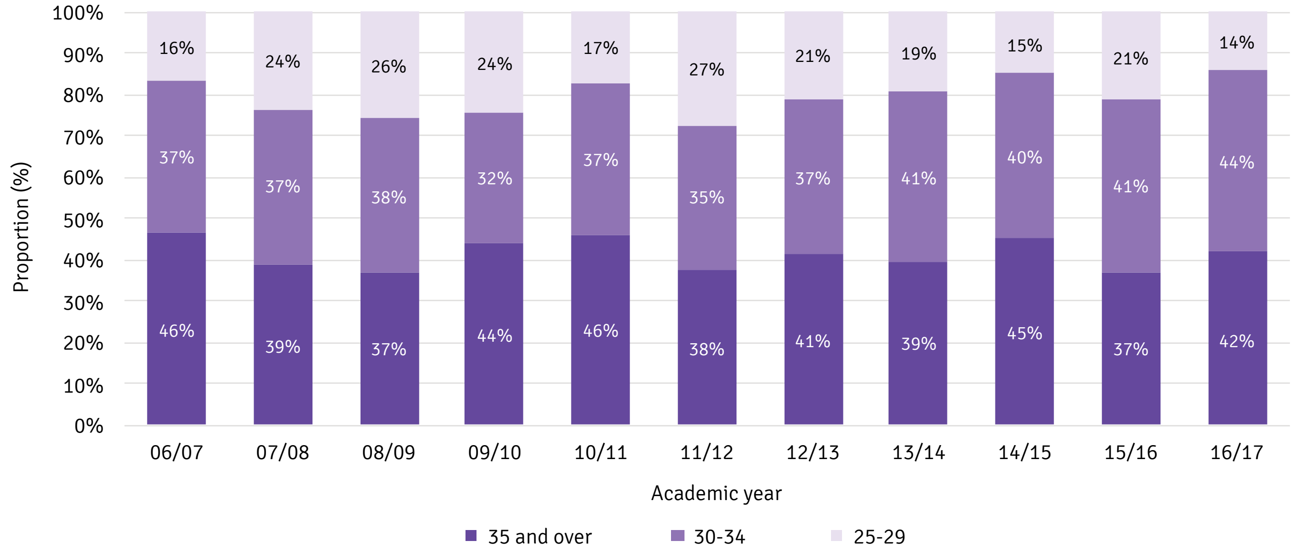


Figure 2.6b. The distribution of doctoral graduates between age groups through academic years 2006/07 to 2016/17[73]
Sources: EHIS, Haridussilm,[74] calculations by Estonian Research Council.

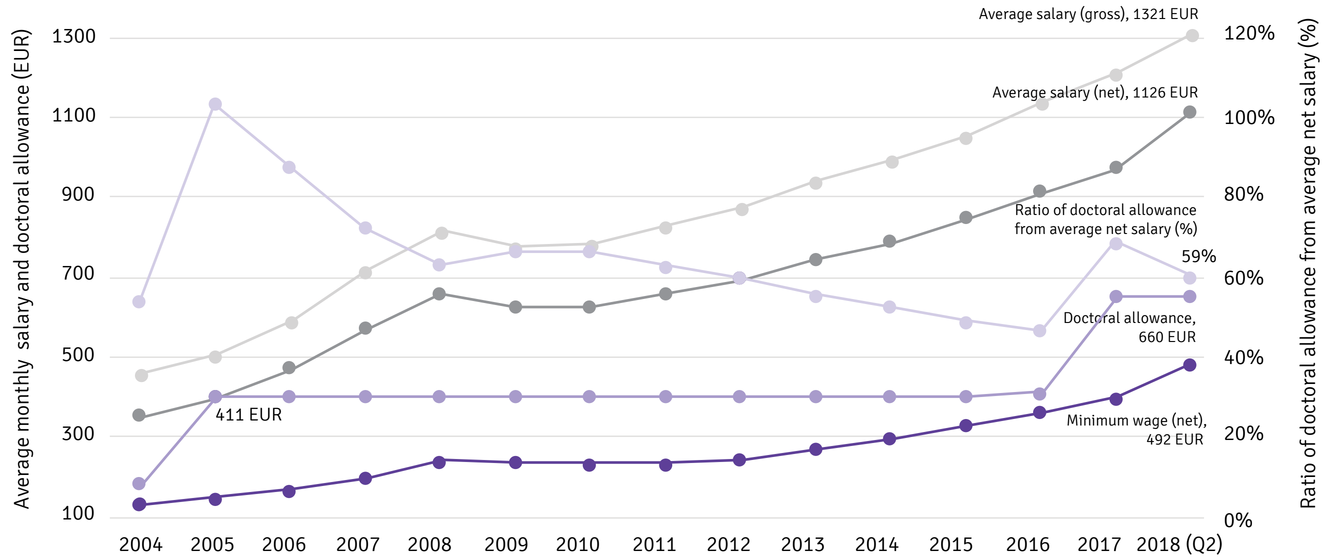


Figure 2.7. Dynamics of Estonian average monthly salary[75] compared to national doctoral allowance in 2004–2018 (salary information for 2018 is based on second quarter)
Source: Statistics Estonia,[76] calculations by Estonian Research Council.

A major reason for the prolonged doctoral studies and low graduation rate is thought to be the low income and social position of doctoral students. Indeed, the tax-exempt doctoral allowance rate relative to the average net salary has decreased from 100% in 2005 to 46% in 2016 (Figure 2.7). Even after the increase of the doctoral allowance in 2017, it comprised only 67% of the average salary (Figure 2.7). Of course, even after the last increase, the allowance is not enough to fully dedicate oneself to the doctoral studies. Nevertheless, paradoxically, the proportion of doctoral allowance in relation to net salary during the period 2006–2016 does not correlate with the proportion of doctoral graduates under thirty or over thirty years of age.[77] Thus, the amount of doctoral allowance does not appear to directly affect the age of doctoral graduates and the overall success of graduation during the observed period. This in itself is maybe not surprising, as doctoral studies are time-consuming, and

[73] Among graduates, only those who defended their doctoral degree are taken into account.
[74] Haridussilm. www.haridussilm.ee (17.09.2018).
[75] The minimum remuneration adjusted for tax includes all deductions but the mandatory funded pension (II pillar).
[76] Statistics Estonia. www.stat.ee (18.09.2018).
[77] Correlation coefficients, respectively, $r = 0.26$, $P = 0.44$ and $r = -0.24$, $P = 0.48$ for linear correlation.

therefore, it might be expected that there is a longer-term influence of the amount of doctoral allowance on graduation success, and also that there is a certain time shift between the rise of the scholarship and time to graduation. On the other hand, doctoral allowance is paid to doctoral students only for the first four years of study, but in practice, doctoral studies last almost twice as much (Table 2.1). Therefore, we can conclude that the doctoral allowance alone does not guarantee for the majority of doctoral students the basic income for the period of doctoral studies. Furthermore, the amount of doctoral allowance alone does not reflect at all the overall "cost" of the doctoral thesis. In experimental sciences, 50,000–100,000 euros per year could be easily spent on doctoral research. In the Estonian university system, it is expected that the money for actual research will be covered using available resources of the research groups, which will then be somehow compensated by the "cheap" labour cost of the doctoral student. In research groups where there are not sufficient resources for research, it is inevitable that the writing of the doctoral thesis will be delayed or be even impossible after all.

The issue of doctoral student income is very important, but is it the only one? I find that one of the biggest bottlenecks is the late entry into doctoral programs, which inevitably leads to late graduation. Literally speaking, if, instead of graduating doctoral studies in their twenties, people do it at the end of their thirties or forties, we basically lose a whole generation of researchers. Another major disturbing problem is that people who drop out from the doctoral program stay in the program as long as the graduates. As a practitioner with experience from multiple foreign systems of doctoral studies, I know that this situation is typical for such doctoral programs where the doctoral student is primarily regarded as a student, and therefore the teaching component in doctoral studies—especially lectures, courses, etc.—is large. This allows the doctoral student to accumulate credit points for courses and stay on the list of enrolled students even with minimum or no research component. However, the doctoral program is not completed until a research-based doctoral thesis is submitted and approved. In a number of countries, a doctoral student is regarded as a young researcher whose main job at the university is research. Estonia is also starting to realise that being in the doctoral program should be treated as a job and that the doctoral student should be paid a salary, not a scholarship.

There is one more key aspect for the success of doctoral studies, which is at least equally important as the other above-mentioned issues, but which, however, cannot be addressed in the light of these statistical data. This is the competence of supervisors. In many countries, such as Germany, the Netherlands, and Finland for example, only senior academics, typically just professors, can supervise PhD theses. This does not mean that there could be no co-supervisors, but the professor is the one responsible for the progress of the PhD studies. Professor is a prominent researcher with an established position in the university, while other faculty members and R&D personnel still advancing on the career path come and go, depending on the availability of funding and opportunities for career advancement. Basically, the only criterion for a doctoral thesis supervisor in Estonia is the existence of a doctoral degree. As the supervisors who are top-level excellent researchers, and researchers who themselves had trouble obtaining their doctoral degree are treated equally, this is likely to result in high unevenness in the qualifications of possible supervisors. On the other hand, the supervisor personal charisma, enthusiasm and willingness to contribute to the development of a young person,[78] as well as the formation of an academic partnership, rather than a relationship of dependence, are important factors in motivating a doctoral student, and the research excellence of the supervisor alone might not guarantee the success. I suggest that in addition to formal academic progress, upon the evaluation of doctoral students, the issues of supervision should also be analysed, up to changing the supervisor or the research topic (similarly to the Finnish system, for example). The role of the supervisor in the success of doctoral studies has so far been clearly underestimated and the statistical data necessary for decision-making are inadequate. This is definitely one of the topics that have to be analytically addressed in the future.

Trends in the number of researchers in the public and private sectors

The total number of researchers (in full-time equivalents), depending on the GDP of the country (Figure 2.8a) and the number of researchers (full time equivalents) in the private sector, depending on the contribution of the private sector (Figure 2.8b), and the number of researchers in the public sector, depending on the contribution of the public sector, show trends similar to the proportion of doctorates in the working age population (Figure 2.1). As in the case of doctorates, in comparison to other countries, the position of Estonia in terms of the number of researchers is modest for all researchers (Figure 2.8a) as well as for the private sector researchers (Figure 2.8b). In both of these comparisons, the position of Estonia matches the statistical relationship very well (Figure 2.8a,b). Similarly to doctorates, the number of researchers in the private sector is increasing disproportionately fast with the expenditure of the private sector on research and development (Figure 2.8d). This again emphasises the need for a certain minimum public sector R&D level, above which the private sector starts to increasingly invest in R&D.

[78] Kindsiko E., Vadi M., Täks V., Loite K., Kurri K. (2017). Eesti doktorite karjääritee ja seda mõjutavad tegurid. Tartu: Tartu Ülikool. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B5jutavad_tegurid.pdf (06.12.2018).

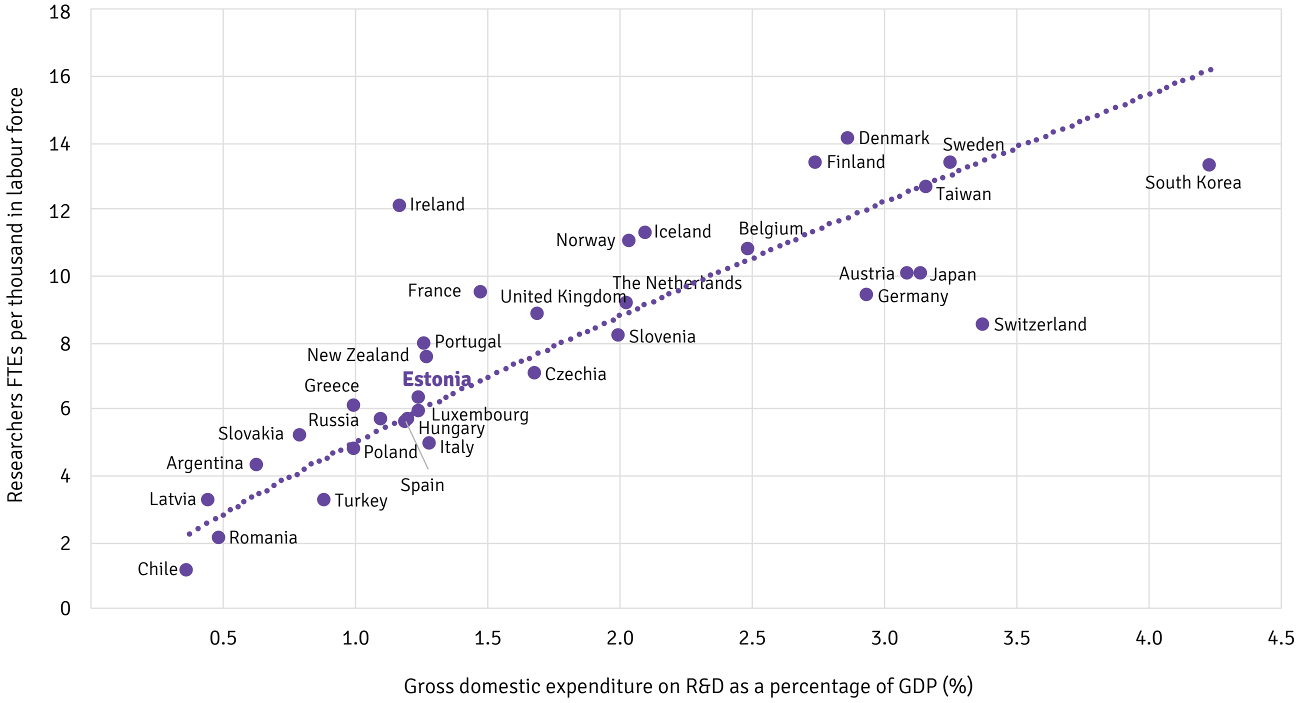


Figure 2.8a.

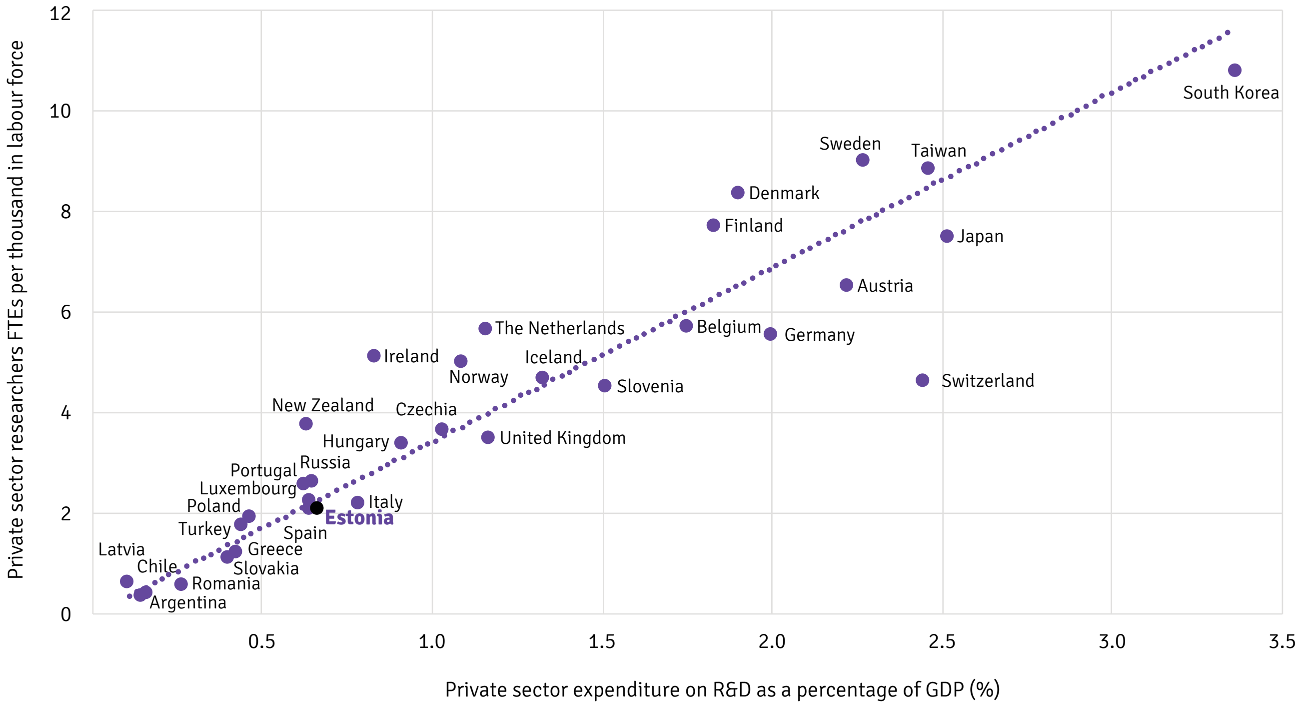


Figure 2.8b.

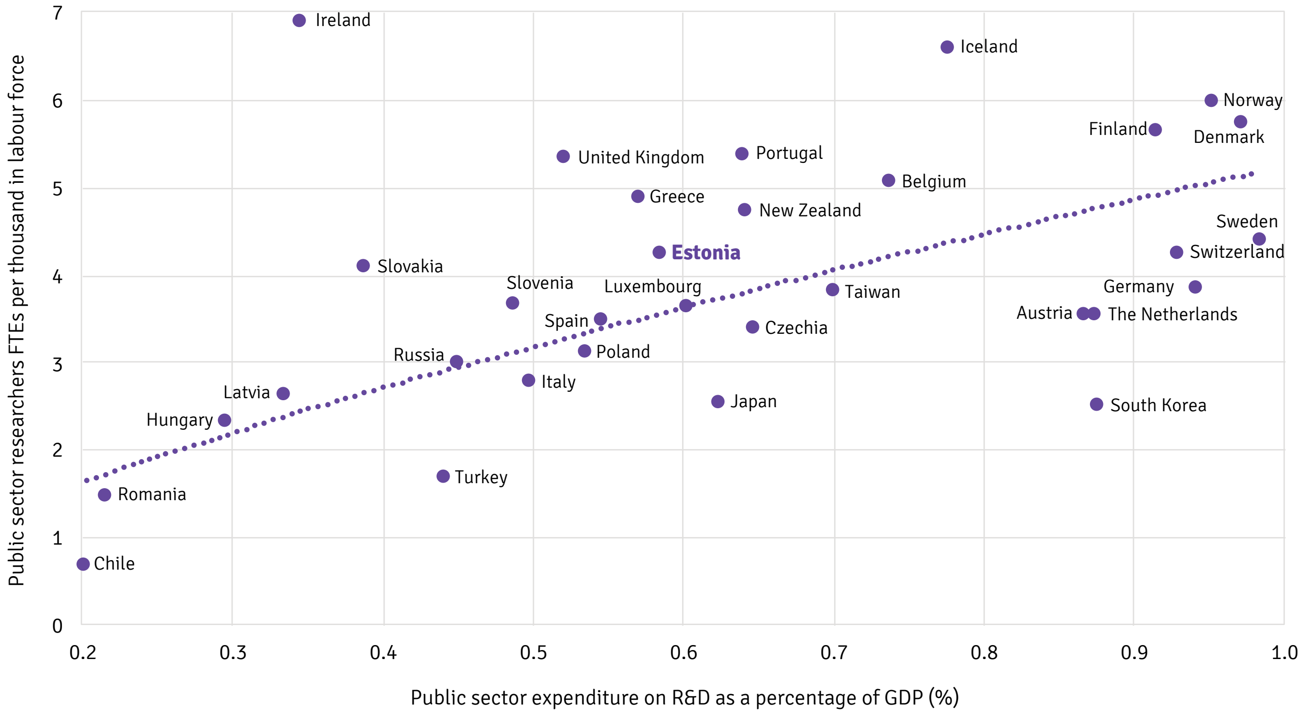


Figure 2.8c.

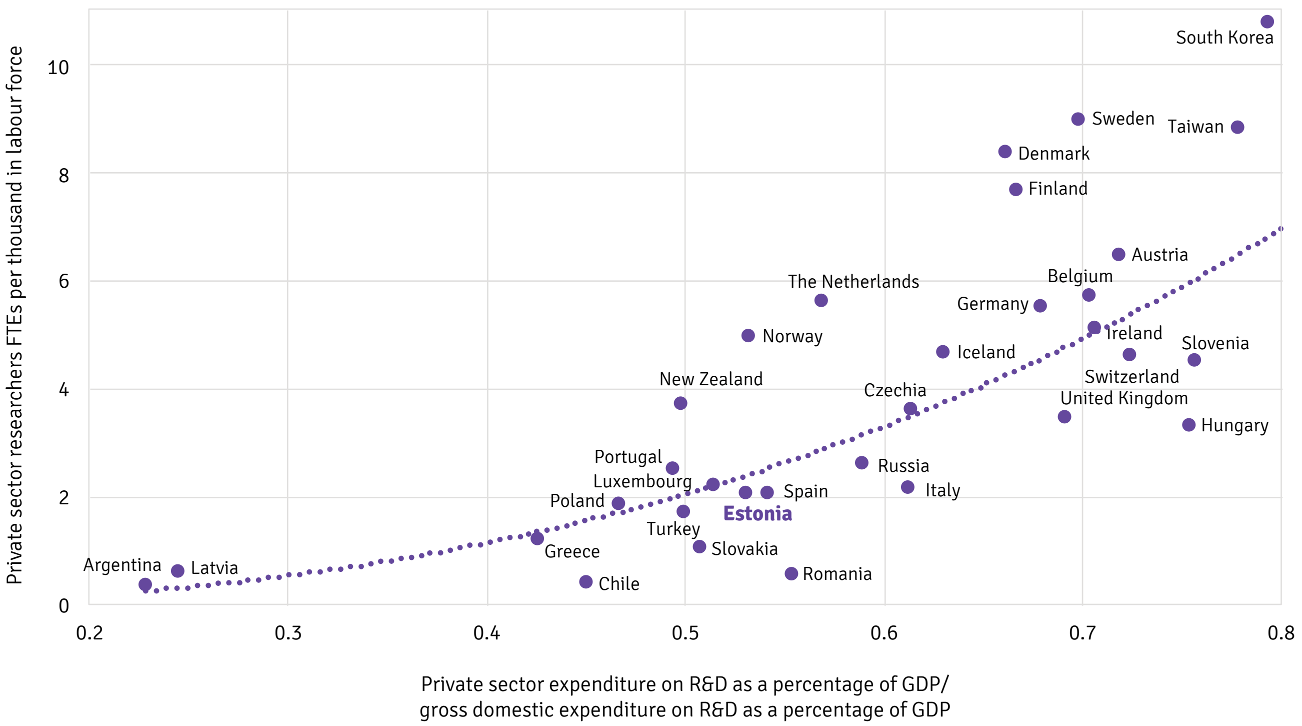


Figure 2.8d.

Figure 2.8. Researchers (in full-time equivalents, FTEs) per thousand in the labour force in dependence on the R&D expenditure as a percentage of GDP (a-c) and private sector researchers in relation to the ratio of private sector and total R&D investments (d). The panels (a)-(c) show the relationships for all researchers vs. total R&D expenditure (a), private sector researchers vs. private sector R&D expenditure (b), and public sector researchers vs. public sector R&D expenditure (c). The data are for 2016 or the last available year[79]

Source: OECD,[80] calculations by Estonian Research Council and the author.

[79] In figures 2.8a, 2.8b, 2.8c and 2.8d, the data were approximated with the function $y = ax^b$ (determination coefficients: r^2=0.78 (a), r^2=0.91 (b), r^2=0.41 (c) and r^2=0.66 (d)).
[80] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (09.05.2018).

However, not all researchers are doctorates and not all doctorates are researchers, and this difference is particularly important in the private sector, which engages almost twice as many doctorates in countries with high private sector expenditure on R&D (cf. Figure 2.1 and Figure 2.8). This means that successful entrepreneurship knows how to appreciate people with doctoral degrees, and it also seems to indicate that a certain critical number of doctorates in private enterprises, and not necessarily a number of researchers, is the necessary catalyst to launch an innovative, research-intensive economy model.[81] The analysis of research in our close neighbour Finland shows that the impact of research for industry and the society is very diverse, involving direct impacts on innovation and high-added value product development, for example through information dissemination and the design of new goods and services. In addition, research contributes to society, for example through debates, increasing decision-making capabilities, and providing science-based solutions to a multitude of societal challenges.[82]

Looking at the temporal dynamics of the number of Estonian researchers (relative to the total population) in 1998–2017, a slow growth can be seen until 2012, followed by stagnation and even some decrease (Figure 2.9). The recent reduction in the number of researchers has occurred hand in hand with the stagnation of Estonian R&D expenditure.[83] A more detailed analysis of the temporal dynamics in the number of researchers and faculty staff employed at the Estonian universities during 2014–2017 shows that over four years, the decline has been dramatic at all academic positions, with an average decline approximately 20% among researchers, senior researchers and leading researchers. Only the number of junior researchers has increased (Table 2.2). Since, according to the Research and Development Organisation Act, only doctoral students can be junior researchers, this is a welcome change, and shows that doctoral students are more and more seen as young researchers, not students. Yet, this is the only positive change.

Regarding the overall increase in the number of researchers in the years 1998–2012, it was mainly caused by the increase of researchers in the private sector. The number of private sector researchers peaked in 2011, reaching 1.19 researchers per 1,000 inhabitants (Figure 2.9). Although the increase in the private sector researchers during the period 1998–2011 is statistically significant, this is just marginal in comparison to the level we have to reach in order to catch up with successful research countries (Figure 2.8b). It only remains to agree with the conclusion that the exchange of Estonian researchers between the academia and private sector is still very moderate.[84,85] Of course, the overall number of researchers in both Estonian private and public sectors is relatively low. Apart from the comparatively low total number of people in research, the other main reasons for low representation of researchers in the private sector are the lack of readiness of Estonian private entrepreneurs to hire specialists with the highest level of education, and the overly simplified understanding of the role of top competence in the business sector. While the role of research in high value-added economy has been emphasised, it is completely wrong to believe that only more research and researchers in the private sector are needed for the economic development. Aside from excellent research level, there is also a need for an "excellent" business sector ready to hire "excellent" highly qualified specialists.[86] This would mean changing mind-sets of entrepreneurs to go beyond traditional low value-added activities and change their business model accordingly.

Table 2.2. Dynamics in the filled positions (full-time equivalents) in the six Estonian public universities in 2014 to 2017

	2014	2015	2016	2017	Changes in full-time equivalents during 2014–2017 (%)
Professor	441	427	416	406	-8%
Docent	481	486	481	469	-3%
Lecturer	859	841	813	736	-14%
Assistant	215	183	190	194	-10%
Teacher	64	62	61	68	6%
Leading Researcher	41	35	34	30	-28%
Senior Researcher	539	506	460	454	-16%
Researcher	651	545	511	535	-18%
Junior Researcher	188	167	197	222	18%
Other academic personnel				88	
Total	**3479**	**3252**	**3164**	**3201**	**-8%**

Source: Universities Estonia,[87] calculations by Estonian Research Council.

[81] Varblane U., Ukrainski K. (2017). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33-43. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).
[82] Academy of Finland. (2017).The state of scientific research in Finland 2016. Special theme: broader impact of research in society (eds. Huutoniemi K., Törnroos J., Mälkki A.), Academy of Finland, Helsinki. http://www.aka.fi/globalassets/30tiedepoliittinen-toiminta/tieteentila/aka_tieteen_tila_2016_eng_150317.pdf (06.12.2018).
[83] See Chapter I of this compendium (A. Koppel).
[84] Tammaru, T. (2017). Doctoral degree holders and researchers in the labour market: Estonia compared with other European countries.— Estonian Research 2016 (ed. K. Raudvere), pp. 19-24. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).
[85] Varblane U., Ukrainski K. (2017). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33-43. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).
[86] Niinemets Ü. (2018). Mis maksab teadus ja teadlase arvamus ja kas me saame selle kohe rahaks vahetada? — Teadusmõte Eestis (IX). Teadus ja ühiskond (toim. J. Engelbrecht), Eesti Teaduste Akadeemia, Tallinn.
[87] Ülikoolide personaliandmed. Rektorite Nõukogu (Universities Estonia). http://www.ern.ee/et/leht/uelikoolide-personaliandmed (20.09.2018).

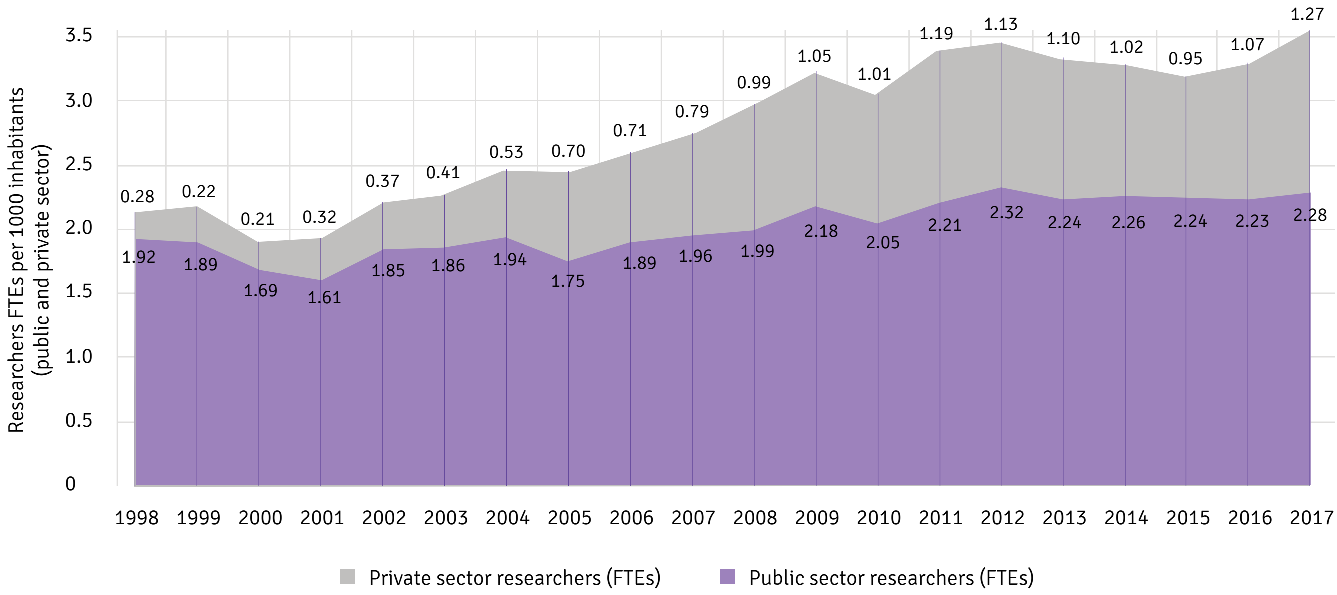


Figure 2.9. Dynamics of Estonian researchers (full-time equivalents, FTEs) public and private sectors together, and separately in public and private sectors in 1998–2017. The number of researchers is normalised per 1,000 inhabitants

Source: Statistics Estonia,[88] calculations by Estonian Research Council.

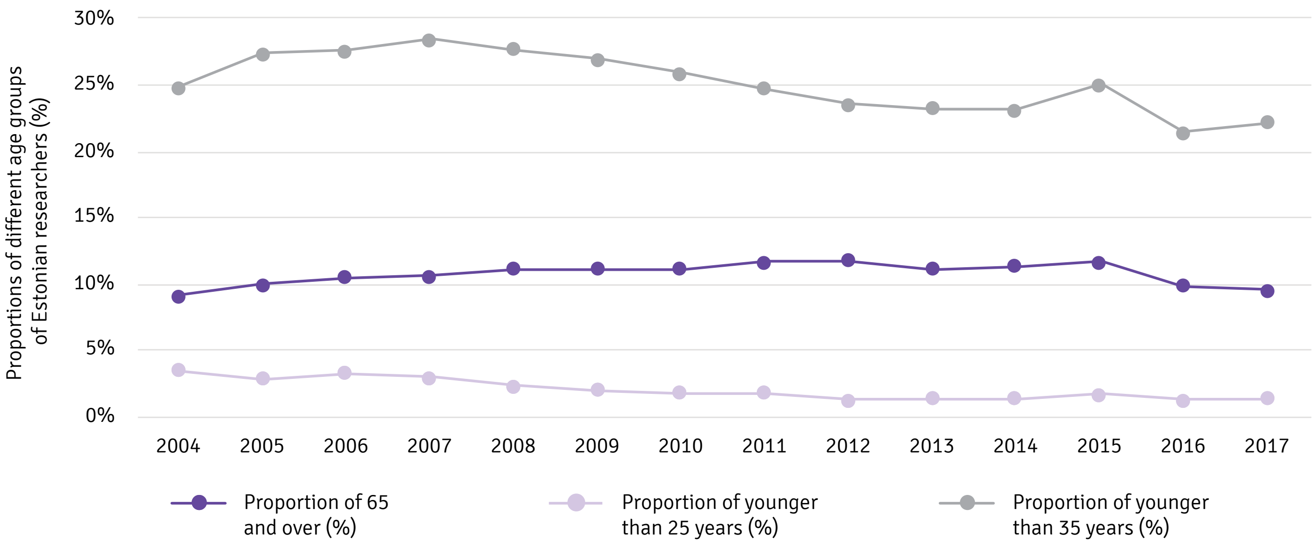


Figure 2.10. Age dynamics of the proportions of Estonian researchers working in the public sector aged 25 and younger, 35 and younger and 65 and over in 2004-2017

Source: Statistics Estonia,[89] calculations by Estonian Research Council.

On the other hand, the pool of researchers working in the public sector is far from that in research-intensive countries (Figure 2.9 and Table 2.2). There is no quick solution to the limited researcher number as the periods of study and maturation required to become an independent researcher take long time, at least ten years. Furthermore, as the overall number of Estonian researchers is currently stagnating, then similarly continuing, there is no hope of attaining a level of private sector researchers comparable to developed research countries in near future (4–5 times increase needed), even if all the public sector researchers were to move to the private sector.

[88] Statistics Estonia. www.stat.ee (29.10.2018).
[89] Statistics Estonia. www.stat.ee (18.09.2018).

The age pyramid of Estonian researchers, their career paths, wage dynamics and gender gap

The overall uncertainty about the academic career in the public sector and private enterprises, and the high risk of burnout have been listed among the possible reasons for the low efficiency of doctoral studies.[90] Uncertainty in academic career arises primarily from the circumstance that it is difficult to enter the academic labour market and advance there, as the opening of positions is not transparent and there are no clear merit-based criteria for advancement. While analysing the age dynamics of the PIs (leaders) of Estonian targeted research funding projects (national large research team grants) in 1998–2013, it becomes clear that the entry of young researchers into the research landscape is erratic and highly dependent on funding periods. In fact, young researchers (below the age of 40) could establish their own team only at the beginning of a new funding period when a large number of projects finished and more funding became available; once the bulk of the money was used up, there was no chance to start a new team for the next 6–7 years (the length of team grants at different periods) until the new funding period started. In addition, the proportion of leading researchers aged 65 and over has steadily increased during the period of targeted research funding.[91] Similar tendencies can be seen looking at the age trends of all public sector researchers in Estonia. The proportion of young researchers, aged under 25 and under 34 years of age, has consistently decreased in the period 2004–2016. During the same period, the proportion of researchers aged 65 and over has increased. The only exception was year 2016, when the number of researchers aged 65 and over fell by 127 in absolute numbers from 602 in 2015 to 475 in 2016, and the proportion of older researchers in the research community also decreased (Figure 2.10). This sharp change is probably due to the lack of EU structural funds in 2016, as well as due to a possible confusion with the statistics of Tallinn University of Technology as the result of changing methodology.[92] Time shows whether this is a start of a new trend or an outlying case, but the lack of vacancies and difficult entry for young people are among the biggest problems in Estonian research landscape.

Another problem concerning vacancies is the lack of clarity in terms of career advancement. In advanced research countries, a transparent merit-based researcher career model has been established, functioning as a roadmap for a young starting researcher planning his/her life in the field. It might be hard for people outside the research system to understand that it is not possible to do top-notch research and at the same time meet other numerous and ever-increasing demands of the society—popularising the area of specialisation, meeting with entrepreneurs, reporting on different projects, participating in the evaluation processes of institutions, providing various expert assessments, etc.—without having a secured future. In countries that have established a tenure-track system—Anglo-American and nowadays also in most of the Nordic countries (Norway, Sweden, Denmark, the tenure system is under development in Finland)—application for a faculty position, typically at assistant professor level, takes place only once. Once in the tenure-track system, clear merit-based rules have been introduced for advancement. Thus, if the first evaluation period, in 3-5 years after appointment, is completed successfully, the candidate is promoted to an associate professor level, and a permanent position will be granted (tenure). Unfortunately, there is basically no work security in Estonia, even for the highest rank faculty positions. Although most non-fixed-term researcher and professor positions might seem to be of indefinite duration, the non-fixed term contracts are overly easy to terminate. In fact, depending on the length of service, the notice period upon job termination extends to a maximum of a few months. The typical one month notice period for termination of an employment contract due to redundancy may be appropriate for high labour mobility positions where there are many suitable positions, for example, auxiliary staff in construction, cleaning workers etc. This is, however, an unacceptable handling of human resources in the case of researchers. That, already given the fact, that a researcher with a doctoral degree has studied for almost 10 years, and typically has also gained experience as postdoc in several labs. There are only a few job openings in the world suitable for top researchers and these are filled through competitions, which generally take place 12–36 months before the actual opening of the job.

Due to these problems, it has been proposed to introduce a research tenure system in Estonian universities and research institutions.[93,94,95] A detailed study comparing different tenure-track systems and their suitability for the Estonian research landscape was carried out in 2018 in the framework of RITA research policy monitoring program.[96,97] As of today, Tallinn University of Technology[98] has been most progressive and achieved the most in the establishment of tenure model, but the current

[90] Kindsiko E., Vadi M., Täks V., Loite K., Kurri K. (2017). Eesti doktorite karjääritee ja seda mõjutavad tegurid. Tartu: Tartu Ülikool. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B-5jutavad_tegurid.pdf (06.12.2018).

[91] Niinemets Ü. (2013). Eesti sihtfinantseeritavate teadusteemade juhid 1998-2013: noorenemine, vananemine ja äraspidi vanuseline diskrimineerimine. — Teadusmõte Eestis (VIII). Teaduskultuur (toim. J. Engelbrecht, H.-L. Help, S. Jakobson, G. Varlamova), lk. 83-98, Eesti Teaduste Akadeemia, Tallinn.

[92] An explanation from Tiina Pärson (Leading Statistician-Methodologist, Statistics Estonia).

[93] Niinemets Ü. (2015). Teadlase karjäärimudel. Milleks, kellele ja kuidas? — Sirp 19 June.

[94] Niinemets Ü., Soomere T., Randma-Liiv T. (2017). Kombineerides vastandeid. — Sirp 14 July.

[95] Soomere T., Niinemets Ü., Niglas K., Pilt E., Randma-Liiv T. (2018). Teadlaskarjääri mudel kui riigi konkurentsivõime tugi. — Riigikogu Toimetised 37, lk. 191-203.

[96] Soomere T., Niinemets Ü., Niglas K., Pilt E., Roosalu T., Randma-Liiv T. (2018). Jätkusuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis. Tallinn: Eesti Teaduste Akadeemia. https://www.etag.ee/wp-content/uploads/2018/04/J%c3%a4tkusuut-likud-teadlaskarj%c3%a4%c3%a4ri-kontseptsioonid-ja-mudelid-Eesti-kontekst.pdf (06.12.2018).

[97] Soomere T., Niinemets Ü., Niglas K., Pilt E., Roosalu T., Randma-Liiv T. (2018). Jätkusuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis. Tallinn: Eesti Teaduste Akadeemia. https://www.etag.ee/wp-content/uploads/2018/04/J%c3%a4tkusuut-likud-teadlaskarj%c3%a4%c3%a4ri-kontseptsioonid-ja-mudelid-Eesti-kontekst.pdf (06.12.2018).

[98] Aaviksoo J., Veinthal R. (2016). Tenuur kui akadeemilise vabaduse tagatis. — Sirp 23 September.

legislation does not allow for its introduction in the classical form. At the moment, the two key acts of legislation, the Research and Development Organisation Act and the Universities Act, are undergoing major revision by the Government. Unfortunately, the proposed amendments are not ambitious enough to introduce a full-scale tenure-track system, as in the light of current developments, the problem of job security remains unresolved.

In the background of the decline in the number of university researchers and professors (Table 2.2), the average wage of R&D personnel has increased by about 14% in 2017 compared to 2015[99] (Table 2.3). This rise is partly related to structural reforms in several universities (the establishment of the tenure-track model at the Tallinn University of Technology during 2016–2017 and the launch of the chair professor system at the Estonian University of Life Sciences in 2017). Besides, the launch of the new period of EU structural funds has allowed for opening of new post-doctoral and top researcher positions with salaries exceeding average. In addition, although the nominal compensation for full-time employment has increased, a large proportion of people at universities work part-time (23% in 2017).[100] Thus, a number of employees have not been affected by the average wage increase at all.

On the other hand, there are large wage differences among public universities for the same level academic positions (Table 2.3). For example, for the six public universities, the standard deviation of the average monthly salary university professors earn is ±690 EUR as at 31 December 2017. It is particularly worth to mention the phenomenon of Tallinn University of Technology, where almost all positions have an average salary higher than in the other Estonian universities (Table 2.3). Given that the income of the public universities comes largely from the public sector, this large wage range is highly surprising.

The visible gender wage gap for academic positions reflects the lower proportion of women holding leading academic positions (27% of professors and 16% of leading researchers, Table 2.3). From a positive note, these figures display a decrease in the gender wage gap compared to the previous analyses.[101] Furthermore, Estonia is positioned in the middle of the EU countries (23.5% of females holding leading academic positions). At the same time, the low representation of females on higher academic positions also reflects the under-representation of females in academic competitions, particularly as regards to competitions for professor positions.[102,103] For this reason, the recent worldwide trend is that female candidates have an advantage over male candidates with equal qualifications.[104] In addition, a tenure-track system, where once appointed to the first level of the track, there is a clear merit-based path for promotion, can be a potential way to reduce the gender gap. At the same time, a certain gender gap is already visible during doctoral studies, since on average, females take more time to complete their doctoral studies (Table 2.1), and this should be considered in the future during the evaluation of tenure track applications.

The gender gap present in the academic career is also accompanied by the wage gap, which, however, is much less. The wage gap varies from 20% (professors at the Estonian University of Life Sciences) to -20% (assistants[105] at the Estonian University of Life Sciences, the negative wage gap means that women earn more than men at the same-level positions), remaining usually within ±10%, with some exceptions among researchers (Table 2.3). Compared to the average wage gap in Estonia (20.9% in 2017[106]), the gender wage gap in public universities is lower. The causes of the gender wage gap remain obscure, since basic salaries upon the opening of a position typically do not differ. For example, there is no wage gap for the professors at the University of Tartu (Table 2.3). However, salaries in the same position may increase as the workload increases, for example with addition of new major projects. The number of projects and additional commitments normally increases with the academic age of the faculty member. Therefore, one of the reasons for the gender wage gap may be the late entry of women into academic career due to longer doctoral studies. The differences in the wage gap between universities in different positions (for example, a positive wage gap in one, negative wage gap in another university, Table 2.3) can also result from several random factors independent of the national system. For example, EU structural funds have allowed creation of top-level positions with salaries higher than the average, and the gender of the appointed faculty member might make a large difference for the average. The influence of such factors could only be addressed by a more detailed analysis that uses personalised data.

[99] Tammaru, T. (2017). Doctoral degree holders and researchers in the labour market: Estonia compared with other European countries. – Estonian Research 2016 (ed. K. Raudvere), pp.19-24. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).

[100] Ülikoolide personaliandmed. Rektorite Nõukogu. http://www.ern.ee/et/leht/ueli-koolide-personaliandmed (03.10.2018).

[101] Deliotte. (2014). Researchers' Report 2014. Country Profile: Estonia. https://cdn5.euraxess.org/sites/default/files/policy_library/estonia_country_profile_rr2014_final.pdf (02.10.2018).

[102] Meyer, M., Cimpian, A., Leslie, S.-L. (2015). Women are underrepresented in fields where success is believed to require brilliance. – Front. Psychol. 6:235. https://doi.org/10.3389/fpsyg.2015.00235

[103] Pautasso, M. (2015). The Italian University Habilitation and the Challenge of Increasing the Representation of Women in Academia. — Challenges 2015, 6(1), 26-41. doi:10.3390/challe6010026

[104] Ceci, S.-J., Williams, W.-M. (2015). Women have substantial advantage in STEM faculty hiring, except when competing against more-accomplished men. – Front. Psychol. 6:1532. doi: 10.3389/fpsyg.2015.01532

[105] Negative wage cap means that women earn more than men in the same position.

[106] Statistics Estonia. www.stat.ee (21.09.2018).

Table 2.3. Average gross monthly salary for full-time academic positions, number of filled positions (full-time equivalents), and gender wage gap at six Estonian public universities as at 31 December 2017[107,108]

	University of Tartu			Tallinn University of Technology			Tallinn University			Estonian University of Life Sciences			Estonian Academy of Arts			Estonian Academy of Music and Theatre			Average trends		
	Average gross salary (EUR/month)	Gender wage gap	Women	Average gross salary (EUR/month)	Gender wage gap	Women	Average gross salary (EUR/month)	Gender wage gap	Women	Average gross salary (EUR/month)	Gender wage gap	Women	Average gross salary (EUR/month)	Gender wage gap	Women	Average gross salary (EUR/month)	Gender wage gap	Women	Change in the average gross salary (EUR/month) during 2015-2017	Average gender wage gap weighted for full-time positions	Women in full-time positions
Professor	3172	0%	23%	3830	9%	18%	2629	14%	48%	2832	20%	23%	1904	3%	43%	2204	-2%	36%	13%	12%	27%
Docent	2158	8%	48%	2632	13%	29%	1720	10%	67%	1688	6%	38%	1547	7%	68%	1507	-6%	31%	22%	13%	45%
Lecturer	1541	6%	64%	1821	7%	51%	1393	9%	65%	1343	3%	57%	1407	*	41%	1248	-6%	56%	20%	7%	59%
Assistant	1376	7%	66%	1755	0%	44%	*	*	*	1003	-20%	53%	*	*	76%	1164	*	91%	13%	8%	64%
Teacher	1187	10%	76%	*	*	52%	1221	*	76%	*	*	*	*	*	57%	*	*	*	14%	9%	74%
Leading Researcher	3461	*	0%	2998	*	27%	*	*	46%	*	*	0%	*	*	100%	*	*	0%	15%	*	16%
Senior Researcher	2097	2%	37%	2179	11%	34%	2052	-3%	45%	1791	12%	46%	*	*	68%	*	*	50%	11%	5%	38%
Researcher	1601	6%	48%	1826	14%	39%	1478	-9%	66%	1499	17%	60%	*	*	90%	*	*	87%	10%	9%	49%
Junior Researcher	1257	4%	57%	1377	11%	42%	1163	5%	62%	1115	8%	58%	*	*	36%	*	*	*	6%	8%	53%
Other academic personnel	*	*	*	2183	19%	34%	*	*	*	*	*	*	*	*	*	*	*	*	*	19%	34%
Weighted average for full-time positions	1887	18%	48%	2247	22%	37%	1689	14%	61%	1559	19%	50%	1630	14%	57%	1596	9%	48%	14%	25%	47%
Average for teaching personnel (for weighted full-time positions)	2013	25%	52%	2446	23%	37%	1677	18%	63%	1618	19%	47%	1630	14%	56%	1596	9%	47%	18%	14%	49%
Average for academic personnel (for weighted full-time positions)	1754	11%	45%	1958	17%	37%	1719	4%	54%	1447	15%	55%	*	*	64%	*	*	63%	8%	0%	45%

Source: Universities Estonia,[109] calculations by Estonian Research Council.

107 Salary data were not provided if full-time positions were absent or there were under five of them for one gender; women's proportions are given also when there were fewer than five full-time jobs for one gender; the negative wage gap represents the higher average salary of women than men; the average gross salary includes, in addition to the basic salary (gross), all bonuses, allowances and disbursements under the law of contract obligations.

108 Large disparities between aggregated results and in-house results arise from the high proportion of women in low-paid positions. For example, in the position of teacher, women had 45.9 FTEs and men 10.6 FTEs. However, the average salary of a teacher is one of the lowest for both women and men. This also applies for the University of Tartu, which has the largest number of teachers among the analyzed institutions; at the University of Tartu women had 34.2 FTEs and men 10.6 FTEs (only the University of Tartu has some male teachers). The lowest paid academic position of the University of Tartu is the teacher position. Therefore, while in the University of Tartu, the internal wage gap between male and female teachers is 10%, a large number of low-paid teachers from the University of Tartu and the proportion of women in academic positions with lower salaries in general ultimately affect the overall wage gaps, both in terms of institutions and positions in terms of lower-paid jobs.

109 Ülikoolide personaliandmed. Rektorite Nõukogu (Universities Estonia) (additional information asked from source). http://www.ern.ee/et/leht/uelikoolide-personaliandmed (03.10.2018).

Conclusions

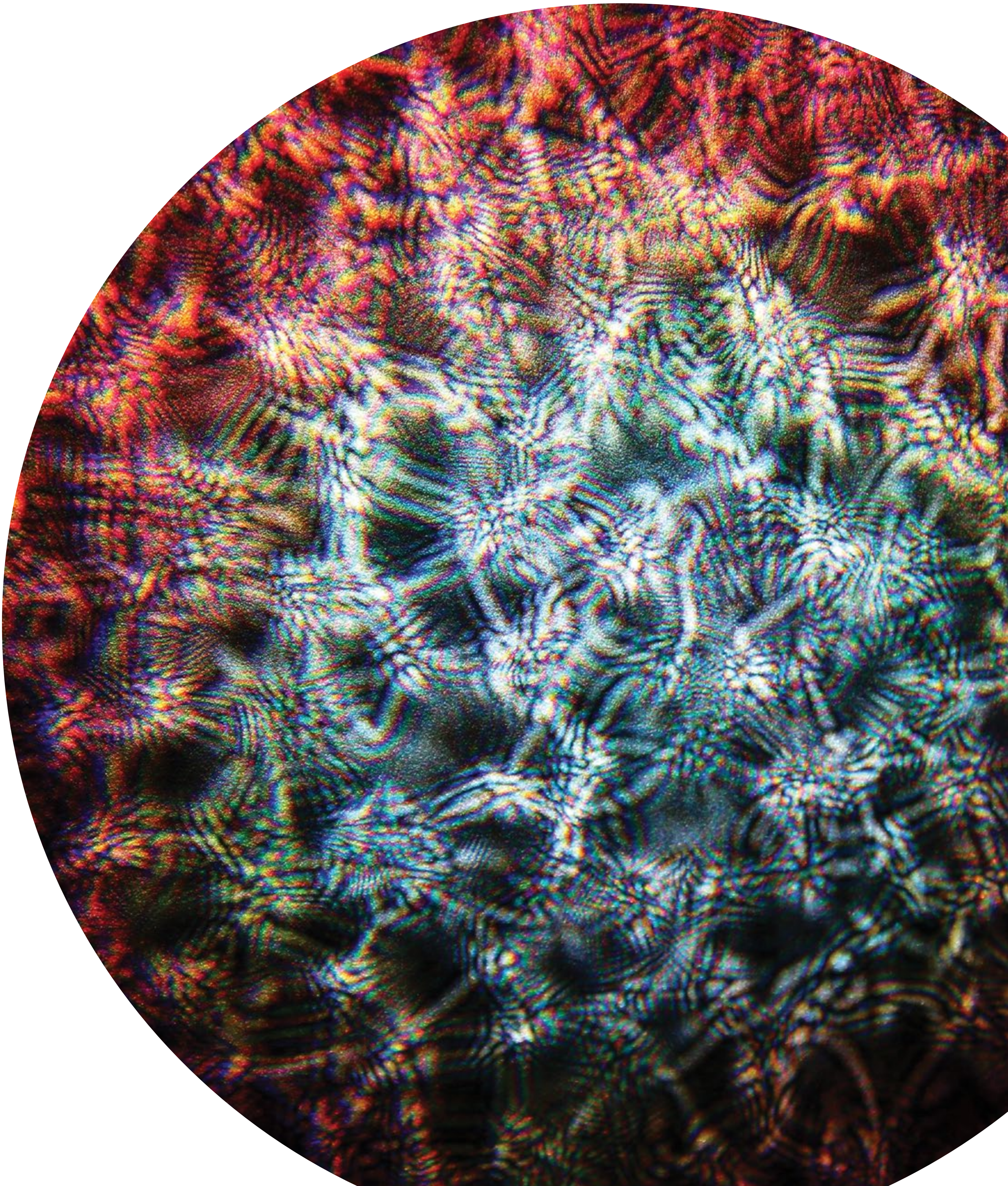
Both positive and negative demographic processes in the research landscape take time and one needs consistency and patience in order to harvest the fruits from the R&D investments. In terms of the proportion of doctorates in the working age population, we are 2–3 times behind the advanced research countries such as Sweden, the US and Switzerland, especially when it comes to the proportion of people with doctoral degrees in the private sector. Unfortunately, there is a widespread misconception in the society that people with doctoral degrees are only necessary as researchers. The balanced development of society and economy requires a larger number of highly educated people who are not necessarily researchers, both employed by public service and business enterprise sectors. The emergence of high value-added economy is only possible with a receptive ground. Researchers alone are not responsible for economic development: the entrepreneurship also needs to be "excellent", and only highly educated people can become the catalyst for such entrepreneurship.

Although an objective need for doctorates exists in the society, Estonian doctoral studies could be considered extremely ineffective. Each year, only a small amount of enrolled doctoral students (approx. 10% of the total amount) defend a doctoral degree, and the number of students who drop out from doctoral programs has always exceeded the number of graduates in the observed period of 2005–2017. The ineffectiveness is further amplified by the fact that students quitting their studies are in the doctoral program basically as long as graduates. This is because the structure of the doctoral programs allows staying in the program by accumulating credit points for courses passed, without necessarily fulfilling the PhD thesis research agenda. Furthermore, the age of PhD students at admission to doctoral studies has increased significantly. On average, the PhD students typically start at thirty years of age, and, with the prolongation of doctoral studies over the nominal study period, we lose almost an entire academic generation due to delayed entry and prolonged stay in the school.

The number of students admitted to doctoral studies drastically decreased in 2012 due to changes in the policy of funding of doctoral studies outside the state-granted places, and the numbers have not recovered. Combining all the factors, the trends indicate that in terms of the proportion of doctorates in the working age population, we keep lagging behind the advanced research countries instead of catching up. In the future, it would be necessary to analyse the content and organisation of doctoral studies (composition of doctoral programs, supervision) and change the social status of doctoral students. A doctoral student is a young researcher who has to gain experience for independent work, yet the content of doctoral studies and the tax-exempt doctoral allowance system treats the PhD candidates as students.

The position Estonia takes in regards to the proportion of doctorates and researchers in the working-age population is a good reflection of the limited state funding of research and development, especially the very modest spending of the private sector. During 1998–2012, increases in the state and private sector research expenditures resulted in an increase in the proportion of researchers in the working-age population, in particular due to an increase in the number of researchers in the private sector. Starting from 2011, there has been a reduction in expenditures on R&D and in line with this decline, starting from 2013, there has been an initial stagnation, followed by a decline in the number of researchers in both the public and private sectors. As a result of these negative developments, the gap between Estonia and the advanced research countries has started to increase. A particularly significant decrease took place at the universities during 2014–2017, when the previous EU Structural Funds period had finished, while the programs in the new period of the structural funds had not yet started. Such cyclicity in funding can be foreseen and mechanisms must be created to prevent it—for example, the relevant ministries should avoid simultaneous preparation of all EU Structural Funds programs (e.g. programs for centres of excellence, postdoctoral researchers, top-level scientists etc.), but rather should prepare them in sequence. As we have experienced, due to lack of human capacity, trying to open all programs at the same time leads to delays in launching all the programs. In addition, budgetary buffers have to be created to exit the structural funds programs and bridge the gap to new funding sources.

Estonian research landscape is characterised by the lack of transparency in creation and filling of vacancies, job insecurity and vagueness in career perspectives. It is particularly difficult for young people to enter the research system. There is also a major gender gap at higher academic positions, where the proportion of females is significantly lower. It is essential to establish a clear, merit-based career model in the near future. A transparent career model will provide a roadmap for younger faculty for entering the academia, staying there and advancing depending on their personal capacities and contributions. A clear career model would also help reduce the gender gap in higher academic positions, as competition for jobs would take place at the early stages of the career, where there is basically no gender gap or even a slight majority of women holding certain academic positions.



Diffused supercontinuum laser beam covering the entire visible light and near-infrared light spectrum
Authors: Heli Lukner, Sandhra-Mirella Valdma, Andreas Valdmann (Estonian Science Photo Competition 2017).

Snow and ice layer observations at the Foxfonna Glacier in Svalbard

Author: Kertu Liis Krigul (Estonian Science Photo Competition 2017).

THE STATE OF ESTONIAN RESEARCH IN MID-2018

Kalmer Lauk
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Jüri Allik
Professor of the University of Tartu and member of the Estonian Academy of Sciences

Similarly to countries' economic prosperity, we can determine their scientific wealth, which is primarily expressed in the number and quality of publications published in renowned journals. The quality indicator is above all the number of references made by other researchers.[110] Countries' scientific prosperity is directly attributable to their economic wealth. Only the wealthiest states can afford to engage in top-level research, the indicators of which can be predicted quite accurately on the basis of GDP and the percentage of the national budget spent on R&D.[111,112,113] The money spent on research does not automatically transform into publications that researchers all over the world find necessary to cite.[114,115,116] Even countries with a very similar way of life can differ by their efficiency in converting funds allocated for research into high-quality research publications. States also differ in terms of how efficient the immediate contribution of investments made into research is for the economy and the growth thereof.[117] In addition to the money that is needed for sustaining research, the success of research depends on countries' innovation policies and the devotion and professionality of researchers and administrators.[118,119,120,121,122]

Even 25 years after the happiest geopolitical event of the 20th century—the collapse of the Soviet Union—former communist states are still haunted by the curse of their past, as the level of their research is far behind the European Union's average.[123,124,125,126,127] Only a few of the former Soviet states, including Estonia and Georgia, have managed to catch up and keep up with the world's best in terms of research quality.[128,129,130,131,132,133] Therefore, the countries that have managed to escape the shadow of their past are highly valued as objects of research since they have served as a place for natural experiments that have shown what kind of funding and policies guarantee success on a global scale. Failing to learn from this experience would be an unforgivable and costly mistake.

As we already mentioned, this analysis is based on a monitoring period in which the whole of 2007 has been replaced with the first half of 2018, i.e., the monitoring lasted from 1 January 2008 to 30 June 2018. Figure 3.1 shows the increase of the impact of Estonian-authored articles (number of citations per article) until the first half of 2018. In 2006, papers by Estonian authors were cited 20% less than 50% of the world's leading countries on average, yet by mid-2018, the number of citations had exceeded the average by nearly 40%.

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111 Allik, J. (2013). Factors affecting bibliometric indicators of scientific quality. — Trames: Journal of the Humanities and Social Sciences, 17(3), pp. 199–214. doi:10.3176/tr.2013.3.01
112 King, D. A. (2004). The scientific impact of nations. — Nature, 430(6997), pp. 311–316. doi:10.1038/430311a
113 Vinkler, P. (2018). Structure of the scientific research and science policy. — Scientometrics, 114(2), pp. 737–756. doi:10.1007/s11192-017-2568-7
114 King, D. A. (2004). The scientific impact of nations. — Nature, 430(6997), pp. 311–316. doi:10.1038/430311a
115 Leydesdorff, L., Wagner, C. (2009). Macro-level indicators of the relations between research funding and research output. — Journal of Informetrics, 3(4), pp. 353–362. doi:10.1016/j.joi.2009.05.005
116 Vinkler, P. (2008). Correlation between the structure of scientific research, scientometric indicators and GDP in EU and non-EU countries. — Scientometrics, 74(2), pp. 237–254. doi:10.1007/s11192-008-0215-z
117 Vinkler, P. (2008). Correlation between the structure of scientific research, scientometric indicators and GDP in EU and non-EU countries. — Scientometrics, 74(2), pp. 237–254. doi:10.1007/s11192-008-0215-z
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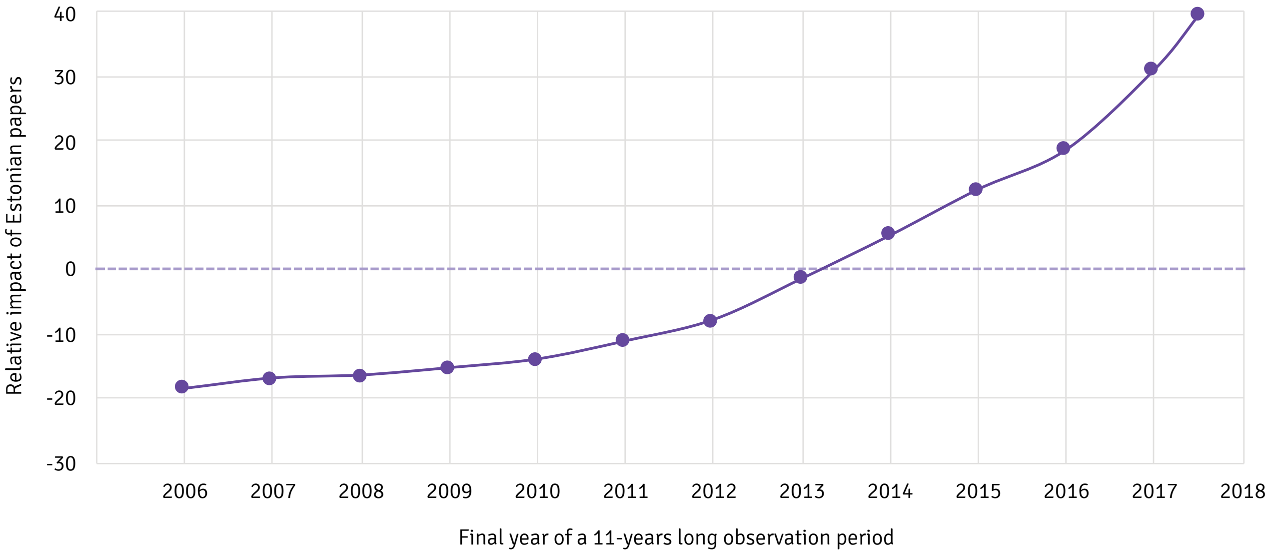

Figure 3.1. Increase in the impact of Estonian-authored publications from 2006 to 30 June 2018

Source: Web of Science, Essential Science Indicators and authors' calculations.

Table 3.1 shows the ranking of the impact of countries/territories on the basis of the third column (C/A or citations per article). The ranking only includes sufficiently large research countries that managed to publish over 4,000 articles in 10 years and 6 months. Senegal, Malawi, Panama, Zimbabwe, Macedonia, Uzbekistan, the Sudan and Burkina Faso came very close, publishing more than 3,000 papers, but the authors decided to exclude them for the analysis for fear of going into unnecessary detail.

The ranking of research impact continues to be dominated by Iceland, Switzerland and Scotland, whose papers were cited 20 times per article on average. Estonia has moved up a few places and is now the 12th most influential research country in the world, if one were to consider all of the parts of the United Kingdom as one whole. The 16,880 articles written with the involvement of Estonian researchers were cited 285,708 times, i.e., 16.93 times per article on average. Estonia beats the average among 50% of the world's best countries—12.16 citations per article—by approximately 40% (Figure 3.1).

The previous report[134] provided cause for celebration over the fact that Estonian research had become as influential as that of France and Israel, which spend 2.3% and 4.3% of their GDP on research, respectively. This is clearly somewhat more than Estonia's 0.52%.[135] However, now we have reason to celebrate another achievement. Estonian research has passed Finland and Germany in terms of its impact!

Research impact is in several ways similar to productivity. In order to better understand the achievements of Estonian research, one can compare the productivity of countries. For instance, the productivity indicators (per person and per hour worked) of Finland and Germany are £19.8 and £23.30 (British pounds) respectively.[136] An Estonian worker, however, can create three times less value in one hour, i.e., only £7.43. Consequently, there is no doubt that research—production of high-value research articles—is Estonia's most successful economic sector when it comes to productivity.[137] Since the growth curve of impact on Figure 3.1 is very regular, it is difficult to make any predictions. As the impact of US research is declining rather than increasing compared to other leading countries, Estonian research is very likely to catch up with and pass that of the US in terms of its influence. Estonia becoming one of five most influential research countries in a few years is not a hollow election promise, but a rather simple mathematical prediction made on the basis of Figure 3.1.

Researchers who measure the impact of research have noted that the impact factor—citations per article—may be deceptive, since good results can be achieved via research of convenience, which avoids risky ideas with great scientific impact.[138] Estonian research seems to be doing well in this respect, too, as 2.52% (last column of Table 3.1) of all of the articles published (first

[134] Lauk, K., Allik, J. (2018). A puzzle of Estonian science: How to explain unexpected rise of the scientific impact. — Trames: A Journal of Humanities and Social Sciences, 22(4), pp. 1–12.

[135] Vassil, K. (2018). Puudu on 114 miljonit eurot. – Postimees, 7. november. https://arvamus.postimees.ee/6447554/kristjan-vassil-puudu-on-114-miljonit-eurot?utm_source=facebook.com&utm_medium=social&utm_campaign=share-buttons&utm_content=6447554&fbclid=IwAR3kd1iPT0mw68E9jFNULvqk8D4XKn5gzjw_90CY7oW8CYRtI88h6htyQ9o (06.12.2018).

[136] The Most Productive Countries in the World: 2017. Expert Market. https://www.expertmarket.co.uk/focus/worlds-most-productive-countries-2017 (06.12.2018).

[137] The economic turnover created by Estonian researchers is far from small. It is estimated that the publication of one research article costs $5,000 on average in the world (Van Noorden, R (2013)). Table 1 shows that Estonian researchers published 16,880 articles, which cost approx. 84 million USD for the publishers, i.e., 75 million euros according to the current exchange rate, which is about 0.8% of Estonian state budget for (Van Noorden, R. (2013). The true cost of science publishing. — Nature, 495(7442), pp. 426–429).

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Table 3.1. World ranking of scientific impact, in which countries/territories that have published more than 4,000 articles in 11 years and 6 months are ranked on the basis of the average number of citations per article (C/A)

	Country/territory	Articles	Citations	C/A	Top articles	Top articles (%)
1	Iceland	9 873	231 417	23.44	301	3.05
2	Switzerland	280 369	5 884 932	20.99	7 619	2.72
3	Scotland	147 189	2 977 267	20.23	3 913	2.66
4	Netherlands	379 242	7 566 912	19.95	9 408	2.48
5	Denmark	162 439	3 116 923	19.19	4 098	2.52
6	Wales	50 628	921 157	18.19	1 128	2.23
7	Singapore	118 424	2 152 243	18.17	3 002	2.53
8	England	962 595	17 477 811	18.16	21 067	2.19
9	Belgium	208 838	3 782 846	18.11	4 693	2.25
10	USA	3 922 346	70 130 397	17.88	72 243	1.84
11	Sweden	252 797	4 474 392	17.70	5 112	2.02
12	Georgia	5 725	100 625	17.58	173	3.02
13	Ireland	79 000	1 374 412	17.40	1 733	2.19
14	**Estonia**	**16 880**	**285 708**	**16.93**	**426**	**2.52**
15	Northern Ireland	24 802	418 098	16.86	471	1.90
16	Austria	144 761	2 429 907	16.79	3 092	2.14
17	Germany	1 042 716	17 452 258	16.74	17 993	1.73
18	Finland	123 030	2 048 793	16.65	2 322	1.89
19	Canada	649 786	10 809 115	16.63	12 169	1.87
20	Norway	122 239	1 985 894	16.25	2 469	2.02
21	France	728 211	11 707 974	16.08	11 905	1.63
22	Israel	137 607	2 168 673	15.76	2 319	1.69
23	Peru	9 508	147 728	15.54	268	2.82
24	Australia	545 752	8 474 129	15.53	10 733	1.97
25	Uganda	8 783	135 288	15.40	144	1.64
26	Kenya	15 233	232 313	15.25	325	2.13
27	Italy	633 688	9 649 571	15.23	9 640	1.52
28	Hong Kong	125 300	1 878 774	14.99	2 492	1.99
29	New Zealand	89 630	1 339 369	14.94	1 596	1.78
30	Spain	549 582	7 907 313	14.39	8 083	1.47
31	Costa Rica	5 412	77 903	14.39	95	1.76
32	Greece	112 736	1 592 532	14.13	1 785	1.58
33	Luxembourg	8 875	124 106	13.98	184	2.07
34	Tanzania	8 151	112 938	13.86	127	1.56
35	Philippines	11 314	154 470	13.65	254	2.25
36	Portugal	127 251	1 696 459	13.33	1 722	1.35
37	Uruguay	8 877	117 504	13.24	108	1.22
38	Cyprus	10 334	136 524	13.21	215	2.08
39	Hungary	67 706	869 434	12.84	1 009	1.49
40	Armenia	7 411	95 089	12.83	150	2.02
41	Sri Lanka	6 906	88 295	12.79	144	2.09
42	Japan	820 886	10 064 483	12.26	7 074	0.86
43	Ghana	7 990	94 561	11.83	115	1.44
44	South Africa	110 689	1 278 094	11.55	1 700	1.54
45	Czechia	114 884	1 320 385	11.49	1 422	1.24
46	Slovenia	38 694	438 115	11.32	459	1.19
47	Argentina	87 125	980 758	11.26	882	1.01
48	Chile	69 496	781 315	11.24	860	1.24

	Country/territory	Articles	Citations	C/A	Top articles	Top articles (%)
49	Lebanon	11 456	124 740	10.89	179	1.56
50	Nepal	5 344	57 931	10.84	79	1.48
51	Taiwan	270 174	2 898 369	10.73	1 943	0.72
52	South Korea	521 368	5 491 701	10.53	4 433	0.85
53	Indonesia	17 090	178 115	10.42	216	1.26
54	Thailand	69 673	725 061	10.41	662	0.95
55	Saudi Arabia	93 063	965 761	10.38	2 151	2.31
56	Bulgaria	24 260	249 702	10.29	273	1.13
57	Qatar	11 996	122 484	10.21	266	2.22
58	Latvia	6 556	66 576	10.15	100	1.53
59	Columbia	37 041	375 465	10.14	541	1.46
60	China	2 272 222	22 723 995	10.00	24 878	1.09
61	Ecuador	7 141	69 864	9.78	121	1.69
62	Bangladesh	15 563	150 183	9.65	192	1.23
63	Oman	6 112	58 976	9.65	90	1.47
64	Croatia	36 391	350 833	9.64	358	0.98
65	Slovakia	34 248	325 318	9.50	327	0.95
66	Venezuela	11 265	106 774	9.48	100	0.89
67	Cameroon	7 536	70 447	9.35	82	1.09
68	United Arab Emirates	17 762	165 353	9.31	206	1.16
69	Mexico	125 519	1 163 658	9.27	1 100	0.88
70	Belarus	11 610	107 203	9.23	160	1.38
71	Cuba	8 524	77 308	9.07	74	0.87
72	Azerbaijan	5 120	46 224	9.03	77	1.50
73	Ethiopia	10 132	90 299	8.91	106	1.05
74	Poland	249 385	2 198 772	8.82	2 122	0.85
75	India	559 822	4 925 388	8.80	3 520	0.63
76	Morocco	17 680	151 361	8.56	162	0.92
77	Vietnam	24 522	209 037	8.52	284	1.16
78	Malaysia	91 685	778 766	8.49	1 052	1.15
79	Brazil	409 878	3 454 699	8.43	2 699	0.66
80	Lithuania	21 896	183 353	8.37	239	1.09
81	Jordan	13 330	107 171	8.04	114	0.86
82	Egypt	86 195	684 668	7.94	579	0.67
83	Kuwait	7 679	60 852	7.92	69	0.90
84	Serbia	49 134	378 573	7.70	429	0.87
85	Iran	261 703	1 964 969	7.51	1 816	0.69
86	Pakistan	72 057	537 844	7.46	801	1.11
87	Romania	76 246	564 616	7.41	679	0.89
88	Tunisia	34 592	247 599	7.16	144	0.42
89	Turkey	267 377	1 912 240	7.15	1 468	0.55
90	Nigeria	24 396	172 785	7.08	199	0.82
91	Macao	5 523	38 320	6.94	116	2.10
92	Ukraine	50 669	349 964	6.91	329	0.65
93	Russia	327 019	2 128 475	6.51	1 763	0.54
94	Algeria	24 574	158 841	6.46	194	0.79
95	Bosnia and Herzegovina	4 529	27 646	6.10	40	0.88
96	Iraq	8 189	48 709	5.95	72	0.88
97	Kazakhstan	6 053	30 472	5.03	41	0.68

Source: Web of Science, Essential Science Indicators.

column) reached among the top-level articles (penultimate column), i.e., among the 1% of most highly-cited articles (in their field and age group). This indicator places Estonia 7th in the world (with the US and Finland ranked as low as 31st and 29th, respectively).

What are Estonia's strong fields? In Table 3.2, fields are distributed on the basis of the percentage ratio in relation to the 50% of the world's leading countries' average. Compared to the 2007–2017 (Table 2),[139] the highest-ranking fields—clinical med-icine and molecular biology-genetics—have gained even more ground on the world's leading countries. In general, the changes are rather small and shifts in the ranking are limited to a few positions. There are currently nine fields of research (medicine, genetics, physics, plant and animal sciences, ecology, pharmacology, biology, microbiology and psychiatry/psychology), the impact of which is greater than the leading countries' average. Additionally, there are seven fields (agriculture, neurosciences, astronomy, mathematics, immunology and chemistry) that are less than 10% behind the average. Economic and business science remains the furthest behind compared to the world's leading countries, with Estonian-authored papers being cited more than 40% less than in the world on average. However, one must not forget that this indicator still places Estonia among the top 50%.

In the 2007–2017 monitoring period, we managed to identify 66 researchers working in Estonia, who ranked among the 1% of the world's most-cited researchers in one or several fields (Annex 1)[140] A random check shows that this number has increased further. In addition to the ranking of those who exceed the 1% threshold, Clarivate Analytics maintains a list of the 6,000 most-cited researchers in the world.[141] The methodology for compiling the list changed this year. In addition to the overall top-cited researchers in every field, the list also includes those who have not exceeded the threshold in one field, but are very close to achieving it in at least two fields. Estonia is represented in the list with 17 names (see Table 3.3).

Table 3.2. Research fields ranked on the basis of the impact percentage ratio in relation to the average impact of the countries among the world's top 50%

	Field	Articles	Citations	C/A	C/A world's average (%)	Top articles
1	Clinical medicine	1 575	49 934	31.7	148.6	92
2	Molecular biology and genetics	764	40 886	53.5	126.7	51
3	Physics	1 897	36 476	19.2	68.4	68
4	Plant and animal science	1 653	24 620	14.9	60.0	61
5	Ecology	1 326	27 260	20.6	60.4	45
6	Pharmacology and toxicology	294	5 172	17.6	38.7	8
7	Biology and biochemistry	759	15 291	20.2	21.2	13
8	Microbiology	261	4 701	18.0	19.2	5
9	Psychiatry and psychology	489	6 263	12.8	5.9	11
10	Agricultural sciences	389	3 256	8.4	-3.7	4
11	Multidisciplinary	55	781	14.2	-4.6	2
12	Neuroscience and behavior	469	7 771	16.6	-7.2	7
13	Space science	272	4 502	16.6	-7.4	4
14	Mathematics	317	1 272	4.0	-7.6	1
15	Immunology	262	4 477	17.1	-9.0	5
16	Chemistry	1 475	19 648	13.3	-9.0	14
17	Geosciences	1 170	12 114	10.4	-16.2	9
18	Engineering	747	4 537	6.1	-20.0	5
19	Materials science	726	6 963	9.6	-21.8	3
20	Social sciences general	1 467	7 532	5.1	-24.8	18
21	Computer science	215	872	4.1	-38.2	0
22	Economics and business	298	1 380	4.6	-43.8	0
	Total	16 880	285 708	16.9	39.2	426

Source: Web of Science, Essential Science Indicators.

[139] Allik, J. (2013). Factors affecting bibliometric indicators of scientific quality. — Trames: Journal of the Humanities and Social Sciences, 17(3), pp. 199–214. doi:10.3176/tr.2013.3.01

[140] Lauk, K., Allik, J. (2018). A puzzle of Estonian science: How to explain unexpected rise of the scientific impact. — Trames: A Journal of Humanities and Social Sciences, 22(4), pp. 1–12.

[141] Clarivate Analytics. Highly Cited Researchers 2018. https://hcr.clarivate.com/ (07.08.2018).

Table 3.3. Researchers working in Estonia ranked among the world's 6,000 most cited researchers in one or several fields in aggregate

	Last name	First name	Field	Primary institution	Secondary affiliation
1	Abarenkov	Kessy	Cross-field	University of Tartu	
2	Bahram	Mohammad	Cross-field	University of Tartu	
3	Esko	Tõnu	Molecular biology and genetics	University of Tartu	
4	Fischer	Krista	Cross-field	University of Tartu	
5	Ivask	Angela	Cross-field	National Institute Of Chemical Physics And Biophysics	
6	Junninen	Heikki	Geography	University of Tartu	University of Helsinki
7	Kahru	Anne	Pharmacology and toxicology	National Institute Of Chemical Physics And Biophysics	
8	Kasemets	Kaja	Cross-field	National Institute Of Chemical Physics And Biophysics	
9	Kõljalg	Urmas	Plant and animal science	University of Tartu	
10	Mägi	Reedik	Molecular biology and genetics	University of Tartu	
11	Metspalu	Andres	Molecular biology and genetics	University of Tartu	
12	Moora	Mari	Cross-field	University of Tartu	
13	Niinemets	Ülo	Plant and animal science	Estonian University of Life Sciences	
14	Perola	Markus	Molecular biology and genetics	Terveyden ja hyvinvoinnin laitos, Finland	University of Tartu
15	Pärtel	Meelis	Cross-field	University of Tartu	
16	Tedersoo	Leho	Plant and animal science	University of Tartu	
17	Zobel	Martin	Ecology/Plant and animal science	University of Tartu	

Source: Clarivate Analytics.

As a comparison, it should be mentioned that Latvian researchers did not make it to the list, while Lithuania was represented by one and Russia with seven people. Since the share of Estonian research articles in world research is approximately 0.11%, our researchers are overrepresented in the list of world's top researchers by around 2.5 times. This is another example of how Estonian research is best assessed on the basis of quality rather than just quantity indicators.

In conclusion, it can be said that the data on the status of Estonian research in the middle of 2018 are contradictory to say the least. Research funding is starting to resemble an experiment to determine whether world-class research can be done with no money at all. For instance, Lithuania spends more than 1% of GDP on R&D, which allows them to place as low as 80th in the ranking of research impact. Knowing that Estonian research has received 114 million less with the 1% promised by the state,[142] one may liken it to a patient suffering in death agony. Each research paper published in international journals in the last ten and a half years and authored or co-authored by a researcher connected to Estonia is referenced approximately 40% more than half of the world's most successful research countries on average. It is considered very good that the Estonian economy is growing with the average speed of world economy (3%). In the last five years, the influence of Estonian research has grown 8% faster than the leading group of world research on average. If it continues to improve at such speed, then it is possible to predict the position of Estonian research in the world ranking of research impact in one or two years. For instance, in around a year or a year and a half, the impact of Estonian research should reach the same level as the US. Ranking among the world's top five most influential research countries is realistic, if Estonian research does not suffer any great setbacks.

For instance, in the ranking of research impact, Estonia is two places behind Georgia. A closer inspection of Table 3.1 reveals that Georgian researchers published nearly three times fewer papers than Estonian researchers, whereas approximately half of them were published in the field of physics. Of the 22 ESI fields, the total number of citations placed Georgia among the top 50% of the world's best countries in only 11 fields. Estonia, however, was in the first half of the world ranking in all 22 fields. While the key to Georgia's success lies in the preferential funding of a couple of fields, Estonia's success is based on supporting all 21 fields (ESI does not keep a record on humanities and the interdisciplinary field is formed rather arbitrarily). It would be a great political mistake to use the lack of resources as an excuse to starve so-called softer fields, because research bureaucrats do not think that they make direct or sufficient contributions to the economy.

[142] Vassil, K. (2018). Puudu on 114 miljonit eurot. – Postimees, 7 November. https://arvamus.postimees.ee/6447554/kristjan-vassil-puudu-on-114-miljonit-eurot?utm_source=facebook.com&utm_medium=social&utm_campaign=share-buttons&utm_content=6447554&fbclid=IwAR3kd1iPTOmw68E9jFNULvqk8D4XKn5gzjw_90CY7oW8CYRtI88h6htyQ9o (06.12.2018).

Cyanobacteria samples in incubation chambers
Author: Kertu Liis Krigul (Estonian Science Photo Competition 2017).

Compressed air car
Author: Ingmar Muusikus (2018).

THE FUTURE AND SOCIETAL IMPORTANCE OF ESTONIAN RESEARCH AND DEVELOPMENT

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Introduction[143]

During the last five years, Estonia's economic growth has remained stable at 75% of Europe's average GDP (Table 4.1). We are facing a challenge comparable to the middle-income trap. On the one hand, further catch-up and competition with Europe's wealthiest regions—from Slovenia and Czechia to Scandinavia—is becoming increasingly difficult. General investments into infrastructure and human capital are no longer sufficient for catching up and outperforming them. The importance of smarter and more effective use of existing natural, human and financial resources is increasing. On the other hand, the European Union (EU) is cutting down the financial instruments supporting the introduction of the necessary structural changes and we need to rely on our own means to better develop and utilize our resources. Regarding that, the smart organisation of research and development and its broader societal impact are becoming increasingly important.

So far, debates on the funding and societal impact of Estonian research and development have rather been favouring the short-term utilitarian view: most of the attempts to assess the impact of research focus on its short-term economic impact. For instance, calculations from 2017 showed that the (direct and indirect) contribution of Estonian universities to the economy is 1.6 million euros per year (GVA – gross value added).[144] Other possible manifestations of the impact of R&D—furthering the general knowledge base and the level of human capital, which influence the potential of economic growth—and the (potential) impact on the public sector, i.e. the quality of public policies and services (one must not forget that the public sector expenditure forms approx. 40% of GDP in Estonia) often remain side-lined. This is essentially an old and familiar linear view to innovation: the more research, the more innovation there is (in the private sector). This kind of biased view paints a very limited and bleak picture of the influence of R&D: there seems to be low R&D cooperation between companies and any other easily measured impact remains insufficient. Additionally, this approach limits research and development policies above all to the logic of supporting and servicing private companies. This objective of research and innovation policies, however, is one of the most controversial and difficult to achieve and measure (compared to e.g. the public sector, or contribution to solving wider social issues), especially in an era that is characterised by the domination of global innovation and production networks, which often have more influence on companies' strategic behaviour than domestic policies.[145]

In this chapter, we will provide an overview of the different aspects of the manifestation of the effects of Estonian research. We will update the analysis of Professors Urmas Varblane and Kadri Ukrainski published in the previous collection (Estonian Research 2016)[146] and see whether their main findings still apply 2–3 years later. Additionally, we will discuss other manifestations of the impact of research, which should be taken into account when understanding the societal importance of Estonian research. In this regard, it is important to remember that quite a few important statistical figures related to the development of R&D policies are actually quite subjective: for instance, GDP statistics are made more accurate for at least several years, which also influences the accuracy of various indicators related to GDP (especially if we want to view short-term timelines). Similarly, a great part of R&D statistics on companies is based on companies' own assessments and we often hear that companies do not understand the importance of collecting R&D statistics, consider reporting too complicated, and submit the related information rather arbitrarily—in other words, the actual situation could be significantly worse or actually even better.

[143] The author thanks Prof Rainer Kattel for comments and discussions.
[144] See e.g. Biggar Econimics. (2017). Economic Contribution of the Estonian Universities, A Report to Universities Estonia. http://ern.ee/files/Biggar/economicimpact.pdf (24.10.2018).
[145] See e.g. Yeung, H. W. C. (2016). Strategic coupling: East Asian industrial transformation in the new global economy. Cornell University Press.
[146] Varblane U., Ukrainski K. (2017). Research, Development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33-43. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2015/12/TA_teaduskogumik_ENG_veeb.pdf (12.12.2018).

Table 4.1. GDP compared to the EU28 average in 2006–2017, EU28 = 100

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Czechia	79	82	84	85	83	83	82	84	86	87	88	89
Denmark	125	123	125	125	129	128	127	128	128	127	124	125
Germany	116	117	117	117	120	123	124	124	126	124	123	123
Estonia	64	69	69	64	65	71	74	75	76	75	75	77
Ireland	148	148	134	129	130	130	132	132	137	181	183	184
Latvia	53	57	59	52	53	57	60	62	64	64	65	67
Lithuania	55	60	63	56	60	66	70	73	75	75	75	78
Poland	51	53	55	60	62	65	67	67	67	68	68	70
Slovenia	86	87	90	85	83	83	82	82	82	82	83	85
Slovakia	63	67	71	71	74	75	76	77	77	77	77	77
Finland	115	119	121	117	116	117	115	113	111	109	109	109
Sweden	125	128	127	123	125	126	127	125	124	125	123	122

Source: Eurostat.[147]

State income level and investments in research and development

International innovation studies reveal that there is a significant connection between R&D investments and state income level in countries that lack mineral and natural resources and those whose geographical location and cultural context are not suitable for functioning as a global centre of foreign investments (this is also indicated on Figure 4.1). Even though this figure does not provide a single and final confirmation of the causal links between these indicators, international comparative studies tend to reflect the common understanding that the quality of R&D policies and other formal institutions becomes a decisive factor in maintaining economic growth and making next qualitative leaps of development as a country's development level increases.[148] While countries like Ireland, the United Kingdom, Norway and Canada have managed to raise their state income level over the OECD average without any significant R&D investments (for instance, Norway and Canada mainly relied on natural resources and Ireland and the United Kingdom on their good position as the mediator of foreign investments and financial markets), most of the other countries that exceed the EU28 and OECD average income levels (e.g. the US, Belgium, Germany, Austria and Scandinavian countries) have managed it (or maintained their respective levels) via significant expenses on R&D (at least over 2% of GDP).

National and regional level analyses reveal significant differences in detailed strategies—for instance, that out all of the Scandinavian countries, Finland has based its growth strategy most clearly on the development of R&D and technological capabilities (while Denmark places the most importance on the flexibility of the educational system and people's skills),[149] but R&D investments (whether as a guide and enhancer for R&D investments and/or a guarantor of the education system's competitiveness) play an important role in raising and maintaining countries' competitiveness and therefore also their income levels. Smaller East-Asian countries (especially South Korea, Taiwan, Singapore and, as a kind of European exception, Israel), which have made it to the frontline of technological advancement in quite a short time and where the proportion of R&D investments—which have been historically used to speed up the process of catching up with developed countries—is conspicuously large, form a separate group.

The comparison of state income levels and R&D expenditure places Estonia in a group of countries with whom we generally do not like to be associated. What is more, the development trends of the last two years have been rather worrying—even though Estonia's GDP per capita has grown (like in most countries), the share of R&D investments in GDP has decreased and we still find ourselves in the same boat as countries with whom we would not like to be compared to (e.g. Greece and Hungary) and relatively far from our main role models (e.g. Germany, Finland and Sweden).

It is important to note that the share of R&D expenditure as a percentage of the GDP decreased or remained unchanged in 2014–2016 in practically all European countries, and especially in the Eurozone. Essentially, it can be said that the R&D rhetoric stressing the core aim of investing 3% of GDP in research and development has not managed to compete with the Eurozone's objectives and rhetoric of austerity and cutbacks in spending.[150] In other words, the rather simplified image portrayed by researchers and R&D bureaucrats of R&D as a necessary long-term investment seems not to sell well enough in the current political and social debates.

[147] Eurostat. https://ec.europa.eu/eurostat/data/database (19.10.2018).
[148] See also Sen, K. (2013). The Political Dynamics of Economic Growth. — World Development, vol. 47, pp. 71-86. doi.org/10.1016/j.worlddev.2013.02.015
[149] Ornston, D. (2012). When small states make big leaps: Institutional innovation and high-tech competition in Western Europe. Cornell University Press.
[150] Karo, E., Kattel, R., Raudla, R. (2017). Searching for Exits from the Great Recession: Coordination of Fiscal Consolidation and Growth Enhancing Innovation Policies in Central and Eastern Europe. — Europe-Asia Studies, 69(7), pp. 1009-1026.

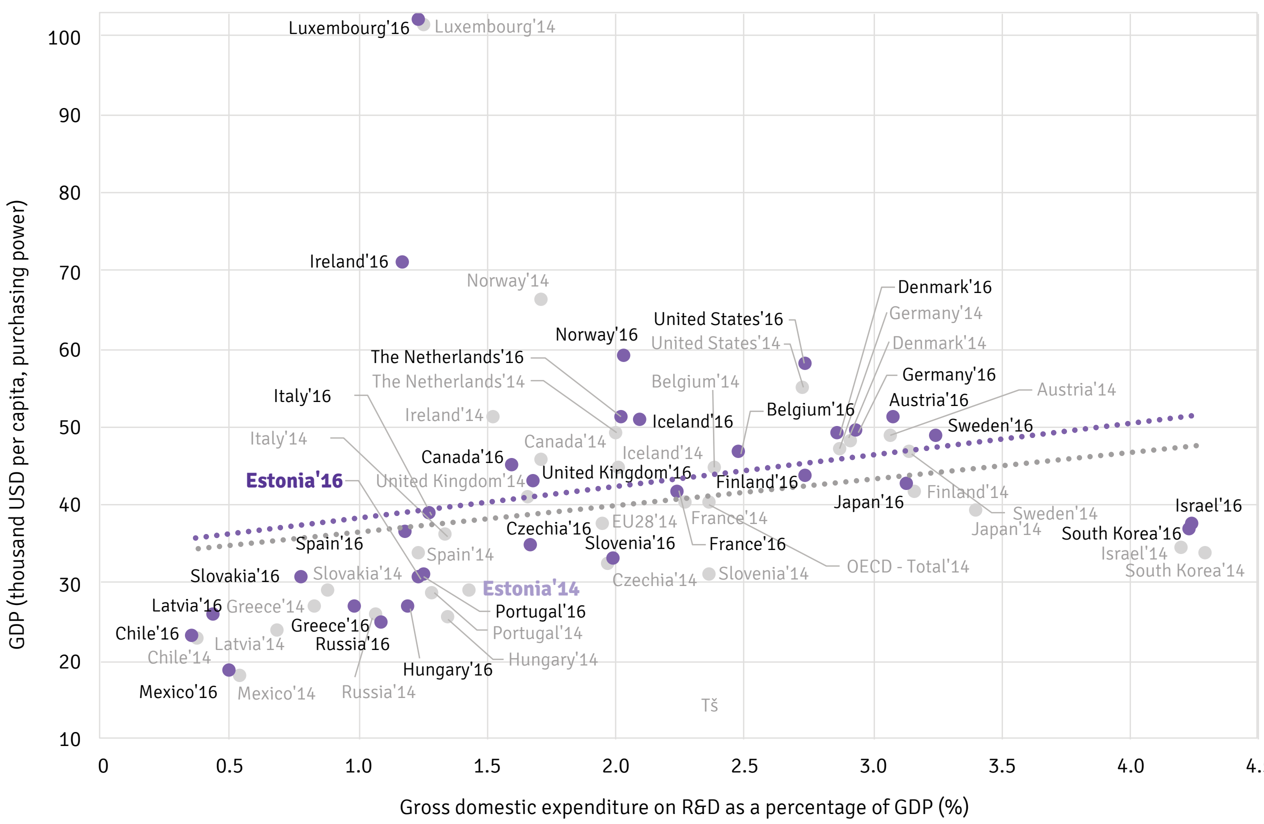


Figure 4.1. Gross domestic expenditure on R&D as a percentage of the GDP (%) and GDP per capita (1000 USD on the basis of purchasing power) in 2016 compared to 2014

Sources: OECD,[151] Statistics Estonia[152] (Estonian % of GDP), calculations by Estonian Research Council.

Considering the above, it is clear that the next leaps towards knowledge-based economic development call for changes in our R&D structure and wider understanding of the role of R&D (or R&D communication): whether it is 'expenditure' or 'investment'. On the one hand, there is a need for a general increase in the share of R&D investments in both the public and private sector. On the other hand, we need to nudge these investments so that in the future, more investments are made not as two extremes, into the universities' basic research and simpler firm-level development activities (purchasing ready-made solutions, updating production facilities etc.), and instead opt for more complex development activities and both internal and external applied research, which is integral for developing the company's R&D capabilities.

Applied research also serves (in addition to educating people) as one of the main platforms for substantive cooperation between universities and companies and the public, and forms a significant part of the R&D portfolios of companies with high added value and countries on the forefront of technological advancement. It pays to remember that historically, the current developed countries (incl. the predecessors of EU institutions) mostly focused on research policy (large-scale public research projects, from CERN to the moon landing) and industrial policy after World War II, which in the 1970s–80s shifted to an industrial technology policy (in other words, towards the gradual development of the companies' R&D capabilities). Innovation policy, or a user- (or demand-) centric view of the technological development only became a core topic in the 1990s.[153] Modern international innovation policy best practices—that mainly aim to facilitate cooperation between universities and companies—require a private sector R&D capability level that is vastly different to the one currently found in Estonia.

The unravelling of the inner structure of Estonian R&D expenditure (Figure 4.2abc) reveals that the distribution of Estonian R&D investments between basic research (approx. 27–30%), applied research (approx. 25–26%) and experimental development (approx. 48%) is quite similar to that of the EU states whose GDP levels are similar to ours (e.g. Poland), but differs, due to the large share of basic and experimental research and relatively small share of applied research, from countries who are our next catching-up targets in terms of GDP levels (e.g. Slovenia and Denmark, see also Figure 4.7). Keeping in mind the overall volumes of R&D funding (e.g. compared to Taiwan, South Korea and Japan), the solution lies not in redirecting existing public investments but rather in focusing new/additional R&D investments on applied research.

[151] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (19.10.2018).

[152] Statistics Estonia. www.stat.ee (18.09.2018).

[153] Soete, L. (2007). From industrial to innovation policy. — Journal of industry, competition and trade, 7 (3-4), pp. 273-284.

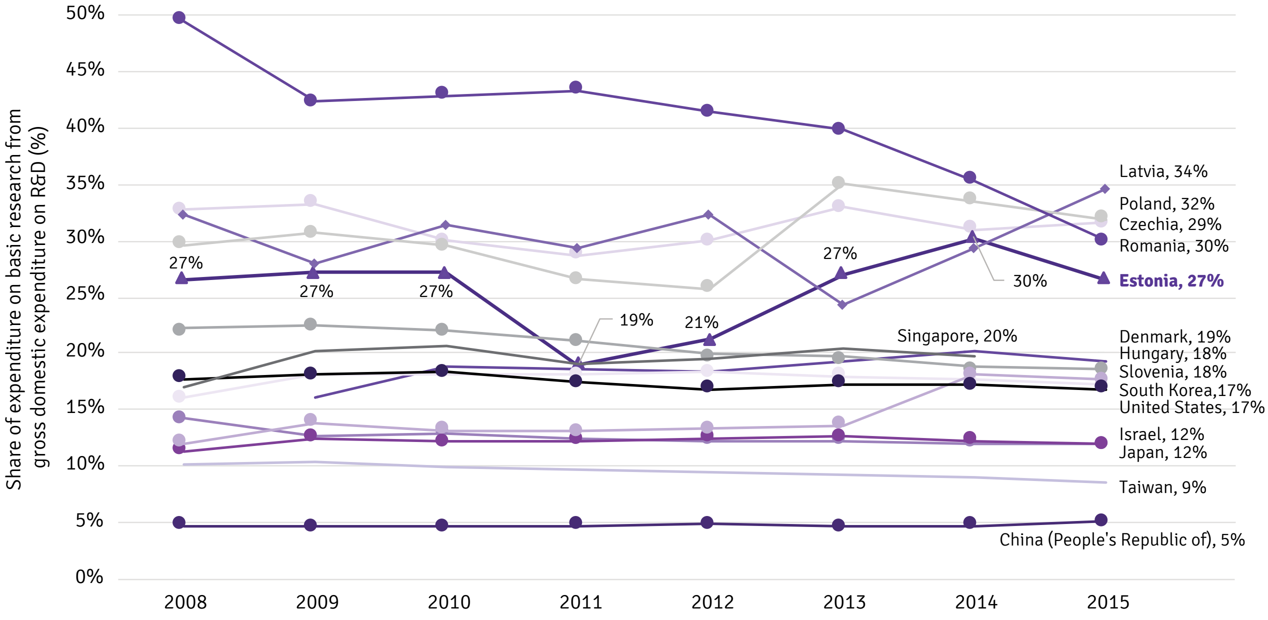


Figure 4.2a. Share of expenditure on basic research from the gross domestic expenditure on R&D in 2008–2015 (%)

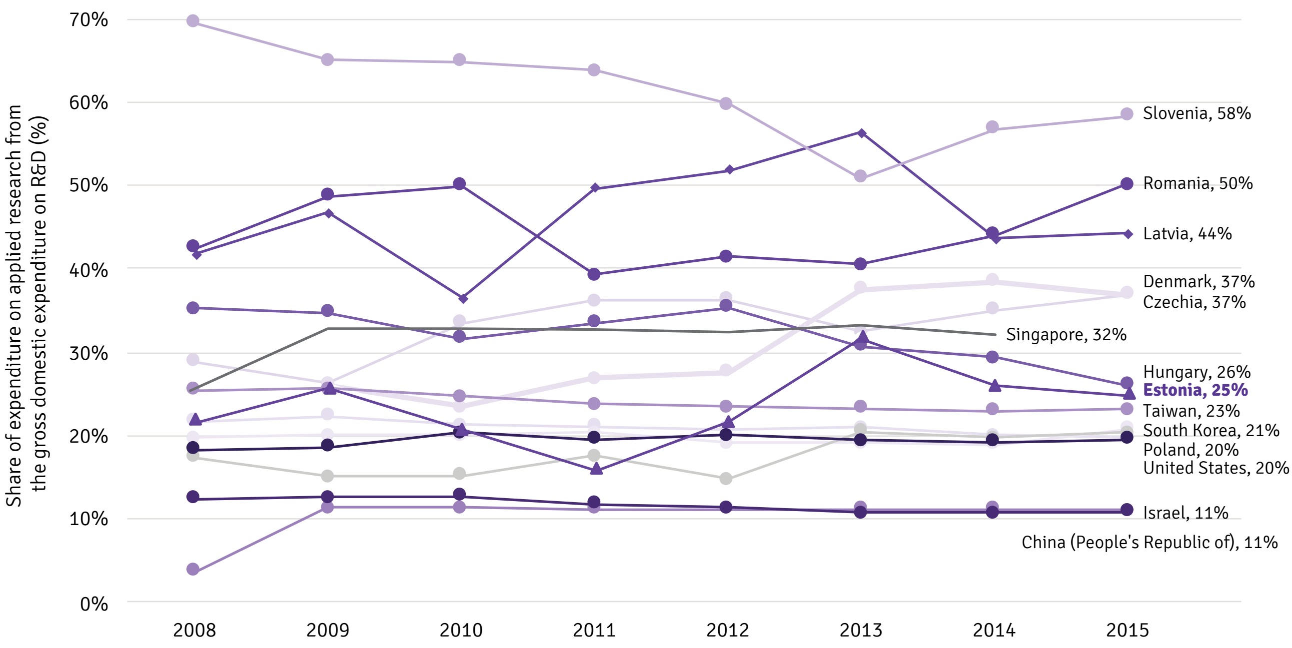


Figure 4.2b. Share of expenditure on applied research from the gross domestic expenditure on R&D in 2008–2015 (%)

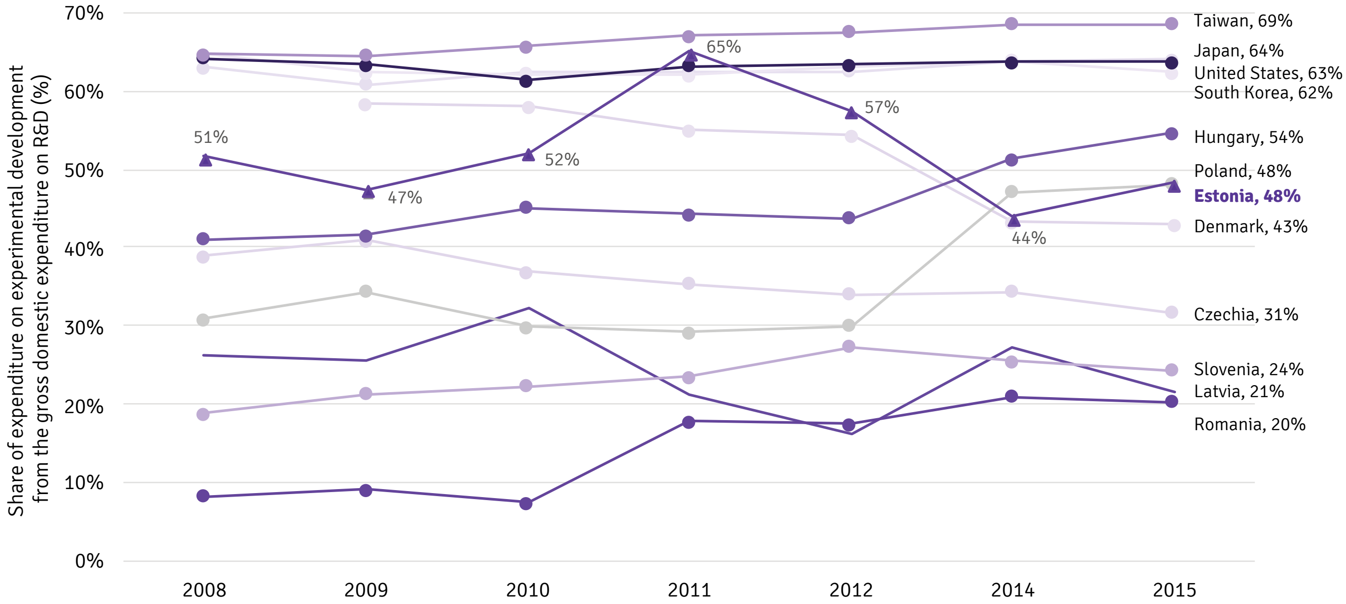


Figure 4.2c. Share of expenditure on experimental development from the gross domestic expenditure on R&D in 2008–2015 (%)

Figure 4.2. Distribution of R&D expenditure by type of R&D in 2008–2015: a) basic research, b) applied research and c) experimental development activities (%)

Source: OECD,[154] calculations by Estonian Research Council.

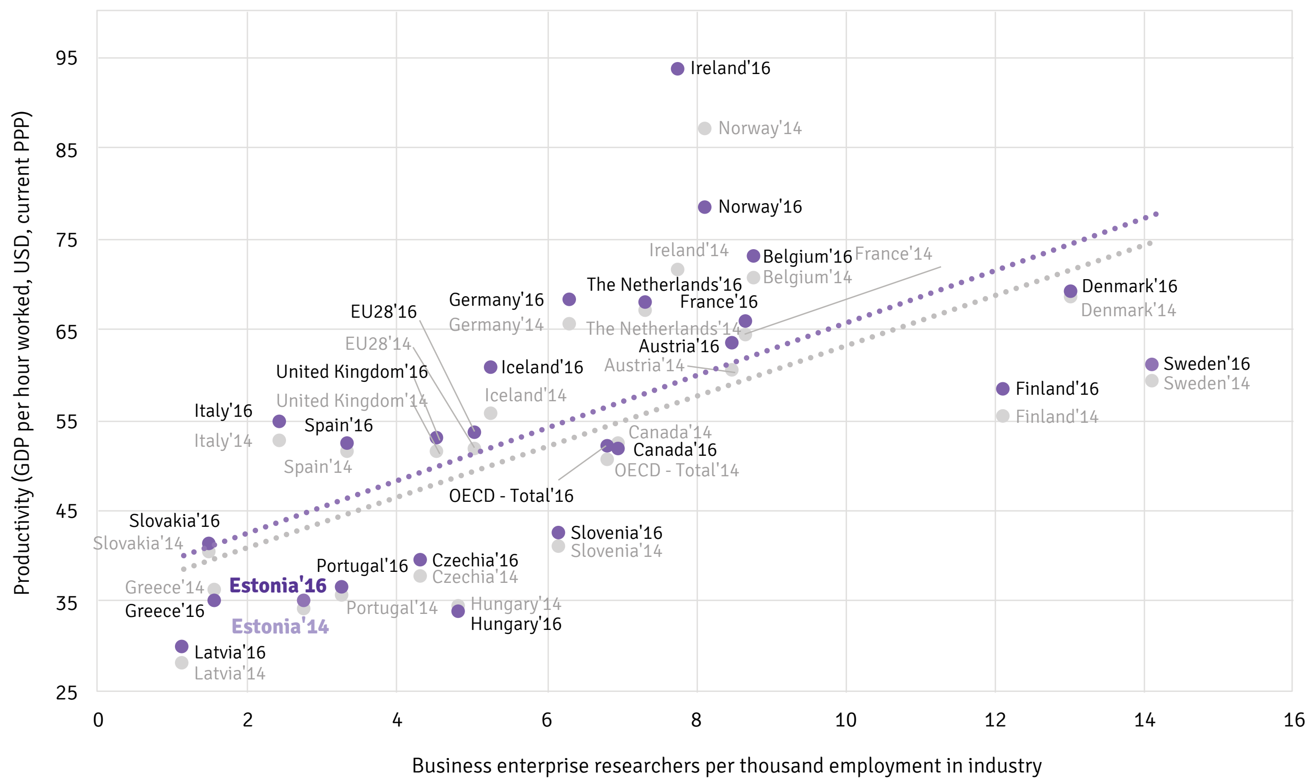


Figure 4.3. Productivity (USD per hour in PPP) vs. business enterprise researchers per thousand employment in industry in 2016 (or last available)

Source: OECD.[155,156]

[154] OECD. Research and Development Statistics. www.oecd.org/sti/rds (22.10.2018).
[155] OECD. OECD Productivity Database. http://www.oecd.org/sdd/productivity-stats/ (22.10.2018).
[156] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (22.10.2018).

Converting research findings into productivity growth

In addition to sufficient strategic investments by public and private sector actors, the collaborative applied research by universities and companies demands that the latter have sufficient basic R&D capabilities—mainly the existence of researchers and companies' willingness to hire them. Without staff that has no substantial R&D experience it is unlikely that long-term R&D activities will become central to strategic company development. In 2016, Varblane and Ukrainski pointed out that when it comes to the number of employees and productivity in the industrial sector, Estonia is at the same level as Turkey, Portugal and Poland, but behind both Czechia and Slovenia, not to mention the Scandinavian countries. The situation has not changed significantly in the last two years (Figures 4.3, 4.4 and 4.5)—the increase in both the number of people employed in research and productivity has been negligible. At the same time, we can still detect a rise in productivity levels in many countries that serve as our role models, where the amounts of R&D funding and the numbers of R&D personnel are several times higher.

The fact that the most important challenge for companies is not the hiring of highly qualified researchers, but their retention and maintaining the stability of R&D capabilities is particularly worrying: in Estonia, since 2011, both the total number of researchers per 1,000 total employment (Figure 4.4) and in the industrial sector (Figure 4.5) has taken a downward turn. In 2011–2015 the number of researchers with a PhD has been constantly decreasing in the business sector as a whole, but also in manufacturing, information and communication industries (Figure 4.6). The small increase of the number of researchers with a PhD degree in 2016–2017 (both in manufacturing industry as well as ICT) largely coincides with the opening of various smart specialisation R&D measures and the movement of finances into companies. However, it must be pointed out that the number of doctoral graduates has not decreased and the labour market is generally characterised by the lack rather than oversupply of labour. In addition to a drop in R&D investment rates, these negative trends essentially point to a structural crisis in the Estonian R&D system. The fewer researchers there are in companies, the harder it is for companies and universities to find a common language and come to a shared understanding of what form their cooperation and joint forward-looking development activities should take. The downward trends in both R&D investments and the number of employees engaged in R&D are often caused by structural reasons (on the demand side of companies, or supply side of universities) and reversal thereof could prove to be a complicated, long-term challenge.

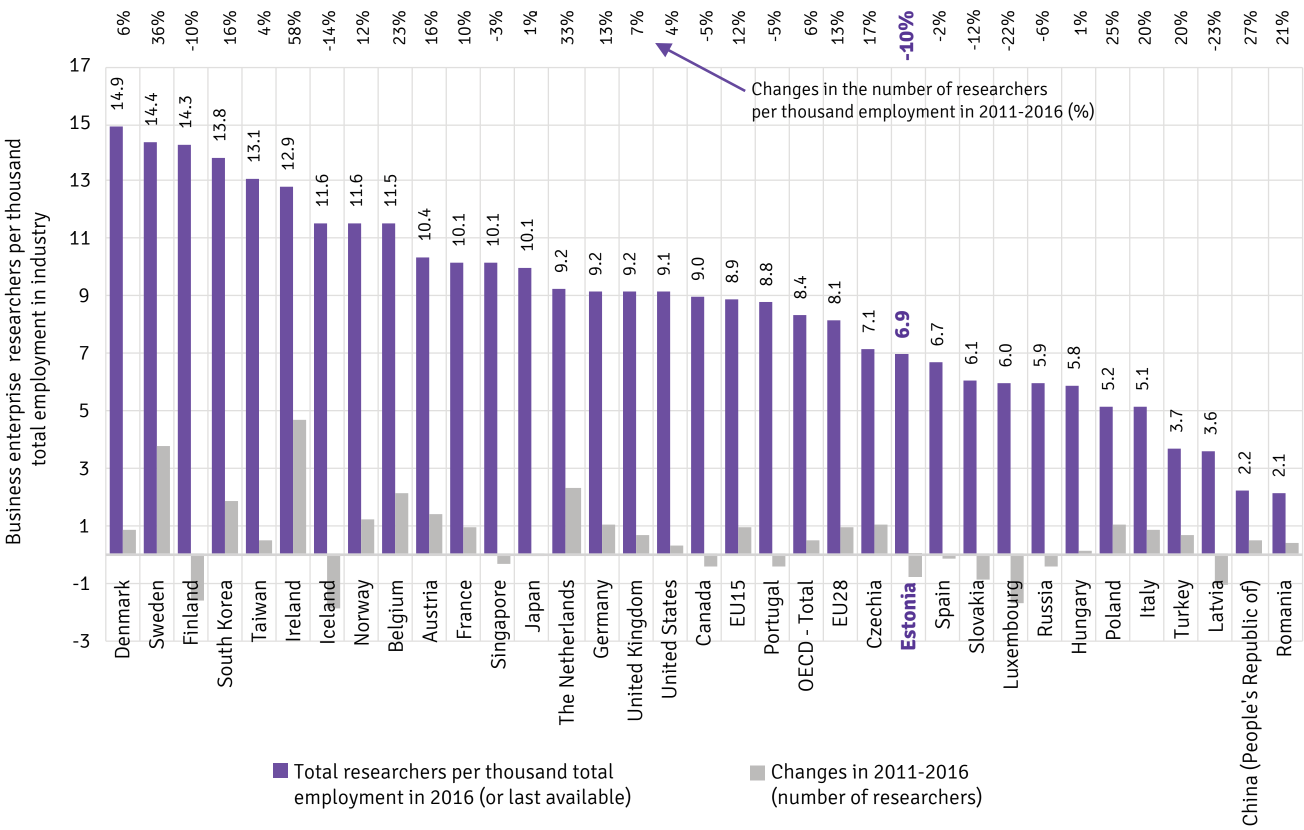


Figure 4.4. Total researchers per thousand total employment in 2016 (or last available) and changes therein in 2011–2016

Source: OECD,[157] calculations by Estonian Research Council.

[157] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (23.10.2018).

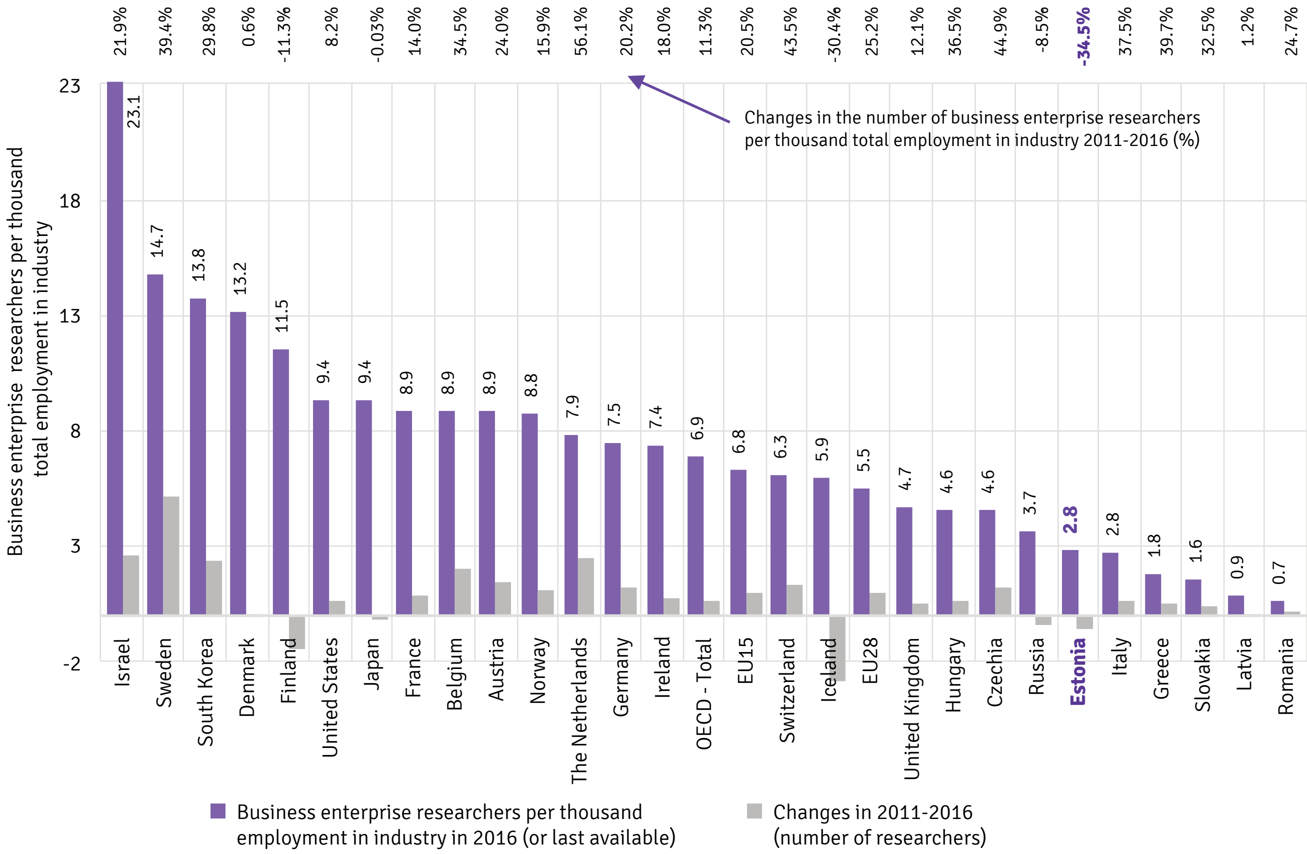


Figure 4.5. Business enterprise researchers per thousand employment in industry in 2016 (or last available) and changes therein in 2011–2016

Source: OECD,[158] calculations by Estonian Research Council.

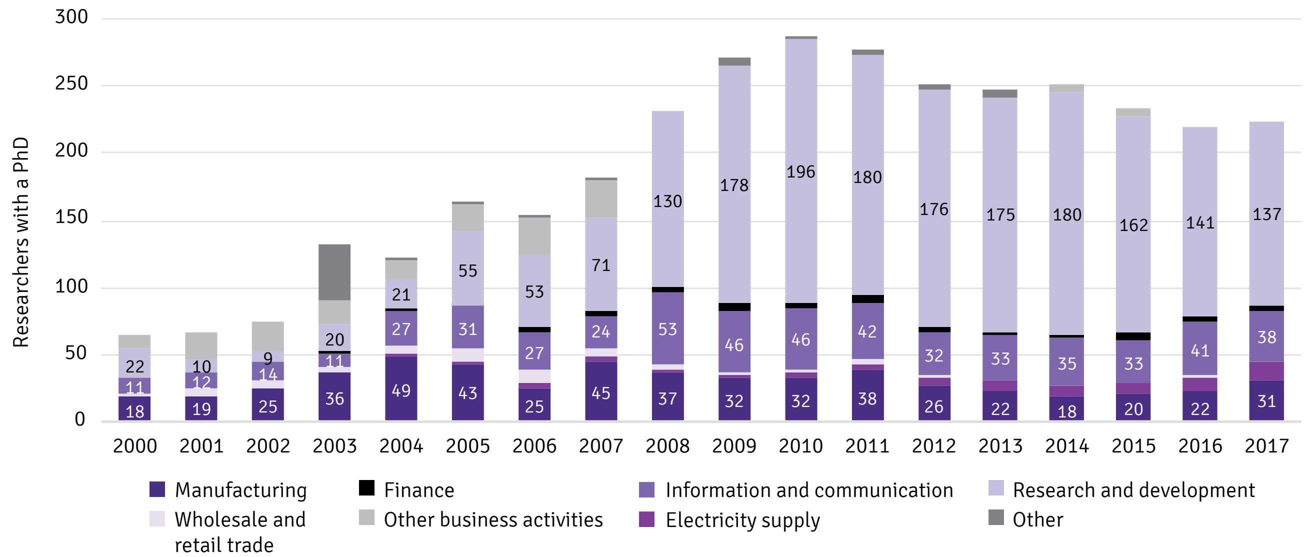


Figure 4.6. Researchers with a PhD in the various parts of the Estonian business sector in 2000-2017

Source: Statistics Estonia.[159]

[158] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (22.10.2018).

[159] Statistics Estonia. www.stat.ee (23.10.2018).

R&D basis of Estonian entrepreneurship and potential for cooperation between companies and universities

These trends that point to a structural crisis in the R&D system are also evident in the relatively low and annually fluctuating share of applied research in companies (see Figure 4.7), which are not balanced out by the existence of national R&D institutions with applied focus (like in South Korea and Taiwan, for instance) nor companies' obvious readiness to finance R&D activities in universities. The last indicator (the percentage of higher education intramural expenditure on R&D financed by the business sector—see Figure 4.8) places Estonia among the OECD and EU average (approx. 7%), but these amounts are small considering the size of our country. In the recent years, approximately 7 million euros of private sector R&D funding is distributed between different universities and R&D fields (Figure 4.9), which does constitute the OECD average as a ratio, but considering the actual volumes and costs of R&D projects, this still comes down to the cooperation projects of a few companies (incl., to a significant degree, state companies such as Eesti Energia AS) in certain fields—and the sum is equivalent to the annual turnover of a few small enterprises.

It is important to remember that the statistical data highlighted in this chapter does not yet include the applied research and product development projects funded under the Smart Specialisation strategy's applied research programme (NUTIKAS) led by the Estonian Research Council (a total of 26 million euros of funding in the 2014–2020 period, which companies are required to co-finance). Since the first of these projects were initiated only a few years ago, assessment of the success or wider impact of these projects is not yet possible.[160] This is the first significant attempt to stimulate (via co-financing) companies that use ICT, biotechnology and various natural resources (from food and wood to oil shale) to order and co-finance applied research projects from R&D institutions.[161]

The low total proportion of formal cooperation contracts could be one of the reasons why the public has developed a general understanding that the R&D activities of Estonian universities do not meet societal expectations—few companies have real R&D cooperation experience. At the same time, the low number of researchers in companies and the volumes and structure of companies' R&D investments also give reason to believe that rather few companies are interested in such cooperation (in the field of applied research). One must remember that a rather significant part of companies' current R&D investments are partially funded by the state—until 2015, Estonian public sector also covered approx. 10% of company level R&D expenses, which is above the OECD and EU28 average,[162] however, in the recent years the state's role has been on the significant decrease here as well, especially since Estonia's Ministry of Economic Affairs and Communications and Enterprise Estonia have closed down or cut several R&D support measures.

Like in the rest of the world, the R&D investments in Estonian private sector are highly concentrated: in the recent years, 75% of the R&D investments in the private sector have been made (or reported to Statistics Estonia) by slightly more than 30 companies. Companies active in the field of information and communication (38.8%) and the manufacturing industry (26.5%) made up the majority of the companies' internal and external R&D investments. In these fields, R&D (reporting) is even more concentrated than in the economy as a whole: 6–7 ICT companies make 75% of the R&D investments in the ICT sector and approx. 15 companies make 75% of the R&D investments in the manufacturing industry.[163] While this kind of concentration poses a significant risk to the development of the state's basic R&D and innovation capabilities—a single company's strategic decisions (e.g. to leave Estonia) could have a considerable effect on the overall levels of R&D investments in Estonia—then in order to implement strategic changes to R&D and innovation policy, there should be an easy way to regularly meet the heads of these 30 companies and representatives from individual fields in order to better understand the general trends of Estonian economy and find ways to improve current R&D policies.

Additionally, recent case studies on the cooperation experiences between universities and companies have shown that successful collaborative projects that focus on technological development do not follow the traditional patterns of simple procurement contracts and commissioned research. Instead, cooperation calls for long-term personal relationships based on mutual trust and patience. The results of such cooperation also rarely result in the initially planned products and solutions, but are more varied and based on a more subtle transfer of knowledge from one person to another and their mobility between universities and companies, etc.[164] In other words, essentially, it is not a formal contractual cooperation, but strategic partnership based on trust, joint risk-taking and a long-term view on R&D investments. The cooperation between universities and companies should be based on the mitigation of R&D risks of the private

[160] Read more about the NUTIKAS programme on the Estonian Research Council's website at https://www.etag.ee/en/funding/applied-research-funding/23917-2/. An overview of the projects funded from the measure is available on the Archimedes website at http://archimedes.ee/str/toetuse-edenemine/periood-2014-2020/projektid/nutika-spetsialiseerumise-rakendusuuringud/ (24.10.2018).

[161] See: Siim Espenberg, Kaidi Nõmmela, Erkki Karo, Egert Juuse, Kadri Lees, Veiko Sepp, Sille Vahaste-Pruul, Uku Varblane, Jari Romanainen (2018). Kasvualade edenemise uuring: lõpparuanne. Tartu Ülikool, Tallinna Tehnikaülikool, Technopolis OÜ.

[162] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (24.10.2018).

[163] According to Statistics Estonia.

[164] See e.g. Lember, V., Ukrainski, K., Mäekivi, R., Hirv, T., Lukason, O., Kärg, M. (2018). Euroopa Liidu tõukefondide perioodi 2007–2013 vahenditest rahastatud valdkondlike teadus- ja arendustegevuse programmide lõpphindamine. Tallinn: TalTech and University of Tartu. http://www.etag.ee/wp-content/uploads/2018/04/EL-tõukefondid-2007-13.pdf (24.10.2018) and Lember, V., Karo, E., Kirs, M., Tõnurist, P., Valdmaa, K., Mäekivi, R., Hanson, R. (2015). Eesti teadussüsteemi ja majanduse seosed: juhtumianalüüsid avaliku ja erasektori nõudlusele vastamisest. Teadus- ja innovatsioonipoliitika seire programmi uuring 5.2. http://tips.ut.ee/index.php?module=32&op=1&id=3701 (24.10.2018).

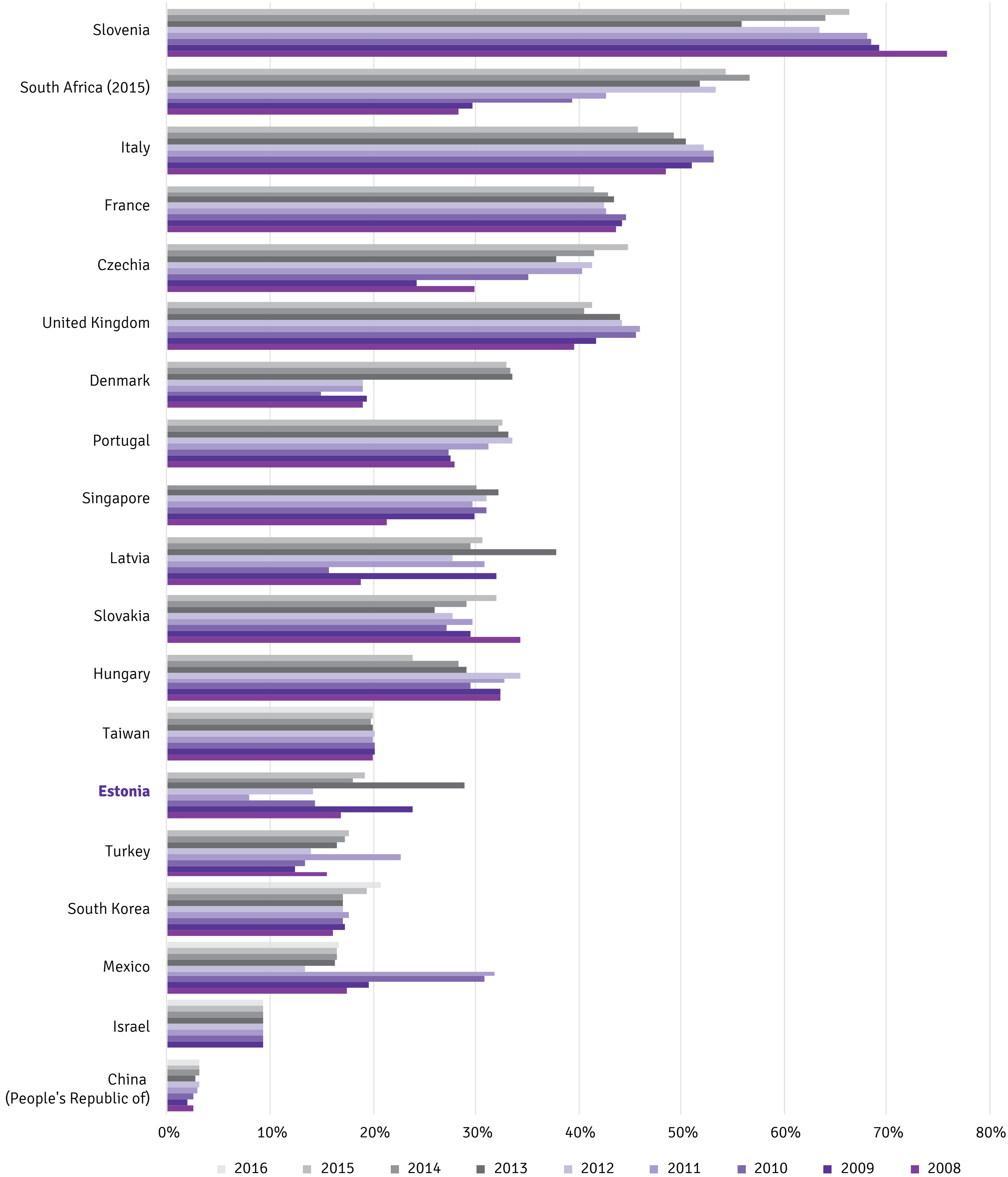


Figure 4.7. The dynamics of the proportion of gross domestic expenditure on R&D on applied research made by the private sector in 2008–2016.

Source: OECD.[165]

[165] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (22.10.2018).

sector (not just R&D-related cost savings). This, however, means that long-term R&D cooperation between universities and companies can above all be led by cooperation platforms (clusters, unions, R&D consortiums) with critical mass and mostly larger enterprises with sufficient basis for long-term investments and risk-taking, rather than SMEs. The above-mentioned industrial technology policy was, in the 1970s–80s, the stage when people attempted to intentionally develop such cross-industrial cooperation platforms (first and foremost R&D consortiums) in almost all high-tech sectors in Asia (e.g. VLSI project in Japan), Europe (e.g. ESPRIT project on the EU level) as well as in the US (e.g. SEMATECH consortium), which in Europe have by now developed into a variety of EU framework programme's co-financed partnership initiatives.

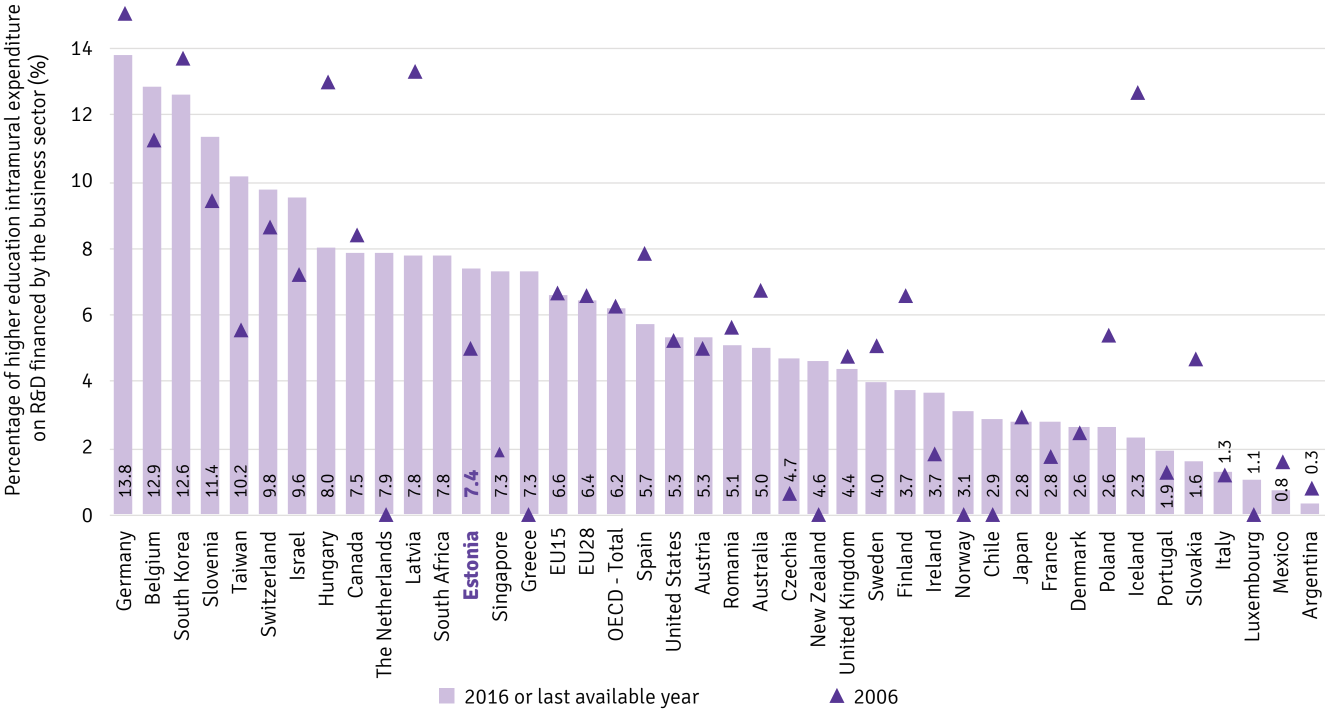


Figure 4.8. Percentage of higher education intramural expenditure on R&D financed by the business sector in 2016 (or last available year) compared to 2006

Source: OECD.[166]

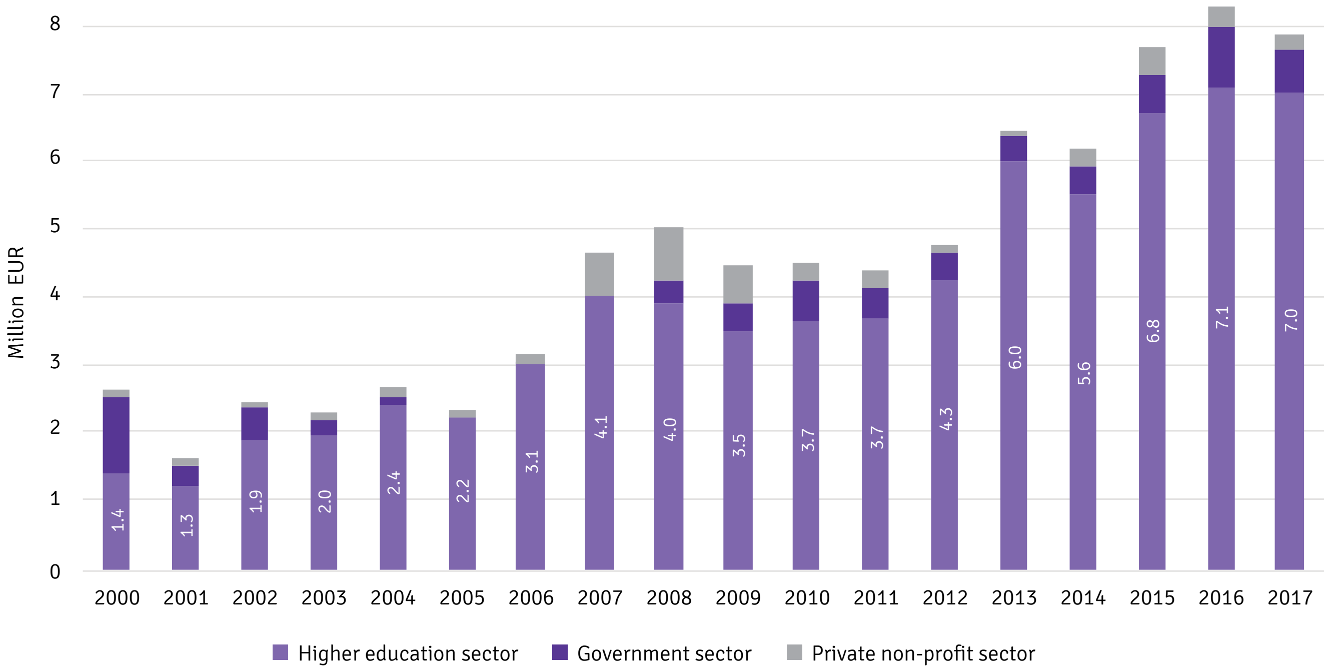


Figure 4.9. R&D expenditure in non-profit sectors financed by the business sector in 2000–2017 (million EUR)

Source: Statistics Estonia.[167]

[166] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (22.10.2018).
[167] Statistics Estonia. www.stat.ee (23.10.2018).

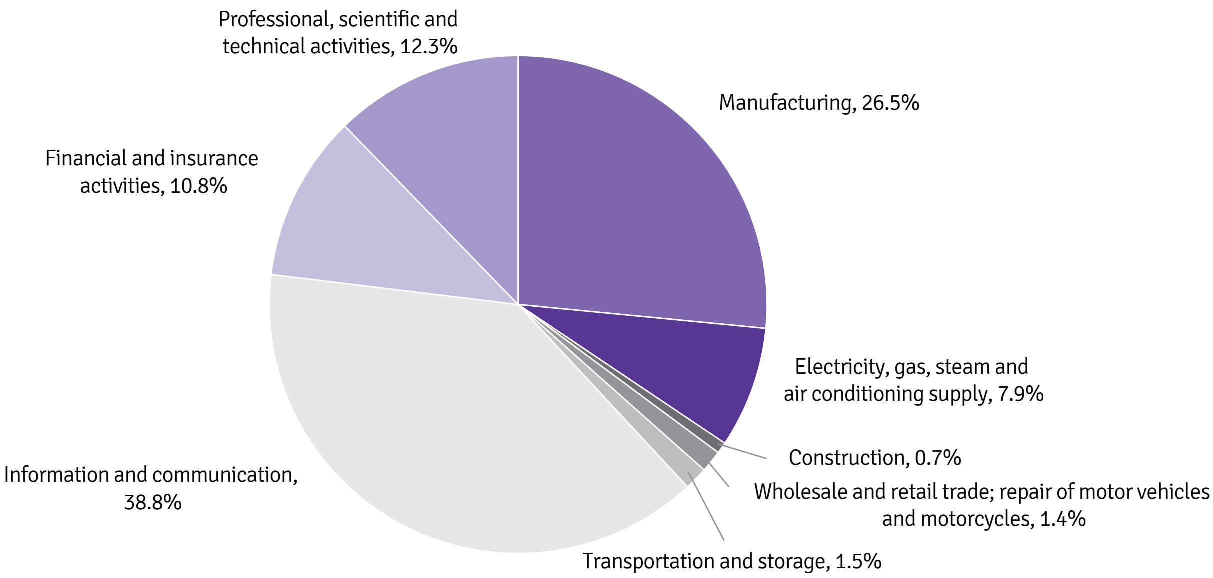


Figure 4.10. Percentages of R&D expenditure of Estonian companies by economic activity (intramural and extramural R&D expenditure summarised) in 2017

Source: Statistics Estonia.[168]

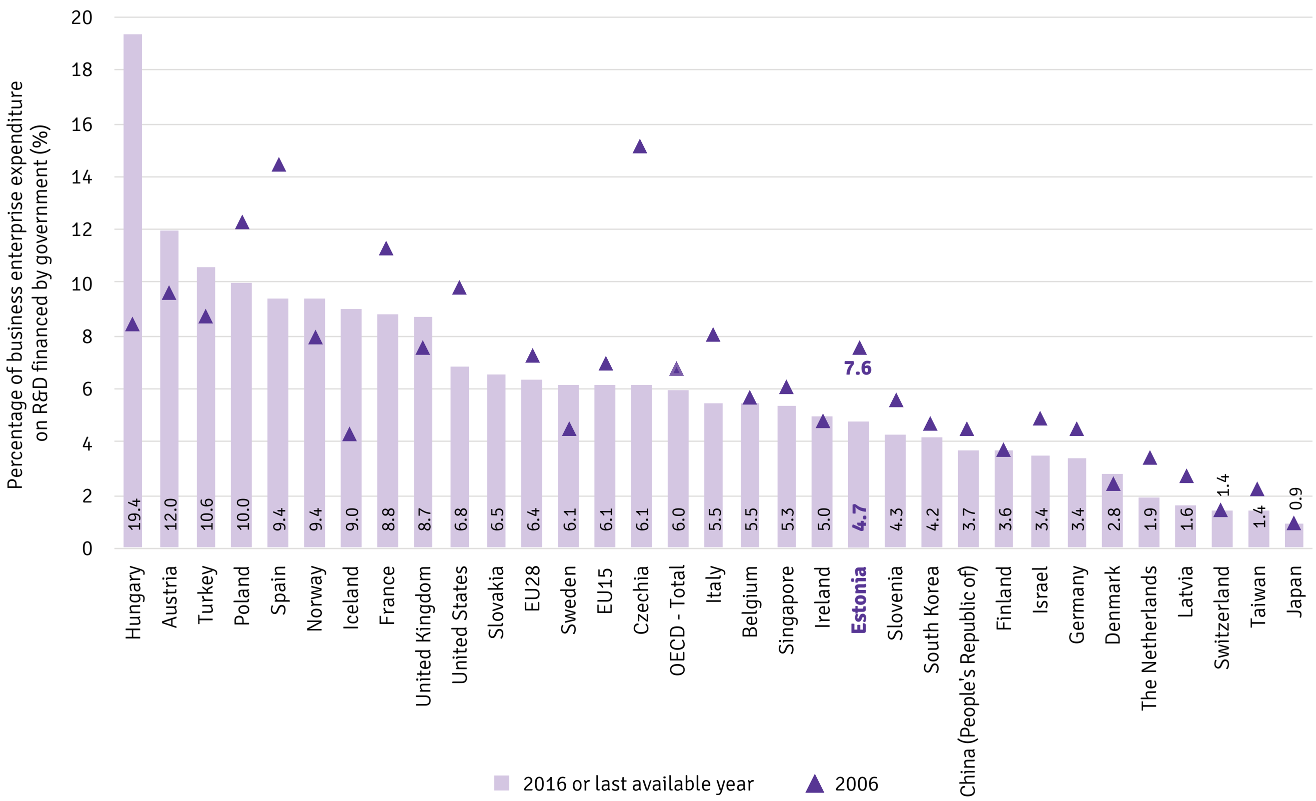


Figure 4.11. Percentage of business enterprise expenditure on R&D financed by government in 2016 (or last available) compared to 2006 (%)

Source: OECD.[169]

[168] Statistics Estonia. www.stat.ee (23.10.2018).

[169] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (24.10.2018).

Cooperation between the public and research sectors and its potential

The case studies of universities and companies referred to in the previous subchapter also reveal that state institutions have been an important partner for Estonian R&D institutions in many fields (from ICT to medicine) and the first implementers of new solutions and technologies. The Ministries of Defence, the Interior, Rural Affairs and the Environment all have their own, rather insignificant R&D budgets and policies (Figure 4.12) and long-term partnerships with specific research groups and researchers. In addition, as at 2016, there were a total of 8,329 doctoral degree holders in Estonia, 3,125 of whom were engaged in R&D, incl. 268 in the government sector (it must be mentioned again that according to statistics, the private sector currently employs ca 220 R&D workers with a PhD degree).[170] At the same time, the debates on the societal effects of R&D have not sufficiently considered the role of public sector institutions in using/implementing R&D solutions developed in universities.

Even though the data (Figure 4.13) indicates that the majority of the R&D budget of the Estonian public sector is distributed without clear and formally prescribed problem foci ("general development of knowledge"), there have been attempts in the recent years—on the initiative of the Ministry of Education and Research—to place more emphasis on solving specific ministries' practical problems via the strategic R&D supporting measure of the RITA programme (a total of approx. 28 million euros in the 2014–2020 period), which is also used to co-finance the positions of science advisors in various ministries.[171] The actual effect of these policy measures can only be assessed in a few years, but the measures themselves represent a significant change in the logic behind R&D funding and policies—the public sector is paying increasingly more attention to defining specific problems, which R&D institutions should try to solve via interdisciplinary research and development activities with a more applied focus.

These initiatives should lead to a wider change in the understanding of R&D in society and public policy: (supporting) R&D and innovation is not only and mainly the objective of research and innovation policies, but one of the potentially most influential tools in all public policy domains, especially in the era of transdisciplinary and wicked policy problems, for which, according to their definitions, there are no solutions that one could buy with cost-minimizing public procurement processes. We must keep in mind that in the US, for example, the NSF budget is only 5% of the entire R&D budget (in Estonia, the Estonian Research Council's budget is 19%[172] of Estonian state R&D financing)—and the rest of the public sector's R&D investments receive their direction, expectations and financing from a number of ministries and institutions (ca 50% of that is made

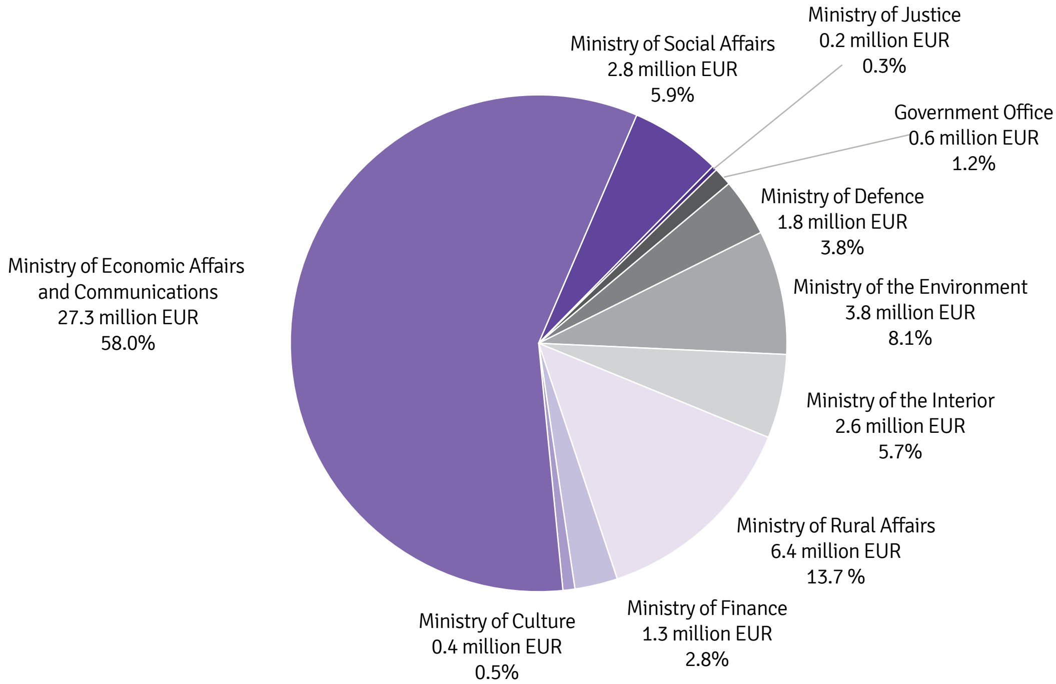


Figure 4.12. Distribution of ministries' research budgets (without the Ministry of Education and Research) in 2017 (million euros)

Source: Ministry of Education and Research.

[170] Statistics Estonia. www.stat.ee (24.10.2018).

[171] Read more at https://www.etag.ee/en/funding/programmes/rita/ (25.02.2019).

[172] The results are based on the total budget of Estonian Research Council in 2017 (https://www.etag.ee/teadusagentuur/avalik-teave/eelarved/2017-aasta-eelarve/) and Statistics Estonia's (www.stat.ee) table TD052 line R&D activity expence funding from state and local budget (2017). (06.11.2018).

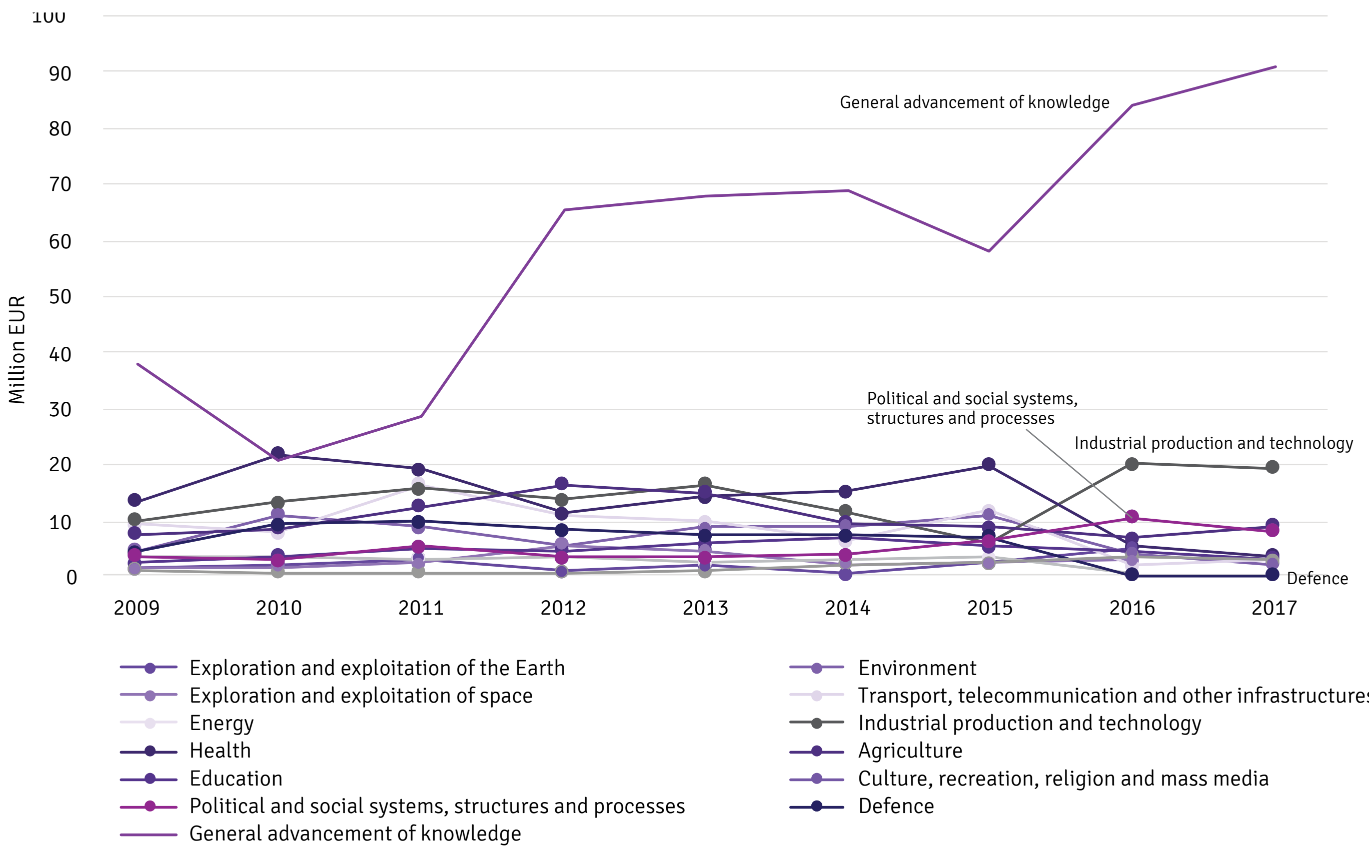


Figure 4.13. R&D funding in the state budget by socio-economic objective in 2009–2017 (million euros) (provisional data until 2015 (inclusive))

Sources: OECD[173] and Statistics Estonia.[174]

up of the US Department of Defence and its jurisdiction). At the same time, it is important to secure the active participation and oversight of the public sector organizations as the smart procurers in order to avoid the experiences of the Estonian national R&D programmes of the previous structural funds period—while there have been plenty success stories, it was also not uncommon that researchers, instead of working on specific practical issues or policy priorities, used these programmes to finance their long-term research projects and priorities.[175]

The role of the State in forging new cross-sectoral agreements for R&D

In the context of decreasing or stagnating public and private sector R&D investments and the diminishing number of researchers, we should abandon the presumption that the current approach to R&D strategies—measurement of the volume of R&D investments and distribution of direct grants (and if these do not work, introduction of more complicated ones)—helps us to increase the impact and social legitimacy of R&D. By now it should be clear that there is a need for new cross-sectoral agreements that would provide R&D investments with new logic and legitimacy.

Otherwise, we will continue in the vicious circle that has been going on in Estonia for the last 10 years or even longer—pressure exerted by researchers forces politicians to make one-off investments into R&D, which at best results in a small increase in R&D investments (as a ratio of the GDP) or, as it often happens, helps them to avoid the drop in the share of R&D investments brought about by GDP growth. Even though such decisions are necessary, they will only solve the R&D funding problem until statistics show another increase in GDP and the related drop in the share of R&D investments.

Additionally, we should acknowledge that the three Knowledge-Based Estonia strategies, which have followed a rather similar logic and covered both the economic boom and severe recession cycles, have not triggered any significant changes in the R&D structures and strategies of universities or companies. Successful enterprises grow and successful research groups participate in international research networks regardless of policy changes.

One might even say that Estonia's current problems with R&D policy and funding are rather similar to the Innovation Para-

[173] OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (24.10.2018).

[174] Statistics Estonia. www.stat.ee (29.10.2018).

[175] See: Lember, V., Ukrainski, K., Mäekivi, R., Hirv, T., Lukason, O., Kärg, M. (2018). Euroopa Liidu tõukefondide perioodi 2007–2013 vahenditest rahastatud valdkondlike teadus- ja arendustegevuse programmide lõpphindamine. Tallinna Tehnikaülikool ja Tartu Ülikool. https://www.etag.ee/wp-content/uploads/2018/04/EL-tõukefondid-2007-13.pdf (06.12.2018).

dox detected by the World Bank in developing countries: even though comparisons with other countries (Table 4.1) show that Estonia could have significant potential for R&D investment and innovation-based economic growth, our innovation system is characterised by companies' low share of R&D and innovation investments and the public sector's limited capacity to stimulate these investments to a greater degree. According to the researchers of the World Bank, one of the main causes of this paradox is the lack of complementarity between physical and human capital—in developed countries, functioning financial markets (incl. regulations) that value the role of R&D, R&D friendly business climate (incl. tax system) and the existence of sufficient human capital ensure that even a small growth in R&D investments has significant impact and the role of the state may be limited to stimulating R&D investments. The challenge of developing countries does not only lie in stimulating R&D investments, but also in ensuring constant investments in the basic capabilities of its innovation system, the most important of which are investments into human capital. However, in the case of Estonia, we should be not talking about simply increasing R&D investments and developing human capital, but above all nudging supplementary investments towards R&D activities with a more applied focus both in companies and in public sector as a whole.

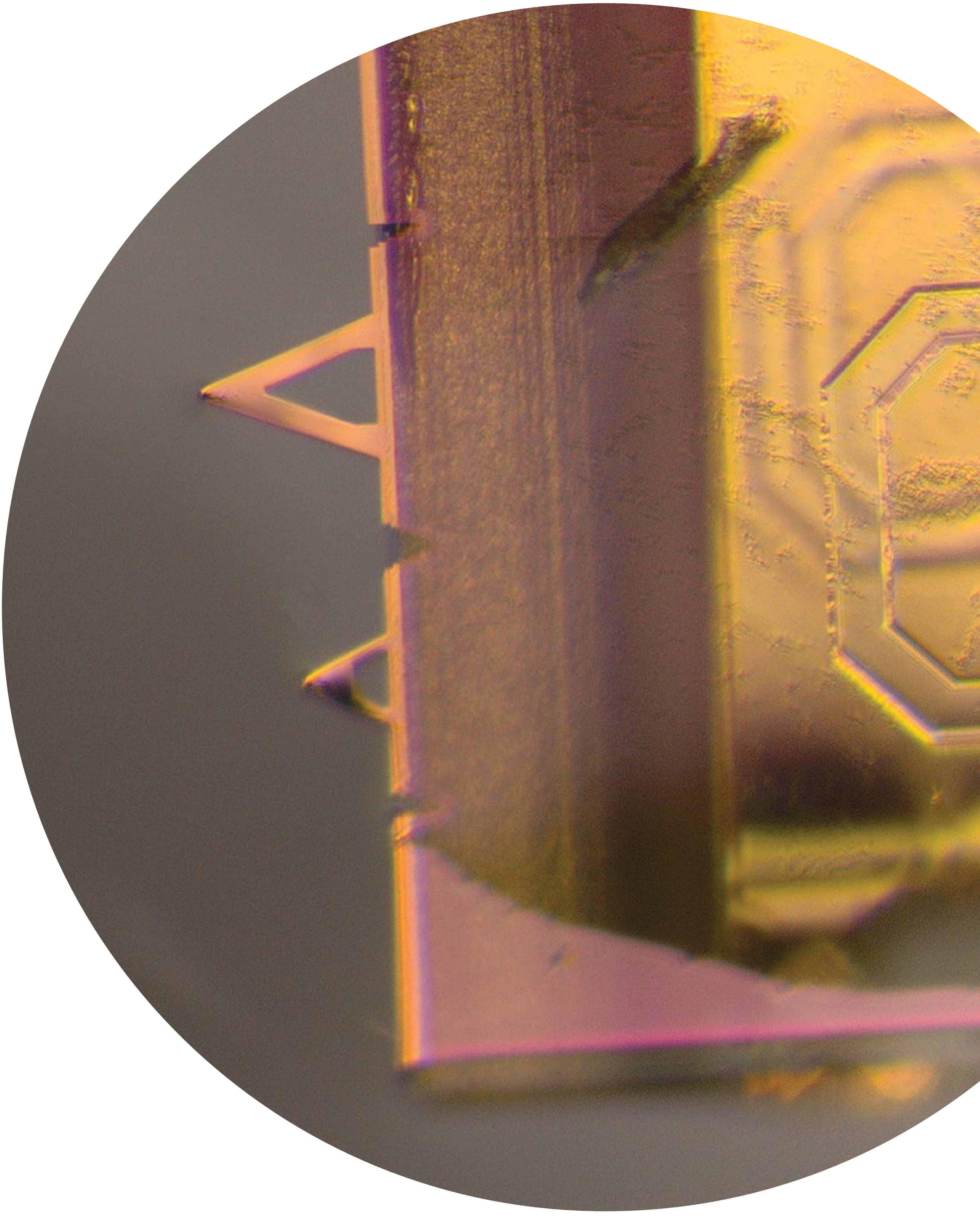
In the current situation, we need to set at least four cross-sectoral agreements at the centre of the next Knowledge-Based Estonia strategy.

Firstly, instead of R&D expenditure, we need to start talking about R&D investments and thereby change the focus of R&D and innovation policy debates—R&D and innovation are not goals but means to speed up/direct economic growth and solving social issues—and set a cross-sectoral goal of increasing the share of R&D investments. This growth should also include a structural change in R&D investments and the increase of investments should bring about a rise in R&D investments and projects with a more applied focus, which presumes changes in R&D strategies both in companies, universities and other R&D facilities. The strategic importance of larger companies in R&D policies must become an important element: even though start-ups and small and medium-sized enterprises are great developers of innovative solutions and pioneers especially in sectors influenced by IT development, a large part of private sector's applied research and technological developments are even today carried out in larger companies (and a handful of sectors), especially in the era of global value chains and platforms.

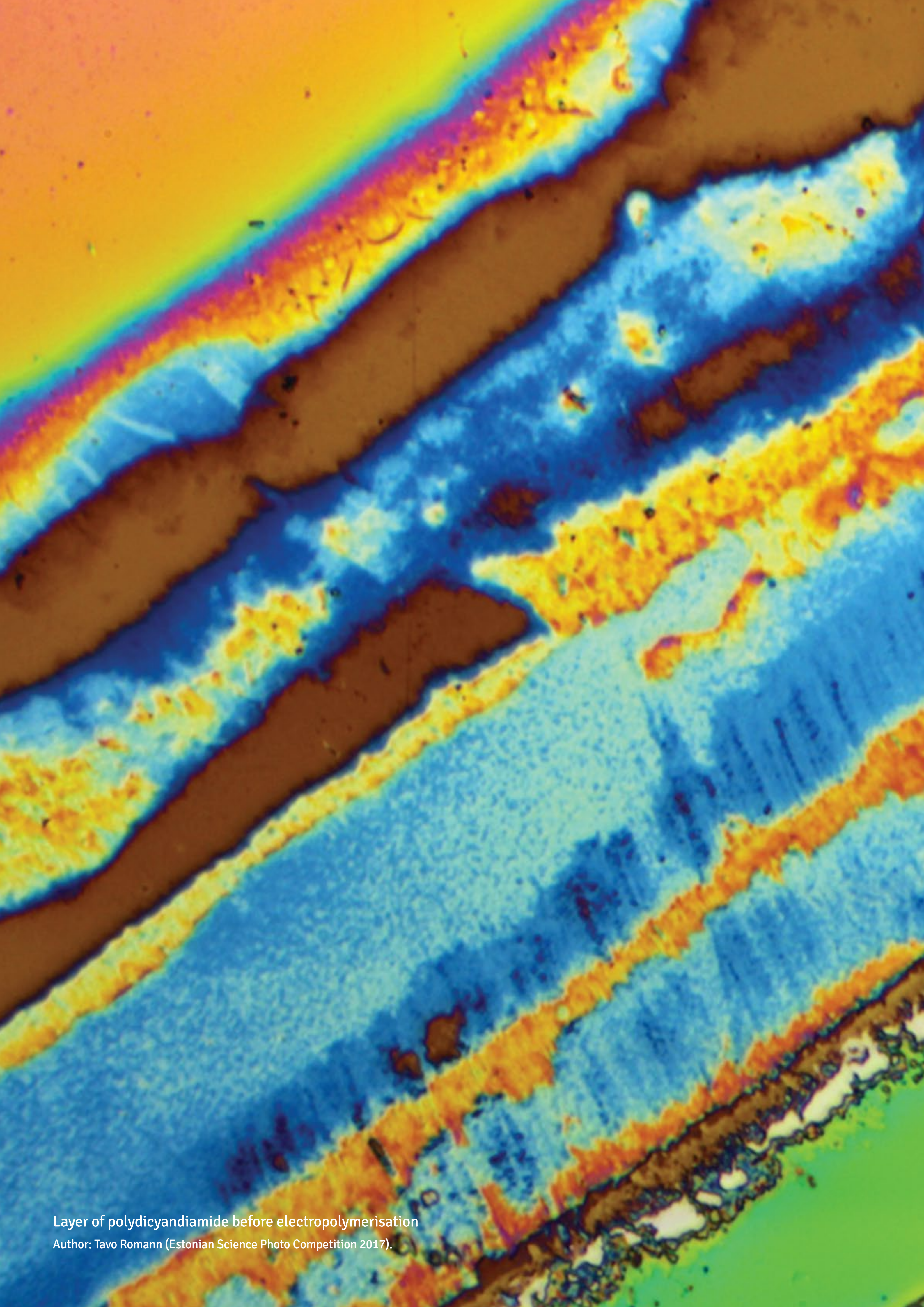
Secondly, we must increase the number of both private sector and public sector R&D personnel (incl. those with PhD degrees) in order to boost companies' basic capabilities for R&D and, above all, conducting applied research. Considering the forthcoming cutbacks in EU structural funds, it would be wise to consider the introduction of a policy instrument that has been missing from current Estonian R&D and innovation policy debates—piloting the idea of a social tax cap and exemptions upon hiring R&D workers in the private sector, especially ones with PhD degrees or various certificates of competence.

Thirdly, R&D and innovation policies should not only and mainly focus on supporting individual companies based on identical intervention logics and measures across sectors (e.g. demand in every sector that universities and companies' applied research be conducted in universities). As the next step, our developmental challenges call for more attention to facilitating and boosting cooperative R&D initiatives and platforms (R&D consortia, etc.). At the same time, the public sector and state measures must become more open to R&D-related risk-taking. Even though our previous R&D and innovation policies have always stressed the importance of cooperation and co-creation, on the level of actual policy measures and their implementation, they key focus has been on control and over-regulation born from distrust.

Fourthly, the public sector's R&D investments and innovation projects must become a policy tool for all policy fields (from education and health to state governance itself) just like regulations, public procurements, etc. As a first step towards a more innovative public sector and smarter procurer, all state institutions should reduce the share of public procurement expenses (public procurements currently make up 35% of the public sector's expenditure and 15% of GDP) and, on account of this, increase the volume of R&D and innovation activities ordered from or conducted together with universities and companies. Raising the public sector's R&D expenses to 1% of the GDP or higher does not necessarily mean raising taxes or the redistribution of funds between various policy fields: it requires a change in the mentality of the public sector itself.



Probe used in atomic force microscopy for studying forces between surfaces
Author: Kertu Liis Krigul (Estonian Science Photo Competition 2017).



Layer of polydicyandiamide before electropolymerisation

Author: Tavo Romann (Estonian Science Photo Competition 2017).

MALE AND FEMALE ESTONIAN RESEARCHERS OR SIMPLY ESTONIAN RESEARCHERS?

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Women and research

Until relatively recently, this combination was seen as unusual. The situation has changed since then, but the linguistic difference remains. We have women scientists as opposed to scientists (not male scientists) and women writers as opposed to writers, but we also have actresses and actors. A play cannot really be performed without involving women, even though this was a common practice in the past. Research, however, has mostly been conducted without female involvement and the related decision-making power (management boards, councils and committees) was solely in the hands of men until fairly recently. Since the majority of the members of decision-making bodies (and not only of those that shape research development) belong to the older generation—and this is only natural, because experience matters—such favouritism of male researchers is still deeply rooted on an archetypal level. As a result, a typical question asked during the process of finding a head for a scientific laboratory (or even a lab involved with a soft discipline) is: don't you have any good guys for this task?

I have been thinking about this topic for two or three months. Oddly enough, my thoughts are starting to move away from my initial intention to defend, justify and promote women scientists towards the problems and joys of the life of a researcher as such. If one were to conduct a SWOT analysis of a specific lab or field of research, which is essentially an interesting exercise in looking into a mirror, it would reveal that men and women tend to worry and rejoice about the same things. Unfortunately, the research career pyramid still displays a gender disparity: while the number of male and female doctoral students is equal, the number of men increases as we move up the academic career ladder. In 2016, 33% of the assistants and teachers, 39% of lecturers and senior assistants, 51% of associate professors and 76% of professors at the University of Tartu were men. Decision-making bodies are still governed predominantly by men and this is not limited to technical fields. As a result, at the beginning of this year, Prof. Rainer Kattel drew attention to the fact that only two members of the 12-head Research and Development Council that advises the government are women and proposed introducing gender quotas for the membership of this decision-making body.[176]

What are these special circumstances that pose a greater obstruction to the work and career of women researchers compared to their male counterparts? One aspect is certainly the birth and raising of children, despite the fact that the Estonian society has clearly changed: young fathers walking on the streets with children in their arms or strapped to their chest, which has now become a relatively common and dignified sight, were hardly seen as recently as ten years ago. Still, in addition to pregnancy, giving birth and nursing, which are solely the joys and woes of women, mundane chores and most of the parenting are also delegated to women. This certainly applies to researchers from the middle and older generation. When a female researcher has several children, her career is bound to be put on hold several times, which may prove fatal to it. One cannot forget one highly significant stage of a career in science—postdoc studies at a renowned foreign laboratory. Half of today's doctoral graduates are women. Finding a postdoc position if you happen to be a young woman with small children and want to keep your family together and children cared for is extremely difficult, if not impossible. This poses further limits to young female PhD holders looking for career opportunities. Thus, women tend to have children (the importance of this is unquestioned) right when they should begin accelerating their research career and it is extremely difficult to find balance, as this requires support from both husbands and the society and the existence of the respective national benefits, for instance, affordable day care. Otherwise, young talented science-minded women (with few exceptions) generally have to choose between two paths: home-husband-children or top-level research. It does not have to be like that. I shall hereby refer to the article "Global Gender Disparities in Science" published in Nature, which emphasises that No country can afford to neglect the intellectual contributions of half its population.[177] At the same time, this problem is much deeper and not limited to research and Estonia.

Estonian research and Estonia 100

Estonia's centenary was the most significant event in 2018. As a result, we have put many things in the historical perspective, thought them through and tried to discuss them. I am certain we all agree that life in Estonia is good and it is home to many wonderful people: women and men, grans and granddads, girls

[176] Hindre, M. (2018). Professor tahab teadus- ja arendusnõukogusse sookvoote. – Novaator, ERR.EE, 21st January. https://novaator.err.ee/655507/professor-tahab-teadus-ja-arendusnoukogusse-sookvoote (28.09.2018).
[177] Larivière, V., Ni, C., Cronin, B., Sugimoto C.R. (2013). Bibliometrics: Global gender disparities in science. — Nature 504, pp. 211–213. doi:10.1038/504211a

and boys who all guarantee our sustainability. There has also been increasingly more talk about Estonian research, mainly of the difficulties of being a researcher and how they are not appreciated by the state. Indeed, in 2015, the state contributed 0.78% of the GDP to research and development activities, which was projected to reach 0.81% by 2018. Thus, increasing the expenditure on research and development to 1% of the country's GDP by 2020 as set forth in the Estonian Research and Development and Innovation Strategy 2014–2020[178] seems unrealistic and positive developments are not evident. On the other hand, in her speech delivered in the Rose Garden of the presidential palace this year, our president highlighted the importance of research: "The rough draft of Estonia's future that will hopefully start to be sketched in the upcoming political season desperately needs a scientific foundation as well as cultural and educational base, so that the superstructure of the three pillars—education, healthcare and social protection—meet the expectations of Estonians and support their dreams." [179]

The current level of state funding of research and development, which allows to finance 14–28% of the projects submitted (in 2013–2018),[180] depending on the application round, and predominantly project-based funding does not even provide top-level researchers with financial security. In order to remain 'fit' for the application rounds that take place every five years, a researcher must be innovative and relatable, keep their finger on the pulse of current events and contribute. Additionally, they must be visible on Facebook, Twitter, Instagram, ResearchGate, LinkedIn and god knows where. They must be familiar with the scene and maintain their reputation.

Perhaps you have been to a full-length concert of a world-famous popstar, which consists of their original songs? It is quite common that well-known melodies and hits form around 20% of the songs performed in the course of several hours. Composing requires talent and inspiration. As a result, the vast majority of the discography of even the most talented musician consists of mediocre tracks. However, if they would not have been able to compose during creative slumps, we would not have immortal tracks either. If we return to research, this too is largely based on creative thinking, inspiration and talent. Project-based research funding assumes that each project for which a researcher submits an application is a hit and declared 'outstanding' by reviewers, because money is given to only such projects. Average projects that are deemed 'good' or 'very good' are left out. However, it is not possible to produce hits all the time. For researchers, funding is not only a question of feeding their ego: it is their income for the next five years and, in the case of researchers who are single parents, money to feed their child. For students, it is not only a question of wages, but also their future in the field of research.

Do female researchers have to sacrifice too much for success?

I have had the honour of participating in several assessment committees in both Estonia and abroad. I can confirm that Estonian researchers are very good despite of the tight budgets of their projects and articles. Does this mean that Estonian researchers are significantly more efficient than their foreign colleagues (probably not) or that their achievements include something that does not really have a monetary value: time that could be used for hobbies, spending time with friends, partners, parents and children? It seems that women sacrifice more for strictly biological and, unfortunately, stereotypical reasons. At least this was the case with women of my generation. Fortunately, I can see that the situation is changing. My experience as the Estonian assessor for the L'Oreal grants for women in science in 2017 and 2018 showed that Estonia has a great many young and talented women scientists: both years produced around 30 applicants. There was an average of 28% of women among the candidates to the Estonian National Research Award in 2000–2018 (over 1,000 candidates in total)—over the years, this proportion varied from 15–41%. An average of 24% women received the award (6–47%). The proportion of women is even a little higher among the most cited Estonian researchers: the study conducted by academic Jüri Allik and discussed in his article in this publication shows that from 2008 to 2018 (1st half), approximately a third of the 1% of most cited Estonian researchers were women.[181] These are promising, encouraging numbers.

Let us start from the beginning. Let us begin from decision-making bodies. Why should more women be included in making (research) decisions?

Society consists of men and women in equal parts. Why should important decisions be made by bodies that do not consider this aspect?

It must be pointed out that the first steps towards change have already been taken. We have a female president, a number of female ministers and increasingly more women are elected to lead political parties. It is amazing to think that five-year-old girls can now grow up believing that being a president is a woman's job.

[178] Peaminister vastas arupärimisele teadus- ja arendustegevuse kulutuste kohta. Istungi ülevaated, 20.11.2017. Riigikogu. https://www.riigikogu.ee/istungi-ulevaated/peaminister-vastas-aruparimisele-teadus-ja-arendustegevuse-kulutuste-kohta/ (01.10.2018).

[179] The President of the Republic at the reception commemorating the 27th anniversary of the restoration of independence, 20.08.2018, Office of the President of the Republic of Estonia, speeches. https://www.president.ee/et/ametitegevus/koned/14499-2018-08-20-16-00-14/index.html (28.09.2018).

[180] Competition based research grants. Estonian Research Council. https://www.etag.ee/en/activities/analysis/ (01.10.2018).

[181] Allik, J., Lauk, K. (2019). The State of Estonian Research in Mid-2018. – Estonian Research 2019 (ed. K. Raudvere) 2019. Estonian Research Council, Tartu. https://www.etag.ee/wp-content/uploads/2019/01/Estonian_Research_2019_veeb.pdf (25.04.2019).

Why do I support the equal or more equal representation of women and men in decision-making bodies (and not only those that concern research), which have thus far consisted predominantly of men?

- Women are decisive and (highly) educated. Therefore, let us not dismiss the intellectual potential of half of the members of the society.
- Nowadays, at least a half of PhD students are women and the proportion of women is also high at the bottom of the research career ladder. Women see the aspects related to the home and children that cannot be removed from young women's studies and work life more clearly. Thus, decisions will be fairer.
- Society needs more empathy. This quality is more prevalent among women. The reasons for this are purely biological. Thus, decisions will be more tolerant.
- Women's self-preservation instinct is important to the society (from the evolutionary perspective, women can't make rash decisions that endanger the lives of children). Thus, decisions will be more reasonable.

To conclude—let us celebrate variety and include men as well as women, the younger and the older, people from the exact sciences as well as the humanities in our decision-making. Only then we will be able to see the society as a whole and make the right decisions. I like that idea.

SCIENCE COMMUNICATIONS IS USEFUL FOR:

RESEARCH:
- in order to **ensure sustainability,** for instance to attract motivated students to sience;
- in order to **ensure the legitimacy and;**
reliability of research in society in general, but also among policymakers and research funders.

SOCIETY:
- helps to utilise research's ability to **increase the economic and social welfare** in society;
- contributes to the **democratic decision-making process** and creates conditions for informed discussion;
- enables **reporting to the taxpayer,** i.e. one of the main financial contributors to research.

THE INDIVIDUAL:
- knowledge about research findings is **intellectually and culturally** valuable;
- **contributes to science literacy,** which can be used to make better decisions in daily life.

SCIENCE COMMUNICATION ENHANCES THE SOCIETAL IMPACT OF RESEARCH BUT ONLY IF A COMPREHENSIVE APPROACH IS ADOPTED

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Editor-in-Chief of science portal ERR Novaator

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"Science is not finished until it's communicated," says Professor Mark Walpole, the Chief Scientific Advisor to the UK government.[182] By this he does not mean the publication of findings in research journals, but informing the public—communication as a tool that can be used to bring research knowledge and its benefits closer to society more efficiently than before.

Every society with an advanced level of research has begun to understand the importance and role of science communication and many of them have implemented measures in order to facilitate it. The policy documents and theoretical treatments that describe the field usually tend to highlight three general perspectives of analysing the necessity of science communication: its contribution to society, research and the individual.

All of the above tasks of science communication are important and kept in balance in well-functioning societies. It is also important that all of the stakeholders participate in it—science communication is not only the task of researchers: it can and should also involve universities, research funders, non-governmental organisations, the education sector, politicians, media, etc.

When defining science communication in this framework, we can see that science communication in Estonia has two main focuses: popularisation of science among young people with the purpose of influencing their career choice, and communication by organisations with the aim of gaining public and financial support via the communication of success stories.

Science popularisation activities that are aimed at young people are focused on natural and exact sciences and engineering in order to encourage them to study these specialities in universities, provide more professionals for the labour market and to make Estonia's economy more knowledge-based and

[182] Yeo. S. (2013). „Science is not finished until it's communicated"– UK chief scientist. – Climate Home News, 3rd October. http://www.climatechangenews.com/2013/10/03/science-is-not-finished-until-its-communicated-uk-chief-scientist/ (19.10.2018).

boost economic growth. Examples of this include science programmes in media (Rakett 99), the activities of science centres (AHHAA and the Energy Discovery Centre) and the promotion of science-oriented extracurricular and other activities targeted at students (incl. open calls for science communication projects).

In an organisation-centred narrative, universities, research institutions and the Estonian Research Council communicate the success stories of Estonian research to the society with the purpose of creating a positive attitude towards research among the public and policymakers.[183] A positive attitude could in turn develop into a wider support of and trust in research, increasing its societal impact. An example of this kind of activities is the Research in Estonia portal run by the Estonian Research Council and universities' cooperation with media outlets (e.g. ERR Novaator).

At the same time, studies show that Estonians have a very supportive attitude towards research. The 2014 Eurobarometer questionnaire[184] revealed that 91% of Estonians believe that research has a positive or rather positive effect on society. This is the second highest percentage in the European Union after Sweden. However, in the same questionnaire, 22% of Estonians admitted that they are interested in research, but they do not consider themselves informed (the EU average was 18%).

Science journalism, which plays an important part in keeping people informed, is usually based on the principles of newsworthiness and focuses on mediating research findings. As at 2018, science journalism is represented in the daily Postimees and the radio programme Kukkuv õun in Kuku Radio in the Eesti Meedia group and, to a somewhat lesser degree, in the weekly Eesti Ekspress and more modestly in Delfi's thematic portal Forte in Ekspress Grupp. In the Estonian Public Broadcasting (ERR), research-themed news is communicated via the research portal ERR Novaator and the radio programmes Labor in Vikerraadio and Puust ja punaseks in Raadio 2. The cultural weekly Sirp and the nature magazine Horisont cover this field in a more detailed manner. ERR Novaator and Sirp occasionally feature news items on research policy and funding.

Is there a need for additional science communication?

Estonia's activities to date and the above figure with the tasks of science communication reveal that the tasks are not evenly addressed. Above all, one may point out science communication activities that are aimed at increasing research's actual impact on society, which require more attention not only in the economic perspective, but also in order to ensure social welfare and democratic functioning of society.

We need every researcher to be able and willing to participate in societal debates and contribute scientific information and to explain complicated topics regardless of their audience.

In order to facilitate this, we need to promote science communication at policy level and institutionally, so that universities and researches would be able and willing to share their knowledge and results with a larger audience and different societal groups could ask for, appreciate and implement them. We should pay greater attention to acknowledging science communication as part of researcher's job that assists in delivering researchers' expert knowledge to society via both media and policy-making. This requires for the topic to be also discussed in the context of research career, funding and strategies.

SCIENCES OF MIND AND SOCIETY IN THE ECOSYSTEM

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The objective of the following article is to ponder on the role of social science and humanities researchers in coping with major social problems. It is noteworthy that resolving ecological conflicts (e.g., pollution or unsustainability of resources) requires scientific calculations on element cycles as well as an understanding of the behavioural patterns and values of people. The prescriptions provided by natural science models are not effective without taking into account behavioural habits and the patterns of changing practices. When we do not take the human element into account, we are left with the non-human.

1. The peculiarity of social sciences and humanities

The distinction between sciences of mind (*Geisteswissenschaften*) and sciences of nature (*Naturwissenschaften*) comes from Wilhelm Dilthey; later the two were analysed as two cultures of science by C. P. Snow. The ontological characteristic of the sciences of mind, or semiotic sciences in a broad sense, stems from its study objects: the meaning-making systems, the structures and processes that contain knowledge. Cultural, historic, linguistic, artistic, economic, legal and belief-related as well as cognitive, emotional, aesthetic and moral aspects in the dynam-

[183] Scheu, A. M., Olesk, A. (2018). National Contextual Influences on Mediatization: The Comparison of Science Decision Makers in Estonia and Germany. – Science Communication, 40(3), pp. 366–392. doi.org/10.1177/1075547018766917

[184] European Commission. (2014). Special Eurobarometer 401: Responsible Research and Innovation (RRI), Science and Technology. http://ec.europa.eu/public_opinion/archives/ebs/ebs_401_en.pdf (19.10.2018).

ics of systems are their field of study. The division of semiotic sciences into social sciences and the humanities was analysed by Jerome Kagan, who outlines that social sciences (similarly to natural sciences) try to explain and predict phenomena, while the humanities attempt to understand phenomena without aiming for rule-based explanations and predictions.[185]

Distinguishing social sciences and the humanities as a group separate from natural sciences requires an understanding of their characteristics, which among other things derives from the ontology that they use. The objects of social sciences and the humanities are themselves subjects, or artefacts created by the subjects.[186] Subjects are generally characterised by the possession of free choice, the ability to interpret, which means they have several concurrent options for behaving, from which the decision picks one. Usually, the choice is not random but motivated by previous experience, habits and goals. Traces of the choices made are called memory. Natural sciences do not presume the ability of free choice from their objects; they rather exclude this, which constitutes the great difference in the nature of the regularities studied. Natural sciences are mathematically precise, but in case of objects with a choice, the patterns are approximate, like habits, customs, agreements, with unexpected exceptions.

The second ontological difference lies in the nature of categories. Physical systems can be strictly classified and defined on the basis of the common characteristics of objects, while semiotic systems, however, are classified on the basis of family resemblance (a term introduced by Ludwig Wittgenstein). In case of family resemblance, each individual in a given category has individuals similar to it in terms of some characteristics, but there need not be any characteristic that would allow to distinguish all individuals in this category from those not in the category. This is why the boundaries separating semiotic categories are blurry, but they do exist.

The third difference lies in the methods. The basic methods in physical sciences are quantitative, while qualitative methods have a supporting role. It is the contrary with social sciences and the humanities, in which qualitative approaches form the basis, calculations only have an assisting function. Therefore, the p-value cannot be the supreme criterion of proof in the sciences of mind.

Naturally, it must be taken into account that each object can be studied with various ontologies. In principle, physical ontology can be applied in the models of society (excluding the issue of the subject from the model); it may even provide results when studying established structures. However, in case of the formation of new communicative structures, the choice processes themselves, semiotic methods usually prove to be more fruitful.[187]

2. Classifications

The natural division of sciences does not proceed from clear criteria; it is not based on any distinct characteristics but follows family resemblance. Often the methodology is also hybrid, especially in social sciences.

Today, mainly three classifications of sciences are in use in Estonia.

(1) The Estonian Research Council's classification lists Culture and Society as one of the four fields of study. It does not include, for example Architecture and Industrial Design, which are categorised under Natural Sciences and Engineering (also including Military Science and Technology, and Industrial Engineering and Management), neither does it include Occupational and Environmental Medicine, which is listed under Health, as well as research relating to Environmental Policy, Environmental Economy and Environmental Law and Agricultural Sciences, which are under Biosciences and Environment (although politics, law and economy are in the category of Culture and Society).

(2) The European Commission's classification distinguishes Social Sciences and Humanities as a separate class (the other three classes are Physical Sciences, Biomedical Sciences, Technological Sciences).

(3) In the OECD's division, the respective classes are Social Sciences and Arts and Humanities (the remaining four branches are Natural Sciences, Engineering and Technology, Medical and Health Sciences, and Agricultural Sciences together with Veterinary Medicine).

In addition, Estonian libraries employ their own, different classifications. All of these are hierarchical classifications. As the actual classification of sciences does not comply with a hierarchical scheme and is clearly relational and network-like, none of the above can be a good representation of the actual situation because of their hierarchical principle.

[185] Snow, C.P. (1959). The Two Cultures and the Scientific Revolution: The Rede Lecture. Cambridge: Cambridge University Press; Kagan, J. (2009). The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century. New York: Cambridge University Press. In Estonian: Snow, C.P., Kagan, J. (2017). Kaks kultuuri ja teadusrevolutsioon. Kolm kultuuri. Translated into Estonian by Mart Trummal. Avatud Eesti raamat. University of Tartu Press, Tartu.

[186] Here belong also the semiotic or meaning-making aspects of biology; see Thompson, E. (2007). Mind in Life: Biology, Phenomenology, and the Sciences of Mind. Cambridge: Harvard University Press; Kull, K. (2007). Biosemiotics and biophysics—the fundamental approaches to the study of life. In: Barbieri, M. (ed.), Introduction to Biosemiotics: The New Biological Synthesis. Berlin: Springer, pp. 167–177.

[187] Other Estonian researchers on this subject: Tamm, M. (editor). (2011). Humanitaarteaduste metodoloogia: uusi väljavaateid. Tallinn: Tallinna Ülikooli kirjastus; Lagerspetz, M. (2017). Ühiskonna uurimise meetodid: sissejuhatus ja väljajuhatus. Tallinn: Tallinna Ülikooli kirjastus.

3. The position of humanities and social sciences

A total of 31 centres of excellence have been established in Estonia since 2001. Four of these have been founded in the field of humanities and social sciences:

The Centre of Cultural History and Folkloristics in Estonia (2001–2007, heads Arvo Krikmann and Mare Kõiva) that focused on systematising the Estonian cultural heritage,

Estonian Centre of Behavioural and Health Sciences (2001–2007, head Jaanus Harro) that undertook to bring together psychological, sociological and health research,

The Centre of Excellence in Cultural Theory (2008–2015, head Valter Lang) that was tasked with creating a strong theoretical basis for cultural studies,

Centre of Excellence in Estonian Studies (2016–2023, head Mare Kõiva) that is dedicated to the interdisciplinary study of cultural mechanisms.

The rationality of the share of humanities and social sciences has been the object of many disputes, especially in this century. It has received extremely harsh criticism from humanities researchers. One source of the persisting tension is probably lacking understanding about each other's methodologies, which causes complaints that the humanities' approach is not scientific or that the physical approach is not humanist. Indeed, we have very few researchers who have thorough knowledge of both, the physical as well as semiotic methodology, and their complementary nature. It is also noteworthy that everywhere in the world the philosophy of science has been engaged mainly with physical sciences and much less with the study of the sciences of mind.

4. The mission of the sciences of mind and society

"One of the central questions of Estonian research is its role and significance for a small nation. We need to talk more about science," says Andres Koppel.[188]

In her study, Helen Small outlines the five primary values of the humanities:[189]

(1) that the humanities study the meaning-making practices of the culture, focusing on interpretation and evaluation, with an indispensable element of subjectivity,

(2) that they are useful to society in ways that put pressure on how governments commonly understand use, in prioritising and measuring economic use,

(3) that they contribute to the happiness of individuals and/or the general happiness of society,

(4) that they are a force for democracy,

(5) that they are good in themselves, to be valued 'for their own sake'.[190]

We should add interpretation, criticism, encompassing the multifaceted and multi-branched nature of culture and thereby maintaining quality in all cultural spheres; nativizing and determining the eco-system through its self-description; capacity of analysing the culture as a whole, constructing the entire understanding of the past, present and future of culture (by studying past and current choice processes, the development of values, preparing the direction of choices).

5. The deepest issue of the modern day

An interesting problem, which has not been addressed enough, is related to society's general developmental tendency—the number of external goals is ever increasing. Never before has there been as much competing as there is now. Objectives with competitive criteria have become a regulating factor in nearly all spheres of life—rankings, voting, highlighting winners etc. Each criterion, however it is derived, forms a unique sequence, which is contrary to the fundamental ambiguity and multi-functionality of semiotic systems. Firstly, it has created artificial needs, the fetish of winning—the need to participate in a competition (collectively as well as individually), striving towards a career, skills, prominence etc. As there is a multitude of parameters for ranking, their meaningfulness becomes arbitrary. It has given rise to a situation where a new convincing (economic, innovative, national, lifestyle etc.) goal can find supporters relatively easy. This has created favourable conditions for manipulating people and populism, as well as for "the end justifies the means" type movements, in other words, for the justification and relatively easy acceptance of indirect violence. Among other things, it encourages favouring gigantic projects. Such a situation is a risk to the health of societies. Although the modern era of "transforming nature" appears to have passed, the base mechanisms that gave birth to it (one of which is measurement-based goal setting) are still going strong. Research provides hope for finding an exit.

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188 Maidla, M. (2017). Milline on teaduse tähtsus ja sotsiaalmajanduslik mõju? — Sirp, 25 August.

189 Small, H. (2013). The Value of the Humanities. Oxford: Oxford University Press.

190 Also: Holm, P., Jarrick, A., Scott, D. (2015). Humanities World Report 2015. New York: Palgrave Macmillan; Brewer, J. D. (2013). The Public Value of the Social Sciences: An Interpretative Essay. London: Bloomsbury.

6. The potential of sciences of mind; projects of sciences of mind

The satisfactory arrangement of life for a relatively small country and its ecosystem in an open world requires choosing suitable modern technology, implementing it with skill and creativity and localising it in the regional context in a multifaceted manner, but it is not important to invent the technology and compete in it on our own. Important technological inventions and discoveries in exact sciences are increasingly more expensive. These choices and applications undoubtedly call for excellent knowledge of technology but implementation itself is largely an issue for the social sciences. Product development benefits from physics and chemistry but the cultural context, design, awareness-raising, operation, i.e., aspects where sciences of mind are useful, play a significant role. Also in coping with extremely innovative technology.[191] Economics, law, political science, demography, human ecology, human geography, cultural anthropology, landscape studies, pedagogy, anthropology of religion, sociolinguistics, communicology, ethnology, conflict studies, psychology, aesthetics—all of these belong to the humanities and social sciences, and knowledge of the respective fields affects and helps the organisation of life in our country to a great extent.

Probably the most important research projects nowadays are those in the overlapping area of social sciences, humanities and ecology. Some examples of these: Humanities for the Environment, Observatories for Humanities Researchers,[192] Bifrost projects,[193] Research Institute for Humanity and Nature's projects.[194]

Analysing the whole of a state or region is primarily the task of social sciences and humanities researchers, together with ecologists if the ecosystem is concerned. The Estonian Human Development Reports commissioned by the Estonian Cooperation Assembly are mainly compiled by humanities and social sciences researchers. Remarkably, nearly all reports of the Club of Rome (research papers concerning acute global problems commissioned by the Club of Rome) have been in the field of social science.[195]

[191] For example: Tegmark, M. (2017). Life in 3.0: Being Human in the Age of Artificial Intelligence. New York: Knopf.

[192] Humanities for the Environment, Observatories for Humanities Researches. https://hfe-observatories.org (11.10.2018).

[193] Bifrost. https://bifrostonline.org (11.10.2018).

[194] Research Institute for Humanity and Nature. http://www.chikyu.ac.jp/rihn_e/about.html (11.10.2018). I thank Kati Lindström for directing me to those.

[195] For example: Pauli, G. (2010). The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs: Report to the Club of Rome. Taos: Paradigm Publications; in Estonian: Pauli, G. (2018). Sinine majandus 3.0: Kasumlikud ärimudelid, mis taastavad planeeti. Aruvalla, Lilleoru. Weizsäcker, E. U. von; Wijkman, A. (2018). Come On! Capitalism, Short-termism, Population and the Destruction of the Planet: A Report to the Club of Rome. New York: Springer.

HOW NATIONAL RESEARCH AND DEVELOPMENT ACTIVITIES ARE MEASURED

Tiina Pärson
Leading Analyst at Statistics Estonia

Research and development activities are regarded as the driving force behind economic growth and productivity and the share of R&D expenditure in gross domestic product (GDP), i.e. the R&D intensity indicator, is seen as the main indicator when comparing countries' capacity for economic growth. In the last five years, Estonia has been in the middle of the ranking of countries. The only exception was the 2010–2012 period when the intensity indicator showed rapid growth due to the considerable investments in new technology in the oil industry. In the following years, as the pilot factory reached the production phase and the share of investments began to decrease, the expenditure on R&D activities decreased considerably, which in turn had an effect on the intensity indicator. The idiosyncrasy of a small country's statistics lies in the fact that the start or termination of a single project can significantly influence a specific statistical indicator. In 2017, the intensity indicator of Estonian was 1.29. According to preliminary data Estonia maintained its central position in the ranking of European Union Member States.

The intensity indicator is partially based on the volume of expenses made on R&D activities in the respective survey year (gross domestic expenditure on R&D—GERD). The total expenditure on research and development (GERD) serves as the main source of consolidated data, which is used to measure the actual state of a country's R&D activities. GERD comprises all of the expenses made on R&D activities on the state level, including funding received from abroad, but not the funding of R&D activities performed abroad.

What can be considered research and development? This question has triggered many discussions and it is likely to continue doing so in the future. Clear boundaries where R&D begins and ends are sometimes very difficult to define, especially in the area of the service sector. This is also confirmed by communication with data suppliers. Statistics Estonia bases, its data collection on the definition of the *Frascati Manual 2015* where R&D activities are defined as follows: research and development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge. In order to distinguish a R&D activity from other similar activities, which can be carried out by the same performers, it must satisfy five core criteria: it must be novel, creative, systematic and, in the preliminary stage, characterised by a lack of solutions to research and technological problems, and its results must be transferable and/or reproducible. In a broader sense, research and development activities can be divided into three subcategories—basic research, applied research and experimental development. Nearly half (52%) of the R&D expenses in Estonia are made on experimental development, a third (28%) on basic research and a fifth (21%) on applied research. The differences between sectors are quite large. Both the higher education and public sectors place greater emphasis on generating new knowledge, i.e. basic research. The business enterprise sector tends to put new knowledge into practice, as expected.

Data are collected in the Statistics Estonia with the help of the questionnaire *Research and development*. The survey is mandatory for all Member States with the respective regulation.[196] It also ensures temporal and substantive comparability between Member States. According to the international methodology, units that are engaged in research and development are divided into four institutional sectors: business, public, higher education and private non-profit sector. The last three fall under the umbrella term non-profit institutional sector. Based on the above, data are collected using two questionnaires—the *Research and development* questionnaire is aimed at the non-profit institutional sector and the *Research and development in enterprises* questionnaire at the business enterprise sector. The two questionnaires are similar in structure, with some differences only regarding the breakdown of R&D expenditures. The submission of the questionnaire is made difficult by the fact that there is no specific data on R&D expenditures in an institution, university or business enterprise's accounting record. Therefore, to a large extent the data are estimated and quite dependent on the awareness of data submitters. This problem is not exclusive to Estonia and can be also be encountered in other EU Member States. It is true that many countries have introduced tax incentives for motivating enterprises to contribute to research and development. Statistics Estonia has implemented various controls to ensure the reliability of questionnaire data both in the collection and processing stages. The funds allocated by the state (but also via various structural funds) for research and development activities must generally be reflected in the data submitted by the recipients. There is also the possibility of using an annex to the annual report that focuses on research and development expenditure when measuring the R&D expenditure in the business sector, but unfortunately, submission of these annexes is not mandatory and therefore the amount of data available, especially those on smaller enterprises, is modest.

In addition to research and development expenditure, it is also possible to measure national budget allocations for R&D activities on the state level. In the *Frascati Manual 2015*,[197] it is defined as GBARD (government budget allocations for R&D). Estonia lacked data calculated on the basis of the respective methodology until 2016. Budget allocations were assessed on the basis of expenditure on research and development activities. Since the data was an estimate, the corresponding data were not published in the public database of the Statistics Estonia. However, according to the regulation, the estimated data had to be transmitted to Eurostat with the corresponding additional note. Based on these estimates, Estonia came across as a real goody two-shoes, as all of the state-allocated funds correlated with the R&D expenditure, which could not be said about other Member States. Since 2016, a new methodology has been introduced under the leadership of the Ministry of Education and Research, and the budget allocations for research and development activities are put together according to the *Frascati Manual 2015* methodology. The corresponding data are published in the public database of Statistics Estonia.

In addition to R&D expenditure, the number of people involved in research and development (R&D personnel) is an important indicator. According to the methodology of the *Frascati Manual 2015*, researchers, engineers, technicians and ancillary staff who spend at least 10% of their working time on research and development are considered to be involved in R&D. In addition to the total number of R&D personnel, data are also collected about the working time R&D personnel spent on research and development work, which is reduced to full-time equivalents. This indicator is generally more important if one wants to analyse the actual working time spent on research and development. In 2017, the number of persons employed in R&D calculated in full-time equivalents was 6,048, which is 5% more than the year before. The number of researchers and engineers calculated in full-time equivalents was 4,674, which is 8% more than in 2016. Compared to 2000, this number has increased by half. This growth is largely due to the higher education and business enterprise sectors. In 2000, the number of researchers employed in the business enterprise sector in FTE positions was 274, yet by 2017, it had grown to 1,585. This indicates that one must keep one's finger on the pulse when operating on a highly competitive business landscape and one way to do so is to engage in constant development in order to launch new or improved products and services.

However, a question arises: how do we get such data about a country? As mentioned above, there is a regulation behind the collection of data, which obliges the Member States to collect the data specified in the regulation. At the same time, the regulation does not define how a Member State should define its own sample of the survey. Since the research and devel-

[196] Commission Regulation (EC) No. 753/2004 of 22 April 2004 implementing Decision No. 1608/2003/EC of the European Parliament and of the Council as regards statistics on science and technology.

[197] OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264239012-en

opment survey consists of two separate parts with different questionnaires, which cover the non-profit institutional sector and business enterprise sector, respectively, the principles of forming the sample of data submitters remain different.

The sample of data submitters of the business enterprise sector is based on a list of enterprises that are connected to research and development prepared on the basis of the enterprise's annual economic indicators. The list is regularly supplemented with enterprises funded by the Estonian Research Council and Enterprise Estonia (EAS); enterprises that presented their R&D expenses in their annual accounts, enterprises whose main field of activity is research and development and on the basis of information acquired elsewhere. The sample of data submitters of the non-profit institutional sector consist of research institutions, higher education institutions, non-profits or foundations, whose fields of activity include research and development activities. The list is supplemented by information on units that are engaged in research and development obtained from the Estonian Research Council, the Environmental Investment Centre, Enterprise Estonia and print and other media. The data timeseries for the non-profit institutional sector and the business enterprise sector data have been periodic since 1994 and 1998, respectively.

In conclusion, it can be said that the results of the measurement of research and development activities are not only necessary for the purposes of international comparison, but the collected data also serve as a significant input for state-level policy making and strategy development. Therefore, it is necessary that the existing data should be in line with the reality, on the basis of which it is possible to set realistic goals. In order to achieve this, Statistics Estonia as a data collector is constantly updating their web environment (eSTAT) to make it as easy as possible for the data suppliers. On the other hand, it is necessary to continue cooperation with data submitters, to ensure the unambiguity of the content of the data collected, especially in the absence of a direct source for access.

ON THE DEVELOPMENT PROSPECTS OF THE RESEARCH AND DEVELOPMENT FUNDING MODEL

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Head of the Research Policy Department of the Ministry of Education and Research

Mariann Saaliste
Chief Expert at the Research Policy Department of the Ministry of Education and Research

The impact of research on societal development is revealed over a long-term period as a result of the convergence of knowledge and the skills for using it. New discoveries and technological advancements are often unpredictable, which makes the impact of research more elusive than that of well-operated transport connections, shorter waiting lists for doctor's appointments or increased pensions. Since research and development competes with other essential needs for state budget allocations, politicians have the temptation to give preference to areas that have a more visible and tangible impact. As a result, the question of how to increase impact and improve the measurability of results has become increasingly topical in the field of research funding all over the world.

In developed countries, research funding mainly relies on two types of resources: institutional grants in the form of general-purpose allocations, which the receiving institutions can use according to their preferences and needs, and project-based grants, the funding of which is tied to the activities and objectives of specific research or development projects.

Estonia has long been a country mainly dominated by project-based funding. In 2016, the situation began to change. In the coalition agreement entered into in late 2016, the government set a clear goal to equalise research grants and baseline funding, as proposed in the new concept of grants and baseline funding in the research and development funding system[198] by the working group operating under the Estonian Research Council during the said year.

Planned changes in the research and development funding model

The aforementioned concept will serve as a basis for changes in research funding proposed as part of the process of updating the

[198] Estonian Research Council. New Framework of Grants and Baseline Funding. https://www.etag.ee/wp-content/uploads/2018/03/New-Framework-of-Grants-and-Baseline-Funding_2016_short-version.pdf (05.11.2018).

Higher Education Code and implemented via the Organisation of Research and Development Act.[199] According to the planned changes, in the future, research and development activities are to be funded via the following measures:

1) baseline funding,
2) research grants,
3) targeted research and development grants,
4) other research and development funding instruments.

Thus, the changes that are to be implemented clearly differentiate between competition-based research grants, baseline funding and targeted research and development grants. Other research and development funding instruments include all of the remaining measures such as centres of excellence, national research and development programmes, etc. Targeted research and development grants are supplementary grants allocated from the state budget when necessary for the research and development activities that arise from the state's strategic objectives and related activities. The legal definition of a targeted grant gives all of the ministries the opportunity to allocate targeted research and development grants in their area of governance to support strategic development in their policy fields through research and development activities. The assessment of public interest is based on the state's strategic objectives and the proposals of ministries, unions of local government units, registered professional associations and other interested parties. Each ministry will have the right to establish the conditions for allocating these grants under clause 13 (1) 1) of the Organisation of Research and Development Act. The core infrastructure grant will henceforth be allocated as a targeted grant. Infrastructure costs must be covered from the increased amount of baseline funding.

Institutional research grants will disappear in their current form. The funding of allocated institutional research grants is to be continued on the basis of current agreements, but new grants will not be given and the de-committed funds will be transformed into research grants for researchers and research groups. The funding of institutions must be henceforth covered from the increased baseline funding and the overhead costs of research grants.

Compared to the current funding system, the new concept reduces the fragmentation of funding instruments, increases the stability in funding and simplifies the application process and the conditions for the use of research grants and baseline funding as well as the related reporting.

Increase of baseline funding

The resources planned for baseline funding in the 2019 draft budget have increased more than four times compared to 2015, amounting to approximately 39 million euros (an overview of the volumes of baseline funding year by year is provided in Figure 1.6. in the article by A. Koppel). This is comparable to the amount that is planned to be distributed through individual research grants via the Estonian Research Council (40.3 million euros).

Allocation of baseline funding to evaluated and qualified research institutions is conducted pursuant to the regulation of the Minister of Education and Research on the conditions and procedure for the baseline funding of research and development institutions (RT I, 04.09.2018, 7[200]): 40% is allocated proportionally to the number of top-level publications published in internationally renowned journals, the number of top-level research monographs (considering the scope of the data submitter's participation therein) and the number of patents and patent applications belonging to the research and development institution on the basis of relevant coefficients; 50% is allocated proportionally to the income accrued from the organisation of basic and applied research or development activities and recorded in the research and development institution's annual statement of financial performance; and 10% is allocated proportionally to the number of defended doctoral theses written on the basis of the university's nationally recognised curricula according to the data about the calendar year derived from the Estonian Education Information System.

The institutions that receive baseline funding are required to submit an annual report on the use of this funding. Reports from the recent years reveal significant differences between institutions concerning the use of baseline funding: some use the funds to cover staff costs, others mainly see it as a supplementary source of funding for creating new research directions and groups, some use it to contribute to the development of infrastructure. This kind of pattern indicates that the basic principle of baseline funding, according to which each research institution can use the respective funds according to their strategic needs, is fully justified.

As a result of the increase in the volume and share of baseline funding, the stable funding of research institutions will increase, which allows them to better shape their strategic choices and steer their development while also giving research institutions the opportunity to build research career models that offer better guarantees when it comes to tenures.

[199] Organisation of Research and Development Act (Teadus- ja arendustegevuse korralduse seadus - TAKS). (1997). Adopted by the Parliament of Estonia on 1st January 2015. - Riigi Teataja, I osa, 1997, nr. 30, art. 471. https://www.riigiteataja.ee/akt/104122014014 (30.11.2018).

[200] Teadus- ja arendusasutuste baasfinantseerimise määramise tingimused ja kord. Välja antud Haridus- ja teadusministri määrusega 7. septembril 2018. a. — Riigi Teataja I osa, 2005, nr. 34, art. 483. https://www.riigiteataja.ee/akt/116122010027?leiaKehtiv (05.11.2018).

From baseline funding to operational grant[201]

The increase in baseline funding alone is, however, not sufficient for maximising the impact of research. In order to make the activities of research institutions more effective, they must be more in line with societal expectations. This, however, requires ministries to consolidate the needs of society and communicate them to research institutions via funding instruments and conditions. Adopting research and development operational grants for research and development institutions would provide a good opportunity for this.

The concept of an operational grant has been used for funding higher education since 2013. In order to allocate an operational grant, contracts under public law are entered into with universities, in which the parties agree on their rights and obligations, liabilities and the procedure for allocating operational grants. In the annual funding agreement, which is entered into as an annex to the contract under public law, the parties agree on the main obligations arising from the university's mission, objectives and tasks and the state's needs, including, for example, the obligations related to the scope, quality and productivity of organising higher education instruction and the funding conditions and responsibilities related thereto.

Agreements that are entered into in this way provide a better opportunity to specify the activity areas arising from the tasks of institutions of higher education and to support areas of development that are of national importance. Other criteria characteristic to competitive higher education can also be considered—one can assess the internationalisation of universities, support services offered to students, cooperation with the business sector and the development of joint curricula—and use the results for allocating funds for activities.

Transitioning to R&D operational grants would also help to specify the state's expectations in relation to the direction and volume of research and development, agree on unique public tasks research and development institutions fulfil in the Estonian research system and to enter into agreements for business cooperation or developing new research areas. As a bonus, it would allow to align the negotiations and allocation of funding for research and development and higher education instruction, which would enhance the coherence of research and development and higher education and reduce the administrative load of universities.

The transition from baseline funding to R&D operational grants was first planned in the course of the legislative proceeding of the new Higher Education Act, but based on the feedback received from the round of approval, the idea was initially abandoned. The main reason for this lay in the need to specify the role of private sector research and development institutions in fulfilling the objectives of the research and development strategy and the specificities related to funding them. Therefore, it was decided to link the reshaping of baseline funding more clearly with specifying the role of different parties in the Estonian research and development system, discuss the topic thoroughly and agree on the strategy for the 2021+ period in the course of planning.

[201] In this article this term is referred to as an operational grant, whereas in previous articles as well as on the website of the Estonian Research Council, it is called a new model/concept of baseline funding (comment by editor).

KUST SA TEAD?

HOW DO YOU KNOW?

Karin Jaanson
Executive Director of the Estonian Research Council

Yuval Noah Harari, Israeli historian and professor at the Hebrew University of Jerusalem, author of several international bestsellers, has devoted one lesson to post-truth in his book 21 Lessons for the 21st Century published in 2018. He writes that although we have reason to worry, we also have opportunities to prevent the world from turning into a scary place. According to Harari, we are all obligated to invest time and effort into uncovering our biases and verifying our sources of information. He recommends that if we find some issue to be of utmost importance, we should make an effort to read the relevant scientific literature about it.[202]

As an open state, Estonia faces similar issues as the rest of the world. Post-truth and the fragility of truth concern us as well. Thus, we have to make a greater effort so that the decisions that impact our lives are based on evidence and science. We must also explain to the public what the limits of science are and how science can help us to get closer to the truth and solve both vast global problems as well as our daily issues. Regardless of our age, job or field of activity, we as citizens must be critical and demanding with respect to the information provided to us. Let us ask this simple question: "How do you know?" whenever it is necessary.

Science communication is only efficient and effective as a result of co-operation between different parties. However, a suitable form of co-operation is not easy to find. The campaign HurVetDuDet?[203] (How do you know that?) organised in Sweden

[202] Harari, Y. N. (2018). 21 Lessons for the 21st Century. London: Jonathan Cape, pp. 243.
[203] #Hurvetdudet? https://hurvetdudet.nu/english/ (07.12.2018).

during the 2018 parliamentary elections inspired the launch of a similar initiative in Estonia and different social groups and partner organisations joined forces for a common goal. Similar initiatives have been organised for quite some time in the US in the focus of the AAAS (American Association for the Advancement of Sciences, Advocacy for Evidence)[204] and in the UK (Ask for Evidence).[205]

The "How do you know?" initiative has been joined by universities, media outlets, non-governmental organisations, science centres, Estonian Research Council, journalists and science journalists, etc. For them, facts and evidence bear the utmost value in making decisions, including in policy-making, and they deem science an effective tool with which we can gain new knowledge and substantiate decisions.

In the framework of the initiative we will talk about the importance of verifying facts and claims as well as science-based politics in making decisions. We talk about science as the best method for studying and improving the world. We notice when claims are not substantiated and check the facts. We organise seminars. We involve partners, and ask "How do you know?" in cases which call for decisions or claims to be substantiated and encourage others to ask the same question.

Although the Estonian initiative focuses on the parliamentary elections held in the spring of 2019, we still hope that co-operation between partners and science-based discussion will continue further and take root in the society in general.

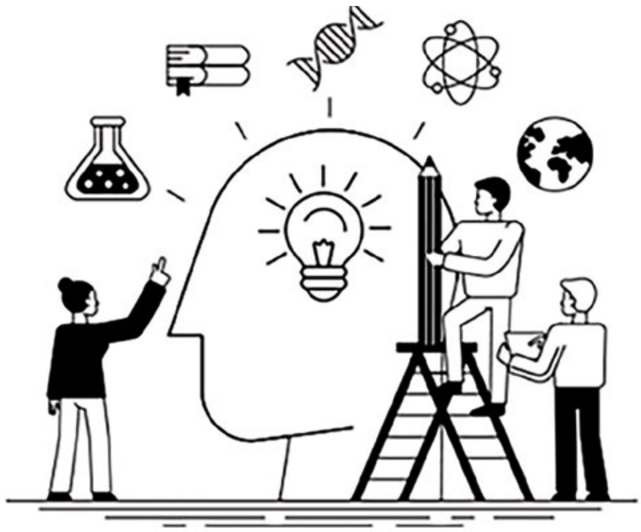
Let us together raise appreciation for politics that respect facts, scientific thought and understanding the world with the help of science.

Find out more about the initiative's activities at

www.kustsatead.ee
https://www.facebook.com/kustsatead

IF YOU CARE ABOUT FACTS AND RESEARCH-BASED DISCUSSION, ASK POLITICIANS:

"HOW DO YOU KNOW?"



[204] Advocacy for Evidence. American Association for the Advancement of Science. https://www.aaas.org/focus-areas/advocacy-evidence (07.12.2018).
[205] Ask for Evidence. http://askforevidence.org/index (07.12.2018).

Metrioptera bicolor, which has arrived in Estonia owing to global warming
Author: Veljo Runnel (Estonian Science Photo Competition 2017).

ESTONIAN RESEARCH AGREEMENT 2018[206]

A social agreement to ensure the further development of Estonian research and innovation

Sharing the common belief that research, development and innovation are strategically important for the well-being of the Estonian people and sustainability of society, the parties to this agreement confirm the need to guarantee the performance of the objectives agreed upon in the Estonian Research and Development and Innovation Strategy 2014–2020 "Knowledge-Based Estonia"[207] and undertake to commit to the achievement of these objectives. For this purpose, they agree upon the following:

1. the undersigned political parties, represented by their Chairpersons, are in favour of increasing the public funding of research, development and innovation to 1% of the gross domestic product and maintaining it at least on the same level in the future. To this end, the parties agree that it will be specified in the 2019 state budget strategy that the target level is to be reached within three years with the addition of equal funding amounts;

2. Estonian research institutions, represented by the President of the Board of Universities Estonia, an association uniting Estonian public universities, affirm that research institutions will establish the institutional arrangements required for conducting and providing further incentive for performing high quality research and cooperation between researchers and entrepreneurs;

3. Estonian researchers, represented by the President of the Estonian Academy of Sciences and the President of the Estonian Young Academy of Sciences, affirm that Estonian researchers will do their best to ensure that the resources at their disposal are used for research and development in a way that guarantees a balance between basic and applied research, with the primary focus on developing fields aimed at the advancement of the Estonian economy and society;

4. Estonia's largest business enterprise organisations, represented by the President of the Board of the Estonian Chamber of Commerce and Industry and the Chairman of the Estonian Employers' Confederation, affirm their readiness to contribute to making the Estonian economy more innovative and finding solutions for improving cooperation with Estonian researchers and research institutions.

Tallinn, 19 December 2018

Jüri Ratas, Chairman of the Estonian Centre Party
Kaja Kallas, Chairwoman of the Estonian Reform Party
Kaul Nurm, Chairman of the Estonian Free Party
Mihkel Kangur, authorised representative of the Biodiversity Party
Kristina Kallas, Chairwoman of Estonia 200
Züleyxa Izmailova, Chairwoman of Estonian Greens
Helir-Valdor Seeder, Chairman of Pro Patria
Jevgeni Ossinovski, Chairman of the Social Democratic Party
Mait Klaassen, President of the Board of Universities Estonia
Tarmo Soomere, President of the Estonian Academy of Sciences
Els Heinsalu, President of the Estonian Young Academy of Sciences
Toomas Luman, President of the Board of the Estonian Chamber of Commerce and Industry
Toomas Tamsar, Chairman of the Estonian Employers' Confederation

[206] Translation form the original in Estonian (see page 79)

[207] Estonian Research and Development and Innovation Strategy 2014-2020 "Knowledge-based Estonia". (2014). Ministry of Education and Research. https://www.hm.ee/sites/default/files/estonian_rdi_strategy_2014-2020.pdf (24.10.2018).

Eesti teaduslepe
Ühiskondlik kokkulepe Eesti teaduse ja innovatsiooni arengu kindlustamiseks

Jagades ühist veendumust, et teadus, arendustegevus ja innovatsioon on Eesti inimeste heaolu ja ühiskonna kestlikkuse jaoks strateegiliselt määrava tähtsusega, kinnitavad käesoleva kokkuleppe osapooled vajadust kindlustada strateegias „Teadmistepõhine Eesti 2014–2020" kokku lepitud eesmärkide täitmine ning kohustuvad pühenduma nende eesmärkide saavutamisele. Selleks lepitakse kokku alljärgnevas:

1. Alla kirjutanud erakonnad, keda esindavad nende esimehed, toetavad teadus- ja arendustegevuse ning innovatsiooni avaliku sektori rahastamise tõstmist 1%-ini sisemajanduse koguproduktis ning edasist hoidmist vähemalt samal tasemel. Selleks lepitakse kokku, et 2019. aastal nähakse riigieelarve strateegias ette sihttasemeni jõudmine kolme aasta jooksul võrdsete summade lisandumisega;
2. Eesti teadusasutused, keda esindab avalik-õiguslike ülikoolide Rektorite Nõukogu juhatuse esimees, kinnitavad, et teadusasutused tagavad kõrgetasemelise teaduse ning teaduse ja ettevõtluse koostöö läbiviimiseks ning täiendavaks motiveerimiseks vajaliku institutsionaalse korralduse;
3. Eesti teadlased, keda esindavad Eesti Teaduste Akadeemia president ning Eesti Noorte Teaduste Akadeemia president, kinnitavad, et Eesti teadlased annavad oma parima selleks, et nende käsu… teadus- ja arendustöö viisil, mis … rakendusteaduse vahel eelisarendades … arengule suunatud valdkondi;
4. Eesti suurimad ettevõtlusorganisatsio… Kaubandus-Tööstuskoja juhatuse esimees… juhataja, kinnitavad oma valmisolekut … innovaatilisemaks muutmisele ja otsida … koostööks Eesti teadlaste ja teadusasutust…

Tallinn, 19. detsember 2018

Eesti Keskerakonna esimees Jüri Ratas

Eesti Konservatiivse Rahvaerakonna esimees Mart Helme

Eesti Reformierakonna esimees Kaja Kallas

Eesti Vabaerakonna esimees Kaul Nurm

Elurikkuse Erakonna volitatud esindaja Mihkel Kangur

Erakonna Eesti 200 esimees Kristina Kallas

Erakonna Eestimaa Rohelised esimees Züleyxa Izmailova

Erakonna Isamaa esimees Helir-Valdor Seeder

Sotsiaaldemokraatliku Erakonna esimees Jevgeni Ossinovski

Rektorite Nõukogu juhatuse esimees Mait Klaassen

Eesti Teaduste Akadeemia president Tarmo Soomere

Eesti Noorte Teaduste Akadeemia president Els Heinsalu

Eesti Kaubandus-Tööstuskoja juhatuse esimees Toomas Luman

Eesti Tööandjate Keskliidu juhataja Toomas Tamsar

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