



ESTONIAN RESEARCH 2022

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Estonian Research Council
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INTRODUCTION

ANU NOORMA

Director General, Estonian Research Council

A small country with scarce natural resources needs a strong research community and excellent universities to ensure the continuation of future generations who will further improve the society. There is a growing recognition in Estonia and elsewhere in the world that investing in research and development may be the only possible way of increasing the country's standard of living. Investing in research and development is investing in the future – it is not a cost to cut back on during difficult times.

On the one hand, the Government of Estonia has allocated successively higher amounts from the national budget to research and development (R&D) in recent years, but the research community is expecting a further increase in funding, as the government committed itself to spending at least 1% of gross domestic product (GDP) on public R&D. On the other hand, politicians and the society are also entitled to know what researchers are doing with this money. In order to do that, more emphasis should be placed on talking about science in a continuous manner.

The long-term development strategy 'Estonia 2035',¹ which aims to increase and support the welfare of our people, was recently approved. In this strategy, the role of knowledge and research is highlighted in implementing the necessary changes. The new Estonian Research and Development, Innovation and Entrepreneurship Development Plan focuses even more intensely than before on enhancing the impact of research and researchers and on maximising the use of research results to resolve the development needs of Estonia. Are both our organisation of research and research community prepared for this?

In *Estonian Research 2022*, the characteristics of Estonian research in 2022 are discussed on the basis of facts and figures: what is the state of play regarding funding in this area and what progress has been made, where do we fit in on the international scene, what are the strengths and weaknesses of Estonian research, are we raising enough future scientists and researchers, and, finally, do research results actually correspond to the needs of the society?

This overview follows the tradition of previous similar overviews – *Estonian Research 2016*² and *Estonian Research 2019*³. For the sake of comparability, the main structure of the overview is similar to the previous one, consisting of two interrelated parts. The first part includes four main articles which explore the resources needed for conducting scientific research: monetary resources on the one hand and human resources on the other. The next two articles describe the performance of Estonian research, focusing on publishing activity and the (international) performance in raising funds as well as the economic impact of research. The data presented in the articles of the first part are comparable to the data provided in the previous two overviews,

making it possible to examine past performance and assess the progress made, should similar overviews be also published in the future. The second part of the overview comprises short articles on topical issues in discussions on research policy.

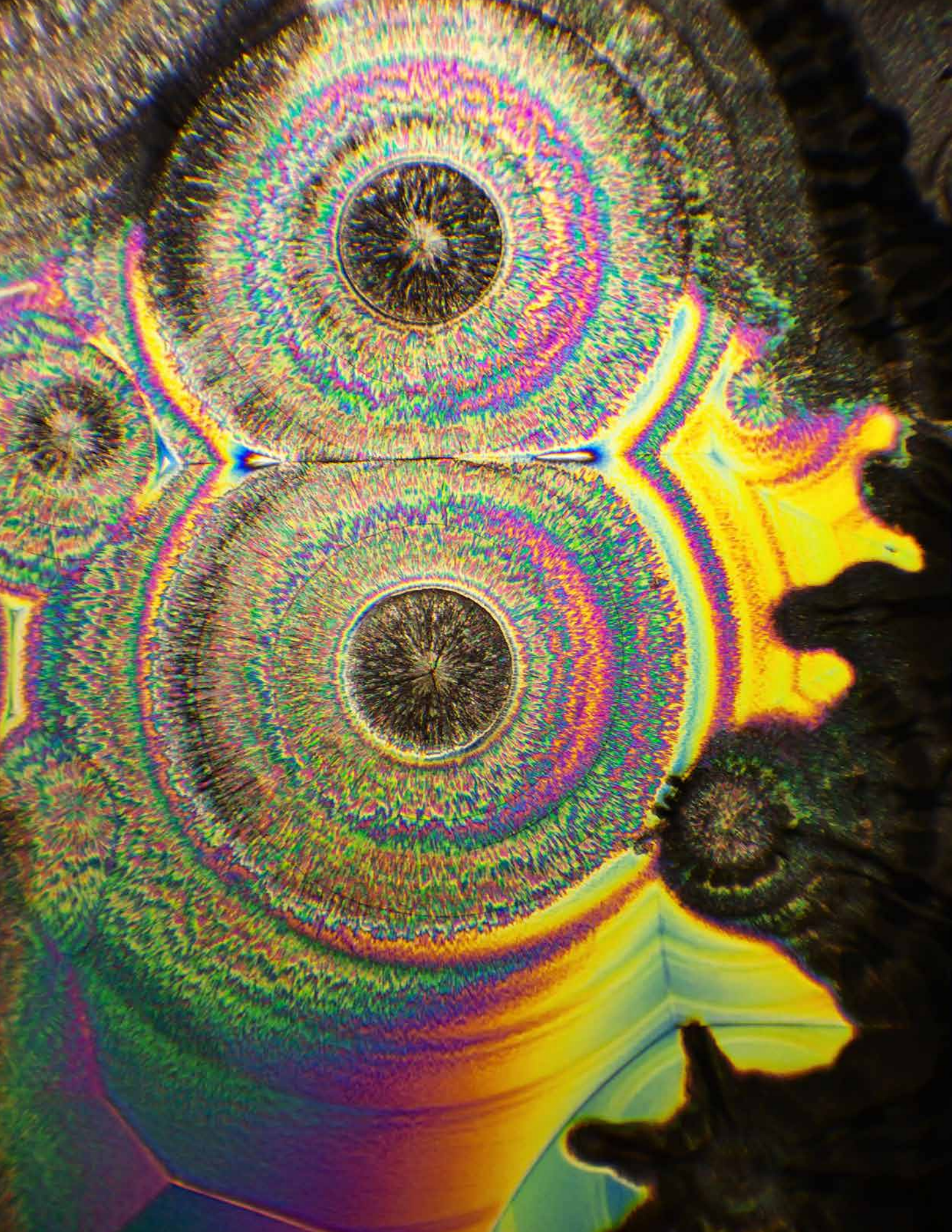
This overview is also special in that it is published on the tenth year of operation of Estonian Research Council. By 2012, re-independent Estonia had completed all its most difficult restructuring operations. It was also time to enter a new phase of development in organisation of research, as a result the Organisation of Research and Development Act was amended and the Estonian Research Council was established. A retrospective look on the origin and activities of the Estonian Research Council is provided by its long-standing Director Andres Koppel. Estonian organisation of research would not be the same without his dedication and hard work.

Estonian Research 2022 and all its figures and datasets are available on the website of Estonian Research Council (the same also applies to previous overviews). The compilation of this publication was overseen by the editorial board consisting of University of Tartu Professor Jaak Vilo, Tallinn University Professor Marek Tamm, Head of the Foresight Centre Tea Danilov, Head of Department of Research Funding at Estonian Research Council Siret Rutiku, and Executive Director of Estonian Research Council Karin Jaanson. The staff of the Department of R&D Analysis at Estonian Research Council as well as the staff of the Estonian Research Information System (ETIS) provided their assistance in compiling all the material. A special thanks to Tiina Pärson, Leading Analyst at Statistics Estonia, and Ingrid Jaggo, Analyst at Estonian Ministry of Education and Research, for their assistance in everything related to data and content. We would also like to extend our thanks to all the authors of the articles and photographs used in this publication.

The overview includes the most recent data available at the time of compiling the publication (end of 2021). Since the compilation of international data often takes up to a year or more, some statistical data date back a few years. The overview mainly relies on data reported by OECD, Eurostat, the Estonian Ministry of Education and Research, Universities Estonia, and Estonian Research Council (including the Estonian Research Information System).

We hope that the articles and data provided in this overview present a comprehensive picture of the current status of Estonian research, offer some food for thought, and provide support in fact-based discussions on how to further promote Estonian research. The publication may thus be of interest to researchers, politicians, officials, and all others interested in research. The overview is also published in English to introduce Estonian research at international level.

1 'Estonia 2035' Development Strategy. Government of the Republic of Estonia. <https://valitsus.ee/strateegia-eesti-2035-arengukavad-ja-planeering/strateegia> (22.11.2021).
 2 Estonian Research Council. (2016). *Estonian Research 2016* (ed. K. Raudvere). <http://dx.doi.org/10.15158/DISS/0002> (22.11.2021).
 3 Estonian Research Council. (2019). *Estonian Research 2019* (ed. K. Raudvere). <http://dx.doi.org/10.15158/DISS/0003> (22.11.2021).



ESTONIAN RESEARCH SYSTEM

KADRI RAUDVERE

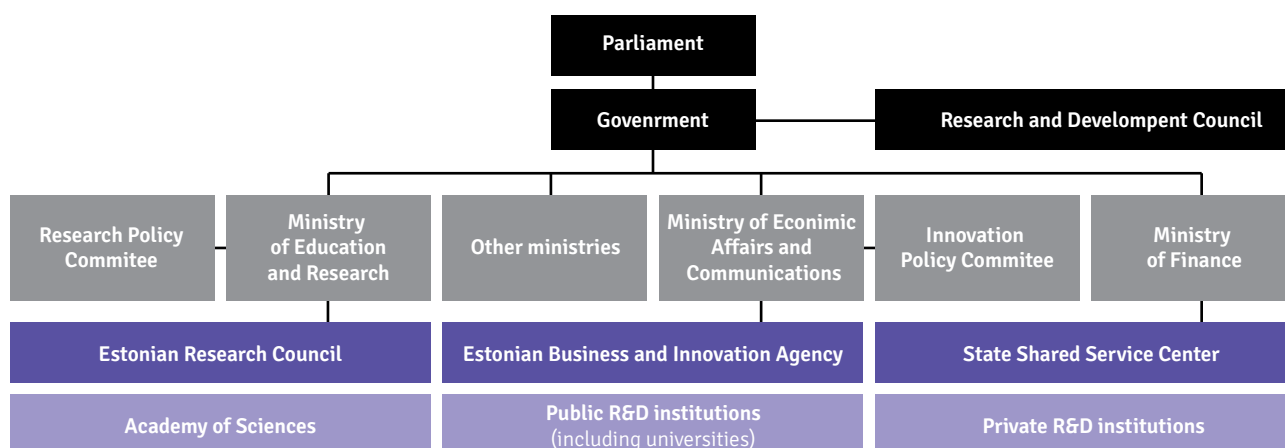
R&D Analyst, Estonian Research Council

The legal basis for the functioning of the Estonian research system is established in the Organisation of Research and Development Act.⁴ The below scheme 'The research and development organisation structure in Estonia' provides an overview of the Estonian research system and all its parts. The different parts of the system have the following functions.

- The Government of the Republic, together with the parliament, shapes policy. The parliament approves the Estonian Research and Development, Innovation and Entrepreneurship Development Plan and state budget for research. Once a year the Prime Minister provides the parliament with an overview of the execution of the development plan.⁵
- The Research and Development Council,⁶ comprising four ministers and eleven members appointed by the government,⁷ guides the national research and development policy and advises the government in such matters.
- Ministries prepare and implement sectoral policies. The Research Policy Committee⁸ and the Innovation Policy Committee of the Ministry of Economic Affairs and Communications⁹ are advisory bodies to the Estonian Ministry of Education and Research.

- The Estonian Research Council within the area of responsibility of the Estonian Ministry of Education and Research and the State Shared Service Center, which operates under the supervision of Ministry of Finance are the principal state foundations organising research. Estonian Business and Innovation Agency is the principal institution funding innovation within the area of responsibility of the Ministry of Economic Affairs and Communications.
- Both public sector (primarily universities) and private sector research institutions carry out research and development activities. The majority of Estonian researchers are employed by universities where most of the research is conducted.

Additionally, the Estonian Academy of Sciences,¹⁰ which is an independent association of top-level researchers aimed at contributing to the development and representation of Estonian research, promoting the application of research in economic and social practice in Estonia, and enhancing Estonian research and scientific thinking, acts on the basis of its own law.



The research and development organisation structure in Estonia

Source: Estonian Research Council.

4 Organisation of Research and Development Act. Passed by Riigikogu on 26 March 1997. – Riigi Teataja I 1997, 30, 471. Translation published 03.06.2019. <https://www.riigiteataja.ee/en/eli/524032014005/consolidate/current> (24.09.2021).

5 Estonian Research and Development, Innovation and Entrepreneurship Development Plan 2021–2035. Estonian Ministry of Education and Research. https://www.hm.ee/sites/default/files/taie_arengukava_kinnitatud_15.07.2021.pdf (24.09.2021).

6 Research and Development Council. Government of the Republic. <https://www.valitsus.ee/valitsuse-eesmargid-ja-tegevused/teadus-ja-arendusnoukogu-tan> (24.09.2021).

7 Approval of the membership of the Research and Development Council. Passed by the Government of the Republic of Estonia on 21 November 2019. – Riigi Teataja III, 2019, 281. Online: <https://www.riigiteataja.ee/akt/326112019002> (24.09.2021).

8 Research Policy Committee. Estonian Ministry of Education and Research. <https://www.hm.ee/et/teaduspoliitika-komisjon> (24.09.2021).

9 Approval of the membership of the Innovation Policy Committee. Passed by the Government of the Republic of Estonia on 31 January 2019. – Riigi Teataja, III, 2019, 22. <https://www.riigiteataja.ee/akt/305022019001> (24.09.2021).

10 Estonian Academy of Sciences. www.akadeemia.ee (24.09.2021).

ESTONIAN RESEARCH INSTITUTIONS

Upon regular evaluation, i.e. external evaluation¹¹, research of a specific field of the R&D institution is assessed, comparing it with the internationally recognised criteria. **Twenty two Estonian research institutions** have successfully passed regular evaluation in at least one field, including 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 R&D institutions acting within the area of responsibility 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 within the area of responsibility of the Ministry of Social Affairs; the Estonian National Museum within the area of responsibility of the Ministry of Culture; and the Estonian Crop Research Institute within the area of responsibility of the Ministry of Rural Affairs. Only one public

research institute operates pursuant to its own separate act: the National Institute of Chemical Physics and Biophysics. The Under and Tuglas Literature Centre acts under the Estonian Academy of Sciences.

Eight private research institutions have successfully passed evaluation: AS Cybernetica, OÜ Protobios, OÜ BioCC, AS Tervisetehnoloogiate Arenduskeskus (Competence Centre on Health Technologies), AS Toidu- ja Fermentatsioonitehnoloogia Arenduskeskus (Centre of Food and Fermentation Technologies), OÜ STACC, OÜ Icosagen Cell Factory, and AS Metroser, the Central Office of Metrology in Estonia. Only one private university, the Estonian Business School, has passed evaluation.

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

PRIMARY INSTRUMENTS FOR THE STATE FUNDING OF RESEARCH IN ESTONIA

The primary R&D funding instruments financed from the state budget are baseline funding and research grants. Structural funds financed by the European Union also contribute a substantial share of the public R&D funding, these are considered part of the state budget in Estonia. Baseline funding means the financing of research and development for the purpose of attaining the development objectives of a research and development institution, including funding allocated for co-financing national and foreign projects, opening new fields of research, and for investing in infra-

structure. The Estonian Ministry of Education and Research organises baseline funding.¹²

Research grants means funding allocated for funding activities necessary for the implementation of high-level research and development projects. Competitions for research grants are organised by the Estonian Research Council, and applications are assessed and grants are awarded by the Estonian Research Council's Evaluation Committee.

IMPORTANT TERMS AND THE METHODOLOGY USED¹³

The use of terminology and the presentation of statistics in this overview is generally based on the methodology set forth in the Frascati Manual¹⁴. National statistical offices also use the same methodology for collecting statistics, including Statistics Estonia¹⁵.

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

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

The understanding of individual entities within the public and private sectors is based on international methodology, according to which:

- **business enterprise sector** – includes all enterprises, organisations and institutions whose main activity is the production of goods or the provision 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 associated with them or under their direct control (research institutes, clinics, scientific centres, etc.), regardless of their source of funding and legal status;
- **government sector** – includes agencies and offices funded by the state or the local government whose main activities are not related to the production of goods or the provision services and which do not belong to the higher education sector, additionally, this sector includes non-profit institutions primarily financed by the state;
- **private non-profit sector** – includes non-profit organisations, societies, funds, and their research units (excluding those primarily funded by the state and those serving private enterprises).

11 R&D Evaluation. Estonian Research Council. <https://www.etag.ee/en/activities/rd-evaluation/> (25.09.2018).

12 Baseline funding and Centres of Excellence in Research. Estonian Ministry of Education and Research. <https://www.hm.ee/et/tegevused/teadus/baasfinantseerimine-ja-tippkeskused> (25.09.2021).

13 Research and development. Statistical presentation. 3.4. Terms and definitions. Statistics Estonia. <https://www.stat.ee/en/find-statistics/methodology-and-quality/esms-metadata/21701#4-Unit-of-measure-3> (29.09.2021).

14 OECD. Frascati Manual 2015. <http://oe.cd/frascati> (05.10.2021).

15 Statistics Estonia. Terms. https://andmed.stat.ee/vana/pub/Dabase/Majandus/19Teadus._Tehnoloogia._Innovatsioon/04Teadus-_ja_arendustegevus/02Teadus_ettev_sektoris/TD_21.html (05.10.2021).

The higher education, government, and private non-profit sectors are also called the non-profit sector to distinguish them from the business sector.

Research and development (R&D) – 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. Research and development covers three types of activity: basic research, applied research and experimental development.

Research and development personnel

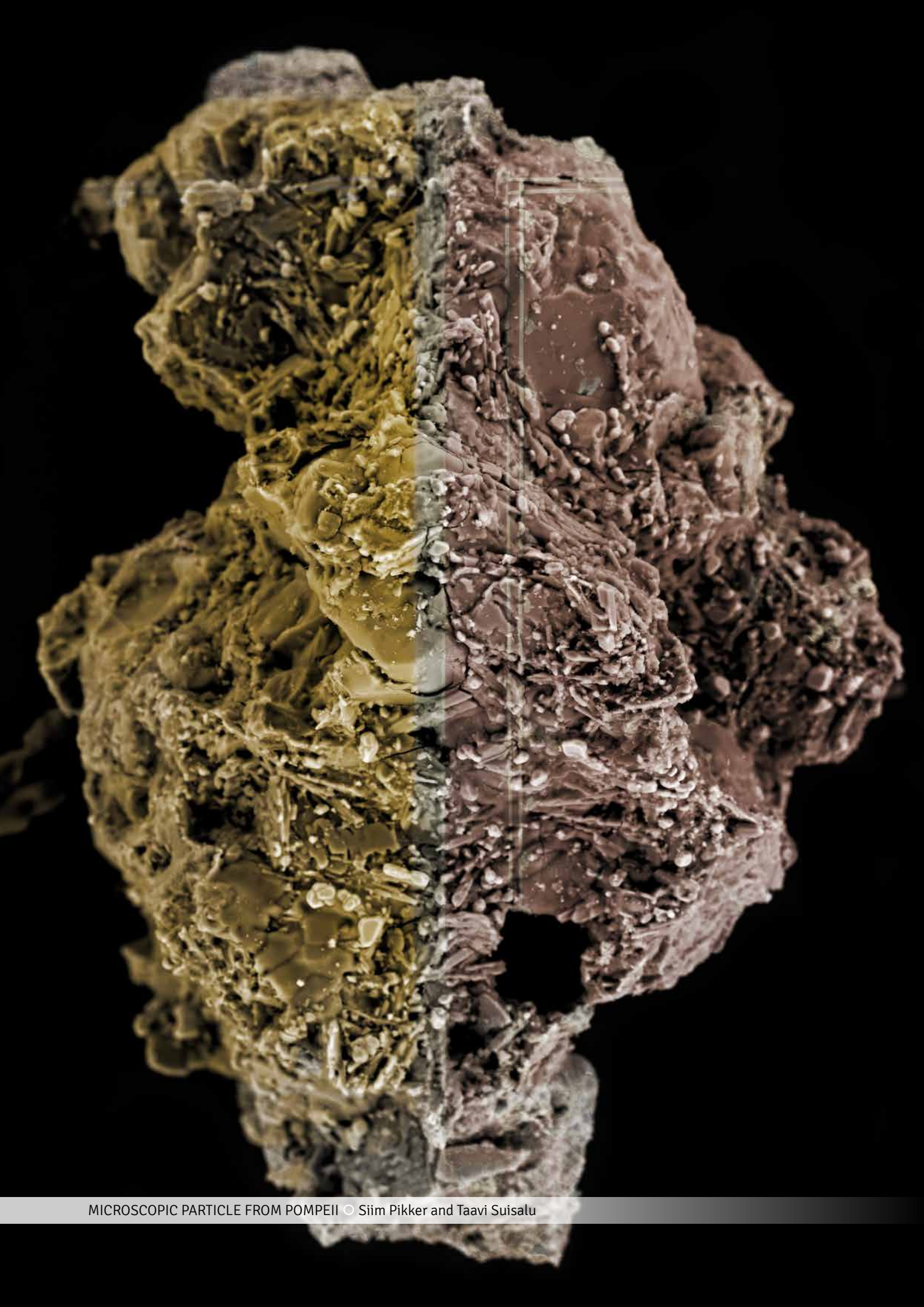
Employee – an individual who sells their labour to an employer (concludes an employment relationship with the employer) and receives financial remuneration for their work (salary, wages, fee, gratuity, piecework pay, compensation, etc.). An employee is engaged in R&D if at least 10% of their working time is taken up by R&D activities.

Research and development personnel is divided into the following three categories:

- **researchers and engineers** (hereinafter ‘researchers’) – individuals with a degree or higher-education diploma who conduct basic and applied research or experimental development as professionals to create new knowledge, products, processes, methods and systems; all teaching staff, including all heads of research institutions and their subdivisions, who plan or manage scientific and technical projects; doctoral students and master’s students conducting original investigation. This category does not include, for example, individuals who are employed in the position of a research fellow or engineer but who do not have a higher education, routine analysts, bibliographers or programmers, they are considered technicians;

- **technicians** – individuals engaged in R&D who have a vocational or technical certificate and who work under the leadership of researchers or engineers; employees working under the leadership of researchers and engineers in the social sciences and humanities field are equal to technicians;
- **supporting staff** – employees, officials and secretaries who participate in or are directly involved with R&D projects.

Research and development personnel does not include, for example, security guards, cleaning staff, caterers, accountants, HR specialists, librarians, IT maintenance staff, equipment maintenance staff. If the individuals included in the aforementioned list provide services to R&D institutions, their labour costs will be calculated from other current R&D expenditure.



MICROSCOPIC PARTICLE FROM POMPEII ○ Siim Pikker and Taavi Suisalu

R&D INVESTMENTS

Options and choices for the funding of R&D

KARIN JAANSON

Executive Director, Estonian Research Council

ANU NOORMA

Director General, Estonian Research Council

WHY DO TAXPAYERS HAVE TO FINANCE RESEARCH?

The public sector, mainly the state, provides substantial funding to research. Local governments play only a small part in research and development (R&D) funding in Estonia. Since the public contribution is so large, it is fair to ask why taxpayers should finance research. From the point of view of an economist, the answer is simple: it is a public good that has positive impacts and benefits the society as a whole. In Estonia, the value of research is primarily assessed by the economic benefits it brings and people want research to have an even greater impact on our economy – for the number of research-intensive enterprises, their investment in R&D and the productivity of workforce to increase. Measuring the value of research solely in terms of economic benefits is too limited as it does not show its wider societal benefits. A number of calculations have been made on this topic, including by the European Commission,¹⁶ and many of these show that the money invested in research delivers multiple benefits to the society in the form of new knowledge, educated citizens, new job opportunities, etc.

In the age of big data, it is not difficult to find links between research and societal benefits. Researchers in the USA¹⁷ integrated large-scale datasets that included scientific publications, government documents, news media articles, and marketplace invention information to study the links between scientific publications and the public uses of science. They concluded that the public uses of science are highly diverse and differ from one research field to another. For example, the research results obtained in the field of computer science, materials science and mathematics are primarily used in patents and less commonly used in government documents and news. All in all, it is important to invest public money in research and development because knowledge spill-overs generate benefits for society.

A targeted and well-functioning funding system is an essential prerequisite for high-level research and its major impact. Public funding for R&D activities is of great importance to the sound development of the society and the implementation of innovation policy; additionally, it also acts as a catalyst for private R&D investments. Therefore, the 'Social Agreement for the Development of Science and Innovation' concluded in December 2018, signed by the chairmen of eight political parties and the representatives of researchers and entrepreneurs,¹⁸ can be seen as a great victory for the development of our country. The so-called one-percent research agreement marks a new period in the public funding of research, the impact of which can only be assessed in the future. This new period could also be called the period of proportional or formula funding.

Unlike in previous years, when the Government of the Republic of Estonia allocated R&D funding each year on the basis of the proposals of ministries, the Research and Development Council has now determined proportions on the basis of which ministries will receive the additional funding for achieving 1% of GDP. The main proportions which must be followed are:

- 1) 40% for research development measures, allocated to the Estonian Ministry of Education and Research;
- 2) 40% for business R&D and innovation promotion and scientific cooperation measures, allocated to the Ministry of Economic Affairs and Communications;
- 3) 20% for R&D and innovation measures supporting research-driven sectoral policies and the achievement of sectoral targets, allocated to all ministries.¹⁹

16 Directorate-General for Research and Innovation at the European Commission. (2017). The Economic Rationale for Public R&I Funding and its Impact. <https://op.europa.eu/en/publication-detail/-/publication/0635b07f-07bb-11e7-8a35-01aa75ed71a1/language-en> (26.10.2021).

17 Yin, Y., Dong, Y., Wang, K., Wang, D., and Jones, B. (2021). Science as a Public Good: Public Use and Funding of Science (No. w28748). National Bureau of Economic Research. <https://www.nber.org/papers/w28748> (26.10.2021).

18 Estonian Research Council. (2018). A social agreement to ensure the further development of Estonian research and Innovation. <https://www.etag.ee/wp-content/uploads/2019/05/Estonian-Research-Agreement-2018-ENG.pdf> (21.01.2022).

19 Government Office. Minutes of the Research and Development Council meeting No. 78 of 13 February 2019. https://vv.riigikantselei.ee/sites/default/files/riigikantselei/strateegiaburoo/tan/tan_protokoll_13.02.2019.pdf (26.10.2021).

The Research and Development Council has recommended that a specific formula be used for the allocation of the 20% of funding between ministries for the 2022–2024 period. The formula provides that the base amount which comprises 50% of additional funding allocated to ministries be divided in half: one half (25% of the total amount) is distributed proportionally on the basis of R&D expenditure within the last three years and the other half (also 25% of the total amount) is distributed evenly between research fields. According to the recommendation of the Research and Development Council, the remaining 50% is allocated to different ministries upon request on a competitive basis for the financing of nationally important R&D and innovation initiatives.²⁰

In 2021, the Research and Development Council recommended that two applications of the Ministry of the Interior

(establishment of a remote sensing R&D centre and developing the Estonian Academy of Security Sciences into an internal security centre) and two applications of the Ministry of Rural Affairs (programmes ‘The precondition for the export of Estonian agri-food products is food safety’ and ‘The sustainability of agriculture and competitiveness of the food sector’) be supported.²¹

The recommendation given by the Research and Development Council in early 2020 to change the current method for determining the volume of grants awarded by the Estonian Research Council is also of key importance. This recommendation was triggered by the rigid and outdated principle that the new fields of research funding volumes should be based on the volume of grants that are ending, without taking into account changes in society.

HOW MUCH DO WE INVEST IN R&D?

A research and development intensity indicator, showing R&D expenditure as a percentage of gross domestic product (GDP), is used worldwide to set national development targets and measure their achievement. This simple and fairly easily measured indicator alongside other indicators assists in R&D policy formulation and provides an indication of the state’s research intensity and level of development.

The state budget for 2021,²² for the first time, allocated 1% of GDP or 286.4 million euros to research and development. This meant that research funding increased by almost a quarter – 56 million euros – compared to the previous year. The additional resources were allocated according to the recommendation of the Research and Development Council: 22.4 million euros to the Estonian Ministry of Education and Research, the same amount was also given to the Ministry of Economic Affairs and Communications, and other ministries received 11.2 million euros. The state budget for 2022 also allocates 1% of GDP or 323.7 million euros to research and

development. Whether it is sufficient or not mainly depends on how and where we invest and what the impact of those investments is.

The level of R&D expenditure in Estonia in the last five years shows that we have overcome the previous stagnation and there is an upward trend (Figure 1.1). The faster growth of private sector expenditure compared to the growth of public sector expenditure (including state and higher education institutions) is particularly positive. Private sector R&D investments have once again exceeded the volume of public sector investments since 2019. Public sector expenditure is still largely dependent on measures funded by the Structural Funds. The volume of Structural Funds measures in the research budget of the Estonian Ministry of Education and Research (together with state co-financing) has fluctuated between 63 and 88 million euros in 2011–2020, constituting 40–60% of the total research budget of the ministry.²³

20 Government Office. Minutes of the Research and Development Council meeting No. 6-1/89 of 31 August 2021. <https://dhs.riigikantselei.ee/avalikteave.nsf/documents/NT00388B8A/%24file/TAN21P89.pdf> (09.12.2021).

21 Government Office. Minutes of the Research and Development Council meeting No. 6-1/90 of 21 September 2021. <https://dhs.riigikantselei.ee/avalikteave.nsf/documents/NT00388E7A/%24file/TAN21P90.pdf> (09.12.2021).

22 Ministry of Finance. State budget. <https://www.rahandusministeerium.ee/et/eesmargidtegevused/riigieelarve-ja-majandus/riigieelarve-ja-majandusulevaated> (20.11.2021).

23 Estonian Research Council. Statistics on R&D funding in Estonia. <https://www.etag.ee/tegevused/uuringud-ja-statistika/statistika/teadus-ja-arendustegevuse-rahastamise-yldepilt/> (26.10.2021).

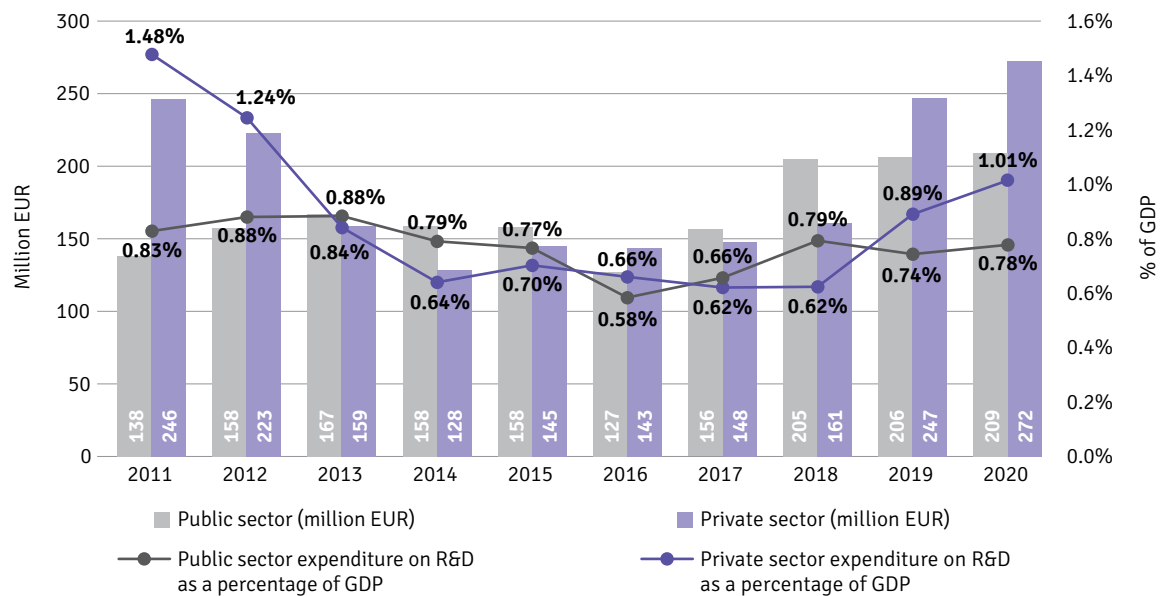


Figure 1.1. Gross domestic expenditure on R&D in Estonia as a percentage of GDP from 2011 to 2020

Source: Statistics Estonia,²⁴ calculations by Estonian Research Council.

Most countries seem to be aware of what level of R&D investment is sufficient for them and have set the achievement of this level as an objective in their strategy documents (Figure 1.2). Estonia has also done this. We had already set the objective of increasing our total R&D expenditure to 3% of GDP by 2014 in the R&D Strategy 'Knowledge-based Estonia' (2007–2013).²⁵ This goal was, and still is, very ambitious. Several other countries, such as Denmark, Germany, Belgium and Slovenia, have also set the same goal. Nordic countries Finland and Sweden have set significantly higher targets: 4.5% of GDP. They are justified in setting such high targets, as they already achieved the goal of 3% of GDP several years ago. Most countries have set very ambitious goals but the achievement of those goals requires time and political will. Which is why only a few have drawn closer to their target. Estonia is one of the countries where the gap between the target and the actual level is still very large. The public sector funding goal (1% of GDP) was 0.22 percentage points below the target in 2020, with regard to the private sector goal (2% of GDP), the actual volume should

have been more than double to achieve the target.

On the international scene, we have been at the bottom of the list among the OECD states in R&D intensity for years (Figure 1.2). We have obviously invested too little in our R&D activities. It is private investments that are too low to increase our productivity and well-being. In 2014, private sector investment in R&D in Estonia was 0.64% of GDP, whereas the EU average (EU 28) in the same year was almost double that figure (1.33%). In 2020, the gap narrowed slightly – Estonian private sector invested 1.5 times less (1.01% of GDP) than the EU 28 average (1.46% of GDP) – but, compared to the top countries, our indicator is more than two and a half times lower. However, our public sector expenditure is higher than the EU average (in 2020, 0.78% in Estonia and EU average 0.70%).²⁶ In terms of this indicator, we have reached the top 8 among EU countries. The following countries are ahead of us: Denmark (1.18%), Germany (1.02), Sweden (0.98%), Austria (0.97%), Finland (0.94%), Belgium (0.93%) and Greece (0.79%).

²⁴ Statistics Estonia. www.stat.ee (Estonian data) (02.12.2021).

²⁵ Knowledge-based Estonia: Estonian research and development and innovation strategy 2007–2013. <https://cs.ioc.ee/excs/policy/teadm-pohine-eesti2-en.pdf> (21.01.2022).

²⁶ Eurostat. <https://ec.europa.eu/eurostat/data/database> (26.10.2021).

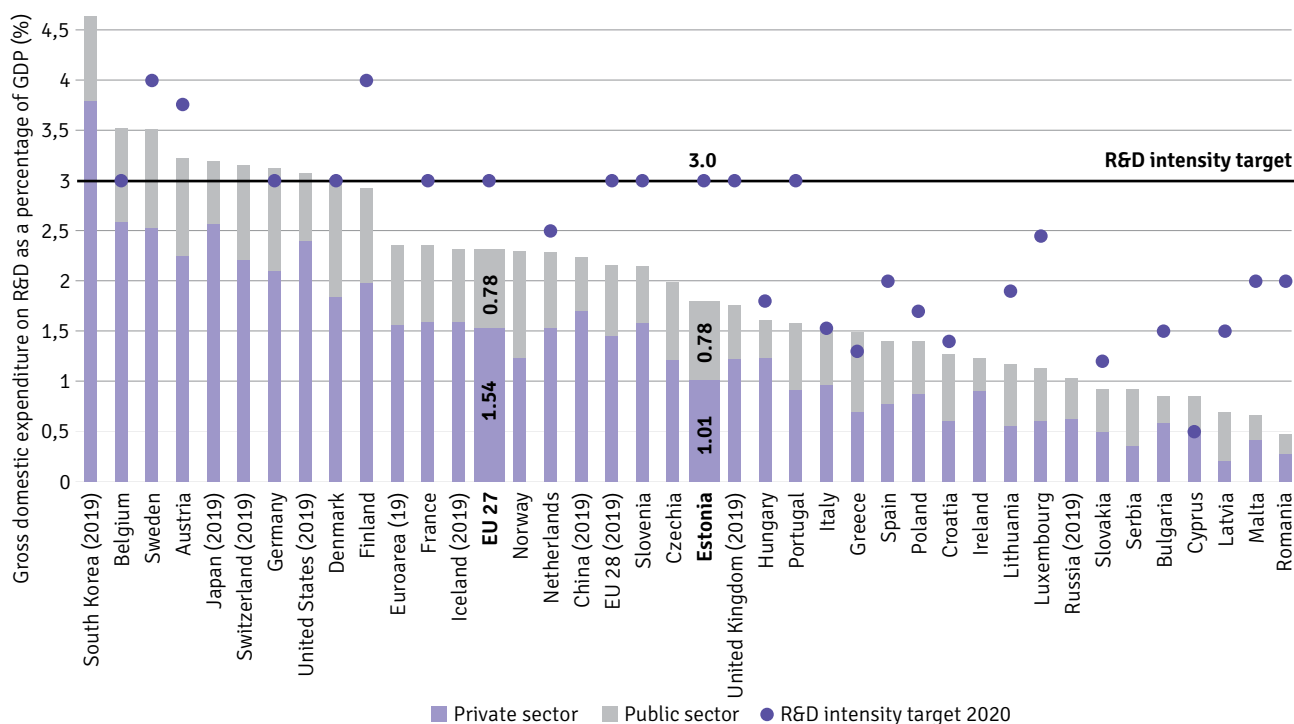


Figure 1.2. Gross domestic expenditure on R&D as a percentage of GDP in 2020

Source: Eurostat,²⁷ calculations by Estonian Research Council.

Following the example of other developed countries, Estonia has set a strategic goal of achieving a ratio of 1 to 2 in public and private R&D expenditure. Now that the public sector objective of 1% has been achieved, we need to boost the private sector in achieving their objective of 2%. This involves identifying appropriate policy instruments and creating an innovation-friendly environment to motivate enterprises to invest more. The resources of national R&D and innovation policies are very diverse, including both direct

grants and tax incentives (Figure 1.3). In 2020, 33 of the 37 OECD countries implemented tax incentives to support the growth of private R&D activities. The four countries that did not provide tax incentives to their enterprises were Estonia, Finland, Latvia and Luxembourg.²⁸ The use of tax incentives has significantly increased over the 2000–2020 period: in 2000, only 20 countries offered tax incentives to enterprises (out of 37), whereas in 2020, the number was already 33.²⁹

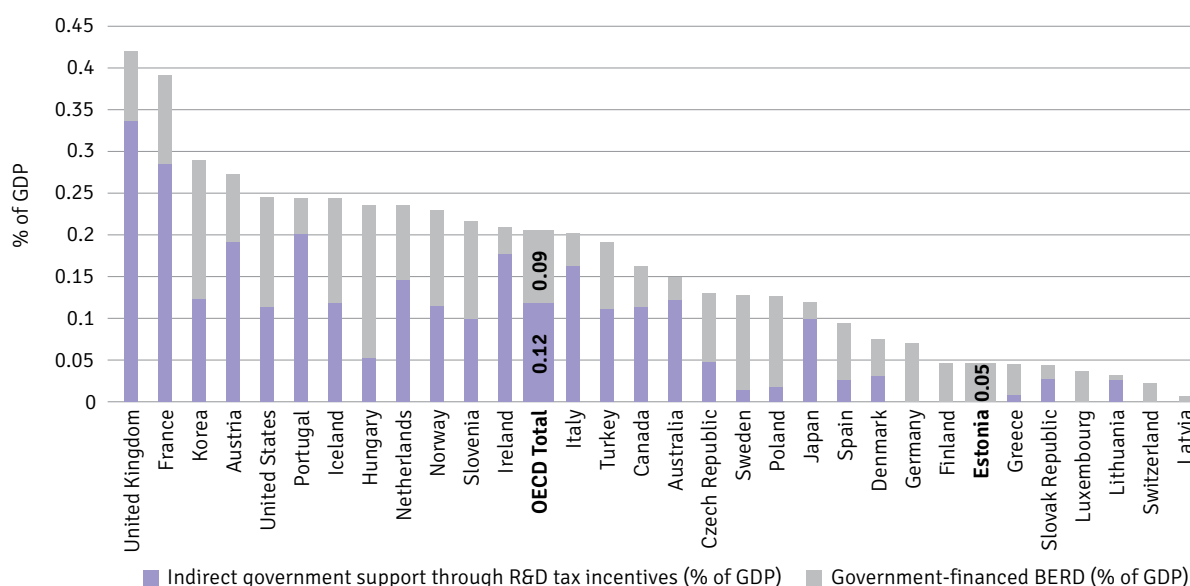


Figure 1.3. Tax support (indirect support) and direct government funding for business R&D in 2019 (% of GDP) (or another year for which recent data is available)

Source: OECD.³⁰

²⁷ Eurostat. <https://ec.europa.eu/eurostat/data/database> (10.12.2021).

²⁸ González Cabral, A., S. Appelt and T. Hanappi (2021), "Corporate effective tax rates for R&D: The case of expenditure-based R&D tax incentives", OECD Taxation Working Papers, No. 54, OECD Publishing, Paris, <https://doi.org/10.1787/ff9a104f-en>.

²⁹ OECD. OECD R&D tax incentives database (2020). <https://www.oecd.org/sti/rd-tax-stats-database.pdf> (16.11.2021).

³⁰ OECD. OECD R&D tax incentives database (2021). <https://oe.cd/rdtax> (16.12.2021).

OECD studies show that tax incentives increase R&D investments by enterprises as well as the number of enterprises that invest in R&D activities. While direct funding allows for better targeting of the support, tax incentives have a greater impact on the wider distribution of R&D activities in enterprises.³¹ In the case of tax incentives, the state does

not determine priority areas, which encourages more enterprises to invest. The widespread use of tax incentives among developed countries clearly indicates that sooner or later a discussion on this topic must be established and appropriate solutions must be determined to encourage enterprises to invest more in R&D activities.

WHERE DOES THE MONEY COME FROM AND WHERE DOES IT GO?

Now that politicians have made commitments to maintain public R&D funding at 1% of GDP and the government has kept this promise in the preparation of the 2021 state budget, it is important to understand what this all means and draw a distinction between R&D funding and expenditure. Data on R&D funding can be obtained from the state budget – this shows how much the states plans to invest in R&D. Data on expenditure is collected by Statistics Estonia.

Statistics Estonia measures the volume of expenditure on R&D activities by means of a survey which by regulation is mandatory for all EU countries to conduct. This ensures comparability between Member States over time and in content.³² The data collected by Statistics Estonia meets the definitions of the 2015 Frascati Manual³³ and does not include data on the activities supporting the R&D system. The state budget reflects the resources allocated by the state to the R&D system for both direct research (according to the Frascati Manual definition) and system support. System support includes, for example, the operational expenditure of research collections, research libraries, databases, the Estonian Research Council, and the Estonian Academy of Sciences. Since Statistics Estonia reflects R&D expenditure submitted by institutions and the state budget reflects the funding allocated by the state, the funding and expenditure of R&D activities in a particular year do not have the same volume.

Figure 1.4, which distinguishes between R&D funders and expenditures made by those who conduct R&D, provides a better picture of the linkages between funding and expenditure. Those conducting R&D are public sector institutions (primarily universities, public R&D institutions) and private sector institutions (primarily enterprises).³⁴ The funders are the private and public sector and foreign sources. In addition to state funds, public institutions also spend resources received from abroad, mainly from the European Union's Framework Programme and other enterprises as part of contractual co-operation. As resources from the Structural Funds are included in the funds received from the state budget, these sums are reflected in public funding sources. The private sector mainly funds its own R&D expenditure, with more than 16% received from state funding or abroad. Thus, part of the 1% of GDP planned in the state budget goes to the private sector. In 2020, the public R&D funding allocated to the private sector amounted to 7.3% or 19.8 million euros.

Although the bulk of public research funding is received from the state, funds received from abroad and as part of contractual agreements with other enterprises represent a significant proportion of public expenditure. The share of private and foreign funding in public R&D expenditure was between 18% (2013) and 27% (2018) over the 2011–2020 period. In 2020, 16.8% of public sector R&D expenditure was covered by funds from abroad and 7.0% by the private sector.³⁵

31 Foresight Centre. (2021). Teadus- ja arendustegevust soodustavate stiimulite kasutamine maksusüsteemis. Arenguseirekeskuse lühiraport (Use of R&D incentives in the tax system. Short report by Foresight Centre). https://www.riigikogu.ee/wpcms/wp-content/uploads/2021/09/Lyhiraport_TA_A4_CMYK.pdf (26.10.2021).
 32 Pärson, T. (2019). How national research and development activities are measured – Estonian Research 2019 (ed. K. Raudvere) p. 69, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>.
 33 OECD Frascati Manual 2015. <http://oe.cd/frascati> (26.10.2021).
 34 For more information on the methodology, see the chapter 'Estonian Research System' in this collection.
 35 Statistics Estonia. Calculations by Estonian Research Council. www.stat.ee (27.10.2021).

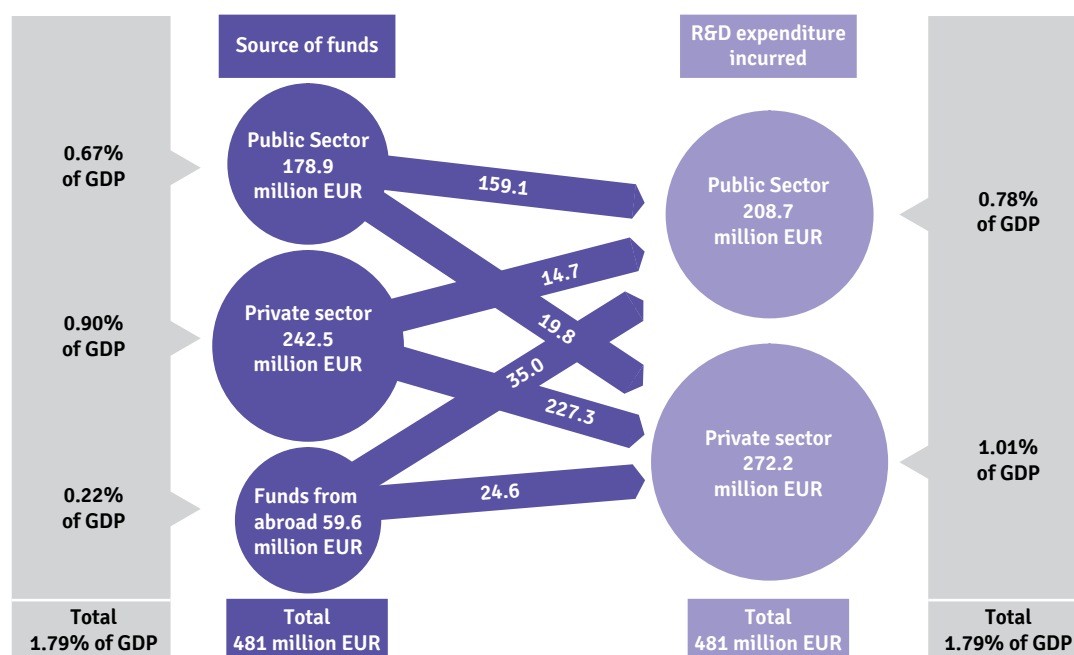


Figure 1.4. Flows of funding and incurred expenditures on R&D between sectors in Estonia in 2020

Source: Statistics Estonia,³⁶ calculations by Estonian Research Council.

While there is no clear trend in terms of public expenditure from funds from abroad, there is a strong upward trend in public funding received from the private sector (Figure 1.5), accounting for 7.0% of all public R&D funding in 2020. This is a clear sign of the growing common share of enterprises

and R&D institutions, indicating that the efforts of all stakeholders (the state, enterprises, institutions) to enhance co-operation between enterprises and institutions are slowly starting to pay off.

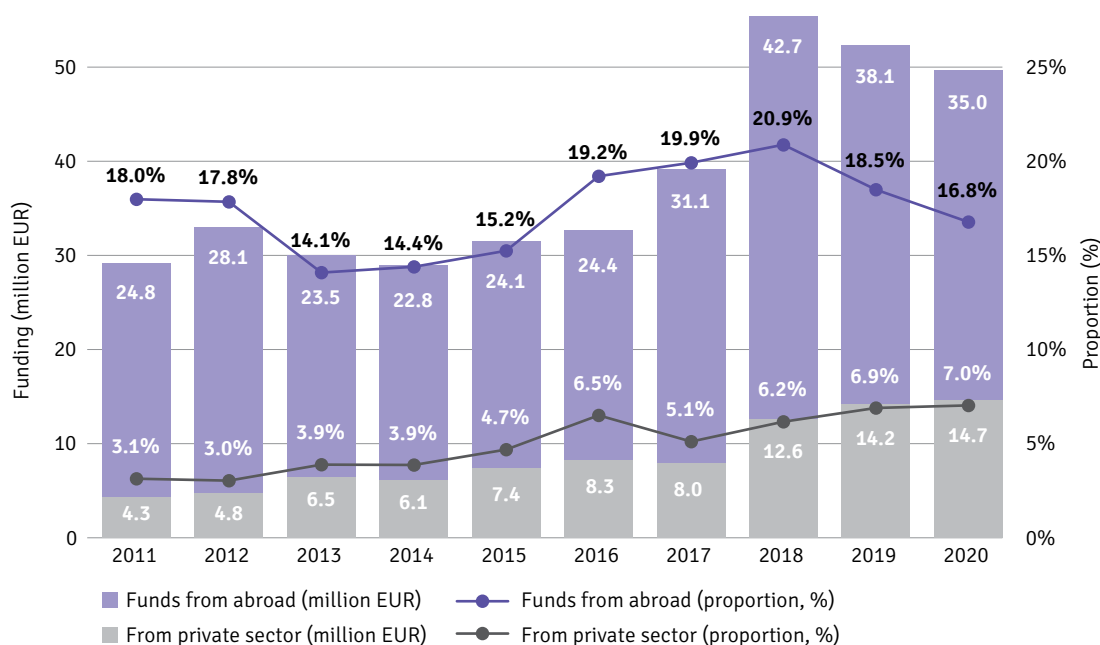


Figure 1.5. Public sector R&D funding from private sector and funds from abroad in 2011–2020

Source: Statistics Estonia,³⁷ calculations by Estonian Research Council.

³⁶ Statistics Estonia. www.stat.ee (02.12.2021).

³⁷ Statistics Estonia. www.stat.ee (26.10.2021).

Despite the increase in co-operation between enterprises and public R&D institutions, Estonia still has some way to go compared to other countries (Figure 1.6). In international comparison, we are still well below the EU average. In 2018,

private funding covered 6.2% of public R&D expenditure in Estonia, while the European Union figure was 10.7%. In 2019, public sector funding by the private sector was 6.9% and 7.0% in 2020 (Figure 1.5).

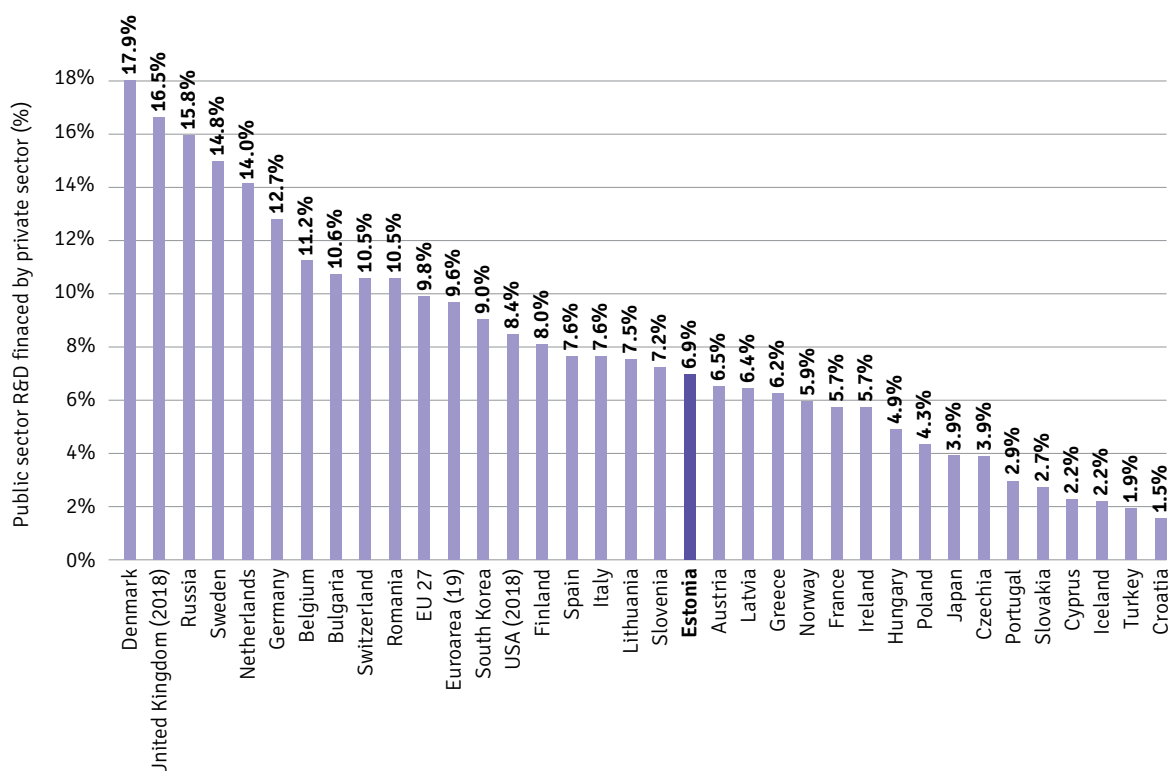


Figure 1.6. Public sector R&D financed by private sector (%) in 2019

Source: Eurostat,³⁸ calculations by Estonian Research Council.

Figure 7.1 provides an overview of the dynamics of the proportions of the main sources of R&D funding. There is no pronounced trend in the last ten years (2011–2020), as the proportions vary from one year to another. The share of funds from abroad in Estonian R&D expenditure accounts for 10–15%. It is, however, confirmed that in 2015–2020 when Estonian R&D expenditure grew by 58.8% on average (from 302.8 million to 480.9 million euros), the growth was mainly driven by the private sector. The financial contribution of the private sector increased by 94.2% (118 million euros). The share of funding from abroad in the same period grew by 61.5% (from 36.9 million to 59.6 million euros).

Over the past decade (2011–2020; except for 2011 and 2012 when the private sector invested heavily in oil and energy industry), the share of private and public funding has remained more or less equal, but in 2020, private sector contribution was already more than a third higher (35.6%) than that of the public sector. The share of funds from abroad in 2015–2020 represented on average 13.4% of total funding, compared to 12.4% in 2020. The share of funds from abroad is smaller in the private sector, averaging 8.1% in 2011–2020. In the public sector, where international co-operation is essential, funds from abroad accounted for 17.5% of total funding in 2011–2020.

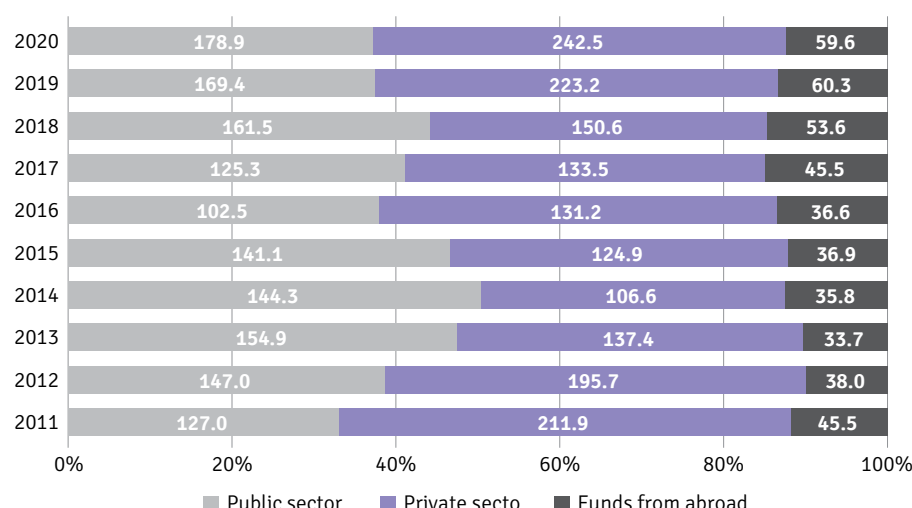


Figure 1.7. Gross domestic expenditure on R&D in Estonia by source of funds in 2011–2020 (%). Figures on the diagram indicate the volume of funding (million EUR)

Source: Statistics Estonia,³⁹ calculations by Estonian Research Council.

INTERNATIONAL SCIENTIFIC CO-OPERATION INCREASES INVESTMENT IN R&D

Participation in international scientific co-operation is vital to address the issues of Estonia and the world and to stay at the forefront of rapidly developing research. It is for this reason that external sources of funding are of key importance to both public R&D institutions and enterprises. The largest source of external funding for Estonia is the Framework Programme for Research and Innovation in the European

Union which is the world's largest funding programme for all research fields in terms of both the budget, number of participants and the number of research projects.⁴⁰ The success of Estonian researchers in the Framework Programme is demonstrated by the high volume of funding from abroad (Figure 1.8) and the comparison with other EU countries.

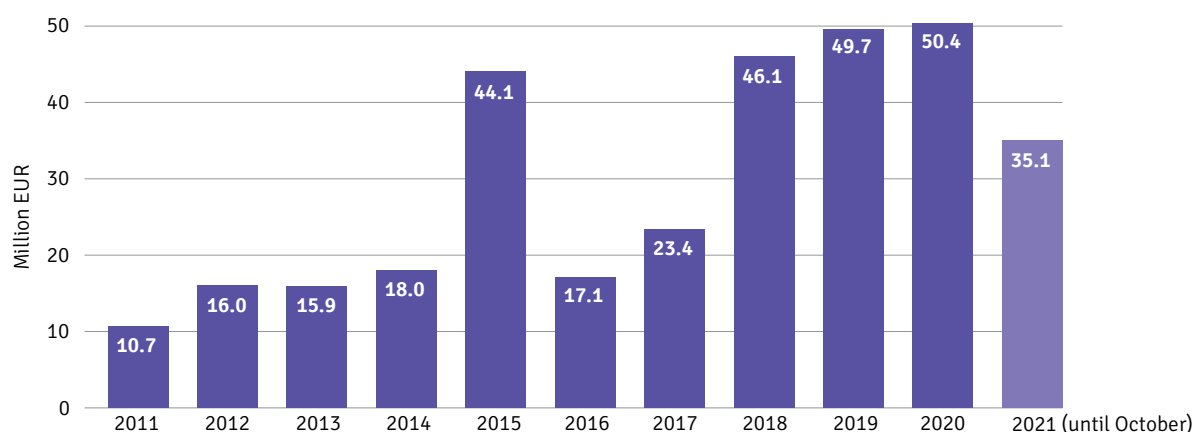


Figure 1.8. Financial contribution from EU Framework Programmes to Estonia from 2011 to 2020. Amounts correspond to the financial volume of the contracts signed in that year. Funding is used for the organisation of projects over the next several years (data as at 4 October 2021).

Source: eCORDA.⁴¹

³⁹ Statistics Estonia. www.stat.ee (02.12.2021).

⁴⁰ Estonian Research Council. (2021). Estonian participation in the Framework Programme for Research and Innovation in the European Union Horizon 2020. https://www.etag.ee/wp-content/uploads/2021/06/ETAG_Horizont-2020.pdf (27.10.2021).

⁴¹ Data from External Common Research Data Warehouse (eCORDA) (04.10.2021). <https://webgate.ec.europa.eu> (17.11.2021). Please note that the contents of the eCORDA database are sometimes corrected retrospectively, thus data extracted from the database at different times may vary.

The participation of Estonian researchers in the Framework Programmes has increased year by year. For example, 560 Estonian researchers participated in the Seventh Framework Programme, but in Horizon 2020, the figure has already increased to 894 (data from October 2020). In addition to public R&D institutions, the participation of enterprises has also significantly increased: 195 in the Seventh Framework Programme, compared to 275 in Horizon 2020. It is worth noting here that 160 different enterprises have participated in Horizon 2020.⁴²

Compared to other countries, Estonia stands out thanks to its financial contribution per GDP, which was 266% of the EU average in early October 2021, as well as financial contribution per citizen, which was 172% of the EU average (EU 28 = 100%) (Figure 1.9). In terms of financial contribution per GDP, only Cyprus is ahead of us. However, nine countries are ahead of us in terms of financial contribution per citizen.

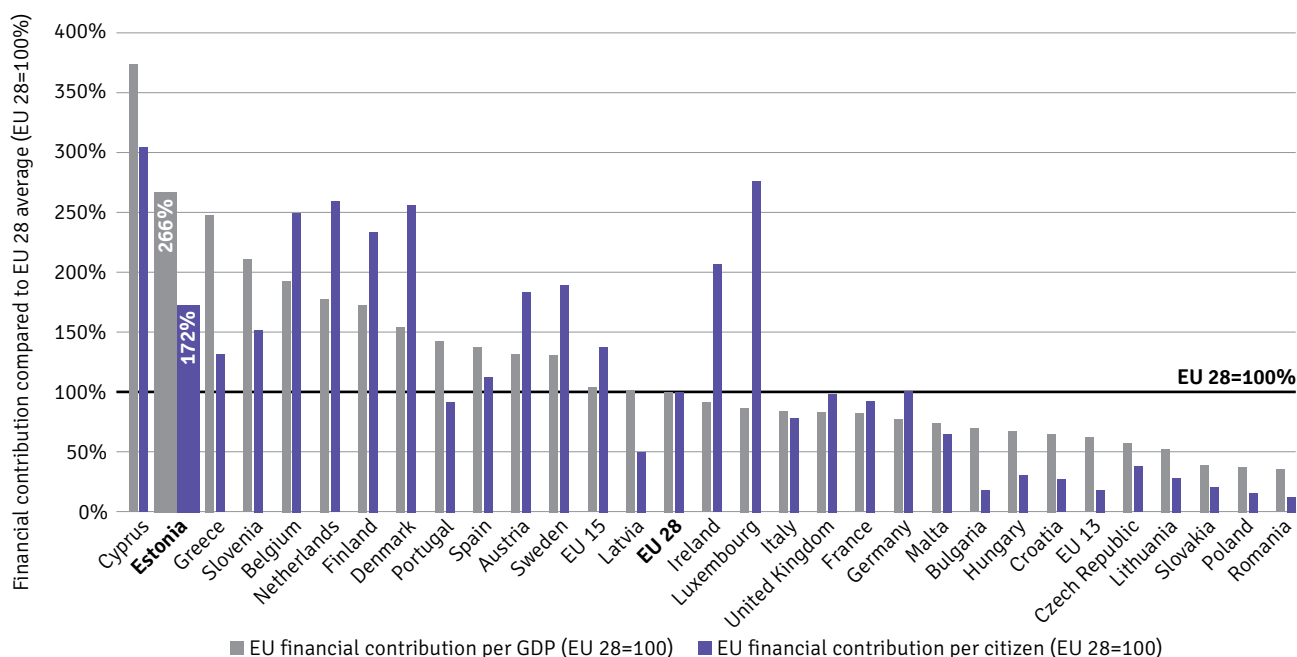


Figure 1.9. EU financial contribution from Horizon 2020 compared by participating EU 28 countries per GDP and per citizen compared to EU 28 average (data as of 04.10.2021)

Sources: eCORDA⁴³ and Eurostat,⁴⁴ calculations by Estonian Research Council.

WHERE SHOULD WE INVEST – IN CONCRETE OR BRAINS?

One of the issues that comes up again and again in the making of strategic choices is whether we should invest in concrete or in brains and what the reasonable balance would be. The establishment of a research and innovation system that supports both social and economic development is one of the main tasks in the initial stage of development in transition countries. Large-scale investment in buildings and laboratories to create an attractive environment for research is fully justified in order to establish such a system. State-of-the-art research buildings and laboratories have been built in Estonia with support from both Estonian and European taxpayers (Structural Funds). The initial stage of development in transition countries is characterised by the high share of investment in public R&D expenditure (Figure

1.10). Between 2011 and 2015, the share of public investment in R&D expenditure averaged 18.3% per year. But over the 2016–2020 period, it fell to 10.9%. In 2011–2015, labour costs represented on average 47.5% of public R&D expenditure, compared to 51.4% in 2016–2020. Therefore, labour costs account for half of public R&D expenditure on average. Furthermore, the share of labour costs increases as the share of investment decreases. With regard to the share of investment, we can consider ourselves successful on the international scene. According to data published by Eurostat in 2018 (Eurostat measures the share of capital investment in R&D expenditure), we were well ahead of such developed countries as Finland (5%) and Norway (8%) in our capital investment (14%).⁴⁵

⁴² Estonian Research Council. (2021). Estonian participation in the Framework Programme for Research and Innovation in the European Union Horizon 2020. https://www.etag.ee/wp-content/uploads/2021/06/ETAG_Horizont-2020.pdf (27.10.2021).

⁴³ Data from External Common Research Data Warehouse (eCORDA) (04.10.2021). <https://webgate.ec.europa.eu> (17.11.2021).

⁴⁴ Eurostat. <https://ec.europa.eu/eurostat/data/database> (24.08.2021).

⁴⁵ Eurostat. <https://ec.europa.eu/eurostat/data/database> (29.08.2021).

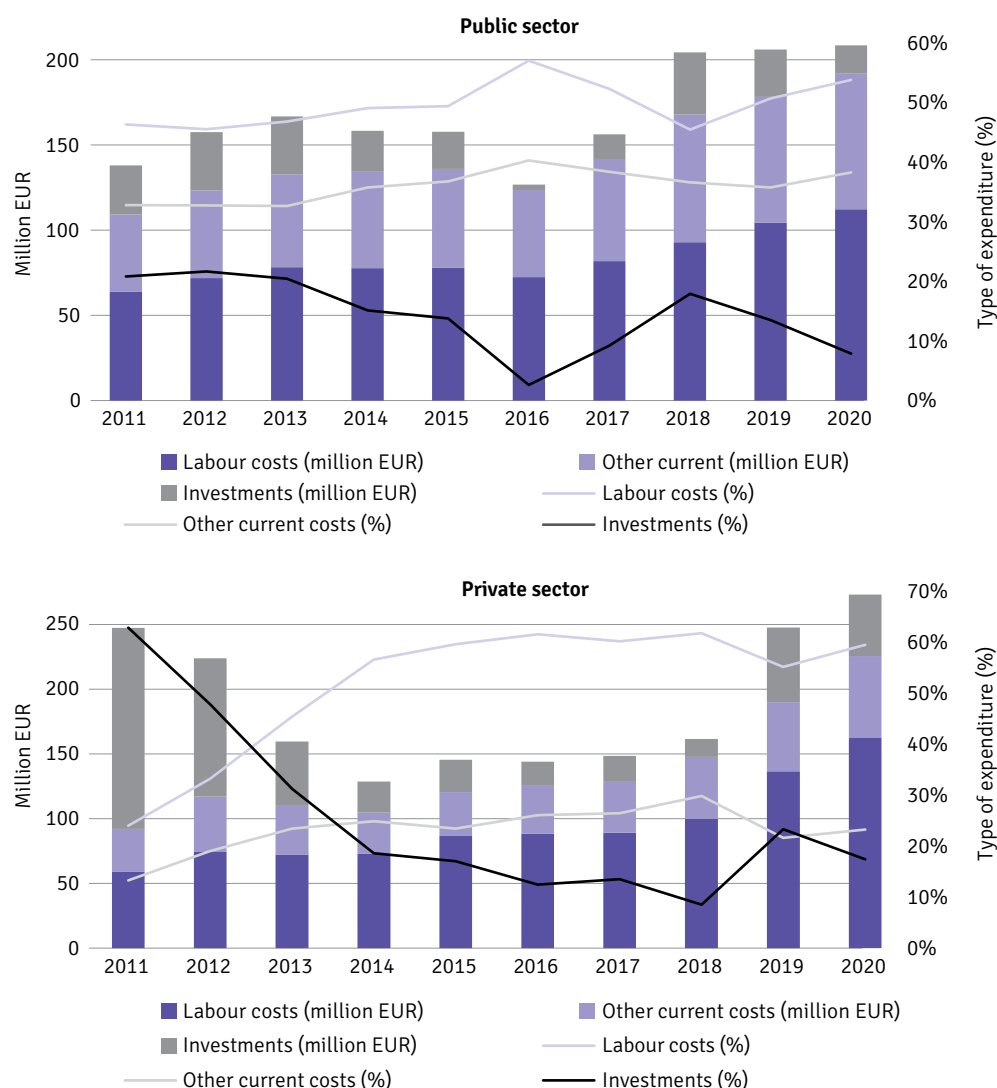


Figure 1.10. R&D expenditure in public and private sector by type of expenditure in 2011–2020

Source: Statistics Estonia,⁴⁶ calculations by Estonian Research Council.

When comparing public and private sectors, it is clear that the share of other current costs in R&D expenditure is the most stable, however, it is considerably lower in the private sector. The share of investments in the private sector has also decreased in the last five years: in 2011–2015 it was

39.9%, dropping down to 16.1% in 2016–2020. This major change was primarily caused by the large-scale investments made in the oil and energy industry in 2011 and 2012 (Figure 1.10).

EXPENDITURE BY FIELD OF RESEARCH

For the development of the country, including for the maintenance of a high level of education and culture as well as economic progress, it is essential to ensure research in key areas, i.e. the diversity of fields of research. Statistics on the diversity of public research are limited to the data collected by Statistics Estonia on the six main fields of research determined in the Frascati Manual. It is far from sufficient to assess the diversity of research at large. The proportions of public research expenditure have generally remained stable

in 2016–2020 (Figure 1.11). The share of natural sciences is the highest (between 33.5% and 37.1%), while the share of agricultural and veterinary sciences is the lowest (between 4.1% and 5.7%). Funding for agricultural and veterinary sciences, engineering and technology has increased more rapidly than the average during the period concerned. Whereas funding for social sciences, the humanities and the arts has increased at a much slower rate than the average.

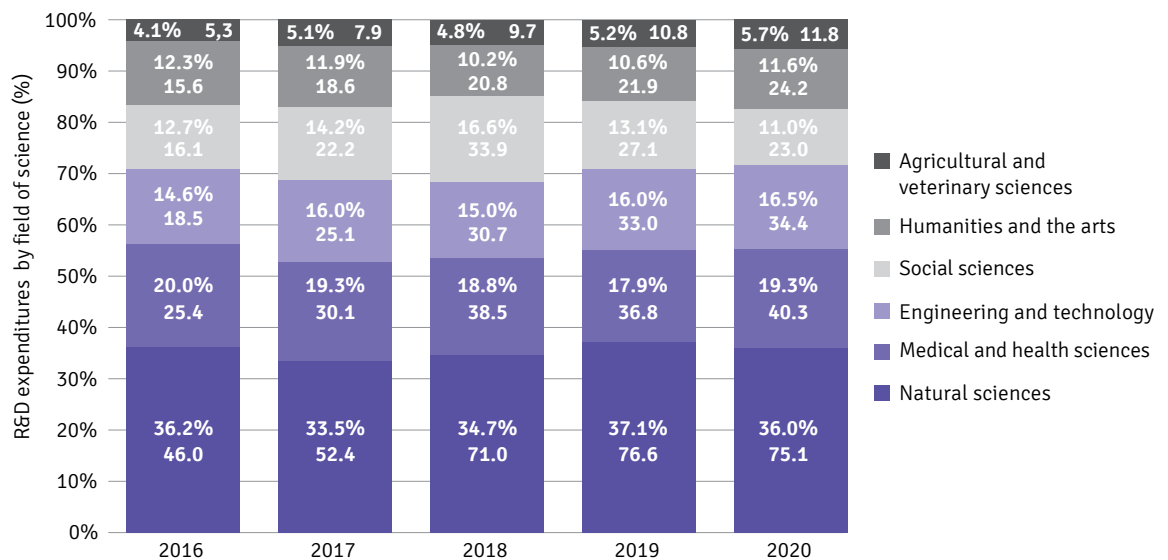


Figure 1.11. R&D expenditures in public sector by field of science in 2016–2020. Figures by columns indicate the funding volume of research fields (million EUR and proportions, %)

Source: Statistics Estonia,⁴⁷ calculations by Estonian Research Council.

From the point of view of research policy makers, it is essential to identify the optimal diversity of fields of research for Estonia, i.e. a suitable balance between them. This obviously requires the existence of an appropriate methodology before any targets can even be set. As long as there is no appropriate methodology, we can only compare our current situation with other countries and think who we want

to resemble the most. After all, each country has its own coherent division of research fields which promotes the development of the country and economy. Among OECD countries, Estonia stands out with its higher than average share of R&D expenditure on natural sciences and lower than average share on engineering and technology as well as medical and health sciences (Figure 1.12).

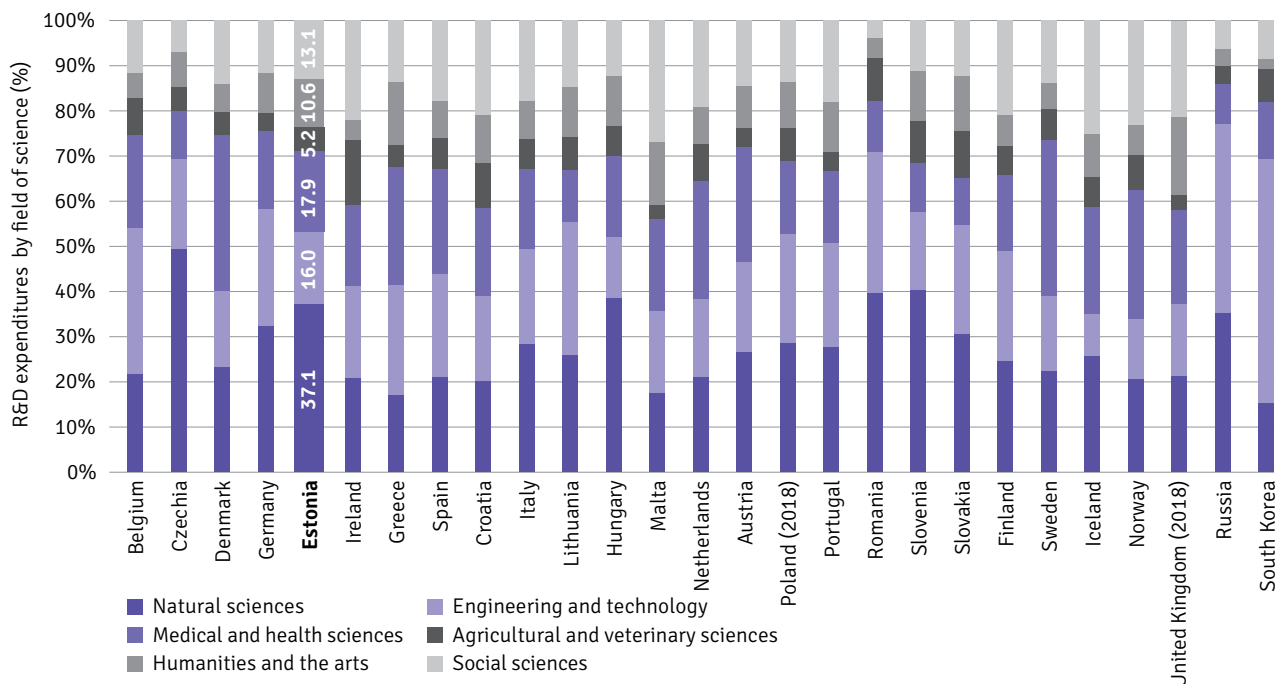


Figure 1.12. R&D expenditures in public sector by field of science in 2019

Source: Eurostat,⁴⁸ calculations by Estonian Research Council.

47 Statistics Estonia. www.stat.ee (24.08.2021).

48 Eurostat. <https://ec.europa.eu/eurostat/data/database> (10.12.2021).

STRUCTURAL FUNDS ARE A DRIVING FORCE FOR RESEARCH SYSTEM DEVELOPMENT

Ministries play an important role in organising the R&D activities and funding necessary for their area of government.⁴⁹ The Estonian Ministry of Education and Research as the largest contributor manages the funding of R&D institutions and implements national research policy. In the state budget of 2022, the share of the Estonian Ministry of Education and Research in the funding of public R&D is 63.3%. The Ministry of Economic Affairs and Communications (21.8%) and the Ministry of Rural Affairs 4.5%) are other large contributors.

Compared to other publicly funded areas, R&D funding is more dependent on Structural Funds. The share of external funding in the state budget is around 10% (in 2022 state budget 10.4%), while the share of Structural Funds in the

2022 budget of the Estonian Ministry of Education and Research is 26%. The sharp decline in the share of Structural Funds in the budget is a positive development as it reduces R&D funding dependency on the Structural Funds. In 2016, the share of Structural Funds was 48% (Figure 1.13). The more than threefold increase in the volume of baseline funding, which also started in 2016, was a policy choice to achieve a 50:50 ratio of research grants and baseline funding. The objective is to use baseline funding to increase the capacity of R&D institutions, ensure long-term stability, and set and achieve long-term operational objectives. The increase in research grants has thus been slower than the increase in the research budget of the Estonian Ministry of Education and Research, which is why its share in total funding has also decreased.

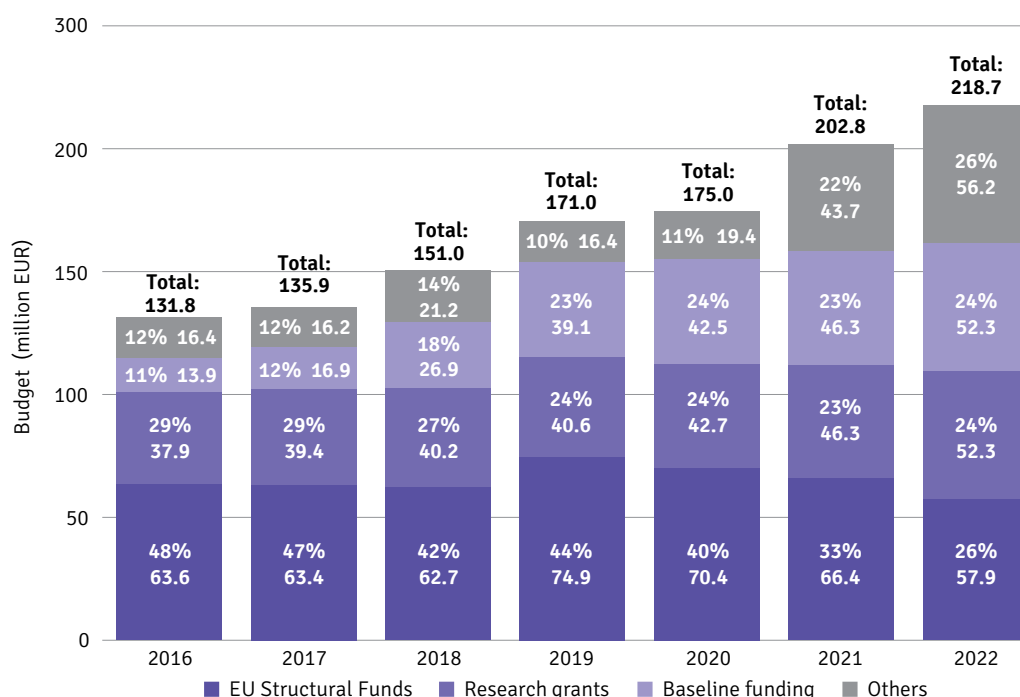


Figure 1.13. The research budget of the Ministry of Education and Research and its main components in 2016–2022 (million EUR)

Source: Estonian Ministry of Education and Research.

Figures 1.13 and 1.14 provide an overview of the measures supporting the R&D and innovation activities of the Estonian Ministry of Education and Research. These measures also include measures supporting higher education (scholarships by research field, DoRa, ASTRA), which is why their volume is larger than that of the research budget of the ministry. Significant and positive structural changes have taken place in the R&D and innovation funding of the Estonian Ministry of Education and Research over the course of seven

years. The share and volume of primary R&D funding instruments (research grants and baseline funding) has increased. In 2016, primary funding instruments represented 39.3% of total funding by the Estonian Ministry of Education and Research, but in the 2022 budget they already represent almost half. Reduced dependency on the Structural Funds is also a positive change. Overall, these changes demonstrate that there is a clear trend towards enhancing the stability of the R&D and innovation funding system.

49 Organisation of Research and Development Act. – Riigi Teataja I, 1997, 30, 471. <https://www.riigiteataja.ee/akt/104122014014> (24.09.2021).

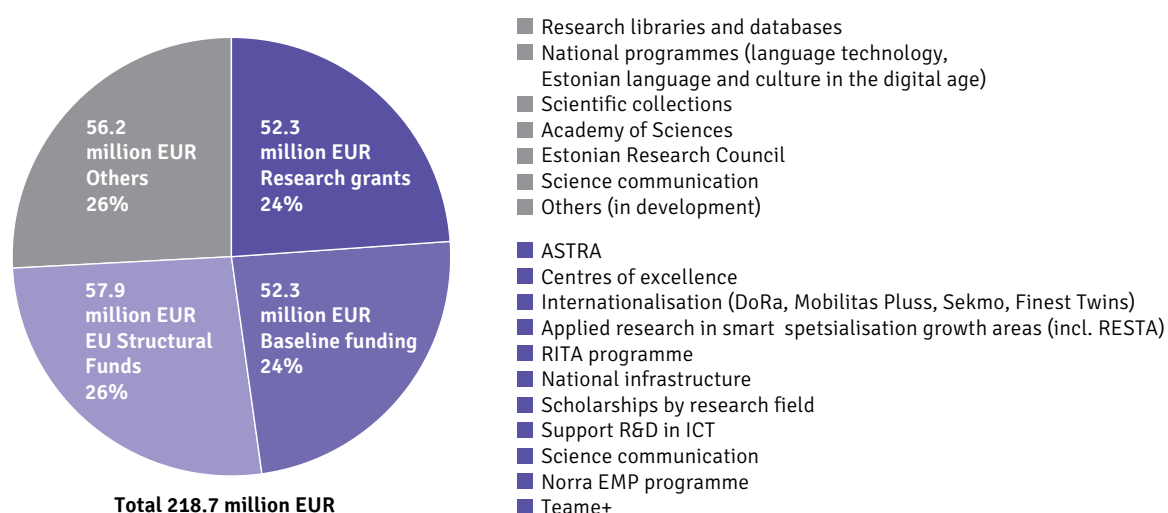


Figure 1.14. The research budget of the Ministry of Education and Research and its main components in 2022 (million EUR and proportions, %)

Source: Estonian Ministry of Education and Research.

Funding from the Structural Funds has been used to implement structural changes in R&D institutions and higher education institutions as well as to develop their specific areas of responsibility (ASTRA), to promote high-level research and international co-operation (centres of excellence, Mobilitas+) and to establish a research infrastructure of national importance. In order to increase the common share of research and entrepreneurship, new measures 'Support for R&D Activities of Resource Valorisation' (ResTA) and 'Inter-sectoral Mobility Support' (SekMo) were initiated.

The organisation and funding of sectoral R&D activities has been the focal point of research policy for a long time. To this end, the RITA programme, funded by the Structural Funds, was launched in 2015 to strengthen sectoral R&D and increase the capacity of ministries in the organisation and funding of R&D activities. Scientific adviser positions were created in ten ministries and the Government Office and support was provided to conduct interdisciplinary applied research with necessary socio-economic objectives

(selection of topics on a proposal from Research and Development Council). The RITA programme provides support for knowledge-based policy formulation through co-financed applied research for ministries. The selection of topics is based on the need for the preparation of specific regulations, measures, etc.

In conclusion, the funding of Estonian R&D activities has increased steadily in comparison with three years ago ('Estonian Research 2019', statistics). Rapid development has taken place in the private sector where R&D expenditure has increased roughly by 1.7 times. Even on the international scene we have been well ahead of a number of countries. The ratio of our R&D investment to the wealth of our state (share of GDP) has increased at a faster pace than on average in the EU countries. In 2016, our total R&D expenditure represented 1.25% of GDP, compared to 1.94% on average in the EU, however, in 2020, these figures were 1.79% and 2.15% respectively.



Competitive research and development funding instruments

SIRET RUTIKU

Head of Research Funding Department, Estonian Research Council

The article written by Karin Jaanson provided a good overview of how diverse and dynamic the overall picture of Estonian research and development (R&D) funding currently is. This dynamism is best illustrated by the decrease in the volume of research funding managed by the Estonian Research Council (ETAg) and the increase in the volume of baseline

funding of R&D institutions over the past ten years (see Figure 1.15), as well as the changing role of both main instruments in the overall R&D funding system. This article thus focuses on some of the competitive funding instruments, the role of which has changed over time or is currently in the process of changing.

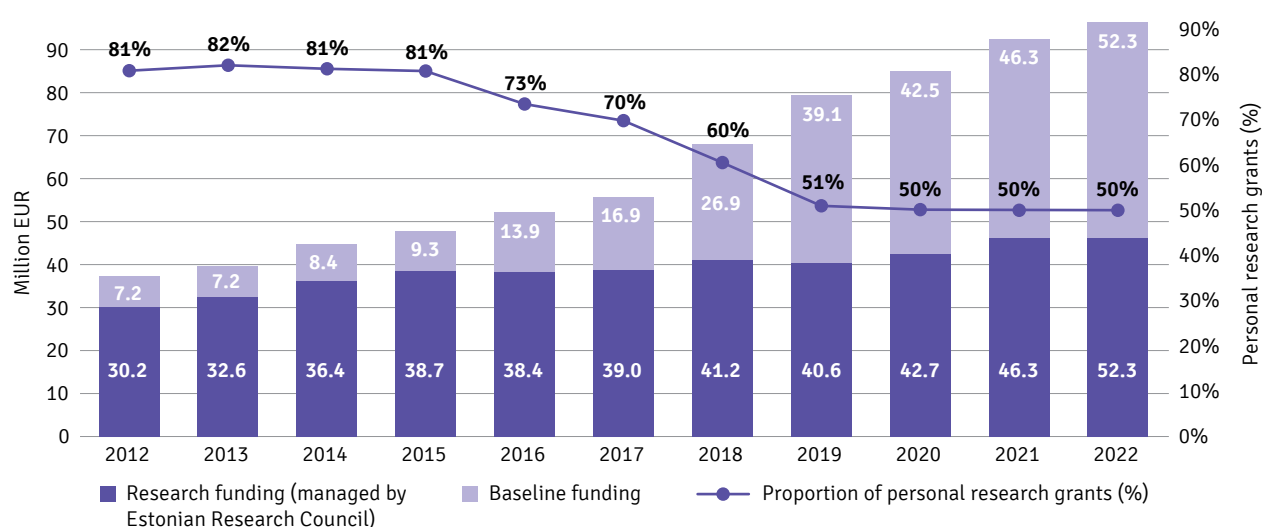


Figure 1.15. The volume of research funding managed by Estonian Research Council (Estonian Science Foundation's grants, until 2017; institutional research funding, until 2020; personal research funding, including postdoctoral grants, from 2014; proof-of-concept grants, from 2019) and baseline funding from the budget of Estonian Ministry of Education and Research in 2012–2022

Source: Estonian Ministry of Education and Research.

R&D FUNDING SYSTEM OF ESTONIAN RESEARCH COUNCIL RECEIVED AN OVERHAUL

In 2020, the transition to the new system of research grants was completed in accordance with the 'New Framework of Research Grants and Baseline Funding'⁵⁰, as the final institutional research funding projects and most of the earlier personal research funding projects were successfully concluded. Instead of targeted research funding, institutional

research funding, Estonian Science Foundation's grants, personal research funding, including postdoctoral grants, and starting grants, the new core of research grants comprises the following three types of grants for researchers: post-doctoral grants, starting grants, and team grants (see Figure 1.16 and Table 1.1).

50 Estonian Research Council (2016). A New Framework of Research Grants and Baseline Funding in the Estonian Research and Development Funding System. http://www.etag.ee/wp-content/uploads/2016/10/Uurimistoetuste_ja_tegevustoetuse_uus_süsteem_ETAg_2016.pdf (04.10.2021).

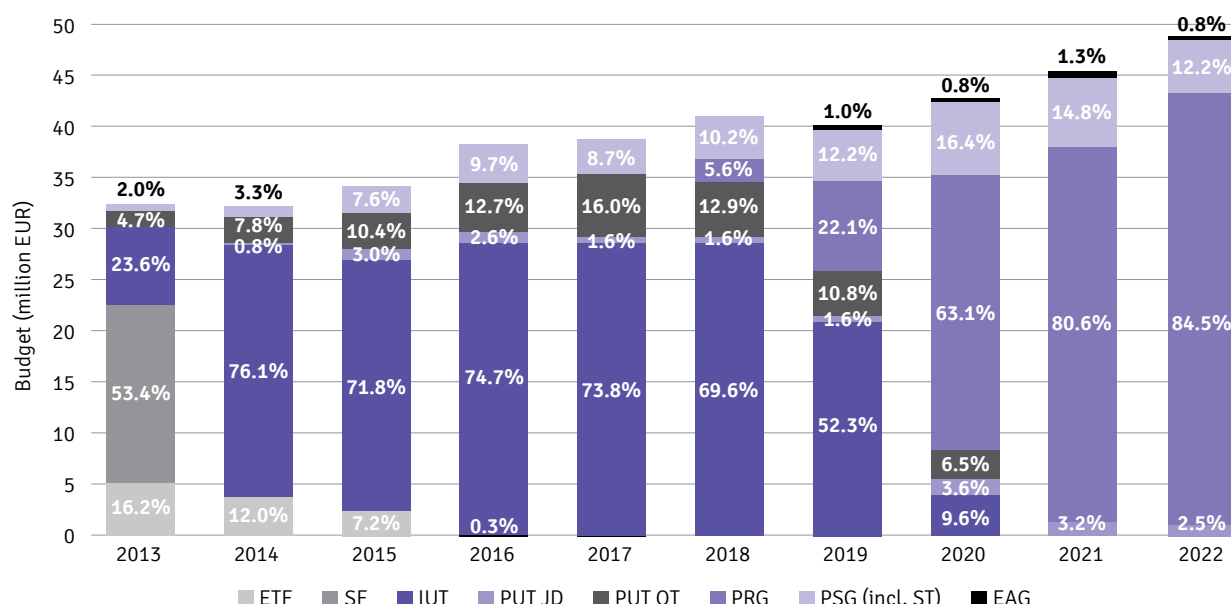


Figure 1.16. Conversion to new grant system in 2013–2022. Proportion of grant types: Estonian Science Foundation's grants (ETF), targeted research funding (SF), institutional research funding (IUT), exploratory research grants (PUT OT), post-doctoral grants (PUT JD), team grants (PRG) and starting grants (PSG, incl. ST) and proof-of-concept grants (EAG). Projects actually funded this year have been taken into account.

Source: Estonian Research Council.

Table 1.1. Conversion to new grant system in 2016–2021. The number of different types of research projects

	SF+ETF+IUT	PUT-OT+ PUT-ST	PUTJD	PRG	PSG	EAG	Total
2016	158	171	36				365
2017	142	186	37				365
2018	140	163	33	14	16		366
2019	109	125	32	52	40	4	362
2020	34	83	43	121	63	4	348
2021		8	38	167	75	8	296

Source: Estonian Research Information System.

In light of the importance of international mobility in research, mobility support in the form of postdoctoral grants, returning researcher grants, and top researcher grants provided under the Mobilitas Pluss programme, which is funded by the Structural Funds of the European Union, is also linked to research careers (see more below).

This framework was intended to reduce the amount of unnecessary bureaucracy across all funding instruments. With regard to the conditions for applying for and using ETag grants and their reporting, emphasis was placed on simplification by fixing the amount of grants (i.e., setting unit costs). Fixed grant amounts were implemented in the 2017 call on the principle that grants should generally cover all direct and indirect costs linked to the research project, including the overhead costs of the institution. Therefore, significantly larger grant amounts were established in 2018, in which overhead costs made up 25% of direct costs instead of the previous 16%. However, the increase in grant amounts has progressed more slowly than originally planned in the document. In the case of grants awarded in 2018, the coefficient 0.7 was used in determining the grant amounts, since 2020, the coefficient 0.9 has been used. The main reasons for gradually increasing the grant amounts were, firstly, the lower-than-expected increase in R&D funding, and secondly, the strong opposition from the research community to the decrease in the total number of

ETag grants caused by the increase in grant amounts.

However, considering that both the average salary of research staff (see the article written by Marek Tamm) and the consumer price index are increasing, it is necessary to increase the grant amounts to at least the level specified in the framework, and thereafter increase it in accordance with the changes in the average salary of research staff and the consumer price index.

As a second step, the application and reporting burden associated with ETag grants was significantly reduced and, inter alia, the requirement to submit annual extension applications for grant projects and prepare annual reports was abolished. The continuation of allocation of research funding will take place in the Estonian Research Information System (ETIS) in a simplified form upon conclusion of the grant agreement.

One of the key challenges in organising the system was the significantly fluctuating budget for new grants over the years. Each year, new grants can only be allocated insofar as the previous ones are concluded and additional funding is received from the state budget. The fact that in previous years, a greater increase in research funding in the state budget was anticipated, and it was not always taken into account that the funding allocated during a single

call would be locked away for up to five years, caused this so-called ebb and flow in research funding calls, in which calls with a very large budget (more than 18 million euros) started to alternate with calls with a very tight budget (even less than 4 million euros). This means that the amount of funding allocated for research grants is always the same

(ca. 42 million euros until 2020 and ca. 45 million euros since 2021), however, the amounts allocated for new grants vary depending on the projects that end each year. This ebb and flow in calls causes discrepancies in the amount of new research grants awarded each year (see Figure 1.17 and Table 1.2).

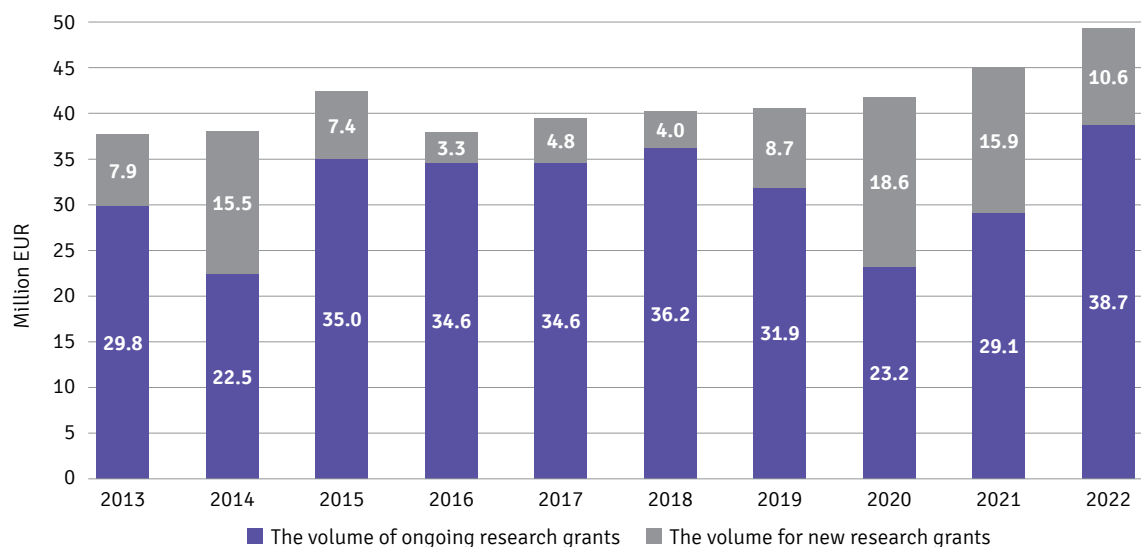


Figure 1.17. Volume of ongoing research grants and for new grant application rounds in 2013–2022. The 2020–2022 also include one-year grants. The amounts allocated for new rounds in one year are not recorded in the amounts of the ongoing projects of that year, but in the amounts for the following year.

Source: Estonian Research Council.

Table 1.2. Applications for post-doctoral grants (PUT JD), starting grants (PSG) and team grants (PRG) and reawarded grants in application calls from 2017 to 2021

Call*	PUT JD		PSG		PRG		Total	
	Applica-tions	Grants	Applica-tions	Grants	Applica-tions	Grants	Applica-tions	Grants
2017	46	13	104	16	166	14	316	43
2018	43	13	93	24	230	38	366	75
2019	47	21	100	23	332	70	479	114
2020	35	8	78	21	300	63	413	92
2021	30	12	72	25	223	42	335	79

*Call for grants starting next year (e.g. the call in 2020 was for grants starting in 2021).

Source: Estonian Research Council.

In order to reduce the significant differences between grant budgets, some team grants and starting grants were awarded for only one year in the 2019 and 2020 call as an exceptional measure. As a result, the differences between grant budgets were significantly reduced. To achieve reasonably stable amounts for grants, it will be necessary to implement this measure again after a certain period of time.

Another major challenge in organising the grant system was the success rate for research grant applications (see Table 1.3). While the success rate is partly related to the described ebb and flow in research funding, it has come to light that the partly very low success rates are not unequivocally linked to the amount of funding allocated. In circumstances where baseline funding has increased 2.4 times in the last five years (2017–2021) and, when compar-

ing 2017 with 2020, the share of ETag grants in the total share of public R&D funding has decreased by 4.7%, one would have expected a certain decrease in the number of grant applications. However, this was not the case, as the number of applications, in fact, increased – researchers who were already involved in projects funded by the Estonian Research Council continued to apply for grants. It thus became clear that some restrictive measures in the application process were necessary to achieve the optimal success rate for grant applications. In 2021, the success rate for grant applications submitted to the Estonian Research Council slowly started to reach the optimal rate (ca. 25%), although there are still significant fluctuations between different research fields and types of grants which need to be eliminated.

Table 1.3. Average success rates for research grants application rounds from 2018 to 2021

Application round	Medical and health sciences	Humanities and the arts	Exact science	Bio- and environmental sciences	Agricultural and veterinary sciences	Social sciences	Engineering and technology
2018 PRG	21.4%	13.2%	18.8%	22.5%	6.7%	14.8%	11.8%
2019 PRG	28.6%	11.5%	27.7%	23.7%	15.8%	9.8%	28.6%
2020 PRG	29.4%	14.8%	17.9%	27.0%	27.8%	16.1%	18.2%
2021 PRG	35.0%	12.5%	10.8%	18.8%	37.5%	21.4%	11.4%
Average for PRG	28.2%	13.0%	19.9%	23.3%	22.1%	15.0%	17.7%
2018 PSG	28.6%	25.0%	31.8%	37.5%	16.7%	16.7%	15.8%
2019 PSG	27.3%	15.4%	35.0%	18.2%	0.0%	5.6%	40.0%
2020 PSG	57.1%	22.2%	21.4%	21.4%	66.7%	30.8%	16.7%
2021 PSG	50.0%	25.0%	47.1%	29.4%	33.3%	33.3%	23.1%
Average for PSG	37.5%	20.6%	34.2%	26.1%	30.8%	18.4%	23.1%
2018 PUTJD	40.0%	33.3%	42.9%	23.1%	50.0%	33.3%	14.3%
2019 PUTJD	50.0%	100.0%	66.7%	41.7%	100.0%	28.6%	20.0%
2020 PUTJD	50.0%	12.5%	33.3%	22.2%	0.0%	25.0%	14.3%
2021 PUTJD	100.0%	36.4%	33.3%	50.0%	0.0%	40.0%	0.0%
Average for PUTJD	53.3%	33.3%	48.0%	32.5%	66.7%	31.6%	14.8%
Total average	32.7%	16.1%	25.7%	25.0%	25.0%	17.4%	18.8%

Source: Estonian Research Council.

As in the case of R&D funding as a whole (see Figures 1.11 and 1.12 in Karin Jaanson's article), the allocation of ETAg research grants by research fields remains a pressing topic. As Figure 1.18 shows, the division of ETAg grants by research fields (according to the Frascati classification⁵¹)

has been relatively stable. What is striking, however, is the high share of natural sciences,⁵² which has consistently increased for a long time, especially in the field of bio- and environmental sciences.

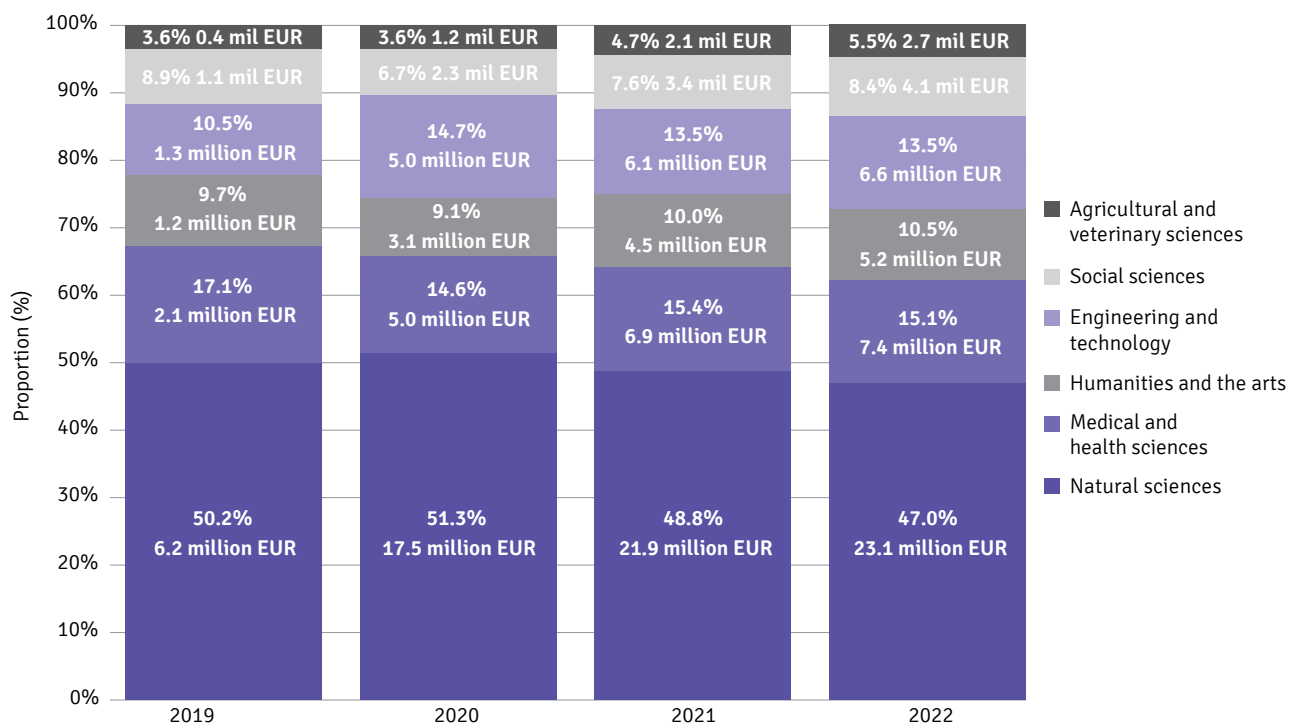


Figure 1.18. Division of post-doctoral grants, starting and team grants by research fields from 2019 to 2022 (payments, million EUR; for 2022 are given reserved bookings). Projects are divided according to expert committee in which the grant application was assessed (i.e. each project is in one research field)

Source: Estonian Research Council.

51 Frascati Manual 2015. OECD. <http://oe.cd/frascati> (26.10.2021).

52 Following the transition to the Frascati classification, ETAg grants in the field of natural sciences (LO) were processed in two sub-fields: exact science (LO1) and bio- and environmental sciences (LO2). In the 2021 call for grant applications, LO1 and LO2 were separated into two main fields of research.

Estonian Research Council conducted the first more thorough analysis of the division of grants by research fields in 2017,⁵³ in the context of the transition from the previous ETIS classification (four fields of research) to the 2015 Frascati Manual classification (six fields of research) in 2018. The next analysis was carried out in 2019.⁵⁴ The analyses showed that in terms of sub-fields, the grants are widely spread: out of 42 sub-fields specified in the Frascati Manual, grants were awarded in 37 sub-fields.⁵⁵ At the same time, there has been a long-term trend towards a slow increase in the share of grants in the (sub-)field of bio- and environmental sciences, whereas the share of grants in the field of engineering and technology, medical and health sciences, and, in particular, in the field of agricultural and veterinary sciences has (significantly) decreased.

In 2019, the diversity of ETag grants across research (sub) fields was discussed at length, even at the Research and Development Council. Different options were considered, including the preparation of a grant budget at policy or administrative level. As a result of in-depth discussions, the Research and Development Council, at its 5 February 2020 meeting,⁵⁶ approved the proposal of Estonian Research Council to implement the algorithm-based division of grants by research fields from the 2020 call for proposals, under which 24% of the call budget is equally distributed between six fields in such a way that at least two grants will be awarded in each field where qualifying applications are available. The remaining call budget (76%) is to be divided between fields in proportion to the share of applications exceeding the quality threshold in the three years preceding the call. In addition, it was decided in 2020 that, in order to improve the diversity of ETag grants across research (sub) fields, additional funding from the state budget was to be put into the fields of medical and health sciences, agricultural and veterinary sciences, as well as engineering and technology. The transition to algorithm-based division of grants will take place gradually over three years.

The issues of R&D funding, including the success rate and field-based division of grants, are intrinsically linked to the **societal value and impact of research**. The society expects a more direct and substantial contribution from research

in tackling current problems and promoting the economy. Thus, three major tasks face the research sector in general, but also the ETag grants more narrowly: firstly, increasing the applied outcomes of research; secondly, maintaining the solid basis of basic research; and thirdly, better explaining the societal value and impact of research.

One of the courses of action specified in the 'New Framework of Research Grants and Baseline Funding' is to pay greater attention to the interconnectedness between the research project and entrepreneurship as well as the needs of the society when determining the evaluation criteria for grant applications and reports. Consequently, in the 2017 call for proposals, the conditions and procedures for ETag grants were supplemented and the criterion 'the potential feasibility of project results, significance for Estonian research, society and economy'⁵⁷ was added to the provisions concerning applications and final reports, additionally, the evaluation criteria in the evaluation guidelines were supplemented accordingly.

Up until now, ETag grants were aimed at basic and applied research. No targeted funding was allocated to experimental development,⁵⁸ the third area of R&D and an essential part of knowledge and technology transfer. Which is why, in 2019, a new competitive research grant was created at the Estonian Research Council – a proof-of-concept (EAG) grant. The aim of proof-of-concept grants is to increase the societal and economic impact of research through supporting experimental development projects and to promote the application of research outcomes in the business sector and society at large. The great interest of researchers and R&D institutions in experimental development was fundamental in establishing the new instrument: in addition to the active participation of researchers in the first call for EAG grant applications in 2019, the concept of EAG grants was adopted by the University of Tartu the same year and later also by the Tallinn University of Technology. Although the funds allocated from the state budget for ETag proof-of-concept grants were lower than expected (see Table 1.4), the activity of R&D institutions in promoting experimental development is a promising sign of even stronger cooperation between the research and business sectors.

Table 1.4. The number of proof-of-concept grant (EAG) applications and grants awarded in 2019 and 2021

Call	Number of applications	Number of grants	Funding (euros)*
2019	59	8	760,000
2021	76	12	1,195,000

*Grants were awarded in the 2019 call for both 2019 and 2020, and in the 2021 call for both 2021 and 2022.

Source: Estonian Research Council.⁵⁹

53 Overview of personal research funding 2013–2017. Estonian Research Council. <https://www.etag.ee/wp-content/uploads/2018/02/%C3%9Clevaade-personaalsetest-uurimistoetustest-3.pdf> (09.11.2021).

54 The division of ongoing publicly funded research projects by research fields. Estonian Research Council. <https://www.etag.ee/wp-content/uploads/2019/11/K%C3%A4imasolevate-riiklike-uurimistoetuste-projektide-valdkondlik-jaotus-2.pdf> (09.11.2021).

55 According to the 2019 analysis, the following sub-fields were not represented: 1.7 other natural sciences, 2.8 environmental biotechnology, 3.4 medical biotechnology, 3.5 other medical science, and 4.5 other agricultural sciences, as it was not possible, upon reclassification, to divide them into new sub-fields according to the Frascati classification.

56 Government Office. Minutes of the Research and Development Council meeting No. 82 of 5 February 2020. https://vv.riigikantselei.ee/sites/default/files/riigikantselei/strategiaburoo/tan/tani_istungi_protokoll_5.02.2020.pdf (09.11.2021).

57 In 2019, the criterion was further supplemented: 'significance for Estonian research, culture, society and/or economy'. On a proposal from the Evaluation Committee of the Estonian Research Council, the coefficient 0.8 is applied in the evaluation of both the scientific and societal impact criteria.

58 Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

59 Summary of the call for proof-of-concept grant (EAG) applications in 2021. Estonian Research Council. <https://www.etag.ee/wp-content/uploads/2021/07/Arendusgrandi-2021.-a-voorukokkuv%C3%B5te-p%C3%A4rast-otsuste-tegemist.pdf> (09.11.2021).

In the case of ETAg grants, the readiness of researchers to find applied outcomes for research is obvious, insofar as applied research accounts for approximately a third of reg-

ular research funding (formerly known as personal research funding) (see Figure 1.19).

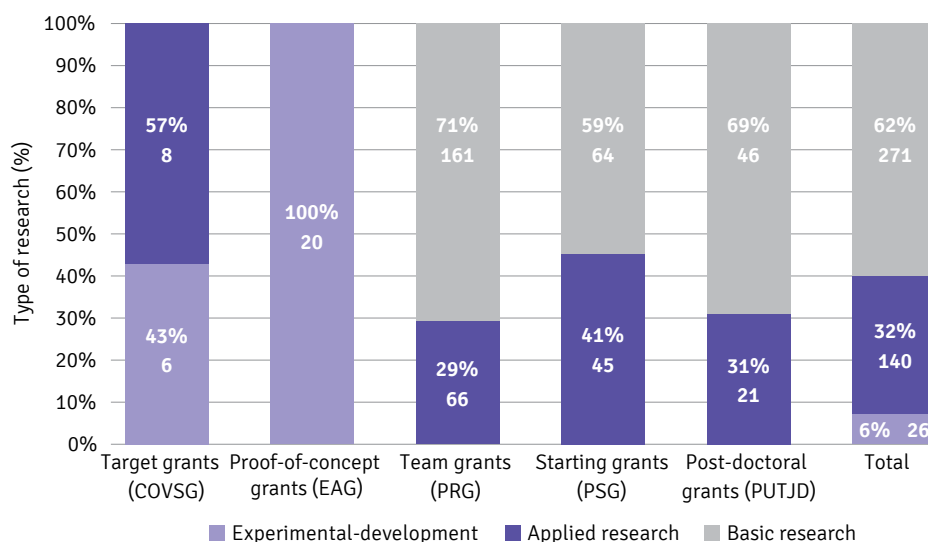


Figure 1.19. Research funding by type of research (experimental development, applied research and basic research) in 2018–2022. The absolute numbers on the columns show the number of grants and the percentages indicate the proportions of grants by type of research

Source: Estonian Research Council.

As the societal value and impact of research is often imperceptible to those outside it, it is crucial to actively introduce research results to the wider public in a clear and comprehensible manner. Thanks to ETAg grants, the popular science section⁶⁰ of final grant reports was supplemented. Since 2019, this section has also been used to publish the online collection *Teadusriikas Eesti*⁶¹ (literally ‘research-rich Estonia’) introducing the results of grant projects to the wider public, including entrepreneurs.

The societal importance of research became a topical subject in the wake of the SARS-CoV-2 pandemic in 2020. In the unprecedented global crisis that suddenly hit the world, solutions were required urgently – not just a vaccine to combat the virus, but also possible ways to mitigate and prevent the effects of the virus in different sectors. To that effect, the Estonian Research Council organised a COVID-19-related brainstorming event in the April of 2020 to obtain a quick overview of the most significant research topics and the readiness of researchers and R&D institutions to study them. In total, researchers submitted 152 research proposals, while ministries and agencies submitted 37 descriptions of their research needs. The Estonian Research Council, in close cooperation with the six public universities, the Estonian Academy of Sciences, the Estonian Young Academy of Sciences, nine ministries, the crisis committee of the Government of the Republic of Estonia, and the Government Office, selected the research topics to be funded.

As a result, the Estonian Research Council opened calls for proposals under the RITA programme to fund four major strategic studies and nine sectoral studies amounting to a total of 2.1 million euros.

In addition, a special funding instrument – target grant (COVSG) – was created and in the application round of which, 14 applied research and experimental development projects in five research fields received funding totalling 2.24 million euros.

Moreover, a total of 246,900 euros was granted to support international research cooperation in combating COVID-19. A health data research programme on COVID-19 was quickly developed together with NordForsk, an organisation that funds Nordic research cooperation. Five projects received funding from its budget of 5 million euros, one of which also involves Estonian researchers (Estonia’s contribution 147,200 euros). Support was also provided for participation in the Horizon 2020 ERA-NET CHIST-ERA call, under which one research project involving Estonian researchers also received funding (Estonia’s contribution 99,700 euros).

A total of 8,1 million euros from the state budget (incl. the supplementary budget of 2020) was allocated to coronavirus-crisis-related R&D activities. In addition to the above activities, the funds allocated also supported the development activities of the third-level bio-laboratory (i.e. a laboratory suitable for coronavirus research) at the University of Tartu’s Translational Medicine Centre (1,5 million euros), the launch of the COVID-19 monitoring system led by the University of Tartu (1,8 million euros), and studies of antibodies (0,3 million euros).⁶²

The article written by Irja Lutsar published in this collection provides a more thorough overview of the rapid response to the epidemic.

⁶⁰ This was part of the significant simplification process in reporting to ensure that the reporting burden of researchers would not increase due to activities targeted at the public.

⁶¹ See the collections of *Teadusriikas Eesti* on the website of Estonian Research Council <https://www.eki.ee/dict/qs/index.cgi?Q=meetmed> (07.12.2021).

⁶² Government supports research and development related to coronavirus. Estonian Research Council. The COVID-19 newsletter of the Estonian Research Council. <https://uudiskiri.etag.ee/2020/05/riik-toetab-koroonaviirusega-seotud-teadus-ja-arendustood/> (09.11.2021).

Estonian Research Council's brainstorming event and the subsequent calls for proposals demonstrated that, in close cooperation with different stakeholders, research grants can be used to promptly remedy acute problems in society. Nevertheless, the system of research grants must be updated frequently. On the one hand, stability is important,

but on the other hand, grants must be updated due to the constantly changing environment and needs. However, new types of grants cannot be created without additional funding to prevent fragmentation in the already wide selection of competitive instruments and high level of competition.

RESOURCES FROM THE EU STRUCTURAL FUNDS HAVE FOSTERED THE INTERNATIONALISATION OF RESEARCH AND THE IMPLEMENTATION OF APPLIED RESEARCH COMMISSIONED BY THE GOVERNMENT⁶³

As of the end of 2015, the Estonian Research Council started to implement several programmes funded under the EU Structural Funds which will continue until 2023, but the

calls for new projects of which will have ended by 2021. The Estonian Research Council is involved in the implementation of six programmes (see Table 1.5).

Table 1.5. Programmes funded by the European Union Structural Funds in 2015–2023 and implemented by the Estonian Research Council

Abbreviation	Programme	Period	Budget (million EUR)
Mobilitas Pluss	Internationalisation of research and support for mobility and the next generation	2015–2023	35.2
RITA	Support for sectoral R&D	2015–2023	32.0
NUTIKAS	Applied research in smart specialisation growth areas	2015–2023	26.6*
TeaMe+	Science Communication Programme	2015–2022	5.1
ResTA	Support for R&D activities of resource valorisation	2020–2023	10.8
SekMo	Inter-sectoral mobility support	2020–2023	1.8*

*Self-financing not included.
Source: Estonian Research Council.

The primary objective of the **Mobilitas Pluss** programme is to ensure the next generation of researchers by bringing new researchers to Estonia, and to provide opportunities for our researchers to participate in international research cooperation projects. Thanks to the programme, more than 100 postdoctoral researchers who have earned their doctoral degree abroad, 68 researchers who have studied in Estonia but then worked abroad, and 13 top researchers invited by Estonian universities to form a research group, have come to Estonia in 2016–2021 to conduct their research. Under the programme, support has been provided to more than 40 projects in which Estonian researchers have been able to cooperate with foreign researchers, and more than 200 training events and study visits for researchers, so that Estonian researchers could successfully apply for more European Research Council grants.

Resources from the EU Structural Funds have, in particular, contributed to the performance of such applied research, that has a specific client and user of its results. Under the **NUTIKAS** programme, 77 cooperation projects between enterprises and research institutions have been funded. The government has invested more than 26 million euros in these projects, while enterprises have also added more than

15 million euros in self-financing. Applied research under the **RITA** programme has been conducted with regard to the needs of the ministries. More than 120 small-scale policy studies and 20 large-scale strategic studies have been commissioned. The interest and capacity of ministries to address R&D issues has increased significantly thanks to the fact that scientific advisers who form a unified network have been employed in ten ministries and the Government Office under the RITA programme. In 2019, it was decided that a similar network should be created for professional associations, providing them an opportunity to employ development advisers under the RITA programme.

Two more programmes were added in 2020. The **ResTA** programme supports 20 applied research projects in the timber, food, and mineral resources sector. In the selection of research topics, emphasis was placed on fulfilling the needs of Estonian enterprises and developing areas with high economic potential. The inter-sectoral mobility grant **SekMo** launched at the end of 2020 provides an opportunity for public authorities to employ researchers with a doctoral degree. The above measures hopefully contribute to expanding the career model of researchers in both the business sector and society at large.

63 In the writing of this section, I wish to extend my thanks to a former colleague of mine, Oskar Otsus from the Department of Research Programmes.

THE RESEARCH CENTRES OF EXCELLENCE MEASURE SUPPORTS THE INTERNATIONAL COMPETITIVENESS OF ESTONIAN RESEARCH

The objective of the Research Centres of Excellence measure is to support and ensure the sustainability of the internationally recognised, top-level R&D activities of Estonian R&D institutions, thus creating the conditions for strengthening the collaborative capability and competitiveness of

Estonian research in the European Research Area. The total amount of funding allocated for research centres of excellence in 2016–2023 is 39,117,647 euros. The measure is managed by the State Shared Service Center.

Table 1.6. Centres of excellence in the period from 2015 to 2022 and the funding volumes (million EUR) for the entire funding period

Centre of Excellence	Total budget* (million EUR)	Beneficiary
Ecology of Global Change: natural and managed ecosystems	4.2	Estonian University of Life Sciences
Dark Side of the Universe	3.8	National Institute of Chemical Physics and Biophysics
Emerging orders in quantum and nanomaterials	3.7	National Institute of Chemical Physics and Biophysics
Advanced materials and high-technology devices for sustainable energetics, sensorics and nanoelectronics	4.5	University of Tartu
Centre of Excellence for Genomics and Translational Medicine	4.8	University of Tartu
Center of Excellence in Molecular Cell Engineering	4.6	University of Tartu
Centre of Excellence in Estonian Studies	4.6	Estonian Literary Museum
Zero energy and resource efficient smart buildings and districts	4.1	Tallinn University of Technology
Estonian Centre of Excellence in ICT Research (EXCITE)	4.8	Tallinn University of Technology
Total	39.1	

*Self-financing not included.

Source: The State Shared Service Center.

SUPPORT FOR RESEARCH INFRASTRUCTURE WILL ENLARGE ITS USER BASE

In 2019, the Government of the Republic of Estonia approved the Estonian Research Infrastructure Roadmap.⁶⁴ In 2020, the second call for the EU Structural Funds measure ‘Support for Research Infrastructures of National Importance under the Roadmap’ was carried out for research infrastruc-

tures specified in the roadmap that did not participate in or were not funded under the first call.⁶⁵ The results of the call were approved by the Government of the Republic of Estonia on 4 June 2020 (see Table 1.7). The total budget of the measure in 2019–2023 is 7,932,921 euros.

Table 1.7. Research infrastructures funded under the second call for the ‘Support for Research Infrastructures of National Importance under the Roadmap’ measure

Research infrastructure	Total budget (million EUR)
Distributed Systems of Scientific Collections (DiSSCo Eesti)	1.26
Estonian Environmental Observatory (KKOBS)	0.66
Development of space research ground infrastructure in Estonia (KosEST)	0.95
Analysis and Experimentation on Ecosystems (AnaEE Estonia)	0.30
Plant Biology Infrastructure (TAIM)	1.56
Marine Technology and Hydrodynamics Research Infrastructure (SCC 2.0)	1.80
Developing new research services and research infrastructures at MAX IV synchrotron radiation source (MAX-TEENUS)	0.71
Estonian e-Repository and Conservation of Collections (phase II) (E-VARAMU)	0.70

Source: Estonian Research Council.⁶⁶

64 Estonian Research Council. Estonian Research Infrastructure Roadmap. https://www.etag.ee/wp-content/uploads/2019/06/ETAg_Teadustaristu_teekaart_2019.pdf (02.11.2021).

65 See also: Koppel, A. (2019). Research and Development Expenditure: Expectations and Reality. — Estonian Research 2019 (ed. K. Raudvere), pp. 9–19, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>.

66 Estonian Research Council. Estonian Research Infrastructure Roadmap. <https://www.etag.ee/rahastamine/infrastruktuuri-toetus/teadustaristu-teekaart/> (02.11.2021).

In addition to the resources of the Structural Funds of EU, funds are allocated from the state budget to the core facilities of research infrastructure. Core facilities are objects of the Estonian Research Infrastructure Roadmap that provide services to other institutions and which are included in the approved list of core facilities of the Estonian Research Council.⁶⁷ The aim of funding for core facilities is to ensure that both public, private and third-sector users have access to open infrastructure of national importance. Funding is provided to cover additional costs of research infrastructure which are related to making the research infrastruc-

ture available outside the facilities of the infrastructure manager, as well as the obligations arising from international cooperation. Between 2013–2019, funding for core facilities was provided from institutional research funding (IUT) grants. After the discontinuation of IUTs, from 2020 onwards, support for core facilities was continued in the form of core facility funding. A total of 17 core facilities received funding for the 2021–2024 period under the first call for core facility funding applications opened in 2020. The total budget for core facilities in 2021 was 965,000 euros.

OUTLOOK FOR COMPETITIVE FUNDING INSTRUMENTS

In order to respond to the changing needs of the society and research, the R&D funding system needs evolve continuously, which, in particular, also applies to competitive funding instruments. The targets set five years ago, in 2016, in the New Framework of Research Grants and Baseline Funding⁶⁸ must be re-examined with a critical eye. How successful has the implementation of the framework been? Have the objectives been achieved? Which activities were not carried out and why? Which activities in the framework are no longer relevant? Should the research grants of the Estonian

Research Council actually be aimed at supporting research careers? What role should the centres of excellence play? Should funding for research infrastructure remain competitive? In 2021, the Estonian Research Council convened the research funding working group once more to thoroughly analyse these and many other issues and to identify the main lines of action for improving and updating the Estonian R&D funding system in cooperation with researchers, R&D institutions and representatives of ministries.

67 Estonian Research Council. Approval of list of core facilities. Decree of Management Board of 16 November 2020. <https://www.etag.ee/wp-content/uploads/2020/11/TT-loend-juhatuse-k%C3%A4skkiri.pdf> (02.11.2021).

68 Estonian Research Council. (2016). A New Framework of Research Grants and Baseline Funding in the Estonian Research and Development Funding System. https://www.etag.ee/wp-content/uploads/2016/10/Uurimistoetuste-ja-tegevustoetuste-uus-s%C3%BCsteem_ETAg_2016.pdf (09.11.2021).



ESTONIAN RESEARCH COMMUNITY AND ITS FUTURE

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INTRODUCTION

Research is conducted by people, specifically researchers, as we generally call them, while statisticians refer to them as “human resources in science and technology” (HRST). Researchers form the foundation of today’s knowledge-based society, contributing to its development in two main ways: firstly, by directly generating and testing new evidence-based knowledge, and secondly, indirectly, by passing it on to future generations. There are probably only a few of those who need convincing that Estonia’s well-being largely depends on the increase of the number of researchers and their best possible application to be of service to the state, economy and society.

This chapter offers one possible insight into the situation of the Estonian research community in the autumn of 2021. In line with established practice, the approach is mainly based on official statistics, but I have also used some recent research on the subject. I will try to avoid, as far as is reasonably possible, the topics already covered in previous similar reviews,^{69,70} although some repetitions are inevitable. Unlike my predecessors, I pay more attention to the disciplinary peculiarities of Estonian research.

The approach is divided into two main parts. First, I map and analyse the Estonian research community from various angles, then I focus on the next generation of researchers, i.e. doctoral students. Thematically, the focus is on the number of researchers, internationalisation, ageing, gender stratification, satisfaction and career patterns.

The chapter was written during a time of significant changes and thus seeks to capture a moving target. During the last three years, which separate this overview from the previous one, a number of important changes have begun in Estonian research, the impact of which is expected to be long term and therefore still difficult to analyse. On 20 February 2019, the Estonian parliament (Riigikogu) passed a new Higher Education Act, which provided a legal basis for creating a new career model for researchers. To date, most universities have developed a tenure-based career system, but it is

certainly too early to assess the results of this reform, especially as the form and pace of enforcement of the career model has varied greatly, depending on the university.

In 2021, the Ministry of Education and Research (MER) and the Ministry of Economic Affairs and Communications (MEAC) completed the “Estonian Research and Development, Innovation and Entrepreneurship Development Plan 2021–2035”,⁷¹ which sets several new goals for Estonian researchers. A thorough renewal of the Research and Development Organisation Act is underway, which is scheduled to be passed by the Riigikogu in the fourth quarter of 2022. In 2021, the Ministry of Education and Research initiated a long-awaited reform of doctoral studies, as a result of which, beginning from the autumn of 2022, doctoral students will start working in universities as junior researchers, receiving the average salary in Estonia, or in a non-university institution/company, contributing to it in a field related to their doctoral thesis.

Another important advancement is that the research agreement signed in Kadriorg, Office of the President, on 19 December 2018,⁷² which provided for an increase in the country’s investment in research and development to 1% of GDP, finally received official support from the government in September 2020.

At the global level, the COVID-19 pandemic has had the greatest effect on the life of the Estonian research community in the last few years. An analysis of the impact of this crisis is yet to come, but the first international studies suggest that the pandemic has left a deep mark on the work of scientists, both in good and bad terms. For example, at the end of 2020, 40% of British researchers surveyed said their workload had decreased during the pandemic, while 20% said it had increased.⁷³ The pandemic has had the greatest impact on the careers of young researchers, in particular due to the postponement of job vacancies.^{74,75} Travelling restrictions resulting from the pandemic have negatively affected those whose research requires travelling and com-

- 69 Tammaru, T. (2016). 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. <http://dx.doi.org/10.15158/DISS/0002>
- 70 Niinemets, Ü. (2019). Career models and job opportunities for the researchers in Estonia: where are we coming from, and where are we heading to? – Estonian Research 2019 (ed. K. Raudvere), pp. 21–36. Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0004>
- 71 Estonian Ministry of Education and Research. Teadus- ja arendustegevuse, innovatsiooni ning ettevõtluse (TAIE) arengukava 2021–2035 (Research and Development, Innovation and Entrepreneurship Development Plan 2021–2035). <https://www.hm.ee/et/TAIE-2035> (20.09.2021).
- 72 Estonian Research Council. Estonian Research Agreement. A Social Agreement to ensure the further development of Estonian Research and innovation. (2018). <https://www.etag.ee/wp-content/uploads/2019/05/Estonian-Research-Agreement-2018-ENG.pdf> (24.01.2021).
- 73 The impact of the Covid-19 pandemic on researchers in universities and research institutes. Science, Technology and Innovation Analysis, Department for Business, Energy & Industrial Strategy, 08.10.2020, <https://www.vitae.ac.uk/impact-and-evaluation/covid-19-impact-on-researchers> (20.08.2021).
- 74 Flaherty, C. (2021). COVID-19’s Impact on Academic Research. – Inside Higher Ed, 01.02.2021. <https://www.insidehighered.com/quicktakes/2021/02/01/covid-19s-impact-academic-research> (20.08.2021).
- 75 OECD. (2021). Reducing the precarity of academic research careers. – OECD Science, Technology and Industry Policy Papers, No. 113, OECD Publishing, Paris., <https://doi.org/10.1787/0f8bd468-en>

municating with people (anthropologists, sociologists, etc.). On the positive side, the pandemic has increased the digital competences and readiness of researchers in both teaching and research communication, and has helped to increase

the importance and visibility of researchers in society (e.g. the role of research councils in advising governments).⁷⁶ COVID-19 has also clearly guided the research interests of researchers, even across disciplines.⁷⁷

ESTONIAN RESEARCH COMMUNITY: GENERAL VIEW

A prerequisite for the growth of the research community is a general increase in the level of education in society. Looking at the experience of successful countries, it can be seen that they are characterised by a relatively rapid progress on all levels of higher education. From the point of view of research, the number of doctoral students is, of course, the most significant. Estonia's development in this field has been rapid (26 people obtained a doctorate in 1996, 221 in 2020), but unfortunately it has slowed down in the last decade. The record year was 2011, when 250 people received their doctoral degrees. From then onwards, the number of new doctors has somewhat decreased, although

the national strategies have maintained the goal of adding 300 doctors per year. The decrease in the number of doctoral graduates is directly related to the decrease in the number of new doctoral positions: 562 people were admitted to doctoral studies in 2010 and 605 in 2011, but 361 were admitted in 2018, 397 in 2019 and 343 in 2020. The reason, of course, is insufficient funding for doctoral studies. At the same time, the number of doctoral students who have interrupted their studies has increased: In 2010, 8.3% of doctoral students dropped out, 11.5% in 2019 and 10.1% in 2020 (Figure 2.1).

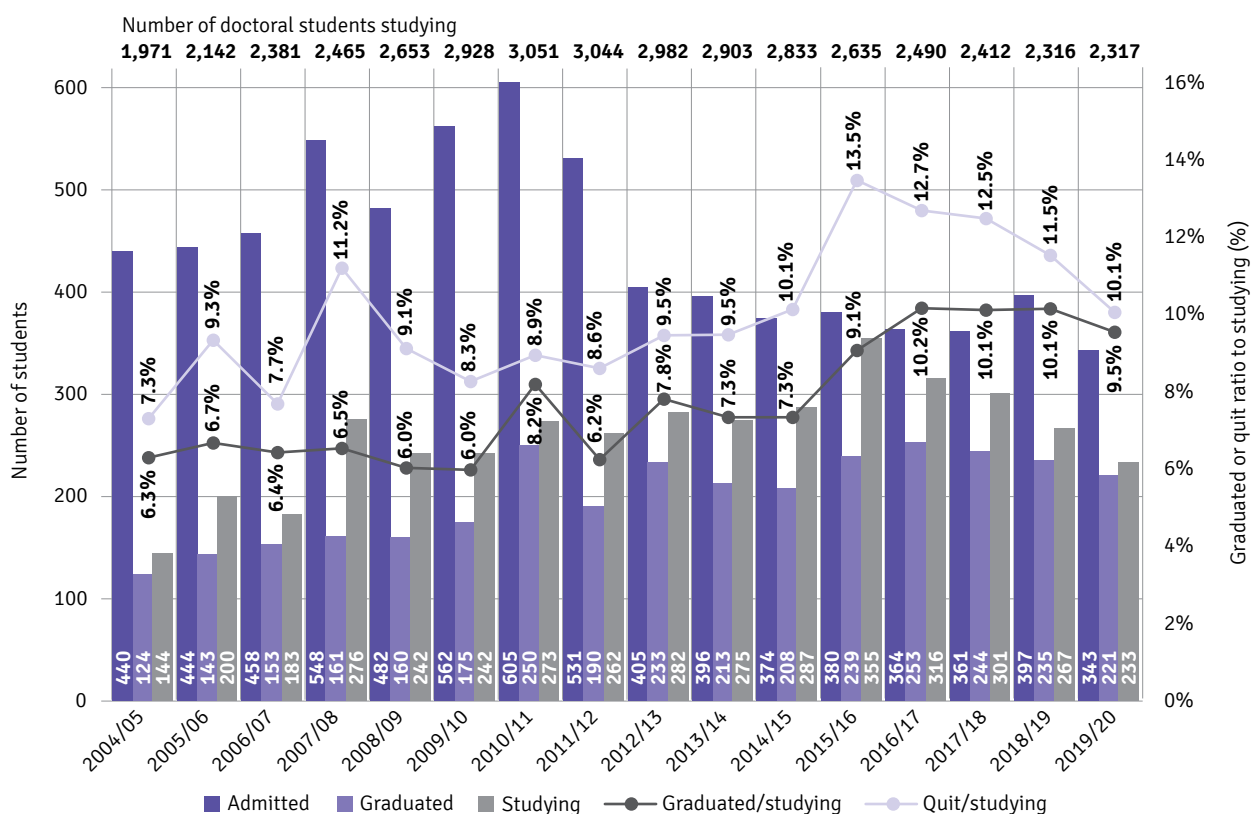


Figure 2.1. The number of students admitted to, graduated from, quit and continuing doctoral studies in 2004–2020

Sources: EHIS and Statistics Estonia (2005 and 2006).⁷⁸

⁷⁶ Marinoni, G., van't Land, H., Jensen, T. (2020). The impact of COVID-19 on higher education around the world: IAU global survey report, pp. 34–35. International Association of Universities. https://www.iau-aiu.net/IMG/pdf/iau_covid19_and_he_survey_report_final_may_2020.pdf (20.09.2021).

⁷⁷ Haleem, A., Mohd, J., Vaishya, R., Deshmukh, S. G. (2020). Areas of academic research with the impact of COVID-19. – The American Journal of Emergency Medicine 38 (7), pp. 1524–1526.

⁷⁸ Statistics Estonia. www.stat.ee (15.06.2021).

If we place Estonian doctoral studies in a broader, higher education background, we can see that the ratio of doctoral degree and bachelor's degree holders has remained at 4–5% for a long time during this century, with an absolute low in 2005 (2.4%). Since 2017, however, the ratio of doctors to those with a bachelor's degree has risen slightly, barely exceeding 7% in the last four years (Figure 2.2). Statistics on all three levels of higher education show that the share

of those admitted to higher education, especially the first level of higher education, has decreased since 2014, which also applies to the number of graduates and drop-outs. The average age of entrants has increased, and thus the share of adult learners (i.e. those aged 30 and over) has increased – in 2020, adults accounted for just over 30% of students in higher education.⁷⁹

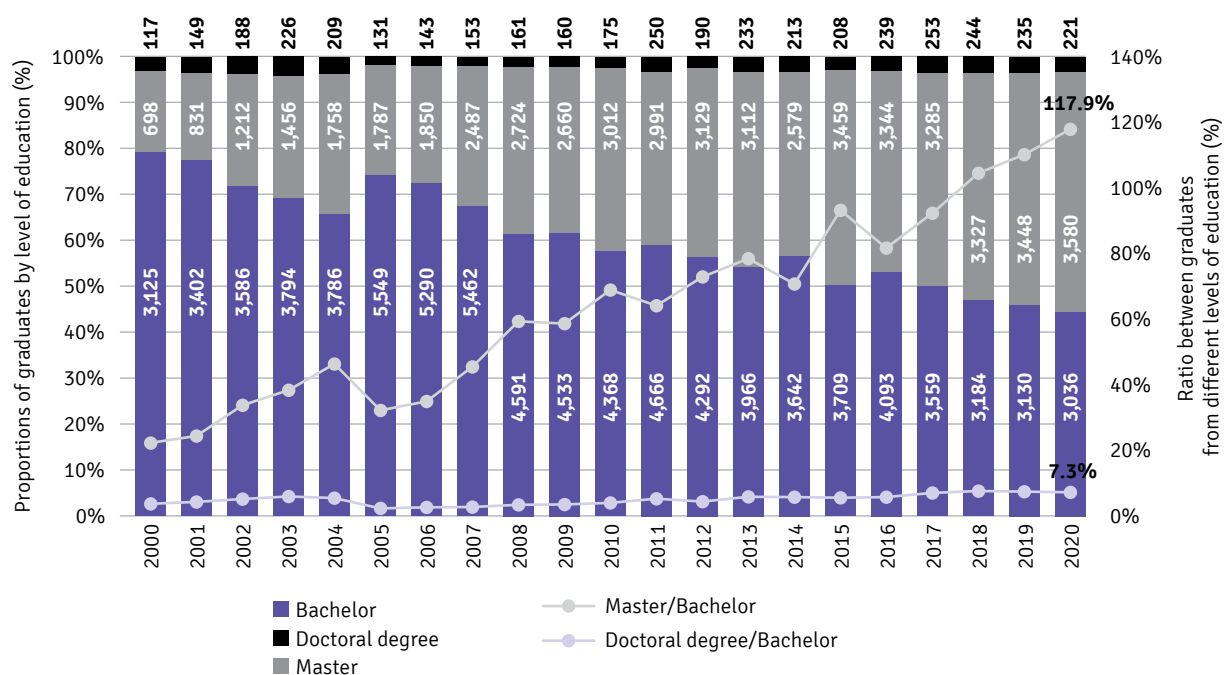


Figure 2.2. Graduates according to the level of education in 2000–2020 (year marks the end of academic year)

Source: Statistics Estonia.⁸⁰

As a positive trend, it can be pointed out that the share of students with a bachelor's degree who also go on to obtain a master's degree has grown strongly during this century: in 2000, there were only 698 master's degree holders (13.3% of bachelor's degree holders), while the number was already 3,580 in 2020 (117.9%) (Figure 2.2).⁸¹ Thus, one of the most important tasks that Estonian higher education faces is how to enable a larger number of master's degree holders to continue their studies at the doctoral level. In principle, all the prerequisites for this already exist.

By international comparison, Estonian doctoral studies still hold a modest position. Across European countries in 2019, the share of doctoral graduates in relation to the holders of a bachelor's degree or equivalent⁸² varied from 1.3% (Poland) to 9.5% (Sweden). The same indicator for Estonia has slightly improved in recent years: it was 3.0% in 2015 and 4.4% in 2019. With this indicator, we remain in the average position among European countries, yet are clearly lagging behind the leaders (Sweden, Slovakia, Germany and Austria) (Figure 2.3).

⁷⁹ Leppik, M. (2021). Kutse- ja kõrgharidusõppe lõpetanute edukus tööturul 2019. ja 2020. aastal: statistiline ülevaade (The success of vocational and higher education graduates in the labour market in 2019 and 2020: statistical overview), p. 4. Ministry of Education and Research, Tartu. https://www.hm.ee/sites/default/files/edukus_tooturul_22072021.pdf (20.08.2021).

⁸⁰ Statistics Estonia. www.stat.ee (26.04.2021).

⁸¹ It should be borne in mind that during the 2002/2003 academic year, Estonia switched to the 3 + 2 (Bologna) higher education model. Before that, the 4 + 2 model was used in Estonia, in which case the so-called master's research degree was obtained when completing the master's degree programme. Admission to the master's research degree curricula ended on September 1, 2005.

⁸² In Eurostat, International Standard Classification of Education ISCED 11.

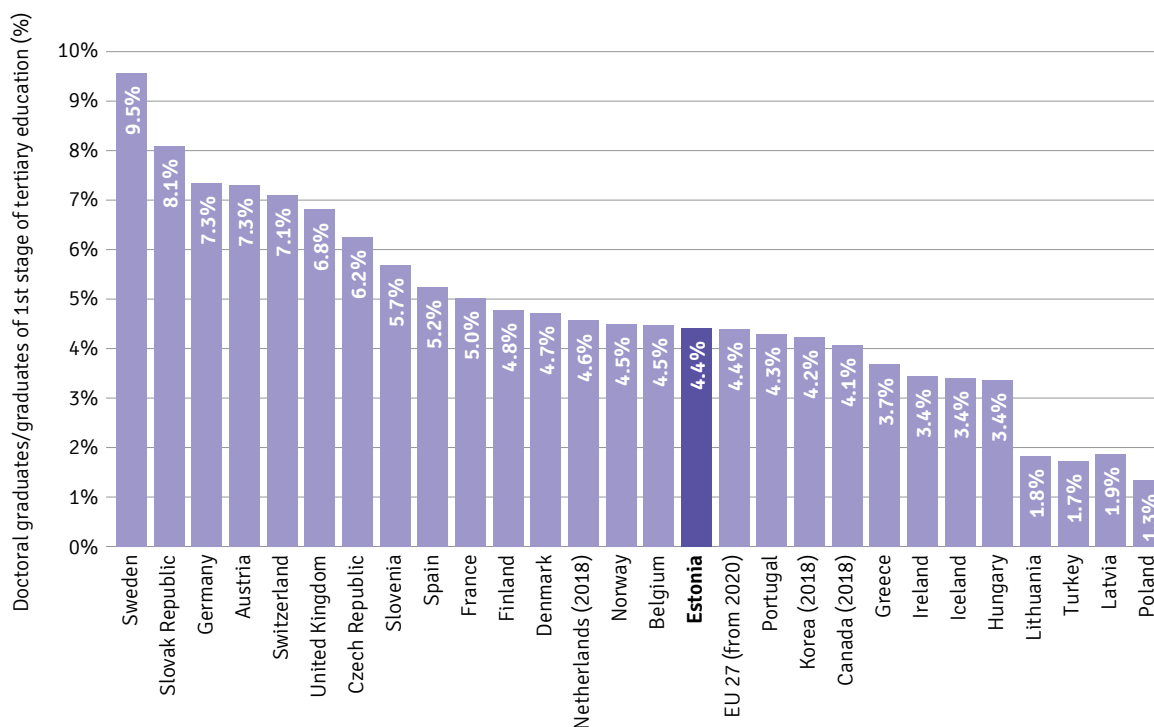


Figure 2.3. Number of doctoral graduates in relation to the graduates of the first stage of tertiary education in different European countries in 2019

Source: Eurostat,⁸³ calculations by Estonian Research Council.

Moving from the general indicators of higher education more specifically to the Estonian research community, it must be mentioned that researchers are not defined uniformly in the statistical view – especially when looking at Estonian data in an international context – and therefore care must be taken in interpreting the data.⁸⁴

As of 2020, there are 8,659 researchers i.e. 6.5 researchers per thousand inhabitants in Estonia, while in 2019 the same figure was 5.8 for a total of 7,734 researchers. This figure leaves us at the bottom of the list among OECD countries, relatively far behind the leading countries Norway, Den-

mark, Sweden and Finland. We are just ahead of Slovakia, Spain and Poland (Figure 2.4)⁸⁵. If we look at the number of full-time equivalent positions of Estonian researchers per thousand inhabitants over a longer period of time, we can see that during the last two decades, a moderate increase (from 1.9 to 3.46 per thousand inhabitants) lasted until 2012, followed by a small decrease until 2016, then again followed by a slight increase, but remained fairly stable for the past three years (Figure 2.5). The new growth is primarily due to the increase in the number of researchers' full-time equivalents in the private sector (0.95 per thousand inhabitants in 2005, 1.53 in 2019).

⁸³ Eurostat. <https://ec.europa.eu/eurostat/data/database> (28.09.2021).

⁸⁴ Statistics Estonia as well as most other authorities collect statistics on research on the basis of the methodology presented in the Frascati Manual. Organisations providing international statistics (e.g. OECD, Eurostat), in turn, compile data collected by national statistics. This ensures that the data is collected on a uniform basis and the results are comparable. According to Statistics Estonia's interpretation of the Frascati Manual, researchers (or "researchers and engineers" as used by Statistics Estonia) include: all persons with a scientific degree or higher education diploma who perform basic and applied research or experimental development of new knowledge, products, processes, methods and systems; all lecturers involved in research and development; heads of research institutions and their subdivisions who plan or organise scientific and technical projects; doctoral and master's students involved in original research. Researchers do not include individuals who are employed in the position of a researcher or engineer but who do not have a higher education, as well as routine analysts, bibliographers or programmers, for they are considered technicians. When technicians and support staff (working under the guidance of researchers and engineers, playing a supportive role in R&D projects) are included in the group of researchers, they are referred to as R&D personnel. An employee is involved in research and development if they spend at least 10% of their working time on respective activities.

⁸⁵ As the latest OECD data on the number of researchers date from 2019, the comparison is based on Estonian data from 2019.

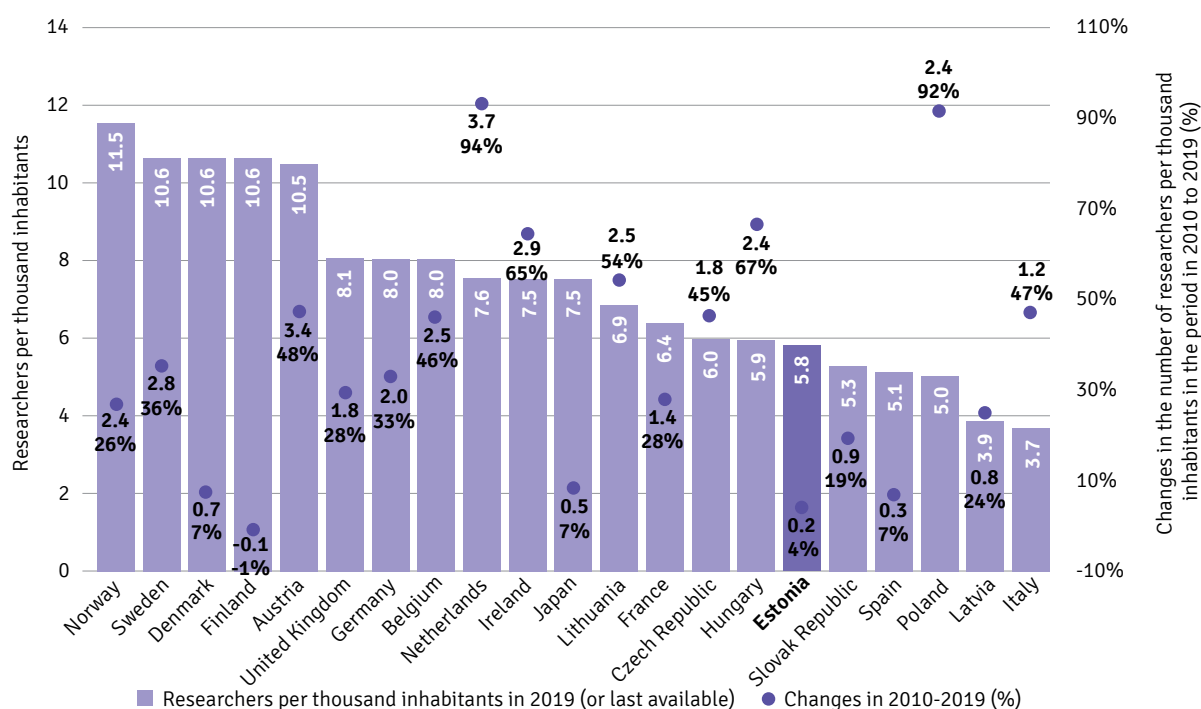


Figure 2.4. Researchers per thousand inhabitants in 2019 and changes therein in 2010–2019

Source: OECD,⁸⁶ calculations by Estonian Research Council.

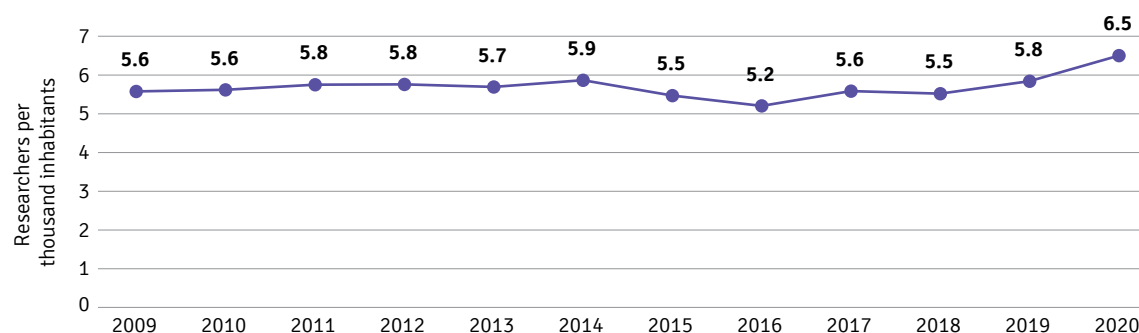


Figure 2.5. Number of Estonian researchers per thousand inhabitants in 2009–2020

Sources: Statistics Estonia⁸⁷ (data from 2020), calculations by Estonian Research Council.

In any case, the main structural problem of the Estonian research community – in addition to the small increase in the number of researchers – is still the gap between the number of researchers working in the public and private sectors, which is particularly evident in international comparisons. In 2020, there were 2,905 full-time equivalent researchers in the public sector in Estonia, while the num-

ber of full-time equivalent researchers in the private sector was 2,196 (43%). Standardised per thousand inhabitants, this means that in 2020, the indicator for researchers working in the public sector is 2.19, and 1.65 in the private sector. The number of full-time equivalent researchers involved in the private sector has remained more or less the same over the last ten years (30–43%) (Figure 2.6).

86 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (07.12.2021).

87 Statistics Estonia. www.stat.ee (02.12.2021).

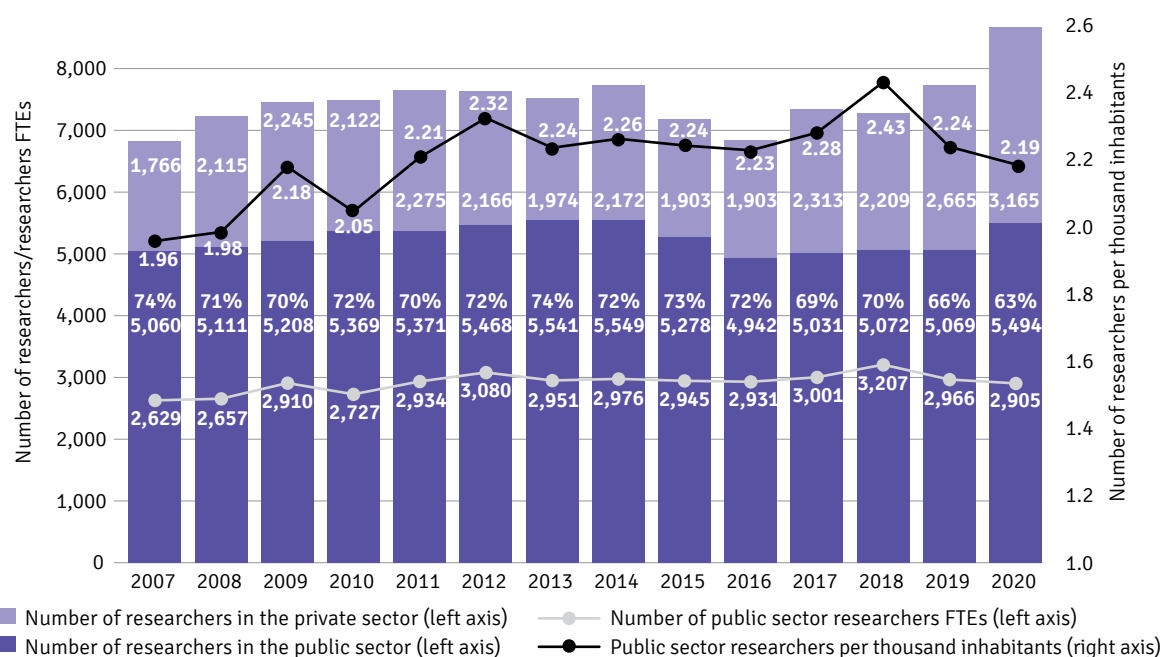


Figure 2.6. Dynamics of the number of researchers (full-time equivalents) in public and private sectors in 2007–2020

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

Looking at the indicators of Estonian researchers' employment in the context of the EU countries, a somewhat clear pattern emerges: in the more successful countries, the employment of researchers in the private sector is clearly higher than in the public sector. According to 2019 data, the EU average share of full-time equivalent researchers in the public sector is 44%. In Sweden, public employment accounts for only 29%, in the Netherlands for 30%, in Austria and France for 36%, in Slovenia for 39% and in Finland for 42%. The respective figure for Estonia is 59% (57% in 2020), while an even higher share of public sector positions

is seen in Lithuania (68%) and Latvia (79%) (Figure 2.7). On the positive side, however, the number of private sector researchers in Estonia has grown strongly over the last two decades, especially in the first decade of the century, in parallel with the general growth of the private sector. Over the last decade, the development has stabilised (the share of full-time equivalent researchers in the public sector was 65% in 2011) – in the view of international tendencies, this indicates a widening gap between Estonia and the more successful countries.

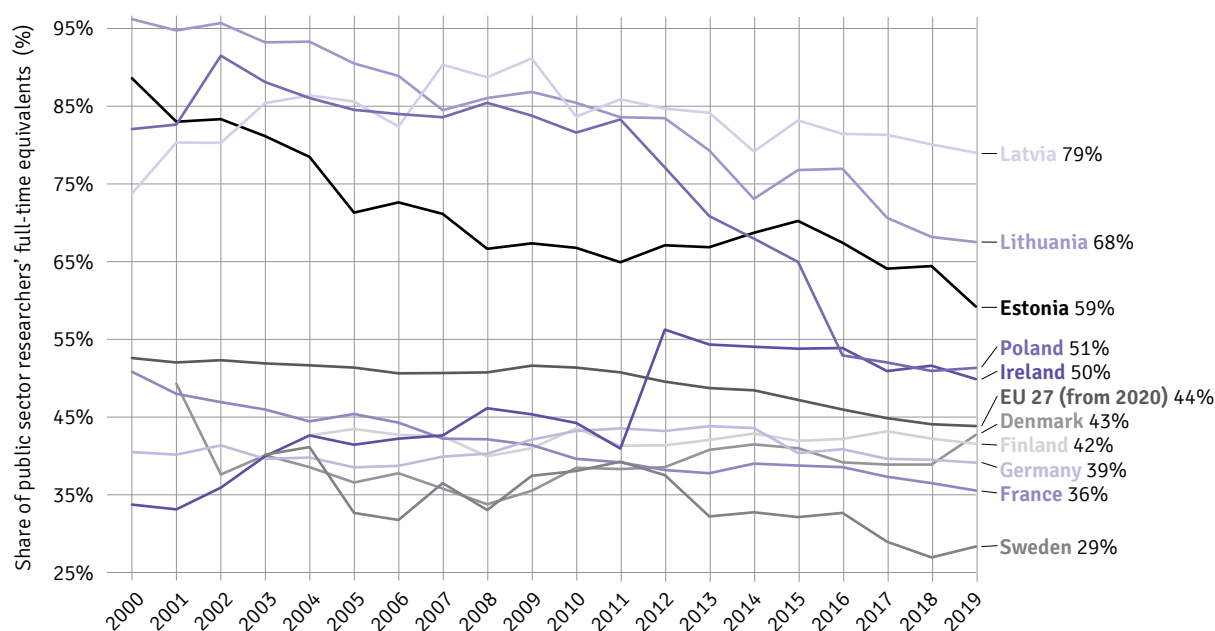


Figure 2.7. Dynamics of the share of public sector researchers' full-time equivalents in selected OECD countries in 2000–2019

Source: OECD,⁸⁹ calculations by Estonian Research Council.

⁸⁸ Statistics Estonia. www.stat.ee (02.12.2021).

⁸⁹ OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (16.09.2021).

As the contribution of researchers to the private sector is further discussed in Chapter 4 of this volume, in the following I will only discuss the public sector research community in more detail. According to Statistics Estonia, in 2020, the full-time equivalent employment of 2,905 public sector researchers was divided as follows: the largest number of full-time equivalent researchers (885 or 30%) worked in the field of natural sciences; followed by almost equal results in the humanities and the arts and social sciences (542 and 518 researchers respectively, or 19% and 18%); 394 researchers (14%) were involved in the field of engineering and technology, 356 (12%) in medical and health sciences and 211 (7%) in agricultural and veterinary sciences. During this century, these research field proportions have remained relatively stable, with a slight decrease in the number of naturalists and an increase in the number of social and humanities researchers (Figure 2.8).

Unfortunately, the available statistics are too episodic to allow for comparison with other countries. However, the 2017 data for some countries, mainly in Eastern and Central Europe, will give us some idea.⁹⁰ What is striking is that in several countries, the field of engineering and technology is represented with a proportionately larger share of researchers than in Estonia (e.g. in Latvia, 26% of the total research community in 2017, in Slovakia 27% and in the Czech Republic 20%), while the share of social science and humanities and arts researchers is generally proportionately smaller (in the Czech Republic 11% and 11% respectively, in Latvia 12% and 11%, in Slovenia 12% and 12%, in Hungary 17% and 16%).

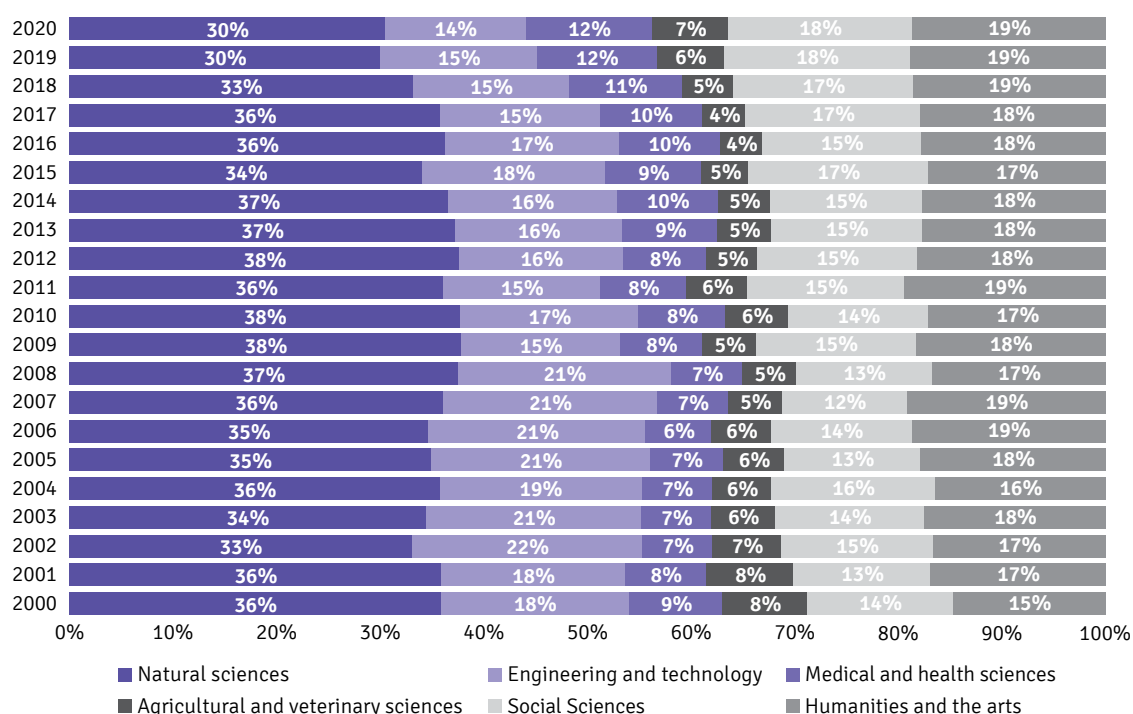


Figure 2.8. Full-time equivalents of public sector researchers by research fields in Estonia in 2000–2020

Source: Statistics Estonia.⁹¹

To supplement the data of Statistics Estonia, it is worth looking at how researchers working in Estonia classify themselves by field. As of 16 September 2021, a total of 9,805 unique academic staff had been assigned a field of research in the Estonian Research Information System (ETIS). As one person can choose several research fields in ETIS, the total number of researchers in different fields

together with duplicates was 10,514. The most frequently mentioned fields were culture and society (37%). 33% of researchers had chosen the field of natural sciences and engineering, 20% had mentioned biosciences and environment as their field, and 11% had mentioned health (Figure 2.9).

⁹⁰ OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (16.09.2021).

⁹¹ Statistics Estonia. www.stat.ee (14.10.2021).

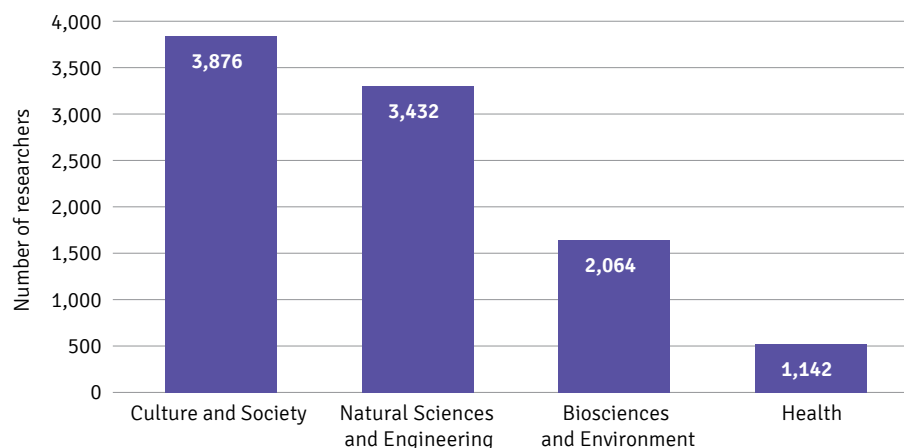


Figure 2.9. Division of researchers by research fields according to the classification by the Estonian Research Information System⁹² (data as of 16.09.2021)

Source: Estonian Research Information System.⁹³

The data of Universities Estonia make it possible to assess the time dynamics of academic positions in six Estonian public universities (Figure 2.10). In 2014–2017, the numbers decreased, especially in the case of researchers (excluding junior researchers, their number increased), as well as in the case of teaching staff, but since 2018, the number of academic positions has started to increase again. It must be said that it will be more difficult to compare the time dynamics from 2020 onwards, as many positions have been renamed in the context of the new career model. In

this overview, the positions of the new classification have been merged with the positions of the old system, but due to the substantive differences in the distribution of positions, the data from 2020 onwards are not fully comparable with the previous ones.⁹⁴ Looking at the number of full-time equivalent positions of the academic staff of six universities, it can be said that the situation has largely recovered to the state of 2014: at that time, the universities had a total of 3,479 academic staff, and the same figure was 3,501 in 2020, while it had been 3,273 in 2018 and 3,295 in 2019.

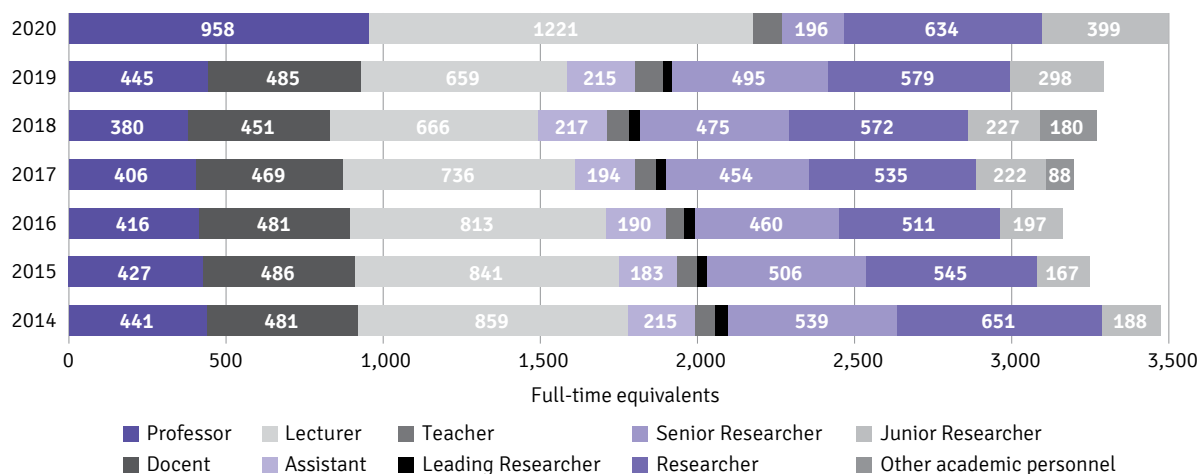


Figure 2.10. Changes in filled positions (full-time equivalents) in six Estonian public universities in 2014–2020⁹⁵

Source: Universities Estonia.⁹⁶

⁹² The data are taken from the CVs in ETIS, which the researchers themselves have added, some of them indicating several fields of research. In such a case, it is not possible to distinguish which is the so-called primary field, nor is it possible to say what are the proportions of the fields. Therefore, the figure presented contains duplicates. The number of persons who have indicated their field of research excluding duplicates is 9,805, while including duplicates it is 10,514. As the assignment of the CERCS classification is not mandatory in ETIS, many have left it unselected and therefore it has not been used in the figure.

⁹³ Estonian Research Information System. www.etis.ee (16.09.2021).

⁹⁴ New classification: two groups of professors: “professor, R3” and “professor, R4” (including former leading researchers); “senior lecturer” (incl. associate professors of some universities); lecturers (incl. former assistants) by qualifications: “lecturer, with a doctoral degree” and “lecturer, without a doctoral degree”; “teacher”; “senior researcher, R3”; “researcher, R2”; for junior researchers, a distinction is made between “junior researcher” and “doctoral student-junior researcher”. For the sake of comparability, this article combines the new classifications “professor, R3” and “professor, R4” under the title of professor, the new classifications “senior lecturer”, “lecturer, with a doctoral degree” and “lecturer, without a doctoral degree” under the title of lecturer and the new classifications “junior researcher” and “doctoral student-junior researcher” under the title of junior researcher. The titles of teacher, senior researcher and researcher have remained the same. See more at <https://statistika.ern.ee/tootajad/> (14.10.2021).

⁹⁵ Data are based on employment contracts in force on 31 December 2020, no wage data are provided for groups with less than three employees. As from 2020, the job classification corresponds to the new career model, and time dynamics by position will not continue. For 2020, the explanations provided on the website of Universities Estonia regarding the renaming of positions by universities have been used.

⁹⁶ Universities Estonia. <https://statistika.ern.ee/tootajad/> (25.06.2021).

ESTONIAN RESEARCH COMMUNITY IN THE VIEW OF INTERNATIONALISATION AND AGE

One of the biggest changes in the Estonian research community over the last decade is its internationalisation, which is most evident among junior researchers and doctoral students (see below). Ten years ago, in 2011, according to

Statistics Estonia, a total of 295 foreign researchers⁹⁷ (5%) worked in non-profit sectors in Estonia, but in 2020, the same number had increased to 774 (Figure 2.11) or 14%.

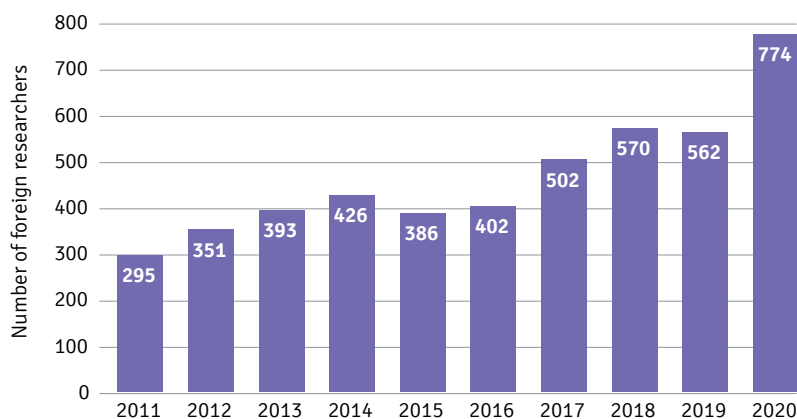


Figure 2.11. Foreign researchers in non-profit institutional sectors⁹⁸ in 2011 to 2020

Source: Statistics Estonia.⁹⁹

Internationalisation can be considered a positive development, but it is also accompanied by a negative trend: the ageing of the Estonian research community over the last few decades. In 2013, Ülo Niinemets showed that, during this century, the share of research project managers over the age of 65 has steadily increased, calling it “reverse age discrimination” – discrimination against young researchers entering science rather than discrimination against the continuation of the old ones.¹⁰⁰ A survey conducted in 2015 showed that the average age of Estonian researchers at any stage of the career is somewhat higher than the European average. The contrasts were particularly pronounced in the view of research fields, where, in some cases, more specifically in the humanities and social sciences, a doctorate was

obtained around the age of 40.¹⁰¹

According to 2018 data, 68% of Estonian academic staff were at least 40 years old. Only 5–6% were under 30 years of age and 19–20% were over 60 years of age. Among the OECD countries, Estonia was at the bottom of the list with these indicators, along with Latvia, Italy, Hungary and others, where the share of academic staff over the age of 60 is also high (20%).^{102,103} If we look at the data concerning the age of Estonian researchers, it can be seen that the share of researchers under the age of 35 has decreased the most in the last 13 years (29% in 2007, 22% in 2020), while the age group 35–44 has grown the fastest (22% in 2007, 32% in 2020) (Figure 2.12).

⁹⁷ According to Statistics Estonia, foreign researchers are researchers and engineers with foreign citizenship.

⁹⁸ Comprised of the higher education sector, government sector and private non-profit sector. No data have been collected on foreign researchers working in companies.

⁹⁹ Statistics Estonia. www.stat.ee (28.06.2021).

¹⁰⁰ Niinemets, Ü. (2013). Eesti sihtfinantseeritavate teadusteemade juhid 1998–2013: noorenemine, vananemine ja äraspidi vanuseline diskrimineerimine (Estonian leaders of research topics with targeted funding in 1998 to 2013: the young, the old, and reverse age discrimination). – Teadusmõte Eestis (VIII): Teaduskultuur (ed. J. Engelbrecht), pp. 83–98. Estonian Academy of Sciences, Tallinn.

¹⁰¹ Vadi, M., Kindsiko, E., Alas, R. (2015). Teadlase karjäär: Eesti rahvusvahelises taustsüsteemis. Uuringu 6.4 lõppraport (The career of scientists: Estonia in the international system. Study 6.4 Final Report), https://majandus.ut.ee/sites/default/files/www_ut/tips_uuringu_6.4_loppraport.pdf (20.08.2021).

¹⁰² Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerens, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), pp. 53–54. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.08.2021).

¹⁰³ See also Kindsiko, E., Mägi, E., Koppel, K., Kõiv, K., Beerens, M. (2019). Miks doktorant professoriks ei saa? Akadeemiliste töötajate karjäär, töölased käitumismustrid ja tööõhkkond (Why doesn't a doctoral student become a professor? Careers of academic staff, behavioural patterns and environment at work). – Sirp, December 6.

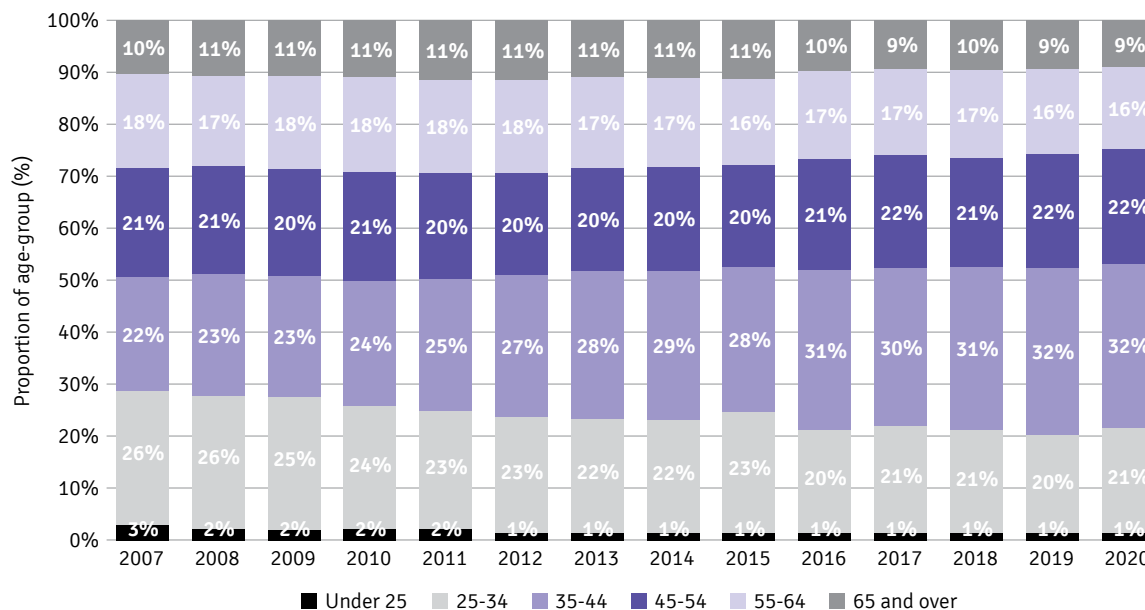


Figure 2.12. Age dynamics of the proportions of Estonian researchers working in the non-profit sectors in 2007 to 2020

Source: Statistics Estonia.¹⁰⁴

The ageing of the research community is causing a number of problems. Firstly, it makes it more difficult for young people to enter the research system because there are few open positions. Based on a 2019 survey, 42% of Estonian academic staff found that it is currently difficult for young people to start an academic career in their field.¹⁰⁵ The same study highlighted the workload and teaching burden of junior researchers. Among the university staff, the workload of junior researchers is almost the highest (49 hours per week), due to both their significant teaching workload (14

hours) and the volume of management and administrative tasks (8 hours). This is not in line with the objectives set for the position of junior researcher or their own preference: 79% of junior researchers prefer research to teaching.¹⁰⁶ Secondly, the ageing of the research community creates a situation where several disciplines are facing a shortage of successors, especially those where the average age of researchers has risen to a very high level and doctoral theses are being defended at a relatively high age.

ESTONIAN RESEARCH COMMUNITY FROM A GENDER PERSPECTIVE

The gender stratification of the research community is one of the global problems that is also present in Estonia. In previous discussions, the image of a “leaky pipeline”^{107,108} has taken root, which sums up the nature of the problem well: while there are more women than men in Estonia among those who have completed higher education – in 2019, women accounted for 63.6% of higher education graduates (and there were slightly more women than men that graduated from doctoral studies) – the share of women in higher academic positions is still modest. Thanks to more recent research, especially the study “Gender equality in Estonian science – current situation and ways of improving”¹⁰⁹

completed in University of Tartu’s Centre for Applied Social Sciences (CASS) in 2020, it is possible to take a closer look at gender inequality in the Estonian research community.¹¹⁰

Over the last ten years, the share of women among Estonian academic staff has grown steadily: In 2010, women accounted for 48.7% of the academic staff, and in 2020, they accounted for just over half with 51% – an increase of 2.3% over ten years (Figure 2.13). As can be expected, the share of women and men differs depending on the univer-

¹⁰⁴ Statistics Estonia. www.stat.ee (28.06.2021).

¹⁰⁵ Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerken, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), p. 8. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.09.2021).

¹⁰⁶ Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerken, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), p. 6. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.09.2021).

¹⁰⁷ Alper, J. (1993). The pipeline is leaking women all the way along. – Science 260 (5106), pp. 409–411.

¹⁰⁸ Soomere, T., Niinemets, Ü., Niglas, K., Pilt, E., Roosalu, T., Randma-Liiv, T. (2018). Jätksuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis (Sustainable concepts and models of research careers in the Estonian context), pp. 75–77. Estonian Academy of Sciences, Tallinn. <https://www.etag.ee/wp-content/uploads/2018/04/J%3c3%a4tkusuutlikud-teadlaskarj%3c3%a4ri-kontseptsioonid-ja-mudelid-Eesti-kontekst.pdf> (29.09.2021).

¹⁰⁹ Urmann, H., Lees, K., Remmik, M., Tubelt, E., Roos, L., Vilson, M., Puur, S. M., Aksen, M., Espenberg, S. (2020). Soolise võrdõiguslikkuse hetkeolukord ja parandamise viisid Eesti teaduses (Gender equality in Estonian science – current situation and ways of improving). University of Tartu’s Centre for Applied Social Sciences (CASS), Tartu. https://www.etag.ee/wp-content/uploads/2021/03/Sooline_vordoiguslikkus_Eesti_teaduses.pdf (20.08.2021).

¹¹⁰ See also Estonian Research Council (2021). Gender balance and gender pay gap, <https://www.etag.ee/en/activities/analysis/gender-balance-and-pay-gap/> (28.09.2021).

sity. The share of women among academic staff is the highest at Tallinn University; in 2020, 62.7% of the academic staff were women. The share of women is also high in the Estonian Academy of Arts, where the proportion of women among the academic staff was 62.2% in 2020, while ten

years earlier it had been 52.9%. At the University of Tartu, women accounted for just over half of the academic staff in 2020 – 52%. The proportion of women is the lowest at Tallinn University of Technology, for their share among the academic staff was 37.4% in 2020.¹¹¹

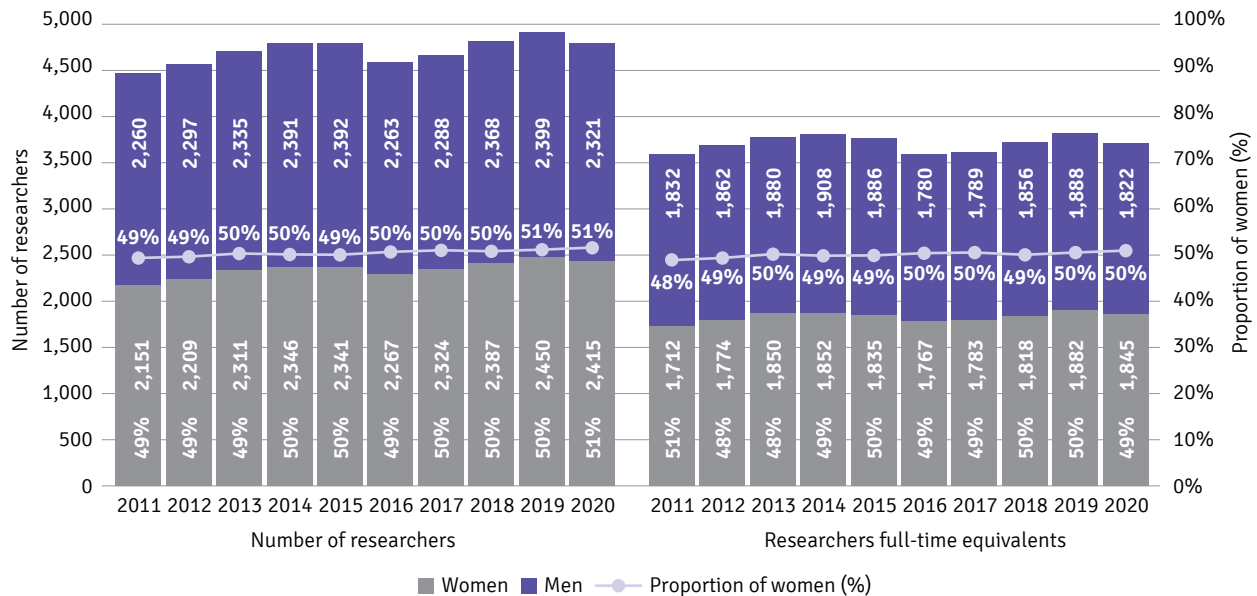


Figure 2.13. Gender in employment at public universities and other research institutions in 2011 to 2020

Source: University of Tartu's Centre for Applied Social Sciences (CASS).¹¹²

However, previous studies have shown that although the share of men and women is more or less equal among Estonian academic staff, there is a big difference in terms of academic positions. Thus, in 2020, the proportion of women holding the position of professor was only 23.9% and their share among leading researchers was 27.3%. Compared to 2010, the share of women among professors has increased (21.3%), while among leading researchers it has

decreased (35.1%). In 2020, the share of women was the highest among assistants (72.2%) and teachers (77.2%). Compared to 2010, the share of women among assistants has increased, but among teachers it has remained at the same level for the last ten years. The share of women among associate professors has also increased: in 2010, women accounted for 41.8%, while their share was 53.2% in 2020 (Figure 2.14).¹¹³

¹¹¹ Urmann, H., Lees, K., Remmik, M., Tubelt, E., Roos, L., Vilson, M., Puur, S. M., Aksen, M., Espenberg, S. (2020). Soolise võrdõiguslikkuse hetkeolukord ja parandamise viisid Eesti teaduses (Gender equality in Estonian science – current situation and ways of improving), p. 31. University of Tartu's Centre for Applied Social Sciences (CASS), Tartu. https://www.etag.ee/wp-content/uploads/2021/03/Sooline_vordõiguslikkus_Eesti_teaduses.pdf (20.08.2021).

¹¹² *Ibid.*, p. 31.

¹¹³ *Ibid.*, p. 32.

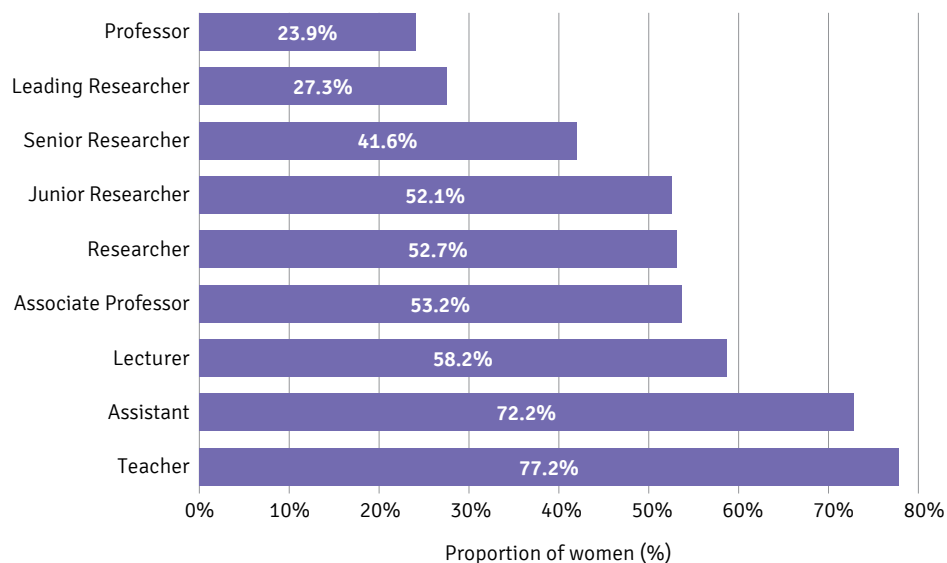


Figure 2.14. Proportion of women by position at public universities and other research and development institutions in 2020

Source: University of Tartu's Centre for Applied Social Sciences (CASS).¹¹⁴

From the research field perspective, the proportion of women among the academic staff has changed relatively little. In the field of natural and technical sciences, men clearly dominate (69% and 62% in 2020, respectively),

while in the field of medical and social sciences women predominate (73% and 62% in 2020, respectively) (Figure 2.15).¹¹⁵

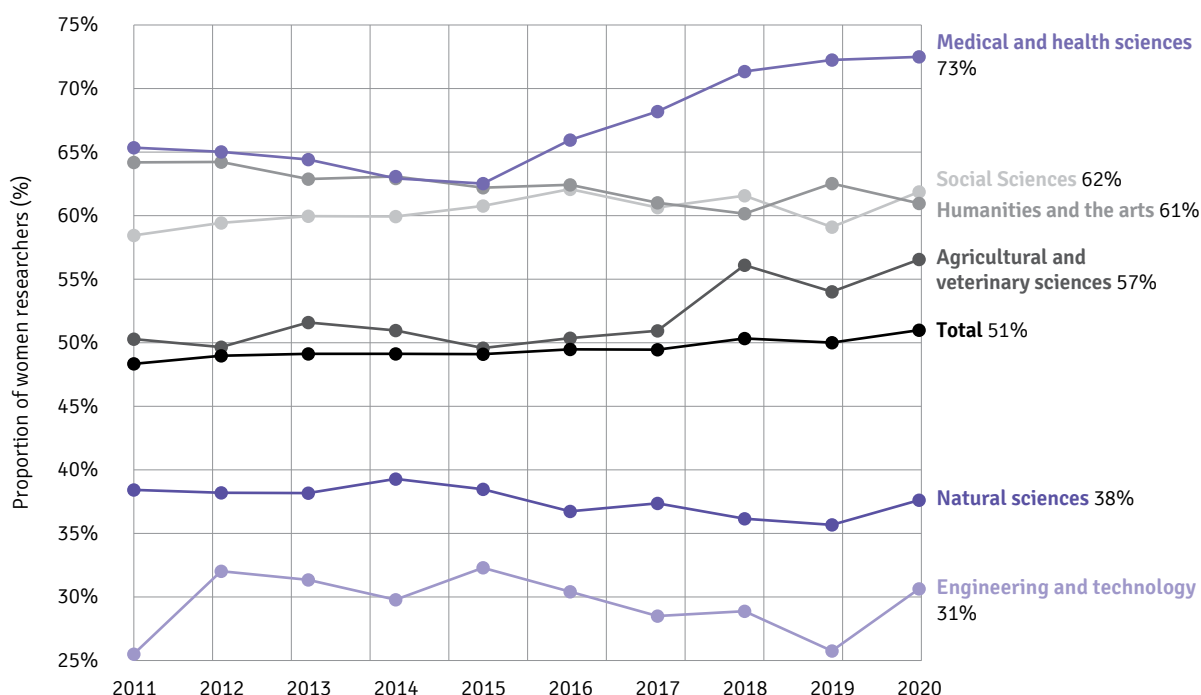


Figure 2.15. Proportion of women researchers by research fields in 2011 to 2020 (non-profit sectors)

Source: Statistics Estonia.¹¹⁶

¹¹⁴ Urmann, H., Lees, K., Remmik, M., Tubelt, E., Roos, L., Vilson, M., Puur, S. M., Aksel, M., Espenberg, S. (2020). Soolise võrdõiguslikkuse hetkeolukord ja parandamise viisid Eesti teaduses (Gender equality in Estonian research – current situation and ways of improving), p. 34, Figure 9. University of Tartu's Centre for Applied Social Sciences (CASS), Tartu. https://www.etag.ee/wp-content/uploads/2021/03/Sooline_vordoguslikkus_Eesti_teaduses.pdf (20.08.2021).

¹¹⁵ *Ibid.*, p. 40 and p. 92.

¹¹⁶ Statistics Estonia. www.stat.ee (07.07.2021).

The gender stratification in Estonian research can also be observed on the basis of some other important indicators. Namely, the cited 2020 survey revealed that men publish more research articles, both in terms of the total number of publications and the most influential article types (Estonian Research Information System classifications 1.1 and 3.1) (Figure 2.16). Between 2014 and 2020, women accounted for 43–44% of those who published at least one type 1.1 publication. The proportion of women in type 3.1 publica-

tions has increased, but is still less than half: it was 35.9% in 2014 and 45.6% in 2020. In total, women accounted for 46.5% of those who have published at least one publication in 2020. This figure has been relatively stable over the last seven years (45–47%). Looking at publication by academic positions, it appears that in almost all professions, except for associate professors and leading researchers, men have published more publications than women (see also Chapter 3).¹¹⁷

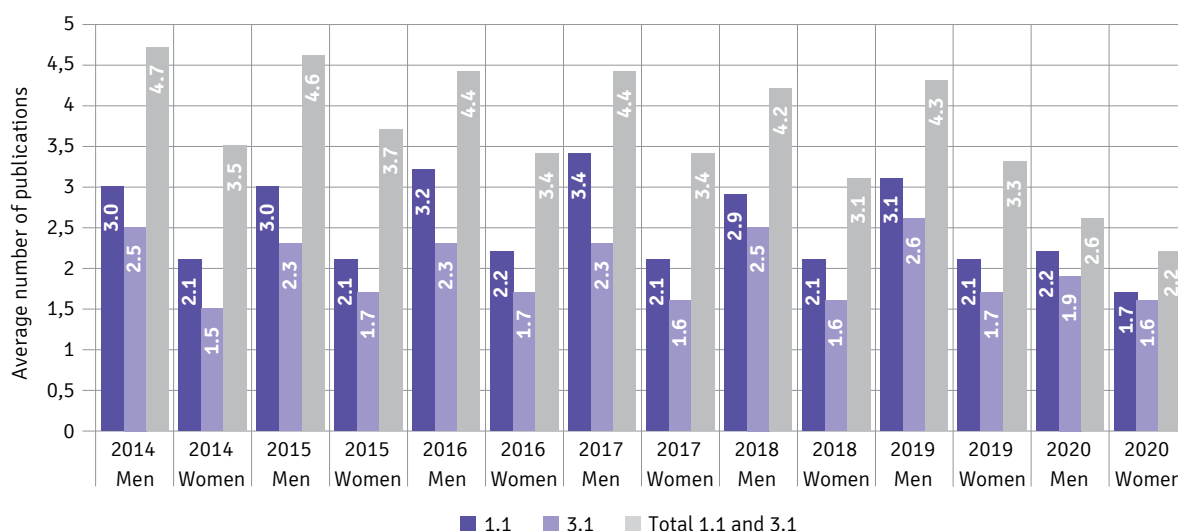


Figure 2.16. Average number of publications per year per researcher who published at least one research article (Estonian Research Information System classifications 1.1 and 3.1) by gender in 2014 to 2020¹¹⁸

Source: University of Tartu's Centre for Applied Social Sciences (CASS).¹¹⁹

The data also show that on average, men supervise more doctoral theses than women in Estonia, whereas the ratio has remained relatively stable for the last ten years. In 2010, male academic staff supervised an average of 3 doctoral theses and women supervised 2.4 doctoral theses, and in 2020, these figures were 3.4 and 2.7, respectively. An interesting development is that, in 2010, the number of supervisees was higher for male researchers, but in 2020, the number of female supervisors was higher (see also Chapter 3 in this volume).¹²⁰

Finally, the wage gap between women and men in universities cannot be overlooked. According to 2020 data, the biggest gap – to the detriment of women – was for the wages of the research staff (12.9% for senior researchers, 7.1% for researchers and 13.2% for junior researchers), as well as for all levels of the teaching staff (including professors and lecturers, almost 6% for both) (Table 2.1).

¹¹⁷ Urmann, H., Lees, K., Remmik, M., Tubelt, E., Roos, L., Vilson, M., Puur, S. M., Aksen, M., Espenberg, S. (2020). Soolise võrdõiguslikkuse hetkeolukord ja parandamise viisid Eesti teaduses (Gender equality in Estonian science – current situation and ways of improving), pp. 44–45. University of Tartu's Centre for Applied Social Sciences (CASS), Tartu. https://www.etag.ee/wp-content/uploads/2021/03/Sooline_vordoiguslikkus_Eesti_teaduses.pdf (20.08.2021).

¹¹⁸ The lower number of publications in 2020 is most likely due to the fact that data on newer publications are entered into the Estonian Research Information System with some delay.

¹¹⁹ Urmann, H., Lees, K., Remmik, M., Tubelt, E., Roos, L., Vilson, M., Puur, S. M., Aksen, M., Espenberg, S. (2020). Soolise võrdõiguslikkuse hetkeolukord ja parandamise viisid Eesti teaduses (Gender equality in Estonian research – current situation and ways of improving), p. 44, Figure 25. University of Tartu's Centre for Applied Social Sciences (CASS), Tartu. https://www.etag.ee/wp-content/uploads/2021/03/Sooline_vordoiguslikkus_Eesti_teaduses.pdf (20.08.2021).

¹²⁰ *Ibid.*, p. 49.

Table 2.1. Average total salary (gross salary) of full-time equivalent academic staff by positions, number of positions filled (full-time equivalents, FTEs) and gender wage gap in six Estonian public universities as of 25 June 2021

	Women	Men	Total	Gender wage gap	Men (FTEs)	Women (FTEs)	Proportion of women in full-time jobs (%)
Professor, R4	3,626	3,845	3,783	5.7%	330	126	28%
Professor, R3	2,601	2,609	2,612	0.3%	280	210	43%
Senior Researcher, R3	2,325	2,670	2,539	12.9%	120	74	38%
Researcher, R2	1,984	2,136	2,065	7.1%	321	311	49%
Junior Researcher	1,499	1,727	1,636	13.2%	29	46	61%
Senior Lecturer	2,306	2,265	2,288	-1.8%	171	156	48%
Doctoral student-Junior Researcher	1,444	1,462	1,454	1.2%	179	137	43%
Lecturer, with doctoral degree	1,840	1,952	1,895	5.7%	127	182	59%
Lecturer, without doctoral degree	1,685	1,792	1,727	5.9%	222	342	61%
Teacher	1,385	1,431	1,440	3.2%	20	73	78%
Total	2,070	2,434	2,265	14.9%	1,800	1,657	48%

Source: Universities Estonia.¹²¹

Based on the 2019 survey, the majority of Estonian academic staff (67%) found that there was no discrimination based on gender, nationality, age or disability in their institution. Equal treatment of all staff was confirmed by more

than half (52%) of the respondents, while a quarter (26%) did not perceive it. Equal treatment was more strongly confirmed by male employees (60% vs 47%).¹²²

SELF-ASSESSMENT OF THE ESTONIAN RESEARCH COMMUNITY

Statistical indicators make it possible to give an outside view of the Estonian research community, but equally important is the way in which researchers themselves assess their situation, their satisfaction with their profession and working conditions. The study “Academic profession in a knowledge-based society” completed in 2019 by the University of Tartu and the Praxis Center for Policy Studies provides an insight into these topics.¹²³ The sample of the survey included regular academic staff in Estonian higher education institutions whose workload was at least 25% full time, who had at least a bachelor’s degree and whose academic activity was teaching and/or research. 861 academic employees from seven universities and ten institutions of professional higher education participated in the survey.

One of the key findings of the survey was that the majority (67%) of academic staff are satisfied with their choice of academic position and would make the same choice again today. The highest levels of satisfaction with career choice are in the medical and health sciences and the humanities and arts (both 75%). The majority of academic staff find their work interesting (84%) and feel that they have the opportunity to learn and develop in their profession (64%).¹²⁴ Given the relatively high level of satisfaction of academic staff with their chosen profession, it may seem surprising that only one in five of them feels valued, and

as many as half of them feel that academic work is not valued.¹²⁵ This discrepancy is explained by the fact that working conditions in universities are relatively unsatisfactory, with 42% of academic staff (and 49% of university staff) dissatisfied with their wages, and almost half of academic staff are dissatisfied with the workload and the working environment (49%). There is also dissatisfaction with job security, especially among the research staff. 61% of the teaching staff feel secure in their position, while in the case of the research staff only 29% do so. Furthermore, only a third of the research staff rate their career opportunities as good (Figure 2.17).¹²⁶ As the authors of the study rightly conclude, job and career insecurity is the result of the instability of competitive research funding. Therefore, it is very important to find a reasonable balance between project-based and stable research funding, in order to ensure greater future security for the research staff and to attract talented new researchers to the university. What needs to be taken into serious consideration is the fact indicated by the study that a quarter of academic staff under the age of 30 consider it likely they will continue working, but only 9% are interested in doing so. This can be interpreted as a reference to the declining attractiveness of academic careers or as an indication that the academic staff see increasingly diverse opportunities to shape their careers, including the opportunity to move beyond academic institutions.¹²⁷

121 Universities Estonia, data requested.

122 Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerens, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic profession in a knowledge-based society. Final Report), pp. 83–85. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.08.2021).

123 *Ibid.*

124 *Ibid.*, p. 9.

125 *Ibid.*, p. 67.

126 *Ibid.*, pp. 9–10.

127 *Ibid.*, p. 62.

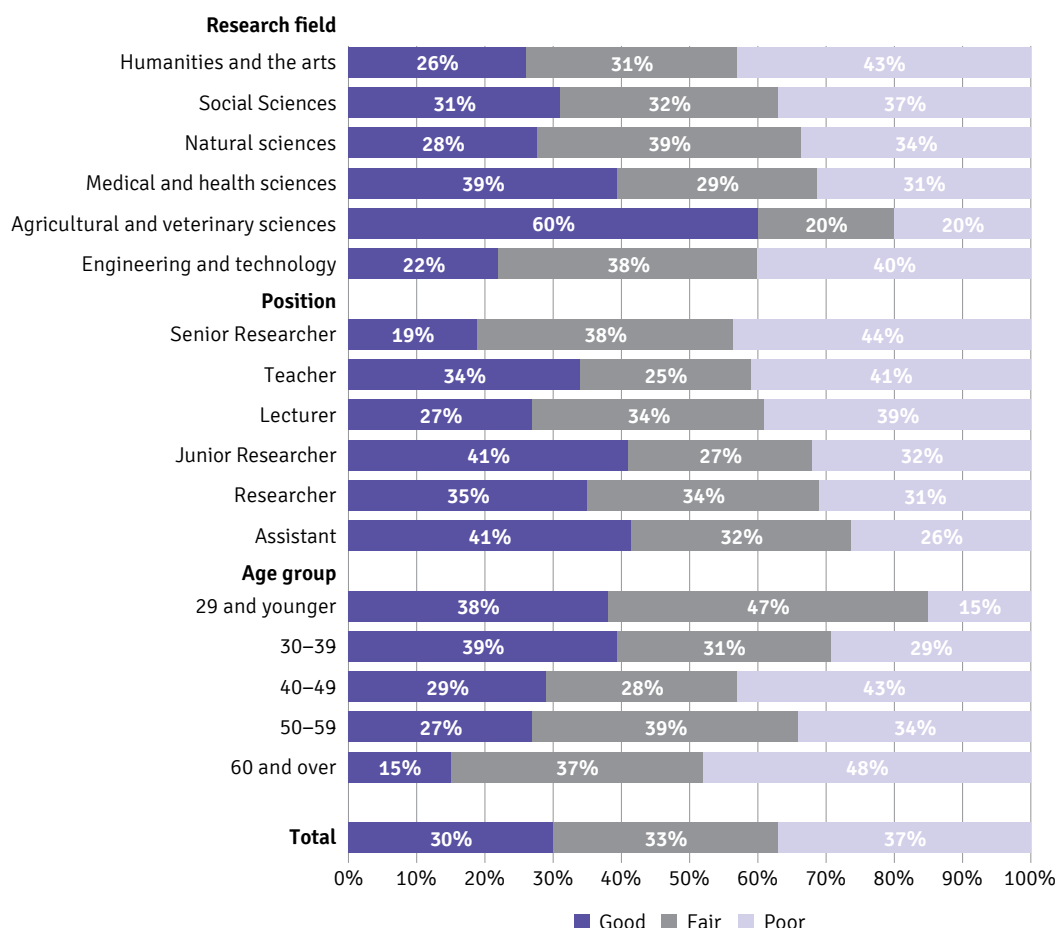


Figure 2.17. Satisfaction of academic staff (excl. professors and associate professors) with career opportunities by age, position and research field (survey of 2018)

Source: Praxis Centre for Policy Studies Foundation.¹²⁸

CAREER OPPORTUNITIES FOR THE ESTONIAN RESEARCH COMMUNITY

For Estonian researchers, one of the most impactful of the recent changes has been the introduction of a new, tenure-based career system in universities. Discussions on a new career model began as early as the beginning of the millennium, becoming particularly intense over the last decade.¹²⁹ An important role in these discussions has been played by the Estonian Academy of Sciences, which set up a working group in 2014 in order to develop the concept of a research career, submitting its proposals to the Ministry of Education and Research in December of the same year. In 2018, an extensive study “Sustainable Research Career Models: Applications for Estonia” was completed under the leadership of the Academy of Sciences, which proposed

specific steps for establishing a new academic career system in Estonia.¹³⁰ Based on the aforementioned proposals, a consensus was formed that, for Estonia, it is most suitable to move to the model of the so-called Anglo-American tenure system, where reaching a higher position mainly depends on the effectiveness of the researcher’s work and collegial feedback. This career model, originally developed in America, has been adopted by several universities in Europe during this century, including Finland, Sweden, Norway, Portugal, Austria, Switzerland, the Netherlands, Belgium, Italy and Germany.¹³¹ The central part of the model is permanent academic positions or tenures, for which the university provides central and permanent funding.

128 Mägi E., Koppel K., Kõiv K., Kindsiko E., Beerkens, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), p. 76. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.08.2021).

129 See for example: Saksa sahtlid ja ameerika redelid (Taagepera R. 2000 German drawers and American ladders). – Akadeemia, No. 7, pp. 1462–1471; Niinemets Ü. (2015). Teadlase karjäärimudel. Milleks, kellele ja kuidas? (Career model of a researcher. Why, to whom and how?) – Sirp, June 19.

130 Soomere, T., Niinemets, Ü., Niglas, K., Pilt, E., Roosalu, T., Randma-Liiv, T. (2018). Jätkusuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis (Sustainable concepts and models of research careers in the Estonian context), pp. 75–77. Estonian Academy of Sciences, Tallinn. <https://www.etag.ee/wp-content/uploads/2018/04/J%C3%A4tkusuutlikud-teadlaskarj%C3%A4%C3%A4ri-kontseptsioonid-ja-mudelid-Eesti-kontekst.pdf> (28.08.2021). See also: Roosalu, T., Raudsepp, M., Aavik, K. (2018). Jätkusuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis: doktorite ja tööandjate seisukohad ja soovitusel teaduskirjanduse ja teiste riikide kogemuste valguses (Sustainable concepts and models of research careers in the Estonian context: views and recommendations of doctors and employers in the light of scientific literature and the experience of other countries). Tallinn University, Tallinn. https://www.etag.ee/wp-content/uploads/2018/07/J%C3%A4tkusuutlikud-teadlaskarj%C3%A4%C3%A4ri-kontseptsioonid-ja-mudelid-Eesti-kontekstis_TL%C3%9C.pdf (20.08.2021).

131 Schiewer, H.-J., Jehle, C., Maes, K. (2014). Tenure and Tenure Track at LERU Universities: Models for Attractive Research Careers in Europe. LERU, s.l.; <https://www.leru.org/files/Tenure-and-Tenure-Track-at-LERU-Universities-Full-paper.pdf> (20.08.2021).

As a general rule, there are three levels of tenure: assistant professor, associate professor, and full professor, which correspond to different levels of academic performance and whose progress is based on the peer review or evaluation of the work done. The tenure is preceded by a so-called tenure track, i.e. a fixed-term position filled by public competition, which becomes permanent as a result of a positive evaluation carried out after a certain period of time. Although there are many solutions to the tenure model in the world, it is generally based on three pillars: job security, long-term planning and a focus on top researchers.¹³²

In Estonia, Tallinn University of Technology was the first to introduce the new tenure-based career system for researchers in 2017¹³³; by now, all four large Estonian public universities¹³⁴ have made the same choice. Two universities in the creative fields, the Estonian Academy of Arts and the Estonian Academy of Music and Theatre, have preferred not to switch to the new career model. As mentioned in the introduction, it is still too early to summarise the results of the tenure reform. Although there is little reason to doubt the need for this reform, especially in larger universities, it must be borne in mind that the tenure system still has its risks. The most important of these are the higher and more difficult-to-plan financial burden on universities, and the possible division of the research community into a privileged “core” and a “periphery” operating in poorer conditions.¹³⁵ The risks are increased by the fact that universities have so far preferred a rigid tenure system, although research by the Academy of Sciences has shown that a flexible tenure system is more suitable for a small country like Estonia.

When organising the career path of researchers, it is certainly important to take into account the field-specific peculiarities. Even a study from 2015 by University of Tartu “The career of scientists: Estonia in the international system” pointed out the need to abandon the notion that career

models are universal.¹³⁶ Career patterns and opportunities as a whole are strongly dependent on the background system of the research field (funding, work experience, involvement with the private sector, etc.).¹³⁷ Several analyses, both international and national, show that the understanding of a researcher's career as a linear and vertical movement is often incorrect in practice, and thus efforts are being made to shift the focus of the analysis onto a more diverse career pattern where atypical pathways may occur.¹³⁸

Until recently, Estonian universities have predominantly followed a so-called horizontal career pattern, in which the priority has not been the vertical course of the career, but rather the preference for a suitable and pleasant position and commitment to work.¹³⁹ A 2019 survey shows that one in three academics has worked in their current position for more than ten years. Employees who have remained in the same position for the longest time are in the field of agricultural and veterinary sciences, while those in the field of social sciences have done so for the shortest time. At the same time, in the fields of agricultural and veterinary sciences and humanities and the arts, there are more of these employees who have worked in the same position for more than 20 years than there are in other fields (Figure 2.18).¹⁴⁰ In the same survey, a third of academic staff rated their career opportunities as good, a third as inadequate and a third were unsure. Senior researchers and lecturers were the least satisfied, with 19% and 27% rating their career opportunities as good, respectively. 25% of teachers rated their career opportunities as very good, but the same can only be said for 4% of researchers and senior researchers, 7% of lecturers and 12% of junior researchers. There were no statistical differences by field, but in absolute terms there was a difference between academics in medical and health sciences (only 4% considered their career prospects as very good) and those in the humanities and the arts (6%).¹⁴¹

- 132 Soomere, T., Niinemets, Ü., Niglas, K., Pilt, E., Roosalu, T., Randma-Liiv, T. (2018). Jätksuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis (Sustainable concepts and models of research careers in the Estonian context), p. 42. Estonian Academy of Sciences, Tallinn. <https://www.etag.ee/wp-content/uploads/2018/04/J%20c3%a4tkusuutlikud-teadlaskarj%20c3%a4%20a4ri-kontseptsioonid-ja-mudelid-Eesti-kontekst.pdf> (28.08.2021).
- 133 Aaviksoo, J., Veinthal, R. (2016). Tenuur kui akadeemilise vabaduse tagatis (Tenure as the guarantee of academic freedom). – Sirp, September 23. See also: Academic Career Management. Tallinn University of Technology. <https://oigusaktid.taltech.ee/akadeemilise-karjaari-korraldus/> (20.08.2021).
- 134 Career model. University of Tartu, <https://www.ut.ee/et/ulikoolist/karjaarimudel>; Tenure system positions. Tallinn University, <https://www.tlu.ee/en/tenure-system-positions>; Academic Staff Positions in Estonian University of Life Sciences. Estonian University of Life Sciences, https://www.emu.ee/userfiles/emu2015/Akadeemilise_karjaari_korraldus_27_02_20_muudetud_2021_tervikekst.pdf (20.08.2021).
- 135 Roosalu, T., Raudsepp, M., Aavik, K. (2018). Jätksuutlikud teadlaskarjääri kontseptsioonid ja mudelid Eesti kontekstis: doktorite ja tööandjate seisukohad ja soovitusel teaduskirjanduse ja teiste riikide kogemuste valguses (Sustainable concepts and models of research careers in the Estonian context: views and recommendations of doctors and employers in the light of scientific literature and the experience of other countries), pp. 19–20. Tallinn University, Tallinn. https://www.etag.ee/wp-content/uploads/2018/07/J%20c3%a4tkusuutlikud-teadlaskarj%20c3%a4%20a4ri-kontseptsioonid-ja-mudelid-Eesti-kontekstis_TL%20c3%9c.pdf (20.08.2021).
- 136 Vadi, M., Kindsiko, E., Alas, R. (2015). Teadlase karjäär: Eesti rahvusvahelises taustsüsteemis. Uuring 6.4 lõppraport (The career of scientists: Estonia in the international system. Study 6.4 Final Report), pp. 35–41. Tartu. https://majandus.ut.ee/sites/default/files/www_ut/tips_uuringu_6.4_loppraport.pdf (20.08.2021).
- 137 Kindsiko, E., Vadi, M., Täks, V., Loite, K., Kurri, K. (2017). Eesti doktorite karjääriritee ja seda mõjutavad tegurid (Career path of Estonian doctors and factors influencing it), p. 7. University of Tartu, Tartu. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B5jutavad_tegurid.pdf (06.09.2021).
- 138 Vadi, M., Kindsiko, E., Alas, R. (2015). Teadlase karjäär: Eesti rahvusvahelises taustsüsteemis. Uuring 6.4 lõppraport (The career of scientists: Estonia in the international system. Study 6.4 Final Report), p. 31. Tartu. https://majandus.ut.ee/sites/default/files/www_ut/tips_uuringu_6.4_loppraport.pdf (20.08.2021).
- 139 *Ibid.*, p. 34.
- 140 Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerens, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), p. 71. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.08.2021).
- 141 *Ibid.*, p. 76.

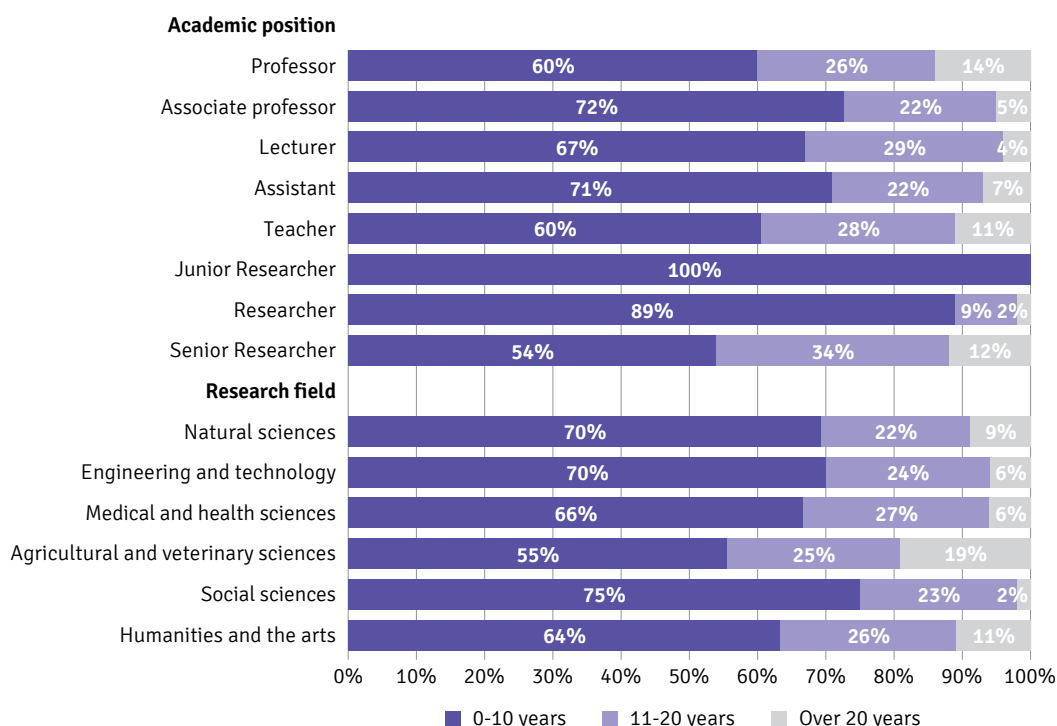


Figure 2.18. Years on current position of academic personnel by position and research field (survey of 2018)

Source: Praxis Centre for Policy Studies Foundation and University of Tartu.¹⁴²

FUTURE OF THE ESTONIAN RESEARCH COMMUNITY: DOCTORAL STUDENTS

The future of the Estonian research community mostly depends on the level and efficiency of local doctoral studies. Although an increasing number of Estonian researchers have obtained their doctorates abroad during this century, they still only form a small minority of the Estonian research community. As stated above, the development of doctoral studies in Estonia was very fast until the end of the first decade of this century, and since then the development has unfortunately stalled, especially in international comparison. For the last ten years (2011–2020), the number of doctoral graduates per year has remained in the range of 190–253. However, the number of admitted doctoral students has decreased even more, as it has remained below 400 for the last seven years. During the same period, the

ratio of dropouts to students has fluctuated between 9.5% and 13.5% (Figure 2.1). Public funding for doctoral studies has been severely lacking for the last 15 years. This is reflected in both the decreasing admission numbers and in the amount and ratio of doctoral allowance to the average net salary. In 2006, the amount of average net salary and doctoral allowance was in the same range, but since then the gap has only increased: in the second quarter of 2021, the difference was already 53% (Figure 2.19). In recent years, universities have had no choice but to pay an additional half of the national doctoral allowance, using their own resources to do so. However, this has meant an even faster decline in new doctoral positions.

¹⁴² Mägi, E., Koppel, K., Kõiv, K., Kindsiko, E., Beerens, M. (2019). Akadeemilised töötajad teadmusühiskonnas. Lõpparuanne (Academic staff in the knowledge society. Final Report), p. 52, Figure 2.2.1. University of Tartu and Think Tank Praxis, Tartu. <https://www.etag.ee/wp-content/uploads/2019/11/APIKS-Eesti-2019.pdf> (20.08.2021).

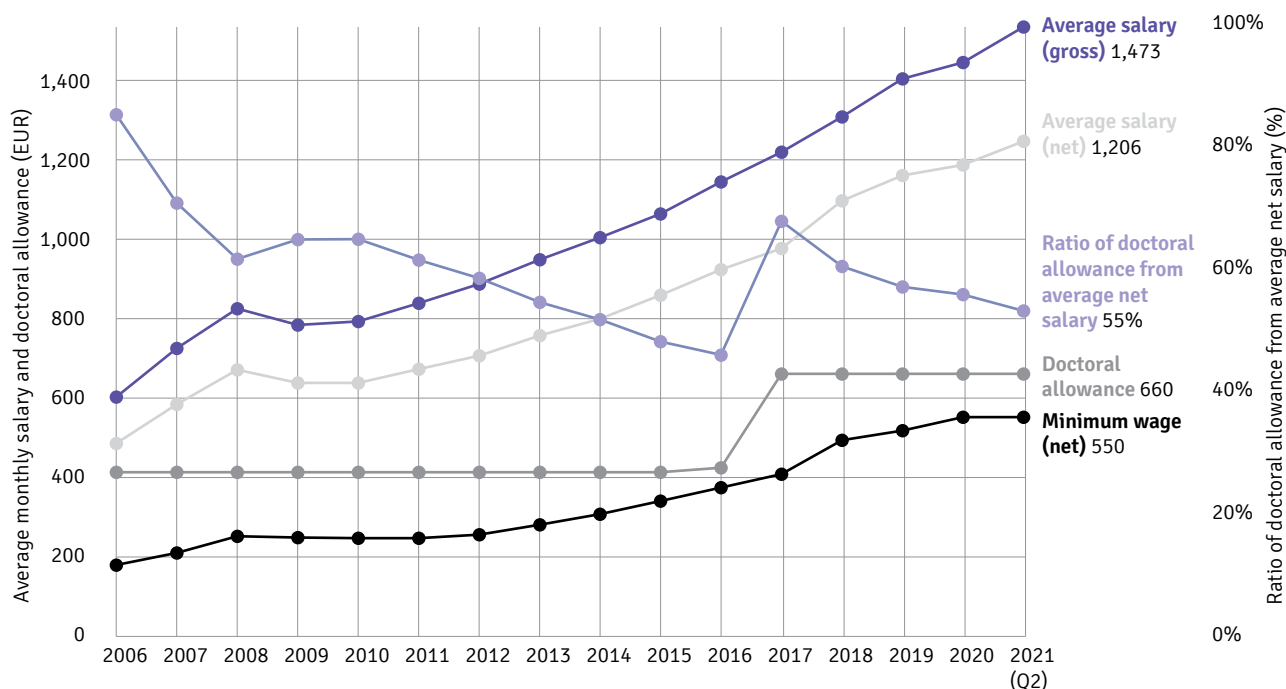


Figure 2.19. Dynamics of Estonian average monthly salary compared to national doctoral allowance in 2006–2021 (salary information for 2021 is based on second quarter)

Source: Statistics Estonia.¹⁴³

However, it is important to look at the dynamics of doctoral studies by field as well. The number of admissions by field varies quite considerably. In 2006–2020, a total of 6,206 people were admitted to doctoral studies in Estonia. The most popular field was natural sciences, mathematics and statistics (1,519 people). This was followed by engineering, production and construction (965), and humanities and the arts (960). During the same period, a total of 2,936 people completed their doctoral studies, 905 in the fields of natural sciences, mathematics and statistics, 484 in the fields of

engineering, production and construction, and 445 in the field of humanities and the arts. By field, there were no significant proportional differences between the admitted students and the graduates, with the largest share of graduates (59.6%) in natural sciences, mathematics and statistics, followed by equal results in engineering, production and construction, and health and welfare (both 50.2%). The share of graduates was the lowest in business, administration and law, and social sciences, journalism and information (34.3% and 35.3%, respectively) (Figure 2.20).

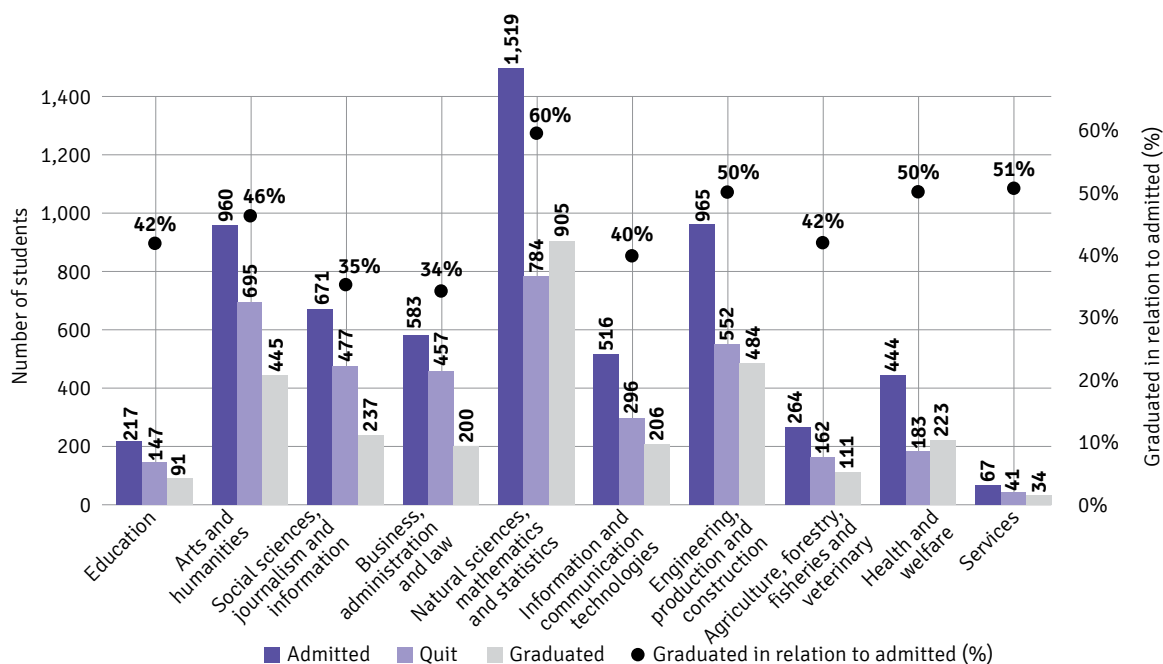


Figure 2.20. The total number of students admitted to, graduated from and leaving studies in doctoral programmes in the academic years from 2006/07 to 2019/20 by fields of study

Source: EHIS, calculations by Estonian Research Council.

Among the OECD countries, the most popular field of doctoral studies is still natural sciences, mathematics and statistics – in 2018, for example, its share of doctoral students was 34% in France, 29% in Germany, 27% in Latvia and 24% in Ireland, Italy and Lithuania. The second most popular are the fields of engineering, production and con-

struction, and health and welfare. Compared to Estonia, the number of doctoral students in the field of humanities is below average in other OECD countries, except in Slovenia, Austria and Poland. On the other hand, the share of Estonia's doctoral students in social sciences is below the OECD average (Figure 2.21).

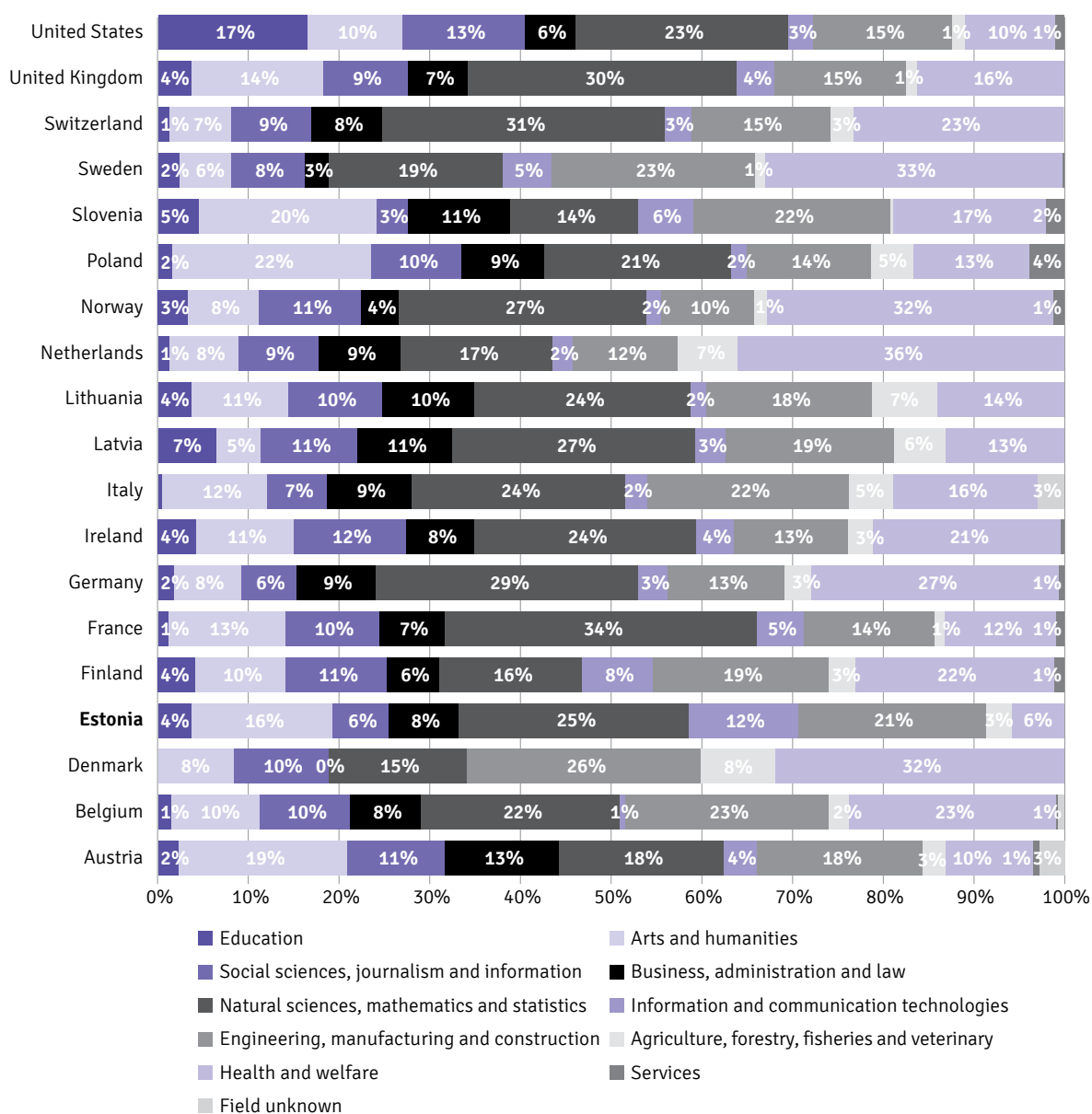


Figure 2.21. Distribution of doctoral degree holders by fields of study in selected OECD countries in 2018

Source: OECD.¹⁴⁴

The duration of doctoral studies also varies from field to field. In the years 2007 to 2020, the average time of completing a doctoral degree in Estonia was 5.1–6.1 years, while completing doctoral studies in the fields of agriculture, forestry, fisheries and veterinary medicine, for example, took 4.8–8.5 years. On average, the most efficient doc-

toral students have been in the fields of natural sciences, mathematics and statistics, with studies lasting between 4.5 and 6.0 years. It takes longer than average to obtain a doctorate in the field of humanities and arts, and in the field of engineering, production and construction (Figure 2.22).

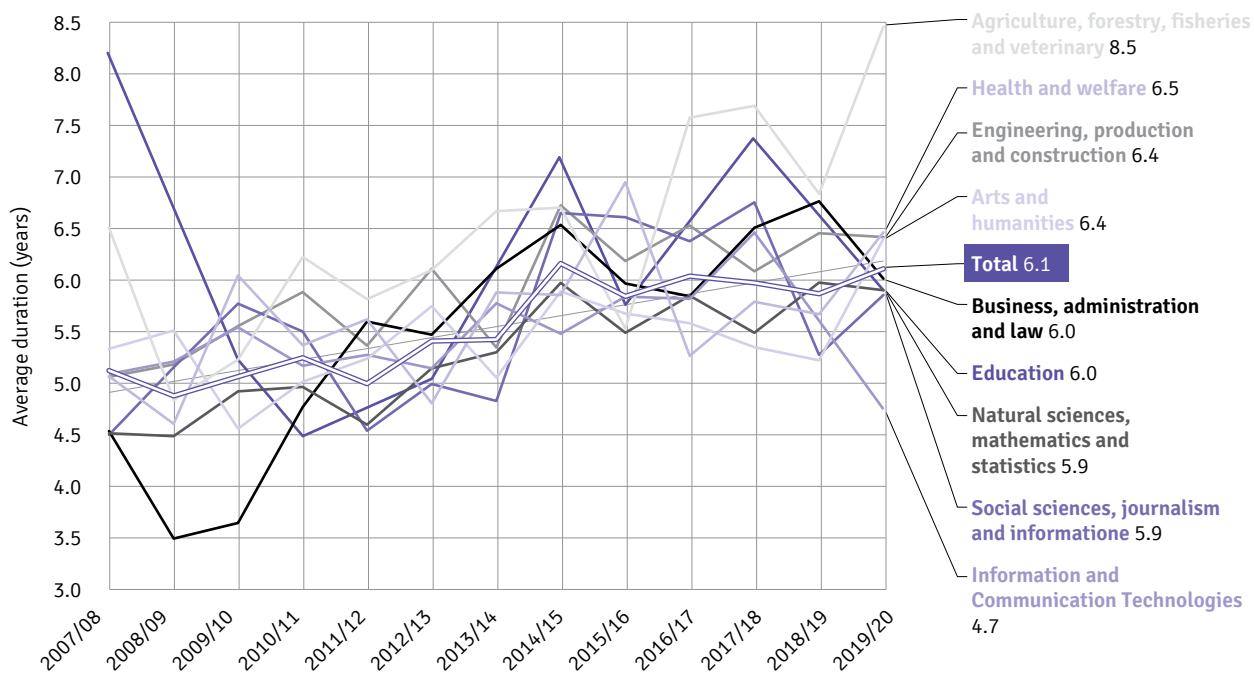


Figure 2.22. Average time spent on doctoral studies through academic years from 2007/08 to 2019/20 by fields of study (doctoral graduates, excluding external students)

Source: EHIS.

In terms of age, Estonian doctoral students have seen a slight ageing in the last 15 years (2006–2020). In 2006, 27% of doctoral students were under the age of 25, but only 15% in 2020. The share of those aged 45 and over has remained

fairly stable (7% in 2006 and 6% in 2020) as well as the share of those aged 40–44 (7% and 5%). The proportion of doctoral students aged 25–29 has increased the most: Their share was 36% in 2006 and 42% in 2020 (Figure 2.23).

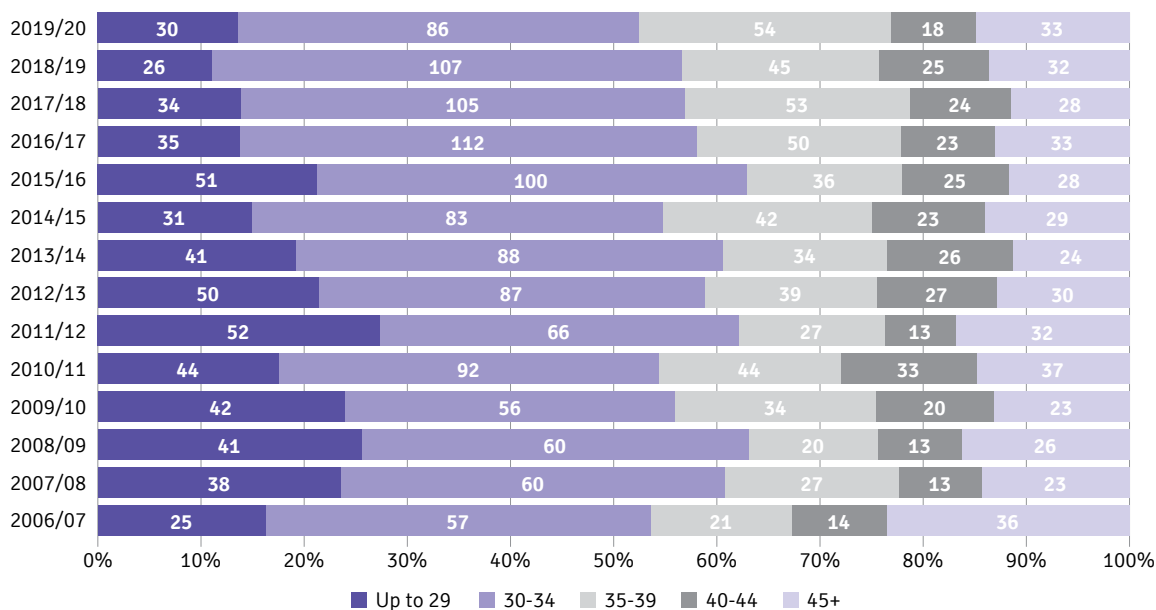


Figure 2.23. The distribution of doctoral graduates between age groups throughout the academic years from 2006/07 to 2019/20

Source: EHIS, calculations by Estonian Research Council.

The youngest students admitted into doctoral studies are in the fields of natural sciences, mathematics and statistics: In 2006–2020, 36% of doctoral students in natural sciences were younger than 25 years old and 47% were 25–29 years old; those aged 40 and over accounted for only 6% in total. Doctoral students in engineering, production and construction were also below the average age (27% under 25, 46% aged 25–29). In contrast, the average age of doctoral students was the highest in the field of education (29% of those aged 40 and over) and in business, administration and law (20% of those aged 40 and over) (Figure 2.24). The 2017 survey found that in recent years, the lower and upper age limits for doctoral degree holders have risen slightly. The

most heterogeneous picture emerged in the humanities, where there were doctoral students in their mid-20s as well as those aged 50–60. The study explains this through three factors: 1) some of the academic staff will start only acquiring a degree after years of work at the university; 2) students from the non-academic sector start doctoral studies in their 30s; 3) studies are significantly extended beyond the nominal time. Looking at the situation on a broader scale, graduates of doctoral studies in the humanities are older than average elsewhere as well, such as 41 in Finland, 38 in the Netherlands and Norway, 37 in Denmark, 35 in the USA and Latvia, and 34 in Lithuania.¹⁴⁵

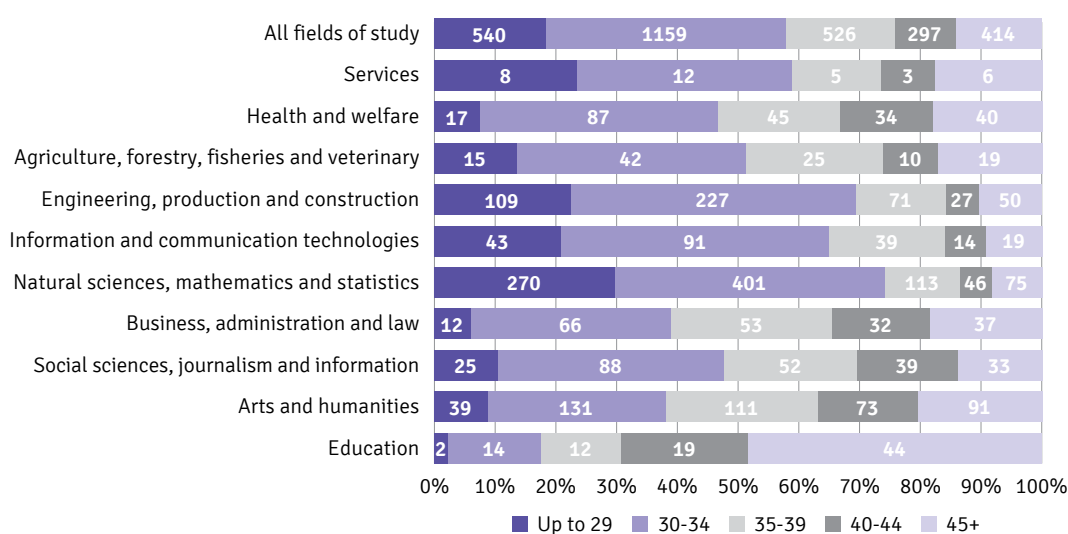


Figure 2.24. The distribution of doctoral graduates between age groups throughout the academic years from 2006/07 to 2019/20 by fields of study

Source: EHIS, calculations by Estonian Research Council.

From a gender perspective, Estonian doctoral studies has made progress towards a greater balance. In 2006, 60% of doctoral students were female, while the same figure was 49% in 2020. During this period, the average ratio of female to male doctoral students was 53% to 47% (Figure 2.25). In terms of fields, male doctoral students accounted for the majority only in the fields of ICT (78%) and engineering,

production and construction (64%). The lowest number of male doctoral students was in education (16%), health and welfare (30%) and agriculture, forestry, fisheries and veterinary sciences (35%). There have been no major gender fluctuations over time. An exception is the clear increase in the proportion of women in the field of ICT (14% in 2006, 32% in 2020) (Figure 2.26).

¹⁴⁵ Kindsiko, E., Vadi, M., Täks, V., Loite, K., Kurri, K. (2017). Eesti doktorite karjäärtee ja seda mõjutavad tegurid (Career path of Estonian doctors and factors influencing it), p. 57. University of Tartu, Tartu. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B5jutavad_tegurid.pdf (20.08.2021).

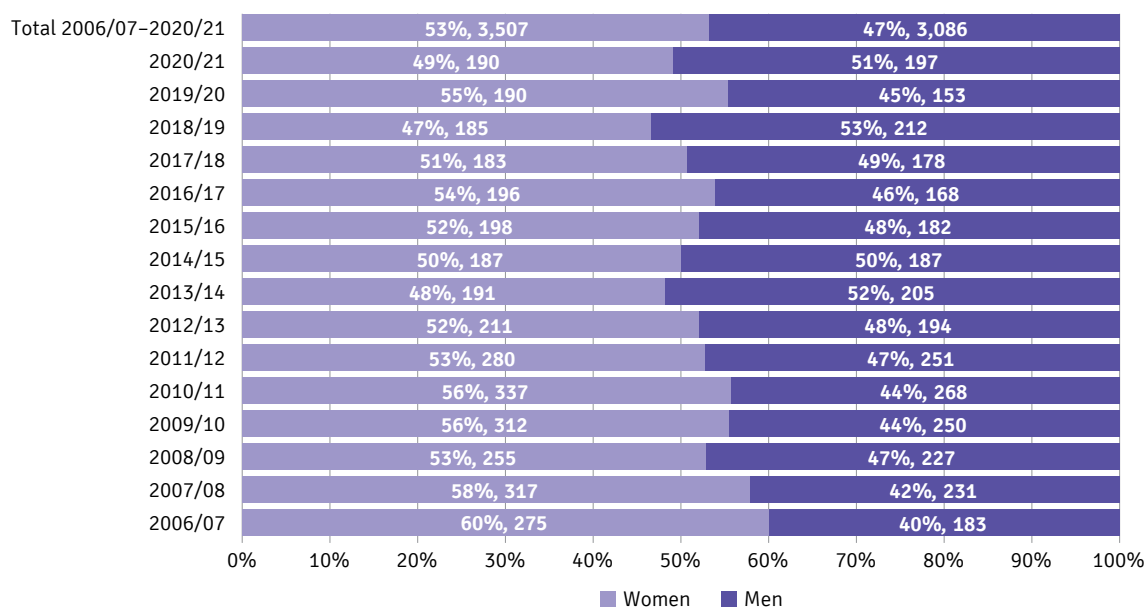


Figure 2.25. Gender distribution of those admitted to doctoral studies from 2006/07 to 2020/21

Source: EHIS, calculations by Estonian Research Council.

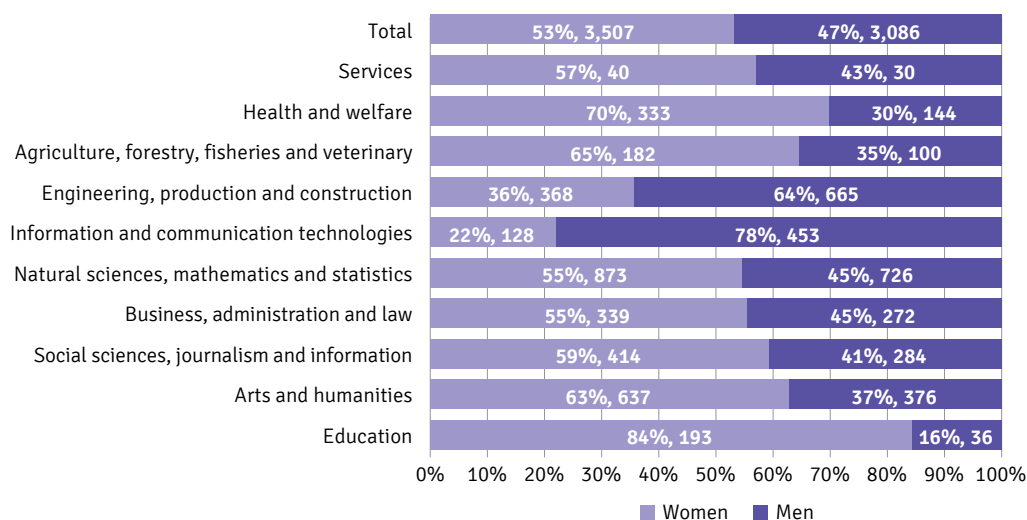


Figure 2.26. Gender distribution of those admitted to doctoral studies from 2006/07 to 2020/21 by fields of study

Source: EHIS, calculations by Estonian Research Council.

The biggest change in doctoral studies in recent years has been the surge of international students. Back in 2006, there were 66 foreign doctoral students, but by 2020, their number had already increased by ten times to 671 (Figure 2.27). Whereas a total of 2,317 people were involved in doctoral studies in 2020, foreign doctoral students accounted for as much as 29%. Among foreign doctoral students, there

are clearly more men than women – in 2019, for example, foreign doctoral students included 352 men and 239 women, and a year later these figures were 406 and 265. By field, foreign doctoral students prefer natural sciences (22.5%) and ICT (19%), as can be expected, followed by the humanities and engineering (16.8% and 16.5%, respectively) (Figure 2.28).

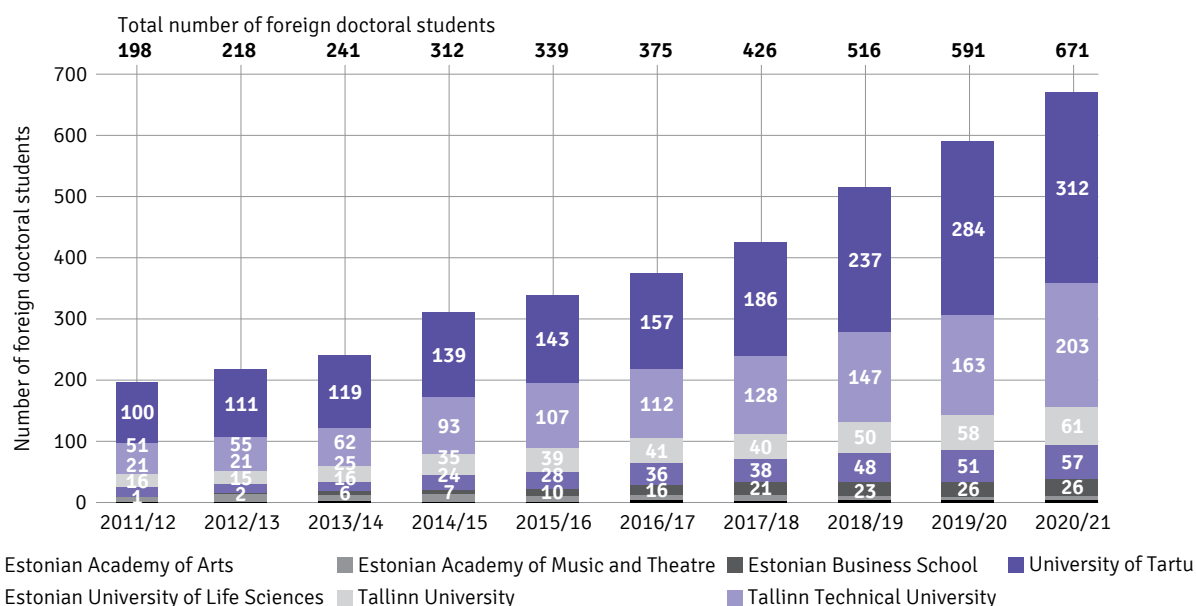


Figure 2.27. Dynamics in the total number of foreign doctoral students in Estonian universities in the academic years from 2011/12 to 2020/21

Source: Haridussilm (EHIS).¹⁴⁶

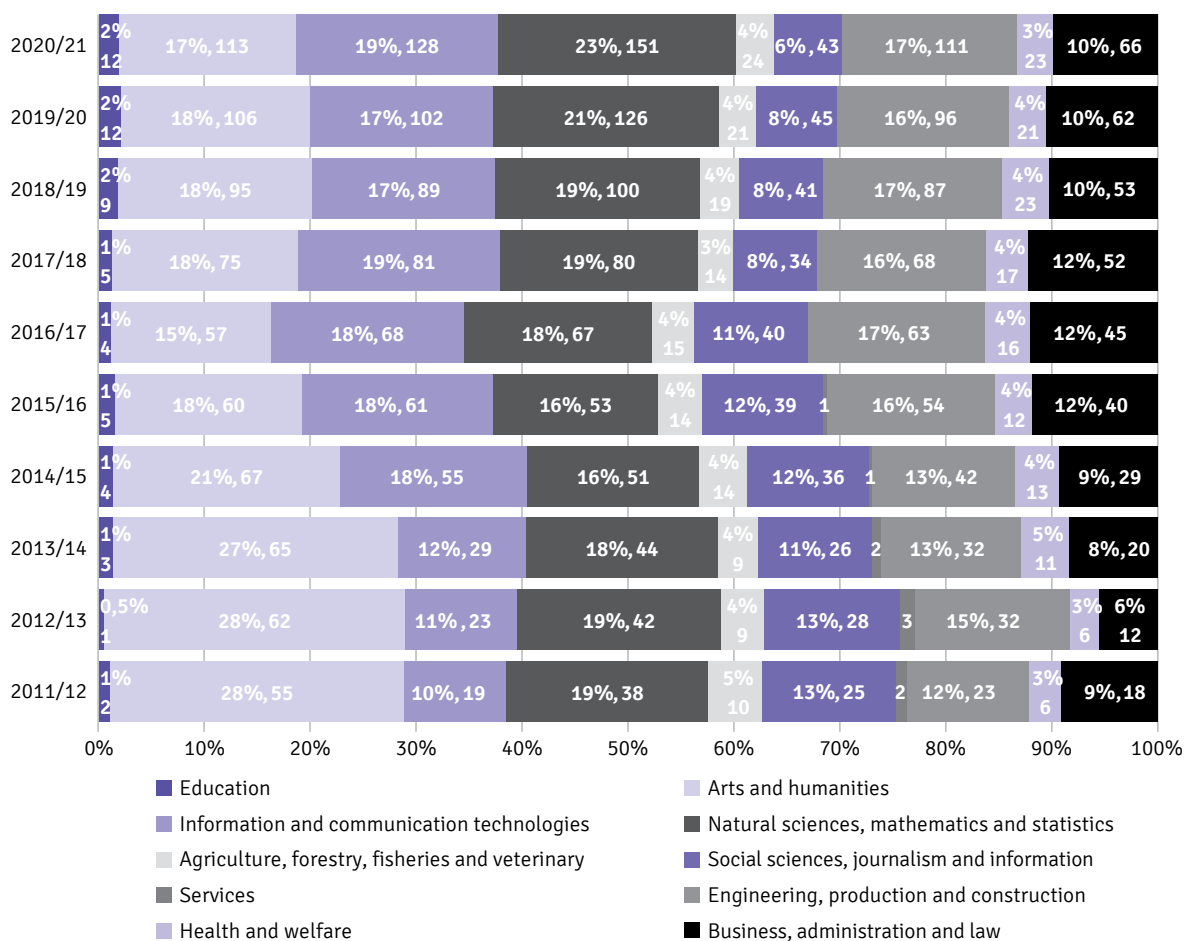


Figure 2.28. Distribution of foreign doctoral students in Estonian universities by fields of study in the academic years from 2011/12 to 2020/21

Source: Haridussilm (EHIS).¹⁴⁷

¹⁴⁶ Haridussilm (EHIS). Haridussilm.ee (14.09.2021).

¹⁴⁷ Haridussilm (EHIS). Haridussilm.ee (14.09.2021).

In terms of what will become of doctoral students after graduation, some insight is provided by the 2017 study “Career Path of Estonian Doctors and Factors Affecting It” conducted at the University of Tartu. According to the study, the share of doctors that continue with an academic career is the highest in the field of natural sciences (on average, more than 75% of doctors). At the same time, only 40% of doctoral graduates in engineering and technology chose an academic field. In the field of medicine and health sciences,

a combined career path prevails: working in both medical institutions and universities (45% of doctors). In the social sciences, either an academic career (45%) or a combined field (45%) is chosen after obtaining a degree, with only 10% leaving the university altogether. In the humanities, 60% of new doctors remain in academic work, 25% go to non-academic work and 15% find a combined solution (Figure 2.29).¹⁴⁸

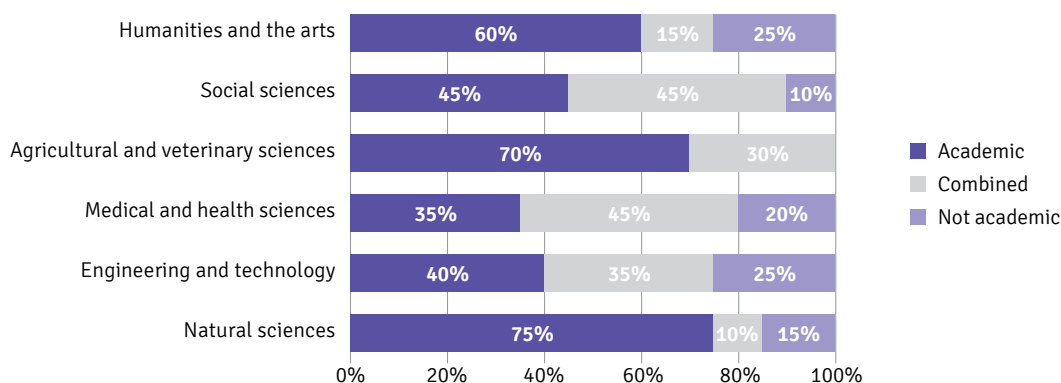


Figure 2.29. Dominant career paths after defending doctoral degree in 2017

Source: University of Tartu.¹⁴⁹

After a long decline, doctoral studies in Estonia have been filled with fresh hope. As mentioned in the introduction, MER started an extensive reform of doctoral studies in 2021. Firstly, the result is that doctoral students are no longer considered as students, but as academic staff – junior researchers whose main task, according to their employment contract, is conducting research related to the topic of their doctoral thesis. At the same time, junior researchers are guaranteed an income equal to the average salary in Estonia. Secondly, it involves creating new forms of doctoral studies, enabling doctoral studies to be conducted in a non-university institution (doctoral studies of knowledge transfer). It can be a private company or a public institution, and the doctoral student is a paid employee. Thirdly, however, it is still possible to pursue doctoral studies in addition to the student's other main work and if the research work is not compatible with the doctoral model based on

cooperation between a university or a company/institution. In the case of such doctoral students, the financing of the studies will be borne by themselves.¹⁵⁰ The described model is planned to enter into force on September 1, 2022.

To a large extent, the success of the doctoral studies reform will certainly depend on sufficient financial resources, especially in terms of increasing the number of doctoral places, as indicated by the international statistics presented above. Current doctoral studies can barely ensure the renewal of academic staff, especially in such fast-growing fields as ICT, while there are essentially no doctoral students working outside the university. As mentioned, we are at the bottom of the list in the EU in terms of the number of doctoral students working in the private sector. At the same time, it is clear that Estonia's greatest growth potential lies in the innovation capacity of the private sector.

148 Kindsiko, E., Vadi, M., Täks, V., Loite, K., Kurri, K. (2017). Eesti doktorite karjääriritee ja seda mõjutavad tegurid (Career Path of Estonian Doctors and Factors Affecting It). University of Tartu, Tartu. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B5jutavad_tegurid.pdf (20.08.2021).

149 Kindsiko, E., Vadi, M., Täks, V., Loite, K., Kurri, K. (2017). Eesti doktorite karjääriritee ja seda mõjutavad tegurid (Career Path of Estonian Doctors and Factors Affecting It), p. 69, Figure 7.1. University of Tartu, Tartu. https://www.etag.ee/wp-content/uploads/2018/02/Eesti_doktorite_karj%C3%A4%C3%A4ritee_ja_seda_m%C3%B5jutavad_tegurid.pdf (20.08.2021).

150 Padar, A. (2021). Üliõpilasest teadustöötajaks, tulemuseks rohkem doktoreid (From a student to a researcher, resulting in an increase in doctors). – Sirp, March 5.

SUMMARY: OPTIMISTIC VIEW

Almost ten years ago, in 2013, Ülo Niinemets painted a rather gloomy picture of the situation of Estonian researchers: “In independent Estonia, the life of a researcher has been extremely nervous and uncertain, and it still is today. During the period of independence, very few young people have entered the field of research, as it is not favoured due to the lack of a career model as well as the opacity and uncertainty in the formation of vacancies. Furthermore – for a long time, conventional measures, such as post-doctoral studies, were lacking in the Western research culture, still far from sufficient even today.”¹⁵¹ How to assess the situation from the current perspective? Although there is still no shortage of problems, it seems that there may be reason for moderate optimism. Firstly, a new tenure-based career model has been introduced in Estonia, which should provide a much clearer and more transparent system for planning research careers – both for young people entering the

research system and for older people leaving it. Secondly, a reform of doctoral studies has been launched, which will allow doctoral students to focus on their research while also being provided with a decent salary, and to join the university on an equal footing with the rest of the academic staff. It also creates an opportunity to deepen cooperation between the university and public and private institutions (doctoral studies of knowledge transfer). Thirdly, R&D funding of at least 1% of GDP has been agreed at a national level, which should provide sufficient resources to implement the reforms described. In the near future, the most important public agreement is to further increase funding for higher education (to at least 1.5% of GDP). This is a decisive step that would ensure the sustainable development of our higher education and research community and thus Estonia’s survival in the international competition of knowledge societies.

Acknowledgements

I thank my good colleagues Ülo Niinemets (Estonian University of Life Sciences), Tarmo Soomere (Tallinn University of Technology) and Tiit Tammaru (University of Tartu) for their comments and clarifications on the first version of the article.

151 Niinemets, Ü. (2013). Eesti sihtfinantseeritavate teadusteemade juhid 1998–2013: noorenemine, vananemine ja äraspidi vanuseline diskrimineerimine (Estonian leaders of research topics with targeted funding in 1998 to 2013: the young, the old, and reverse age discrimination). – Teadusmõte Eestis (VIII): Teaduskultuur (ed. J. Engelbrecht), p. 83. Estonian Academy of Sciences, Tallinn.



A LOOK AT THE STATE OF ESTONIAN RESEARCH

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Research generates new knowledge and solutions. The skills for discovering and creating new knowledge are passed on through higher education and all specialties taught in universities are based on science and research. What is important is not only the current state of our knowledge, but also how this knowledge was discovered in the first place and how we can develop it further on our own. In addition to the joy of discovery, science also teaches us to apply the results of research. Application of results is a natural part of research validation. The scope of action of many top researchers consists of both the discovery and validation of applicability. All in all, science plays a central role in what we know or do not know universally, what our higher education and education system as a whole is like, and how the society is able to deal with and develop it in a changing world.

Science teaches us how to face the unknown – a skill which should also be instilled into students through higher education. While textbooks do contain essential information, all of it is already rather well-known. Therefore, it is more important to know the limitations of the information presented and understand how to handle matters not taught in textbooks. Next to significant scientific breakthroughs, there is a wealth of ordinary research that facilitates the identification of details and the opportunities for their application. A distinction should be drawn between the issues science can (quickly) answer and those it cannot as well as the reasons why they can or cannot be resolved. Not every new piece of research is going to revolutionise science, production or profits for business. Greater development requires the input and continuous advancement of many people as well as the examination of the issues relevant at the time.

In the narrow sense, research does not guarantee huge profits for every business, but it is essential that research is conducted by knowledgeable, confident, hardworking and innovative people. Business proposition, competition on the market, negotiation and sales skills, marketing, image and even the protection of intellectual property by a trade secret or patent are all factors that play a critical role in the success of the company. However, in most cases, success just depends on acting faster than others while making use of one's own extensive experience and creativity. The success of modern businesses can, among other things, also be attributed to the diversity of views and disciplines which allow new and innovative products to be created.

Companies often do not require their employees to have a degree at all. They do, however, need assurance that the individuals employed by them have received a holistic education and have the knowledge and attitudes that allow them to develop together with the company in the acquisition of new skills. A university education in a competitive labour market generally ensures that the person is interested in self-development and has the skills to generate and apply new knowledge where necessary.

With regard to the state of research, consideration should be given to both excellence and sectoral, methodological as well as discovery- and application-oriented diversity. What are the strengths of research, how much research is conducted, which areas have been completely left out, and what could be improved? In order to provide such a full picture, an analytical insight into and a qualitative and substantial understanding of numerous nuances would be required, but as a creator of one story of thought, I cannot promise to offer all the answers in this article. Nevertheless, certain arguments can be put forward. For example, without basic research, applied research in any area would also be practically impossible. Areas of specialisation cannot therefore be classified according to what type of research should be conducted in each area, e.g. only excellent basic research in one and applied research in another. To implement research results, a higher education that contributes to it and basic research on which it is based are needed.

Whether it be basic or applied research, it is common practice to publish the results achieved and share them with other researchers and implementers. Otherwise we would not know what knowledge exists in the world. Peer reviewing of research before publication is an essential process to verify the accuracy of the results and the quality of the methods used. It is precisely for this reason that published articles are the quantitative measure of research, because they have the ability to impact other researchers. The impact is multi-dimensional, but the simplest way to measure it is to look at how frequently a certain article is referenced in the works of other researchers.

Therefore, since the measure of research is the knowledge presented in research articles, let us first take a look at the total volume of Estonian research results. Estonian researchers currently publish approximately 5,000 research papers per year.

Table 3.1. The number of publications by Estonian researchers¹⁵² by their type according to the classification of Estonian Research Information System in 2015–2020¹⁵³

	1.1.	1.2.	1.3.	2.1.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	5.1.	Total
2015	2,569	673	292	80	90	41	194	1,021	731	118	130	5,939
2016	2,673	618	235	75	88	44	195	885	726	102	98	5,739
2017	2,620	520	196	61	87	35	159	905	762	58	103	5,506
2018	2,646	473	176	81	72	39	201	912	589	78	88	5,355
2019	3,070	409	224	84	68	27	204	1,031	772	96	108	6,093
2020	3,114	387	172	79	56	20	186	1,004	555	226	62	5,861
Total	16,692	3,080	1,295	460	461	206	1,139	5,758	4,135	678	589	34,493

Source: Estonian Research Information System.¹⁵⁴

The final reports of research projects also play an important role. These reports are often commissioned by the same state agencies who commissioned the research. In terms of peer-reviewed articles, international and critically assessed works hold the most significance. The most important of these are categories 1.1, 1.2 and 3.1. Different fields have different publication practices. For example, in the field of computer science, highly competitive conferences with a swift publishing process, classified under category 3.1, are also of great importance alongside journal articles. Whereas, in the case of life sciences, new information is primarily published in journals and conferences are organised to introduce already published or ongoing research.

The majority of Estonian research is conducted in the four largest universities in Estonia, followed by smaller specialised research institutions (National Institute of Chemical Physics and Biophysics, National Institute for Health Development, Estonian Literary Museum), hospitals (Tartu University Hospital, East Tallinn Central Hospital, North Estonia Medical Centre), museums and some private sector research and development entities (Technology Competence Centres, AS Cybernetica), etc. Table 3.2 shows that, compared to other institutions, the four largest universities are significantly more prolific in publishing the most important articles (**1.1, 1.2, 3.1**), accounting for 90% of research published in Estonia.

¹⁵² Estonian researcher means a researcher associated with an Estonian institution.

¹⁵³ Publication classification of the Estonian Research Information System. Estonian Research Information System. <https://www.etis.ee/Portal/Classifiers/Details/81e52bde-a1a1-490a-a9c4-2df9f3fc3a70?#> (19.10.2021). Classifier numbers indicate the following: 1 – articles in journals; 2 – a book/monograph; 3 – articles in proceedings/a chapter in a book or in a collection/specific research publications; 4 – editing scientific publications; 5 – published meeting abstracts; 6 – other publications. Further details on the classification can be found at the above link. Classifier 2.2 is not included in the table as it was removed in 2014 when the classification was revised.

¹⁵⁴ Estonian Research Information System. www.etis.ee (19.10.2021).

Table 3.2. The publication of the most important Estonian articles (1.1, 1.2, 3.1)^{155,156} by institution in 2017–2020

Institution	2017	2018	2019	2020	Number of publications
University of Tartu	1,791	1,879	2,058	2,061	7,789
Tallinn University of Technology	959	1,023	1,202	1,276	4,460
Tallinn University	500	443	472	543	1,958
Estonian University of Life Sciences	312	354	400	412	1,478
National Institute of Chemical Physics and Biophysics	212	195	180	85	672
Tartu University Hospital	82	93	120	109	404
The National Institute for Health Development	77	66	67	77	287
Estonian Literary Museum	73	63	48	63	247
Estonian Academy of Arts	36	35	26	54	151
The Estonian Military Academy	30	24	31	50	135
Estonian Business School	35	30	19	28	112
Institute of the Estonian Language	23	16	32	26	97
Competence Centre on Health Technologies	19	25	28	23	95
East Tallinn Central Hospital	18	24	33	20	95
The North Estonia Medical Centre	37	10	15	32	94
Estonian Crop Research Institute	21	21	19	24	85
Estonian Academy of Music and Theatre	24	13	19	13	69
Tartu Observatory	53	15			68
Estonian Academy of Security Sciences	13	7	21	24	65
Under and Tuglas Literature Centre	19	10	11	20	60
Cybernetica AS	15	9	11	25	60
Baltic Defence College	10	14	12	21	57
Bank of Estonia	18	8	11	18	55
Tallinn Health Care College	5	16	19	14	54
Estonian Academy of Sciences	13	12	8	19	52
Estonian Entrepreneurship University of Applied Sciences	9	6	16	11	42
Tartu Health Care College	8	13	8	11	40
TTK University of Applied Sciences	5	8	16	11	40
Center of Food and Fermentation Technologies	7	10	7	14	38
Others	257	230	219	192	898
Total	4,033	4,013	4,489	4,493	17,028

*If an article is related to more than one institution, it is reflected in the data of all related institutions.

Source: Estonian Research Information System.¹⁵⁷

To assess the diversity of disciplines, the internal structure of the largest universities must be examined. The specialist institutes of universities (divisions) are often larger than smaller independent research institutions. Since the divisions – faculties, schools and institutes – are generally specialised in a certain field, the following table, Table 3.3, better shows the distribution of the volume of Estonian

research in specific fields. All data in the table is from the Estonian Research Information System (ETIS) database. I can only praise this dataset and recommend that the reader make their own queries in the etis.ee database and investigate the articles contained therein (see the ‘Research’ subpage).

155 Classification of the Estonian Research Information System. <https://www.etis.ee/Portal/Classifiers/Details/81e52bde-a1a1-490a-a9c4-2df9f3fc3a70?#> (19.10.2021).

156 According to the classification of the Estonian Research Information System, the codes indicate the following: 1.1 – scholarly articles indexed by Web of Science Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Emerging Sources Citation Index and/or indexed by Scopus (excluding chapters in books); 1.2 – peer-reviewed articles in other international research journals with an ISSN code and international editorial board, which are circulated internationally and open to international contributions; 3.1 – articles/chapters in books published by the publishers listed in the Annex (including collections indexed by the Web of Science Book Citation Index, Web of Science Conference Proceedings Citation Index, Scopus).

157 Estonian Research Information System. www.etis.ee (19.10.2021).

Table 3.3. The divisions of Estonian universities that published the most research articles (1.1, 1.2, 3.1) in 2018–2020. The selection includes divisions that have published at least 200 articles within three years. The rows of larger structural units also reflect the amount of articles published by smaller divisions not included in the table.

	2018	2019	2020	Total
University of Tartu	1,879	2,058	2,061	5,998
Faculty of Science and Technology	867	984	1,009	2,860
Institute of Ecology and Earth Sciences	194	234	233	661
Institute of Physics	187	159	146	492
Institute of Computer Science	136	193	151	480
Institute of Technology	100	102	120	322
Institute of Chemistry	90	82	93	265
Institute of Molecular and Cell Biology	53	100	98	251
Faculty of Arts and Humanities	329	337	332	998
Institute of Cultural Research	82	103	83	268
Institute of History and Archaeology	71	70	64	205
Faculty of Social Sciences	297	344	343	984
Faculty of Medicine	243	315	300	858
Institute of Clinical Medicine	117	148	132	397
Institute of Biomedicine and Translational Medicine	66	101	85	252
Tallinn University of Technology	1,023	1,202	1,276	3,501
School of Engineering	347	492	485	1,324
Department of Electrical Power Engineering and Mechatronics	129	167	149	445
Department of Mechanical and Industrial Engineering	85	123	124	332
Department of Civil Engineering and Architecture	54	103	100	257
School of Information Technologies	266	269	291	826
Department of Software Science	95	140	147	382
Department of Computer Systems	84	72	69	225
School of Business and Governance	219	213	256	688
Ragnar Nurkse Department of Innovation and Governance	77	64	79	220
Department of Business Administration	55	91	74	220
School of Science	186	215	200	601
Department of Chemistry and Biotechnology	68	76	79	223
Tallinn University	443	472	543	1,458
School of Humanities	161	178	180	519
School of Governance, Law and Society	83	81	111	275
School of Natural Sciences and Health	64	61	83	208
Estonian University of Life Sciences	354	400	412	1,166
Institute of Agricultural and Environmental Sciences	161	179	192	532
Institute of Veterinary Medicine and Animal Sciences	66	61	87	214
Institute of Forestry and Rural Engineering	64	78	68	210

Source: Estonian Research Information System.¹⁵⁸

Since the data in ETIS is directly linked to institutions and persons, it is possible to raise more complex questions, such as at what age are researchers most productive, how many researchers of different ages publish research, etc. Such statistics could and should be compiled by institution and field of research, but the volume of such data would be outside of the scope of this review. For this reason, I will limit myself to providing an overall picture of this topic.

Figures 3.1 and 3.2 show that maximum productivity is achieved at approximately the age of 50 and from then on the workload slowly decreases. At the same time, it is clear that Estonian research has a young face – as it should. There are more young researchers and in total they publish

more articles. If this is any indication, the future of Estonian research seems rather bright. At the same time, young people face increasing competition when applying for academic positions, but not all of them can or even should stay and work in academia. The situation can vary greatly from one field to another, as there have been examples where the researchers grow old and without a new generation difficulties arise and the specific field starts to decline. Such a decline can mostly be perceived in small research groups and fields rather than in science or research in general. Research evolves according to its own logic and young researchers develop new directions which may not coincide with the vision of the previous generations.

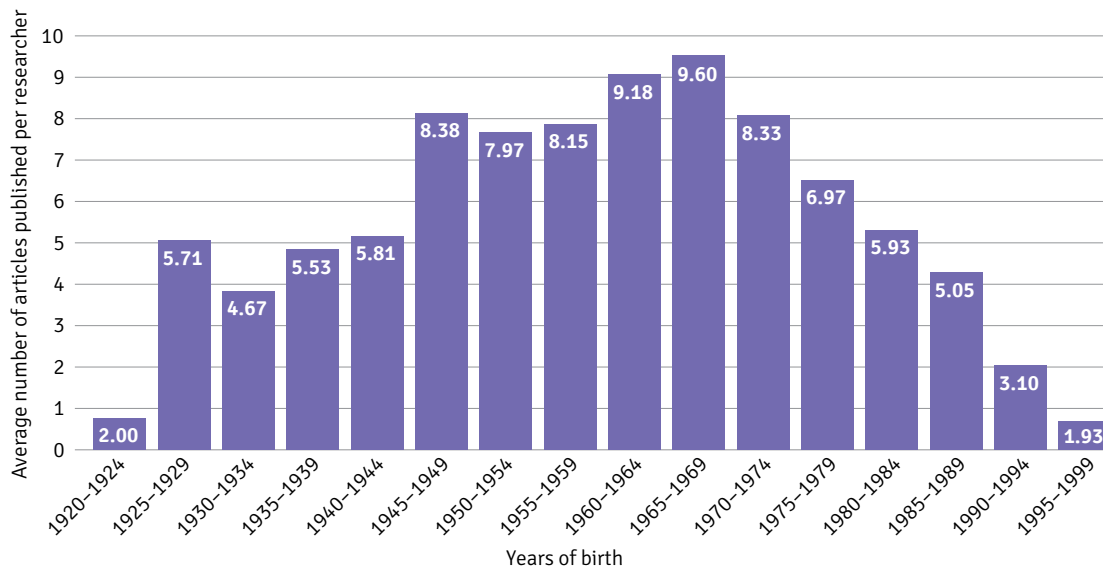


Figure 3.1. Average number of articles (1.1, 1.2, 3.1) published in 2015–2020 per researcher by years of birth (articles entered in the Estonian Research Information System)

Source: Estonian Research Information System.¹⁵⁹

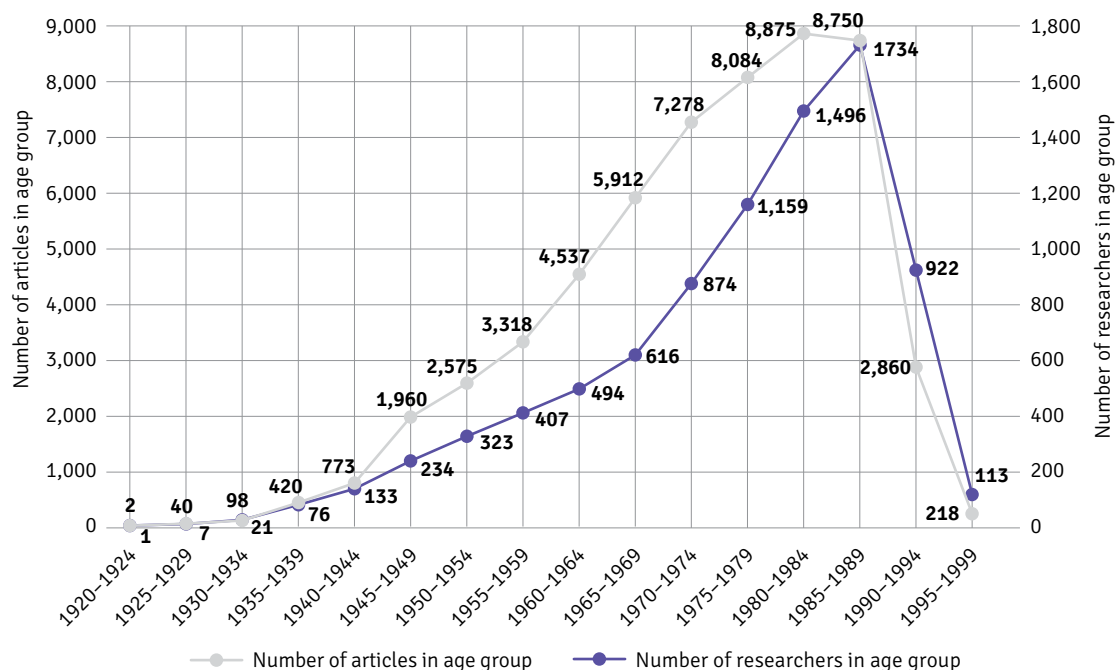


Figure 3.2. Number of articles (1.1, 1.2, 3.1) published in 2015–2020 and number of researchers in age group (articles entered in the Estonian Research Information System)

Source: Estonian Research Information System.¹⁶⁰

¹⁵⁹ Estonian Research Information System. www.etis.ee (19.10.2021).

¹⁶⁰ Estonian Research Information System. www.etis.ee (19.10.2021).

Publication data can also be broken down by gender (Figures 3.3 and 3.4). Based on such data, men publish more articles on average compared to women. Differences can also be seen in the supervision of master's and doctoral theses. While men supervise considerably more doctoral theses, the distribution is much more equal in the supervision of master's theses. The fact that, in absolute terms, men have supervised more master's and doctoral theses than women is primarily the result of men's higher presence in senior-level academic positions¹⁶¹ from among whom supervisors are generally chosen. Regardless, during 2015–2020 men supervised 1.5 doctoral theses on average while

women supervised 1.45, and in the case of master's theses, the figures were 3.62 and 3.94 respectively. As research articles in ETIS are not directly linked to research fields and many general journals do not have a narrower specialisation (e.g. nature, science, etc.), it is difficult to analyse the data by fields of research (the same methodological error likely occurs when analysing ISI/ESI fields of research). In theory, such data could be analysed on the basis of the institutions and departments in which the respective persons work. As research work and job positions are public information, a more detailed analysis of such data would not violate the privacy of anyone concerned.

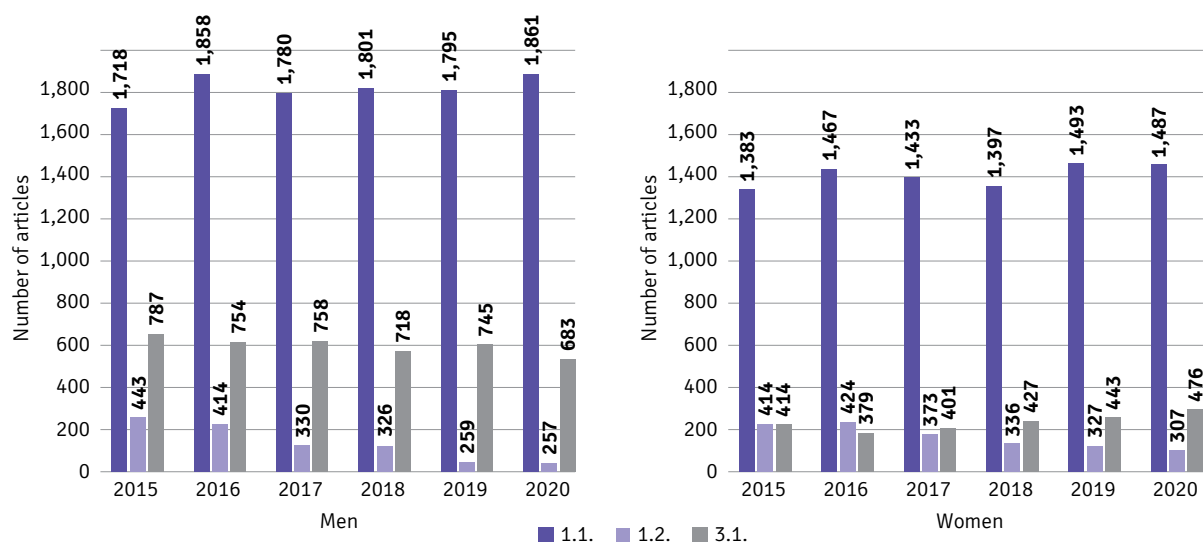


Figure 3.3. Number of articles (1.1, 1.2, 3.1) published in 2015–2020 by gender

Source: Estonian Research Information System.¹⁶²

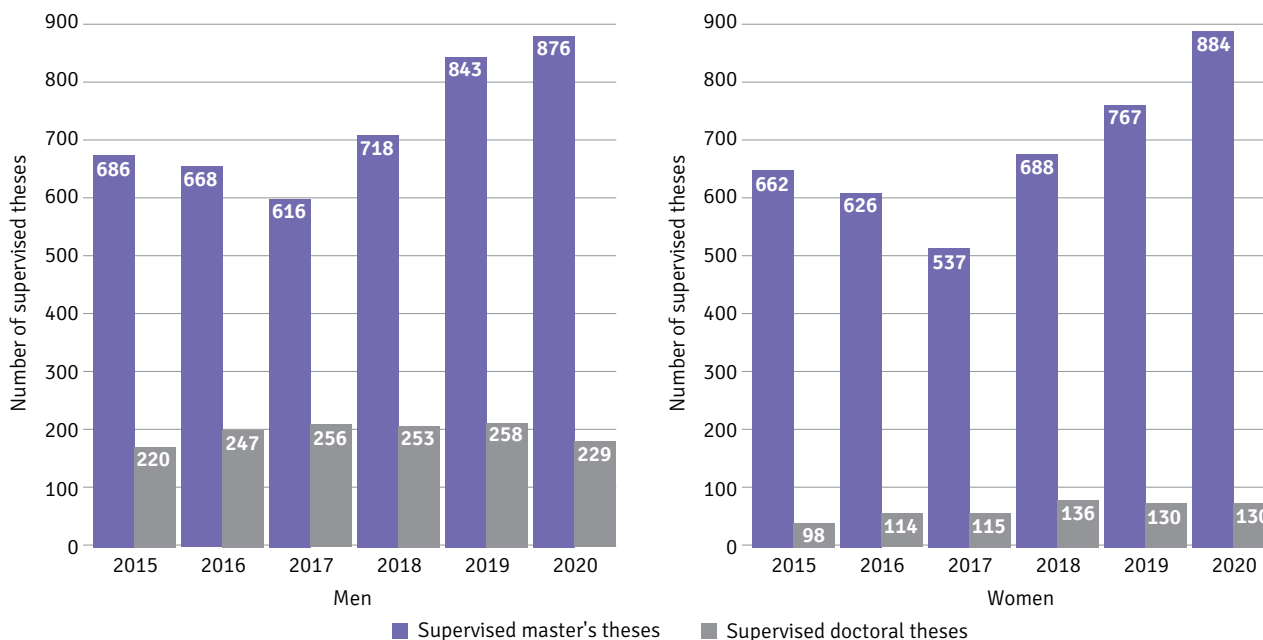


Figure 3.4. Supervision of master's and doctoral theses by gender in 2015–2020

Source: Estonian Research Information System.¹⁶³

161 Gender balance and gender pay gap. Estonian Research Council. <https://www.etag.ee/tegevused/uuringud-ja-statistika/statistika/sooline-tasakaal-ja-palgalohe/> (05.11.2021).

162 Estonian Research Information System. www.etis.ee (01.07.2021).

163 Estonian Research Information System. www.etis.ee (01.07.2021).

THE IMPACT OF RESEARCH

As already mentioned in the introduction, quantitative indicators do not tell the whole truth about science and research. It is also important to somehow assess what impact articles have on research as a whole, i.e. what their value is. Currently, the best and most straightforward measure is still citation impact (with all its faults). However, for the most part, the strengths and weaknesses of this measure balance each other out and citation counts paint a picture of the relevance of the research work according to other researchers.

It is not as simple to collect citation data as it used to be and ETIS does not readily provide this information either. For that purpose, different international databases which operate on a commercial basis are used. These include, for example, Scopus (Elsevier) and Web of Science (Clarivate

Analytics) databases as well as Google Scholar (which is simple and free, but largely depends on people creating their own profiles). At the researcher level, it is difficult to address the issue of authors with identical names, the problem of different narrow fields of research, or to identify the contribution of each discipline in interdisciplinary articles, etc. Computer scientists or physicists, for instance, are free to publish some of their results and applications in other fields of research such as life sciences. Large-scale paid databases, on the other hand, provide an opportunity to analyse and compare countries, institutions, etc. With help from the analysts of the Estonian Research Council, the international impact of research fields was analysed on the basis of the InCites (Clarivate Analytics) database (Tables 3.4 and 3.5).

Table 3.4. Volume and impact of research fields according to InCites database, in order of top 10% most cited articles

Field of science	Articles	Citations	Top 10% most cited articles	Top 1% most cited articles	Citation impact	Top 10% most cited articles (%)	Top 1% most cited articles (%)
Clinical and Life Sciences	4,390	148,413	953	250	33.81	22%	6%
Agriculture, Environment & Ecology	2,789	38,686	493	100	13.87	18%	4%
Physics	1,953	36,374	334	47	18.62	17%	2%
Social Sciences	2,895	13,804	272	34	4.77	9%	1%
Electrical Engineering, Electronics & Computer Science	1,951	13,241	228	31	6.79	12%	2%
Chemistry	1,655	21,820	168	19	13.18	10%	1%
Earth Sciences	1,034	9,555	80	16	9.24	8%	2%
Arts and Humanities	645	1,375	79	12	2.13	12%	2%
Engineering and Materials Science	495	2,810	39	1	5.68	8%	0%
Mathematics	266	2,925	30	4	11.00	11%	2%
Total	18,073	289,003	2,676	514	15.99	15%	3%

Source: InCites, Citation Topics (Macro) (29.06.2021).

Table 3.5. Publication and citation of articles published in 2015–2020 by research field (Frascati classification) according to Web of Science¹⁶⁴

	Research field (Frascati classification)	Articles	Cita- tions	Cited articles (%)	Category Norma- lised Citation Impact	Internatio- nal colla- boration articles (%)	Citation Impact	Top 1% most cited articles	Top 10% most cited articles	Top 1% most cited articles (%)	Top 10% most cited articles (%)
1	Natural Sciences	9,124	108,348	80.20	1.20	68.3	11.9	111	1,073	1%	12%
1.1	Mathematics	444	1,695	63.51	0.93	49.3	3.8	5	39	1%	9%
1.2	Computer and information sciences	1,443	7,291	63.13	1.05	54.3	5.1	10	135	1%	9%
1.3	Physical sciences and astronomy	1,670	17,799	82.04	1.18	74.1	10.7	21	204	1%	12%
1.4	Chemical sciences	1,529	17,975	87.25	0.93	66.5	11.8	4	124	0%	8%
1.5	Earth and related environmental sciences	1,907	20,954	86.21	1.06	71.9	11.0	20	202	1%	11%
1.6	Biological sciences	3,308	54,488	82.98	1.40	74.0	16.5	70	481	2%	15%
1.7	Other natural sciences	90	474	61.11	1.01	35.6	5.3	0	12	0%	13%
2	Engineering and technology	4,493	36,995	73.67	1.12	64.4	8.2	37	469	1%	10%
2.1	Civil engineering	328	2,133	77.44	1.54	55.2	6.5	3	46	1%	14%
2.2	Electrical engineering	1,579	6,727	56.87	1.12	61.2	4.3	12	154	1%	10%
2.3	Mechanical engineering	320	2,142	80.94	0.97	66.6	6.7	0	29	0%	9%
2.4	Chemical engineering	110	1,749	92.73	1.01	55.5	15.9	1	9	1%	8%
2.5	Materials engineering	996	11,959	90.56	0.93	75.9	12.0	3	88	0%	9%
2.6	Medical engineering	119	767	63.03	1.02	46.2	6.4	1	13	1%	11%
2.7	Environmental engineering	1,182	11,426	71.66	1.29	61.3	9.7	10	129	1%	11%
2.8	Environmental biotechnology	179	2,632	86.03	1.32	70.9	14.7	2	21	1%	12%
2.9	Industrial biotechnology	36	353	88.89	1.08	77.8	9.8	0	4	0%	11%
2.10	Nano-technology	208	2,951	87.50	0.86	83.7	14.2	1	12	0%	6%
2.11	Other engineering and technologies	706	6,906	79.46	1.64	62.9	9.8	12	98	2%	14%
3	Medical and health sciences	3,485	41,684	73.46	1.50	71.8	12.0	60	541	2%	16%
3.1	Basic medical research	1,149	13,065	76.41	1.26	67.9	11.4	11	147	1%	13%
3.2	Clinical medicine	1,903	21,667	67.95	1.54	73.8	11.4	38	294	2%	15%
3.3	Health sciences	917	11,394	79.83	1.63	70.1	12.4	19	159	2%	17%
4	Agricultural and veterinary sciences	871	7,687	81.17	1.25	62.7	8.8	11	107	1%	12%
4.1	Agriculture	607	5,216	80.23	1.19	59.3	8.6	7	72	1%	12%
4.2	Animal and dairy science	57	287	70.18	0.92	68.4	5.0	0	7	0%	12%
4.3	Veterinary science	115	967	80.00	2.01	78.3	8.4	5	26	4%	23%
4.4	Other agricultural science	166	1,593	82.53	0.98	60.2	9.6	1	12	1%	7%
5	Social sciences	3,669	17,686	63.23	1.20	43.7	4.8	47	385	1%	10%
5.1	Psychology	564	4,571	75.71	1.12	57.8	8.1	10	63	2%	11%
5.2	Economics and business	796	3,909	65.70	1.12	51.0	4.9	11	72	1%	9%
5.3	Educational sciences	698	2,069	55.30	1.37	33.1	3.0	7	93	1%	13%
5.4	Sociology	388	1,730	60.31	1.39	49.5	4.5	4	48	1%	12%
5.5	Law	142	200	40.14	0.75	21.8	1.4	0	6	0%	4%

164 Frascati Manual 2015. OECD. <http://oe.cd/frascati> (19.10.2021).

	Research field (Frascati classification)	Articles	Cita- tions	Cited articles (%)	Category Norma- lised Citation Impact	Internatio- nal colla- boration articles (%)	Citation Impact	Top 1% most cited articles	Top 10% most cited articles	Top 1% most cited articles (%)	Top 10% most cited articles (%)
5.6	Political science	523	1,715	57.55	1.39	34.2	3.3	6	62	1%	12%
5.7	Social and economic geography	718	4,584	65.74	1.18	50.0	6.4	8	83	1%	12%
5.8	Media and communication	224	870	57.59	1.05	33.9	3.9	1	19	0%	8%
5.9	Other social sciences	407	1,561	56.76	1.28	28.7	3.8	9	43	2%	11%
6	Humanities and the arts	1,996	2,361	33.77	1.24	18.2	1.2	18	183	1%	9%
6.1	History and archaeology	730	922	26.85	1.28	17.0	1.3	10	68	1%	9%
6.2	Languages and literature	502	478	32.67	0.81	20.7	1.0	3	35	1%	7%
6.3	Philosophy	269	492	41.26	1.28	21.6	1.8	2	30	1%	11%
6.4	Art	261	289	31.42	1.48	22.6	1.1	7	25	3%	10%
6.5	Other Humanities	351	598	51.85	2.68	14.8	1.7	10	81	3%	23%

Source: In Cites, Web of Science.

Research is carried out by researchers who begin as doctoral students and then climb the career ladder, reaching various positions in academia or other enterprises and institutions. Many of them certainly stop conducting active research after obtaining their doctoral degree and taking up

the position of an analyst, or another executive or complex position. Nevertheless, trained researchers are needed in both public and private research to reach innovative solutions.

NUMBER OF DOCTORAL GRADUATES

The state of doctoral studies reflects the state of Estonian research. Firstly, it shows the active research being conducted, primarily by doctoral students. Secondly, doctoral studies are the only way of guaranteeing a new generation of teaching and research staff. In many fields, doctoral degree holders are needed in both private and public sector institutions. A low level of interest in doctoral studies calls into question the sustainability of the field.

A goal of granting 300 doctoral degrees per year was set some time ago in Estonian research. Unfortunately, this

goal has not been achieved as there have been fewer and fewer doctoral graduates in recent years and soon we may reach a point where less than 200 doctoral degrees are awarded each year. The education statistics portal haridussilm.ee provides an excellent overview of higher education in Estonia. For instance, it includes data on the performance indicators of doctoral studies (higher education level III): admissions, total numbers and graduates (Figure 3.5). Marek Tamm's article 'Estonian research community and its offspring' in this collection also discusses the subject of the next generation of researchers.

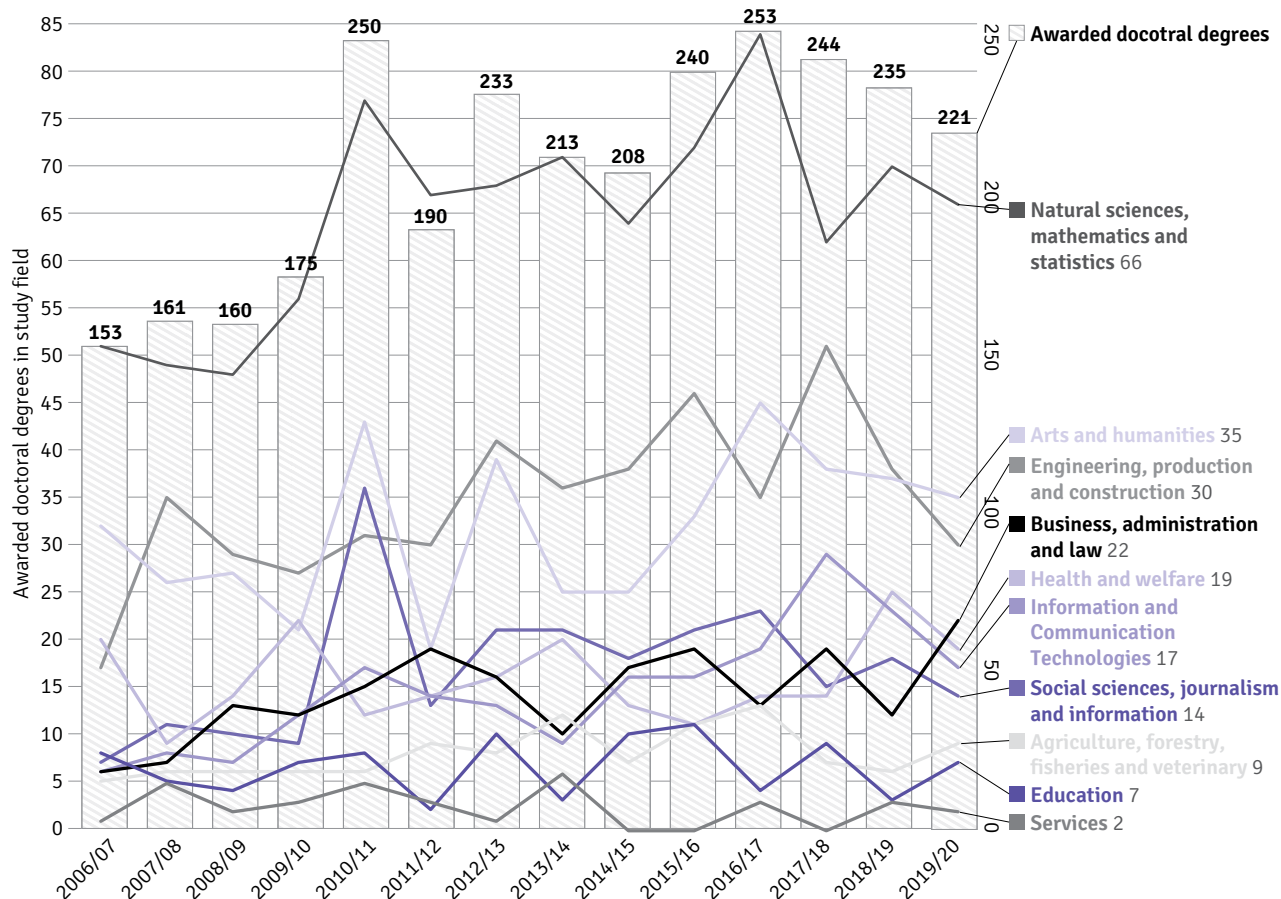


Figure 3.5. The number of doctoral degrees granted by field of study in the Estonian education system in academic years 2006/07–2019/20

Source: Haridussilm.¹⁶⁵

In order to implement structural changes, the distribution of doctoral students by study field should be taken into account to understand whether the number of doctoral students meets expectations. One necessary strategic input is

to assess whether the number of doctoral degrees is in line with the need for providing higher education in the respective fields.

Table 3.6. Comparison of the number of doctoral degrees awarded in Estonia with the number of students currently pursuing higher education. The ratio shows the average number of students during an academic year in 2016/17–2020/21 and the awarded doctoral degrees during 14 years (academic years 2006/07–2019/20)

Total number of students studying at higher education levels I, II and III*	2016/17	2017/18	2018/19	2019/20	2020/21	Average number of students during an academic year (in period 2016–2021)	Awarded doctoral degrees (total in period 2006/07–2019/20)	Ratio
Natural sciences, mathematics and statistics	2,929	2,825	2,698	2,619	2,726	2,759	905	3.0
Engineering, production and construction	7,793	7,293	6,877	6,661	6,587	7,042	484	14.6
Arts and humanities	6,082	6,096	6,167	6,068	6,075	6,098	445	13.7
Social sciences, journalism and information	3,438	3,011	2,848	2,867	2,828	2,998	237	12.7
Health and welfare	5,492	5,428	5,691	5,873	5,944	5,686	223	25.5
Information and Communication Technologies	4,155	4,059	4,377	4,569	4,860	4,404	206	21.4
Business, administration and law	10,836	10,652	10,519	9,873	9,359	10,248	200	51.2
Agriculture, forestry, fisheries and veterinary	1,050	971	947	942	1,023	987	111	8.9
Education	3,272	3,137	3,162	3,257	3,422	3,250	91	35.7
Services	2,746	2,682	2,529	2,449	2,435	2,568	34	75.5
Total	47,793	46,154	45,815	45,178	45,259	46,040	2,936	15.7

*Studies at the level of higher education consist of three levels: 1) the first level involves bachelor's studies, studies in professional higher education, and integrated bachelor's and master's studies; 2) the second level involves master's studies; 3) the third level involves doctoral studies.

Source: Haridussilm.¹⁶⁶

According to Table 3.6, the number of awarded doctoral degrees almost seems to meet the need for higher education in various fields, if the target is to train one teacher per 15–20 students. This would require all doctoral graduates to work at a university as a teacher for 15 years on average. However, doctoral graduates are not only needed in universities. For example, in the field of ICT, universities struggle to attract and recruit the younger generation to teaching and research positions because they are also needed in the businesses sector and more than half of the graduates take up a position in such enterprises immediately after graduation. This trend is upwards and we can expect to see an increase in the number of doctoral graduates employed in the business sector. This is also the reason why the reproduction of teachers is currently unbalanced, i.e. the number of doctoral graduates in the field of ICT does not meet the expectations and needs of the state, business sector and higher education.

If we want to ensure a good level of teacher training and fill technological and executive positions in both the public and business sector with doctoral graduates, then, according to the data, we should award more than 300 doctoral degrees per year, although additional needs may be very unevenly distributed among different fields of study. Increasing the number of doctoral students does not need to be universal, but rather based on the needs of the respective field and the establishment of new technical specialties (e.g. cybersecurity, artificial intelligence, epidemiology, oncology, teacher training or smart production). Achieving excellence depends on funding and teaching capacity. As we lack people in strategic areas, it is necessary to promote the production of highly-skilled teachers in the respective fields as well as encourage young people to study abroad in those fields.

FUNDING

National research policy is currently not very strategic. Decision-making is rather tactical in nature, while baseline funding is based on indicators and centered around institutional processes and the decision-making bodies comprising the representatives of the research community in various fields. The risk of favouring one's own field or institution in decision-making is always present. In principle it

is understandable because all those conducting research in good faith consider their field to be the most necessary, important and interesting. Otherwise they would not be working in this field.

In order to decide on competitive funding, the key players in all fields should be determined and adequate rankings

should be prepared. In Estonia, however, rankings in their current form should not be prepared within one field of research but on the basis of all of them. As a result, we are basically comparing apples with oranges and assessing whether an apple is the best orange or vice versa. Of course, the best orange or grape in Estonia may not be competitive at a global level. Nevertheless, when global change is underway and it is necessary to prepare to cope with global trends, whether it be digital or green transition or socio-economic catastrophes, we cannot sit back and wait for these capabilities to somehow emerge.

I put forward an argument earlier that applied research and applications cannot easily be achieved without the con-

tribution of fundamental research in the respective field. Otherwise we would not have people who could understand the theory on which the application is based. Similarly, if we ever needed to overcome new challenges regarding the application, there would be no one who could come up with the necessary theoretical solution. Therefore, the funding of blue skies research is a key determinant of the kind of training that can be organised in the state and the kind of applications that can be developed. The number of researchers and doctoral graduates in Estonia is clearly too low. In order to encourage faster development, we would need more than half the current number. Thus we should distribute funding between and within disciplines, focusing on the most promising and necessary fields and the most outstanding people.

Table 3.7. Funding of all active (i.e. ongoing) research projects according to the Estonian Research Information System in 2018–2021 and the ratio of funding in all research fields (%) according to the Frascati classification. The main research grants awarded by the Estonian Research Council (PUT, IUT, PRG, PSG grants) have been separately highlighted, as well as all other grant types, contractual and corporate projects, including foreign financed projects.

	Research grants awarded by the Estonian Research Council (PUT, IUT, PRG, PSG grants) (million EUR)					All active research projects in Estonian Research Information System (incl. foreign, contractual and corporate financed) (million EUR)					Ratio (all active projects/research grants awarded by Estonian Research Council) 2021
	2018	2019	2020	2021	Share (2021)	2018	2019	2020	2021	Share (2021)	
1. Natural Sciences	18.5	18.4	21.2	21.9	48.4%	38.2	48.6	50.3	50.6	45.4%	2.3
1.1. Mathematics	0.6	0.5	1.1	1.2	2.6%	0.0	0.0	0.4	0.5	0.4%	0.4
1.2. Computer and information sciences	1.6	1.3	1.6	1.8	3.9%	7.4	12.0	14.2	12.7	11.3%	7.1
1.3. Physical sciences	3.4	2.9	4.1	4.0	8.9%	3.7	4.0	4.2	4.7	4.2%	1.2
1.4. Chemical sciences	2.4	3.1	3.4	2.9	6.4%	5.5	4.8	4.6	5.8	5.2%	2.0
1.5. Earth and related environmental sciences	2.3	2.3	2.5	1.9	4.1%	5.5	8.3	8.9	8.4	7.5%	4.5
1.6. Biological sciences	8.2	8.3	8.6	10.2	22.6%	16.1	19.4	17.9	18.6	16.7%	1.8
2. Engineering and technology	4.7	4.9	6.2	6.4	14.1%	19.0	22.5	25.8	23.5	21.0%	3.7
2.1. Civil Engineering	0.4	0.3	0.5	0.6	1.2%	2.9	3.1	4.8	4.5	4.0%	8.2
2.2. Electrical engineering, electronic engineering, information engineering	1.2	1.4	1.4	1.6	3.5%	7.8	8.8	7.9	6.1	5.5%	3.8
2.3. Mechanical engineering			0.2	0.2	0.5%	0.4	0.3	0.5	0.7	0.6%	3.1
2.4. Chemical engineering	0.0	0.1	0.4	0.2	0.3%	0.4	0.8	1.3	0.9	0.8%	5.7
2.5. Materials engineering	0.1	0.5	2.2	2.3	5.0%	1.3	1.7	2.9	3.2	2.8%	1.4
2.6. Medical engineering	0.0	0.0	0.1	0.1	0.2%	0.1	0.2	0.2	0.0	0.0%	0.5
2.7. Environmental engineering		0.0	0.1	0.2	0.3%	0.8	1.4	1.7	1.3	1.2%	8.6
2.9. Industrial biotechnology		0.2	0.2	0.5	1.1%	0.5	0.6	0.6	0.8	0.7%	1.6
2.10. Nano-technology	0.1	0.1	0.3	0.3	0.7%	0.0	0.3	0.6	0.8	0.7%	2.4
2.11. Other engineering and technologies	2.8	2.3	0.8	0.5	1.0%	4.8	5.3	5.2	5.1	4.6%	11.0
3. Medical and health sciences	5.2	5.2	6.0	6.7	14.8%	8.8	8.8	12.8	11.1	9.9%	1.7
3.1. Basic medicine	3.5	3.6	3.8	3.9	8.6%	4.3	4.6	4.8	4.9	4.4%	1.3
3.2. Clinical medicine	1.1	1.2	1.6	2.1	4.8%	1.7	1.5	2.7	1.9	1.7%	0.9

	Research grants awarded by the Estonian Research Council (PUT, IUT, PRG, PSG grants) (million EUR)					All active research projects in Estonian Research Information System (incl. foreign, contractual and corporate financed) (million EUR)					Ratio (all active projects/research grants awarded by Estonian Research Council) 2021
	2018	2019	2020	2021	Share (2021)	2018	2019	2020	2021	Share (2021)	
3.4. Medical biotechnology			0.2	0.4	0.8%	0.6	0.6	0.5	0.1	0.1%	0.2
4. Agricultural and veterinary sciences	1.1	1.1	1.7	2.1	4.7%	3.9	4.8	6.5	5.8	5.2%	2.8
4.1. Agriculture, forestry, and fisheries	0.9	0.7	1.2	1.5	3.4%	3.5	4.0	5.4	4.5	4.0%	2.9
4.2. Animal and dairy science		0.2	0.3	0.3	0.7%	0.2	0.2	0.3	0.4	0.4%	1.4
4.3. Veterinary medicine	0.2	0.1	0.1	0.1	0.2%	0.1	0.3	0.6	0.6	0.5%	5.5
4.4. Agricultural biotechnology		0.1	0.1	0.2	0.3%	0.1	0.2	0.2	0.3	0.3%	2.2
5. Social sciences	2.4	2.6	2.8	3.4	7.5%	15.0	13.6	15.5	14.9	13.3%	4.4
5.1. Psychology and cognitive sciences	0.4	0.2	0.4	0.6	1.3%	0.5	0.4	0.5	0.8	0.7%	1.4
5.2. Economics and business	0.3	0.3	0.3	0.5	1.1%	2.4	2.7	3.1	3.1	2.8%	6.1
5.3. Education	0.3	0.2	0.1	0.1	0.2%	3.0	2.5	3.1	2.4	2.2%	26.4
5.4. Sociology		0.1	0.2	0.2	0.5%	1.0	1.8	2.1	2.0	1.8%	9.0
5.5. Law	0.1	0.1	0.3	0.3	0.6%	0.6	0.5	0.5	0.8	0.7%	2.7
5.6. Political science	0.0	0.1	0.1	0.3	0.6%	0.6	0.8	1.5	1.2	1.1%	4.3
5.7. Social and economic geography		0.2	0.2	0.2	0.5%	0.1	0.3	0.8	0.8	0.7%	3.2
5.8. Media and communications		0.0	0.0	0.1	0.3%	0.2	0.9	0.9	0.6	0.6%	4.9
5.9. Other social sciences	1.4	1.4	1.0	1.0	2.3%	6.5	3.7	3.0	3.1	2.8%	3.0
6. Humanities and the arts	3.6	3.7	4.0	4.8	10.5%	4.1	4.9	5.9	5.4	4.8%	1.1
6.1. History and archaeology	0.7	0.9	1.0	1.5	3.2%	0.5	0.7	0.9	1.1	1.0%	0.7
6.2. Languages and literature	1.4	1.4	1.2	1.4	3.0%	1.6	1.5	2.0	1.6	1.4%	1.2
6.3. Philosophy, ethics and religion		0.2	0.5	0.6	1.4%	0.2	0.3	0.3	0.4	0.3%	0.6
6.4. Arts (arts, history of arts, performing arts, music)			0.2	0.2	0.5%	0.1	0.2	0.3	0.4	0.3%	1.8
6.5. Other humanities	1.5	1.3	1.1	1.1	2.5%	1.7	2.3	2.3	2.0	1.8%	1.8
Total	35.4	35.9	41.9	45.2	100%	89.0	103.4	116.9	111.5	100%	2.5

Source: Estonian Research Information System.¹⁶⁷

Decoding the contents of Table 3.7 is one of the biggest challenges facing Estonian research, as excellence in Estonian research is currently highly linked to natural sciences. However, these natural sciences also include mathematics, physics, chemistry and computer science. Not all research fields are equal, nor should they be, as there are many reasons for developing one or another field more than before. For instance, it is imperative to ensure research funding in areas where more doctoral students are needed. In addition to the need for providing further training to doctoral students and teachers, it is also important to ensure the sustainability of those fields necessary for business through

state funding. This can best be achieved through the development of doctoral studies and excellence (both basic and applied research) in the respective fields.

The distribution of public research funding should also be compared with the percentages of R&D expenditure of Estonian companies by economic activity, which are presented in Figure 4.18 of Tea Danilov's article in this collection. For example, information and communication, financial and insurance activities accounted for approximately half of the intramural and extramural R&D expenditure of the business sector – in 2020, the amount already exceeded 139 million

euros (Figure 3.6). If we truly wish to reach the target of receiving 2% from business investment in addition to the 1% of GDP from public funding, then we cannot forget that enterprises also expect state support in areas most important to them. This concerns not only the expectations of applied research in respective fields but also the vitality of basic research which ensures the functioning of higher

education and doctoral studies and creates a basis for the development of applications. Perhaps the sentiment that applied research cannot be separate from basic research is the reason why universities do not currently consider it practicable to establish an applied research centre in Estonia.

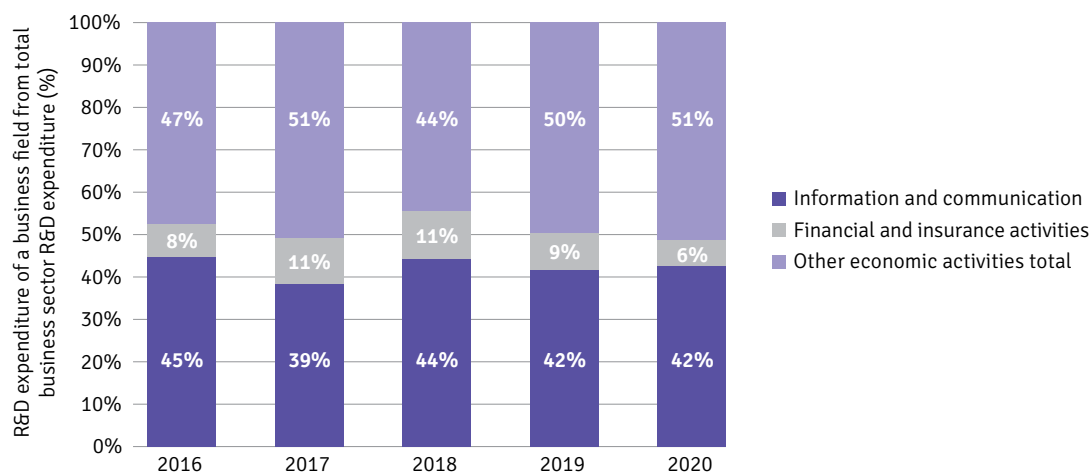


Figure 3.6. Intramural and extramural R&D expenditures in information and communication, financial and insurance activities compared to business sector total in 2016–2020. These so-called fintech sectors are the most IT intensive. It may be assumed that automation and digitalisation receive the bulk of R&D investment in other sectors as well

Source: Statistics Estonia.¹⁶⁸

EXCELLENCE IN RESEARCH

Excellence in Estonian research can be defined on different grounds, e.g. citation impact, international grants and recognitions for excellent researchers, etc. Highlighting some of the possibilities raises the question of why we should limit ourselves to a short list of indicators.

From a subjective point of view, it is clear that excellence in Estonian research is centered around the strongest schools, such as ecology, botany, mycology and other related sub-fields (University of Tartu Institute of Ecology and Earth Sciences, University of Tartu Natural History Museum, Estonian University of Life Sciences), as well as the Estonian Genome Project and more broadly around the fields of genetics, bioinformatics and physics (National Institute of Chemical Physics and Biophysics – NICPB, Tartu Observatory). Strong schools and international networks create a good basis for co-operation and ensure that research impacts the greatest number of people. Scientific devel-

opment is often generated by a certain group of people, the so-called giants, on the shoulders of whom Estonian research stands.

The most recent success in Estonian research took place in September 2021 when the world's leading science journal *Nature Genetics* published three articles^{169,170,171} by Estonian researchers in one week, the first author and leading author of two of which was a University of Tartu researcher. All three researchers were from different research groups: two from the Estonian Genome Project and one from the Institute of Computer Science. An illustration of an article by Estonian researchers was chosen as the front cover of the journal *Nature*.¹⁷² In addition, an article by an Estonian research group was the cover story of *Communications of the ACM*, the leading publication for the computer science and IT fields.¹⁷³

¹⁶⁸ Statistics Estonia. www.stat.ee (03.12.2021).

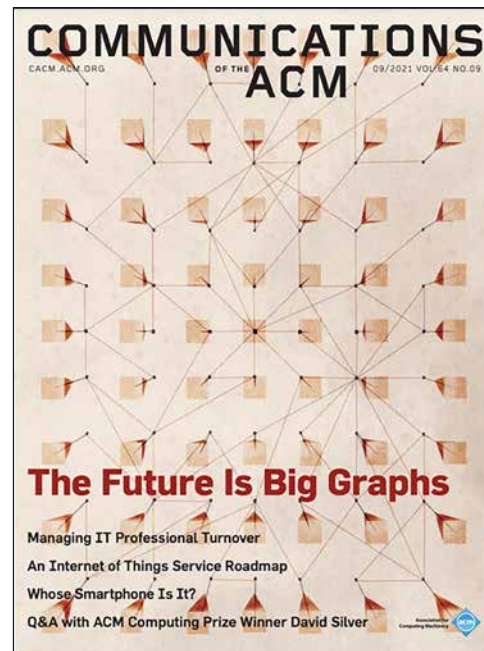
¹⁶⁹ Min, J. L., Hemani, G., Hannon, E., Dekkers, K. F., Castillo-Fernandez, J., Luijk, R., ... & Davey Smith, G. (2021). Genomic and phenotypic insights from an atlas of genetic effects on DNA methylation. *Nature genetics*, 53(9), 1311–1321.

¹⁷⁰ Kerimov, N., Hayhurst, J. D., Peikova, K., Manning, J. R., Walter, P., Kolberg, L., ... & Alasoo, K. (2021). A compendium of uniformly processed human gene expression and splicing quantitative trait loci. *Nature genetics*, 1–10.

¹⁷¹ Min, J. L., Hemani, G., Hannon, E., Dekkers, K. F., Castillo-Fernandez, J., Luijk, R., ... & Davey Smith, G. (2021). Genomic and phenotypic insights from an atlas of genetic effects on DNA methylation. *Nature genetics*, 53(9), 1311–1321.

¹⁷² Carmona, C.P., Bueno, C.G., Toussaint, A. et al. Fine-root traits in the global spectrum of plant form and function. *Nature* 597, 683–687 (2021). <https://doi.org/10.1038/s41586-021-03871-y> The article on the cover of *Nature*, 597, published 30th September 2021 <https://www.nature.com/articles/s41586-021-03871-y>, cover photo reproduction rights obtained from SpringerNature.

¹⁷³ Sherif Sakr et al. (2021). The Future Is Big Graphs: A Community View on Graph Processing Systems. *Communications of the ACM*, September 2021, Vol. 64 No. 9, Pages 62–71. <https://doi.org/10.1145/3434642> On the cover of *Communications of the ACM*, published in September 2021. Cover photo reproduction rights obtained from ACM Copyrights and Permissions, Association for Computing Machinery, artist Alli Torban.



Large commercial databases, such as Clarivate Analytics, compile rankings of the most cited researchers by field of research. The list currently includes ten researchers from

Estonia, most of whom are engaged in ecology, botany, mycology and environmental physics (Table 3.8).

Table 3.8. Researchers working in Estonia who have reached top 6,000 most cited researchers in the world in one or several fields

	Name	Category	Primary affiliation	Secondary affiliations
1	Kessy Abarenkov	Several	University of Tartu	
2	Urmas Kõljalg	Plant and Animal Science	University of Tartu	
3	Mohammad Bahram	Several	King Abdulaziz University	University of Tartu
4	Mari Moora	Several	University of Tartu	
5	Maarja Öpik	Plant and Animal Science	University of Tartu	
6	Leho Tedersoo	Plant and Animal Science	King Saud University	University of Tartu
7	Martin Zobel	Several	King Saud University	University of Tartu
8	Ülo Niinemets	Plant and Animal Science	Estonian University of Life Sciences	
9	Heikki Junninen	Geosciences	University of Tartu	University of Helsinki
10	Linda D. Hollebeek	Economics and Business	Montpellier Business School	Tallinn University of Technology

Source: Clarivate Analytics.¹⁷⁴

EXCELLENCE IN EUROPEAN RESEARCH

European Research Council (ERC) awards the world's most prestigious grants to researchers on subjects of their choice. The advantage of such a method is that the researcher knows what they are capable of achieving in their field and they will make it a reality. From a practical point of view, these grants have delivered many novel solutions and applications which have brought about significant economic growth in various countries. These grants have been awarded to a wide variety of research fields in Estonia. So far, all research grants have been awarded by different evaluation panels. Two grants have only been awarded in computer science, one for quantum cryptography and the

other for the improvement of business processes – two very different areas. The foreign researchers in Estonia are also very successful and greatly contribute to the excellence of Estonian research (Table 3.9).

Under the Seventh Framework Programme (FP7), 50 ERC grant applications were submitted from Estonia, and under the next Framework Programme Horizon 2020 (H2020), 186 applications were submitted. Funding was received for four and eight projects respectively, i.e. the rate of success was 8% under FP7 4.3% under H2020.

174 Source: Highly Cited Researchers, Web of Science, Clarivate Analytics. <https://recognition.webofscience.com/awards/highly-cited/2020/> (20.10.2021).

Table 3.9. Researchers employed in Estonia who have received an European Research Council grant

Principal investigator	Host institution	ERC grant type	Budget (million EUR)	Duration	ERC panel
Mälksoo Lauri	University of Tartu	Starting grant	0.5	2009–2014	SH2 – Institutions, values, environment & space
Päivärinta Lassi Juhani	Tallinn University of Technology	Advanced grant	1.8	2011–2016	PE1 – Mathematics
Tambet Teesalu	University of Tartu	Starting grant	1.5	2012–2016	LS7 – Applied medical technologies
Ülo Niinemets	Estonian University of Life Sciences	Advanced grant	2.3	2013–2018	LS8 – Ecology, evolution and environmental biology
Mart Loog	University of Tartu	Consolidator grant	2.0	2015–2020	LS1 – Molecular biology
Tambet Teesalu	University of Tartu	Proof of concept	0.2	2018–2019	Proof of Concept
Liisi Keedus	Tallinn University	Starting grant	1.4	2018–2023	SH6 – The study of the human past
Dominique Peer Ghislain Unruh	University of Tartu	Consolidator grant	1.7	2019–2024	PE6 – Computer science & informatics
Marlon Dumas	University of Tartu	Advanced grant	2.3	2019–2014	PE6 – Computer science & informatics
Vasileios Kostakis	Tallinn University of Technology	Starting grant	1.0	2019–2022	SH2 – Institutions, values, environment & space
Girsh Blumberg	National Institute of Chemical Physics and Biophysics	Advanced grant	2.5	2021–2026	PE3 – Condensed matter physics
Eneken Laanes	Tallinn University	Starting grant	1.5	2020–2024	SH5 – Cultures & cultural production

Source: European Research Council.¹⁷⁵

CENTRES OF EXCELLENCE IN RESEARCH

In addition to research groups, grants, and various institutions, centres of excellence, which are funded by the Structural Funds, are also a key element of Estonian research. Centres of excellence develop inter-agency co-operation in broader research areas. It is estimated that about half of Estonian researchers in total participated in the call for applications. However, only half of the applications received funding. The list of those who received funding is also an

indicator of the fields in which Estonia excels. The beneficiary is one institution but every centre of excellence comprises several institutions. Since these are rather large, long-term, and institutional grants, the main concern of the research community is the lack of funding for measures that would enable and enhance co-operation in Estonia. The first chapter of this collection also provides an overview of the centres of excellence and their funding.

INTERNATIONAL RESEARCH INFRASTRUCTURES

Research is international by nature and consists of sectoral networks which make use of the necessary research infrastructures. For instance, academic research databases are necessary for all researchers as they enable the exchange of information on research results and provide access to data from previous experiments. Other similar examples include expensive experimental equipment which is jointly funded and digital distributed data infrastructures which are accessible to all researchers.

The Estonian Research Infrastructures Roadmap brings together all the nationally important research infrastructure units for Estonian research. The list includes both local and

regional units as well as international and pan-European infrastructures. Despite the compilation of the Estonian Research Infrastructures Roadmap, research infrastructures have not yet received the necessary funding. Siret Rutiku provides more information on research infrastructures in the first chapter of this collection.

Below is a list of all the international joint infrastructures, initiatives and the European Strategy Forum for Research Infrastructures (ESFRI) roadmap objects in which Estonia is already a member or in the process of becoming a member (e.g. EMBL).

175 Databub of ERC-funded projects. European Research Council. <https://erc.europa.eu/projects-figures/project-database> (20.10.2021).

Estonian participation in international research infrastructures.¹⁷⁶

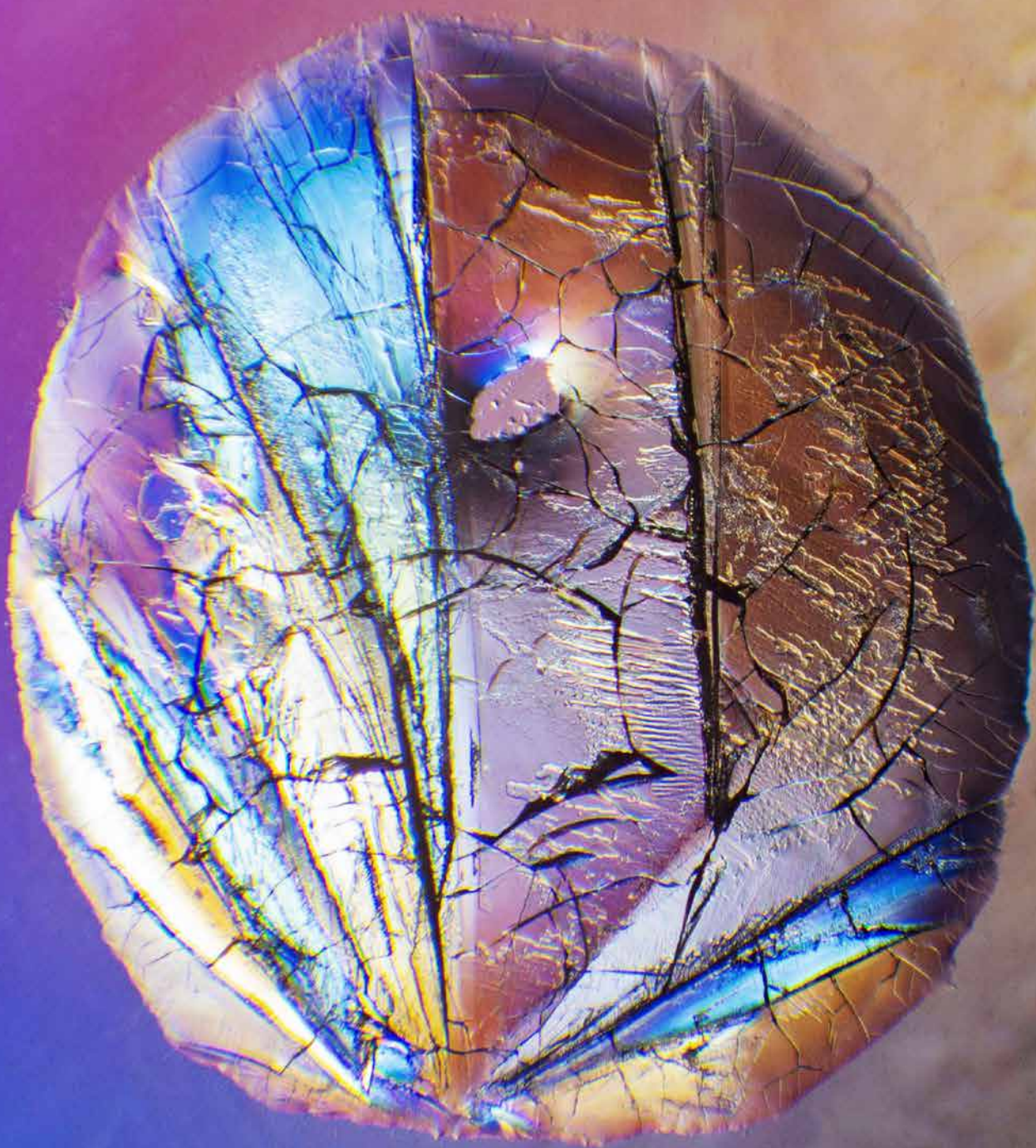
- BBMRI ERIC: Biobanking and Biomolecular Resources Research Infrastructure
- CLARIN ERIC: Common Language Resources and Technology Infrastructure
- ELIXIR: A Distributed Infrastructure for Life-Science Information
- NeIC: Nordic e-Infrastructure Collaboration
- ESS ERIC: European Social Survey
- ICOS ERIC: Integrated Carbon Observation System
- AnaEE: Analysis and Experimentation on Ecosystems
- DiSSCo: Distributed Systems of Scientific Collections
- GGP2020: Generations and Gender Programme
- Estonian Beamline at MAX-IV Synchrotron Radiation Source (FINESTBEAMS)
- European Spallation Source ERIC
- European Space Agency (ESA)
- European Organisation for Nuclear Research (CERN)
- European Molecular Biology Laboratory (EMBL)

CLOSING REMARKS

In the author's opinion, Estonian research has reached such a high international level that our main universities are not far behind the average universities in Western Europe. Our research capacity is diverse, but, in terms of overall figures, Estonia is still very small. This is why we cannot ensure the sufficient representativeness of all necessary research fields in Estonia. Nevertheless, centres of excellence promote the development of Estonian research as a whole, raising the bar even higher. It is essential to ensure sufficient diversity in research and identify new trends and needs.

This does not mean that stronger areas should be pushed to the side, but rather through making informed choices, providing opportunities for the promoters of new disciplines, and supporting the state in expanding new directions. We must ensure that young people have the opportunity to prove themselves to guarantee continuous stimulation of research. Young researchers bring with them many new ideas, energy and capacities, while the older generation is responsible for maintaining a certain stability and continuity and taking care of administrative matters.

¹⁷⁶ Estonian participation in international research infrastructures. Estonian Research Council. <https://www.etag.ee/rahastamine/infrastruktuuritoetus/teadustaristu-teekaart/> (02.11.2021).



RELATIONSHIP BETWEEN RESEARCH AND INNOVATION IN ESTONIA

TEA DANILOV

Head of the Foresight Centre

INTRODUCTION

In this article, I try to give an overview of the relationship between research and the economy and thus shed light on the economic and social impact of Estonian research. There is, of course, no clear answer here, nor can there even be such a thing, because much depends on the data on which the conclusions are based as well as the worldview of the interpreter of those data. No less significant is whether the world is viewed through dark or rose-tinted glasses, or whether the glass is half empty or half full.

In this article, a two-sided approach is chosen. First, I establish links with the approaches of both Prof. Urmas Varblane and Prof. Kadri Ukrainski (2017)¹⁷⁷ and Prof. Erkki Karo (2019)¹⁷⁸ to assess whether their main conclusions are still valid or whether significant changes have taken place in the last few years.

Secondly, this time I will take a closer look at the development of the innovation capacity of Estonian companies. It is an old recognition that the so-called science push mechanism, which translates research results into economic applications, remains too weak to have a wider economic impact. This is especially true in the so-called transition countries, which still applies to us as well – the GDP per capita in Finland, for example, is one third higher than in Estonia (Table 4.1). Just as two partners are needed to dance the tango, the science push mechanism must be complemented by the demand pull of entrepreneurship. Therefore, we will take a closer look at how innovation capacity has developed in Estonian companies. We will also ask, if and when could a new and much wider range of R&D companies develop?

Table 4.1. GDP compared to the European Union (27) average in 2009–2020, EU 27 (from 2020) = 100

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EU27 (from 2020)	100	100	100	100	100	100	100	100	100	100	100	100
EU28 (2013–2020)	101	101	101	101	101	101	101	101	101	101	101	:
Czech Republic	87	84	84	84	86	88	89	89	91	92	92	94
Denmark	127	131	129	129	130	129	128	128	130	129	130	136
Germany	118	121	124	124	125	127	125	125	124	123	120	121
Estonia	65	66	72	75	77	79	77	78	80	82	84	86
Ireland	130	132	131	133	133	138	181	177	185	190	193	211
Latvia	53	54	58	61	63	64	65	66	67	69	69	72
Lithuania	57	61	67	71	74	76	75	76	79	81	83	87
Poland	60	63	66	67	67	68	69	69	70	71	73	76
Slovenia	86	85	84	83	83	83	83	84	86	87	89	89
Slovakia	72	76	76	77	78	78	78	73	71	71	70	71
Finland	119	118	119	117	115	113	111	111	112	111	111	115
Sweden	126	128	130	130	129	127	129	124	122	120	119	123

Source: Eurostat (last updated on 28.07.2021, data extracted on 20.09.2021).¹⁷⁹

¹⁷⁷ Varblane, U., Ukrainski, K. (2016). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33–43, Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0002>

¹⁷⁸ Karo, E. (2019). The future and societal importance of Estonian research and development. – Estonian Research 2019 (ed. K. Raudvere), pp. 47–60, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>

¹⁷⁹ Eurostat. <https://ec.europa.eu/eurostat/data/database> (20.09.2021).

Globally, there has been a great deal of discussion about how much of the economic performance and growth of the state's income level is determined by research and development (R&D). In any case, the correlation between these two indicators is indisputable: there is little R&D in low-income countries and a lot in high-income countries (with the possible exception of some oil countries). And simple wisdom could be enough to conclude that if the development results in more complex products and services, a higher price can be charged for them.

However, there are certain nuances to this. It may not be the case that research comes first. TalTech professor Kadri Männasoo and her colleagues have found that it is often exports that come first. Based on comparative data of companies in the 11 new EU Member States and Russia, an examination of the links between exports and innovation has shown that exports are a necessary condition for innovation rather than the other way around.¹⁸⁰

Starting with exporting entails the so-called learning by exporting, which involves the learning process and the transfer of knowledge when interacting with foreign business partners and customers. As a result, companies will start to invest in improving the skills of their employees and in research and development. At the same time, the more developed the market of the export destination country, the more effective the learning will be.

The question of the relationship between the level of state income and the level of R&D can therefore also be viewed in such a way that an increase in the level of state income, in which export earnings play an important role, leads to greater investment in research and development. Consciously aiming at provocation, one might therefore ask whether the best R&D policy is an export policy. In any case, it is clear that the economic impact of research cannot be limited to push factors, but must shed light on the pull factors as well.

IS ESTONIA HAUNTED BY THE AVERAGE INCOME TRAP?

The fact that the relationship between the level of R&D and GDP growth, especially in transition countries, is not working well, and that Estonia's economic growth so far should rather be attributed to other factors (for example, cost advantage, flexibility, favourable business climate), is confirmed by a glance at several Estonian indicators. The development of Estonia's income level has been rapid, yet there were only 286 companies investing in R&D in 2019,

and the record number from recent history is 303 companies in 2009 (Figure 4.1). Over the last seven years, Estonian private sector expenditure on R&D has fluctuated at around 0.6–1% of GDP (Figure 4.2), remaining almost twice below the EU average (27, from 2020) (1.47% of GDP (2019))¹⁸¹ and even more so compared to the OECD average (1.83% of GDP (2019)).¹⁸²

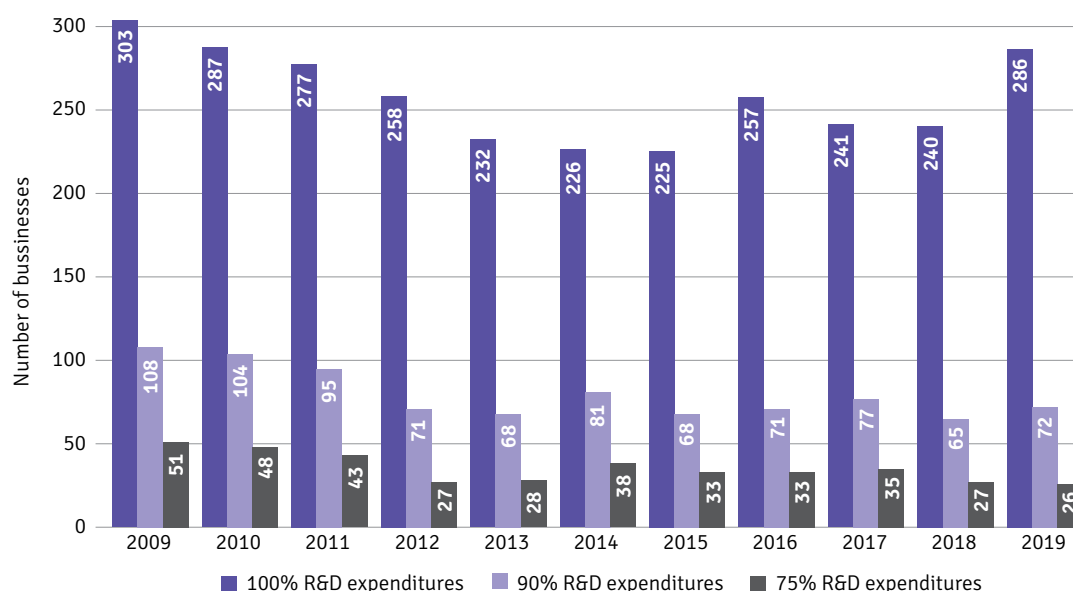


Figure 4.1. Number of businesses reporting R&D expenditures and the concentration of R&D expenditures in Estonia 2009–2019

Source: Statistics Estonia.¹⁸³

180 Männasoo, K., Tasane, H., Viires, I. (2018). Export and Innovation in Companies: A Comparative Study of Transitional Countries. – Riigikogu toimetised, No. 37, pp. 125–134. <https://rito.riigikogu.ee/wordpress/wp-content/uploads/2018/06/M%C3%A4%C3%A4nasoo-Tasane-Viires.pdf> (30.09.2021).

181 Eurostat, calculations by Estonian Research Council. <https://ec.europa.eu/eurostat/data/database> (20.09.2021).

182 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (29.09.2021).

183 Statistics Estonia. www.stat.ee (data order by Estonian Research Council).

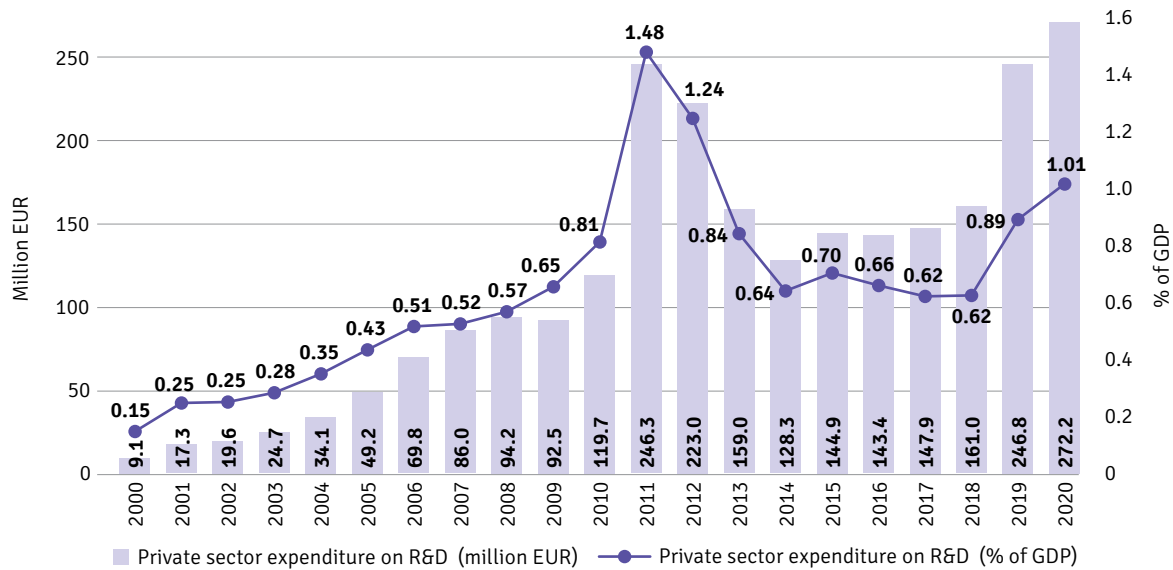


Figure 4.2. Estonian private sector expenditure on R&D (million EUR and % of GDP) 2000–2020

Source: Statistics Estonia,¹⁸⁴ calculations by Estonian Research Council.

In 2017, Urmas Varblane and Kadri Ukrainski wrote: “In the comparison of the state income level and R&D investments, Estonia belongs to the group of countries with which we generally do not like to compare ourselves. More importantly, the development trends of the last two years have been rather worrying – although GDP per capita has grown (as in most countries), the share of R&D investment in GDP has fallen, and we are still in the same group as countries that we do not want to compare ourselves to (e.g. Greece and Hungary), and relatively far behind our great role models (e.g. Germany, Finland, Sweden).”¹⁸⁵

In 2019, Erkki Karo expressed concern that in 2013–2017, Estonia’s economic development remained at 75% of the European average GDP. He illustrated the situation as the average income trap and said: “General investment in infrastructure and human capital is no longer sufficient to catch up with and pass others. The smarter and more productive use of existing natural, human and financial resources is

becoming increasingly more important. On the other hand, the European Union is providing us with fewer and fewer tools to make the necessary structural changes.”¹⁸⁶

Looking at the same time series and circumstances two years later, I am pleased to say that the situation no longer looks as pessimistic. GDP per capita compared to the European Union (EU 27) average has increased steadily between 2017 and 2020 (see Table 4.1 above). The difference with Finland is still 1.34 times, but it was 1.79 in 2010.

Investments in research and development (as a share of GDP), which went through a decline in 2013–2017, have moved at a growth rate in 2018–2020 (Figure 1.1). However, we are almost twice as far behind the leading countries, such as Sweden, Austria and Germany. It must be borne in mind that we are trying to catch a running rabbit – the others are continuously moving forward (Figure 4.3).

¹⁸⁴ Statistics Estonia. www.stat.ee (02.12.2021).

¹⁸⁵ Varblane, U., Ukrainski, K. (2016). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33–43, Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0002>

¹⁸⁶ Karo, E. (2019). The future and societal importance of Estonian research and development. – Estonian Research 2019 (ed. K. Raudvere), pp. 47–60, Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0003>

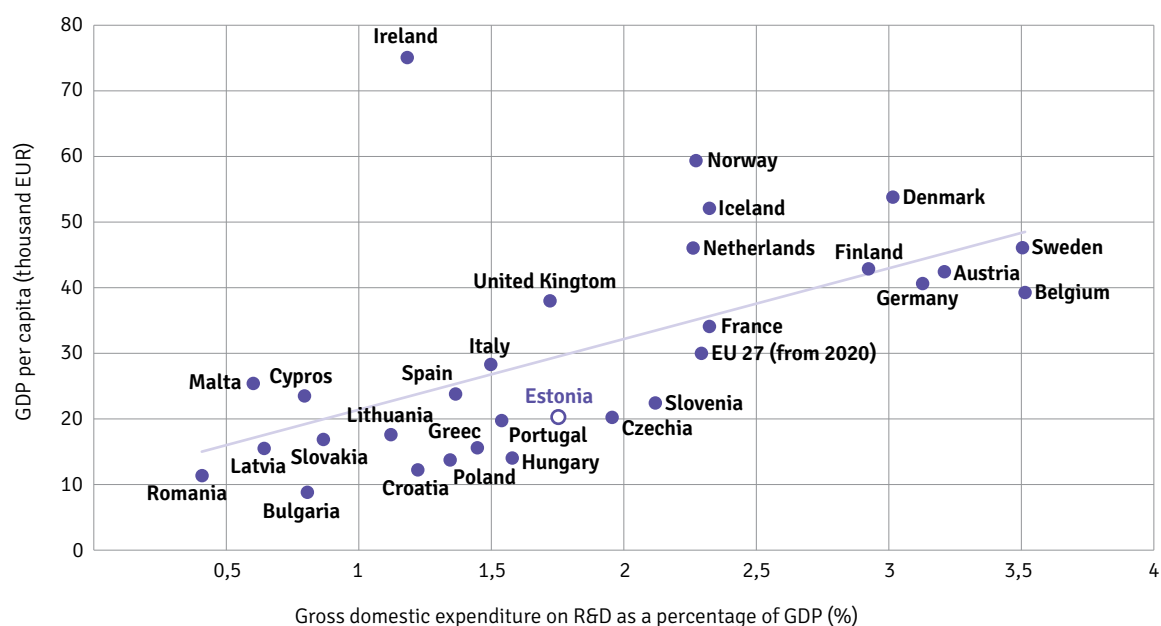


Figure 4.3. Expenditure on R&D as a percentage of GDP (%) and GDP per capita (thousand EUR) in 2020

Source: Eurostat,¹⁸⁷ calculations by Estonian Research Council.

However, positive developments were also seen in the European Commission's Innovation Scoreboard,¹⁸⁸ published in the summer of 2021, according to which Estonia is one of the top ten innovators in Europe this year¹⁸⁹. Compared to the previous year, Estonia's results improved by more than 20%, and in the last seven years we have made the biggest development leap among EU countries. Systematic connections, innovation of small companies and intellectual property have been highlighted as Estonia's strengths.

In the category of intellectual property, Estonia's strength is its high activity in applying for international trademarks, which among EU countries is second-best after Malta (Figure 4.4). In the area of international (PCT) patent applications (as a share of GDP adjusted for purchasing power standard), Estonia is below the EU 27 average by about a third.

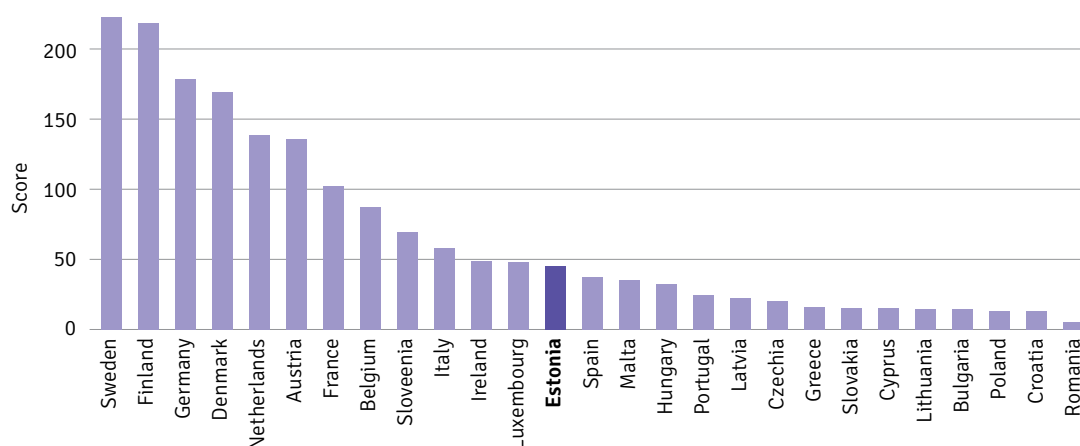


Figure 4.4a PCT patent applications

¹⁸⁷ Eurostat. <https://ec.europa.eu/eurostat/data/database> (03.12.2021).

¹⁸⁸ European Commission. European Innovation Scoreboard 2021. https://ec.europa.eu/growth/industry/policy/innovation/scoreboards_en (30.09.2021).

¹⁸⁹ Estonia made the biggest leap forward in innovation in the EU. Ministry of Economic Affairs and Communications. <https://www.mkm.ee/et/uudised/eesti-tegi-innovatsiooni-alal-suurima-arenguhuppe> (19.10.2021).

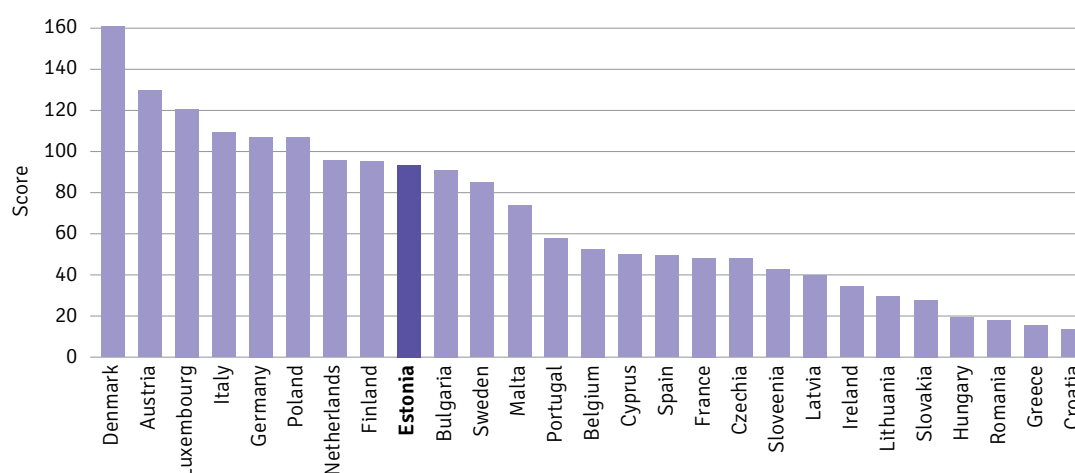


Figure 4.4b. Design applications

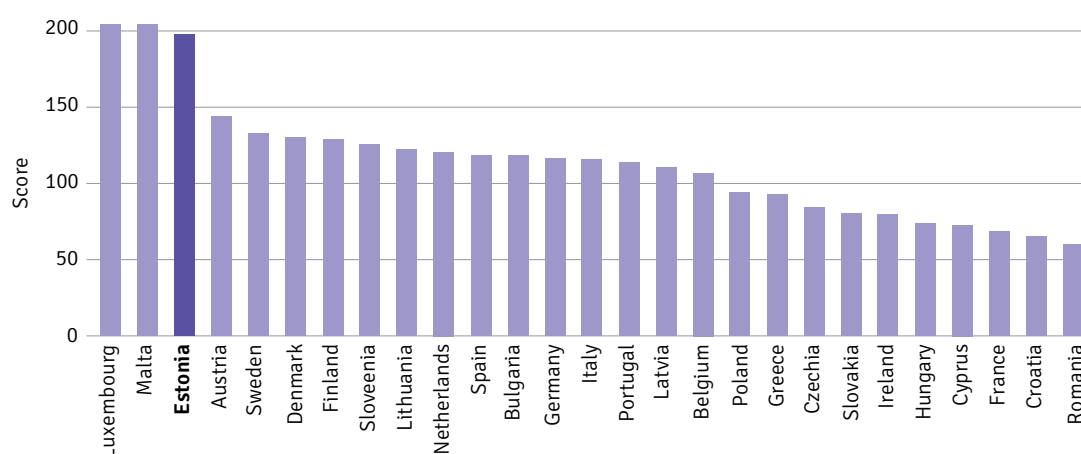


Figure 4.4c. Trademark applications

Figure 4.4. Dynamics of international (PCT) patent applications: (a), design applications (b), and trademark applications (c) in Europe (scores: ratio of number of applications to GDP)

Source: European Commission.¹⁹⁰

The innovation index also highlights Estonia's problems – the low level of state support for promoting the research and development activities of companies, as well as the low resource productivity related to the use of oil shale and low value of wood and food raw materials.

There is also additional hope for escaping the average income trap: a few years ago we assumed that the EU structural funds would decrease, meaning the need to take the missing part from Estonian tax revenue, which would probably lead to a decrease in funding in many areas, but instead Estonia can expect a rapid growth of incoming sub-

sidies from the EU. For the period of 2021–2035, 4.83 billion euros are planned for Estonia, and the Ministry of Finance forecasts an increase in the volume of investments from EU funds from about 1.4 billion euros per year to 2.6 billion euros in 2023.¹⁹¹

Strangely enough, we must be grateful for the two crises – the coronavirus crisis and the climate crisis – for which the European Commission has been quick to set up a number of new funds and funding measures. Undoubtedly, however, it will remain a major challenge to make wise decisions and ensure good administrative capacity to invest the money.

¹⁹⁰ European Commission. European Innovation Scoreboard 2021. https://ec.europa.eu/growth/industry/policy/innovation/scoreboards_en (18.11.2021).

¹⁹¹ Government of the Republic. Press conference on external funding. <https://pilv.rtk.ee/index.php/s/DAwZbBjKxRtDsXb> (30.09.2021).

THE STRUCTURE OF R&D AND LINKS TO BUSINESS ARE STILL WEAK

The general definition of R&D includes basic research aimed at generating new knowledge without a specific applied purpose, applied research with a practical purpose, as well as experimental and development work aimed at developing new products or processes. Karo (2019)¹⁹² points out that in Estonia, the share of applied research in the structure of R&D is too small, while applied research is the most important factor in the development of companies' innovation capacity and even more so for the development of collaboration between companies and universities.

It must be acknowledged that, although experimental work and development is also very important, cooperation between companies and research institutions in this area remains quite standard and within the strict roles of the customer and the service provider, such as conformity assessment services. However, in the case of applied research carried out in collaboration between companies

and universities, an unfamiliar territory is entered into, in an attempt to arrive at research results that can lead to entirely new commercial outputs. This type of cooperation leads to significantly stronger and longer-term links between companies and universities.

However, applied research is not only needed for business purposes but also for the public sector, in order to ensure better policy making and increase the effectiveness of policy implementation. For some time, Estonia has been implementing the principle that the sectoral ministry is also a strategic guide and financier of research and development in its area of responsibility.

Since 2015, the share of applied research in the investment structure of Estonian R&D has slightly increased – from 27% to 30% – and emerged from a previous decline, the lowest point of which was 21% in 2016 (Figures 4.5 and 4.6).

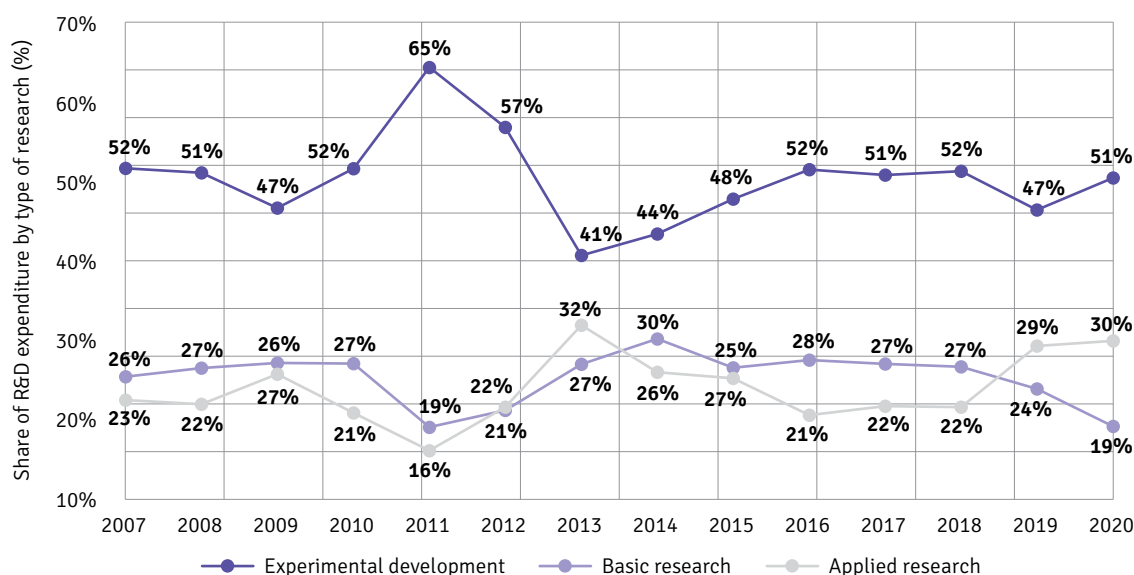


Figure 4.5. Distribution of R&D expenditure in Estonia by type of R&D in 2007–2020: a) basic research, b) applied research, and c) experimental development activities

Source: Statistics Estonia,¹⁹³ calculations by Estonian Research Council.

192 Karo, E. (2019). The future and societal importance of Estonian research and development. – Estonian Research 2019 (ed. K. Raudvere), pp. 47–60, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>

193 Statistics Estonia. www.stat.ee (02.12.2021).

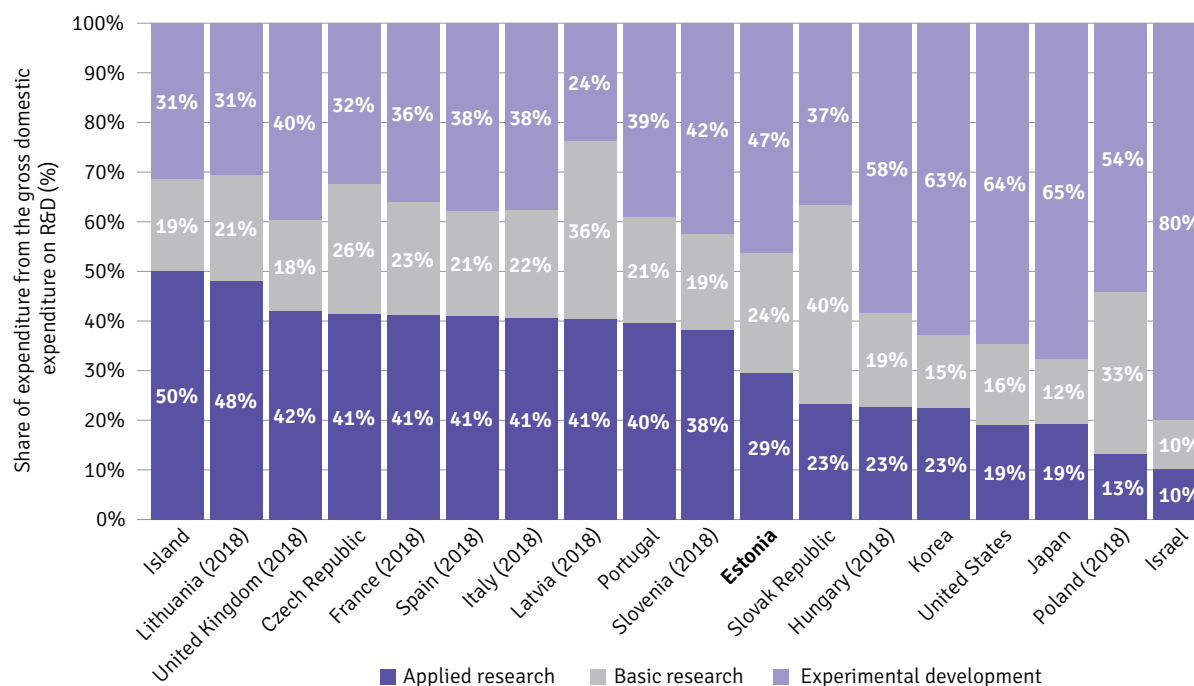


Figure 4.6. Distribution of R&D expenditure by type of R&D in 2019 (or latest available): a) basic research, b) applied research and c) experimental development activities

Sources: OECD,¹⁹⁴ calculations by Estonian Research Council.

The spectrum of public sector institutions commissioning research has become more balanced compared to 2017 (Figure 4.7). Several ministries (such as the Ministry of Social Affairs, Defence, Rural Affairs and the Environment) have increased their research budgets. However, due to a significant decrease in the research budget of the Ministry of Economic Affairs and Communications, the total volume of research budgets of the ministries was smaller in 2020 than it was in 2017 – 37 and 47 million euros, respectively.

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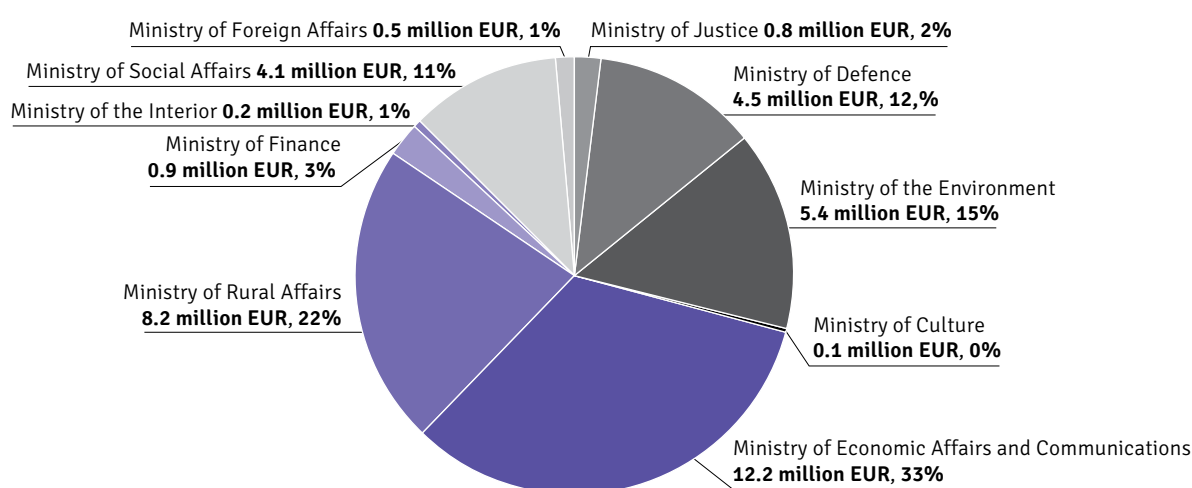


Figure 4.7. Distribution of ministries' research budgets (without the Ministry of Education and Research) in 2020 (million euros)

Source: Estonian Ministry of Education and Research.

From 2018, an increase in the amount of a few millions can be seen in the absolute amount of money received from entrepreneurship in universities and other non-profit sectors (Figure 4.8), which coincides neatly with the launch of the NUTIKAS programme supporting applied research in smart specialisation growth areas. Approximately one million euros in 2017, two million in 2018, four million in 2019, and six million in 2020 have reached companies – and through them also research institutions – under this measure (Figure 4.9). At the end of the NUTIKAS funding, the Applied Research Programme of Estonian Business and

Innovation Agency will take its place, within the framework of which a total of 23 million euros will reach companies in 2020–2023. It is clear, however, that further efforts are needed to increase the share of applied research. By comparison: in 2019, total R&D expenditure was 452 million euros, of which around 130 million euros was applied research. So far, it is difficult to consider the amounts already invested and to be invested within the frameworks of both NUTIKAS and the Estonian Business and Innovation Agency to be sufficient to bring about the necessary change in the structure of research.

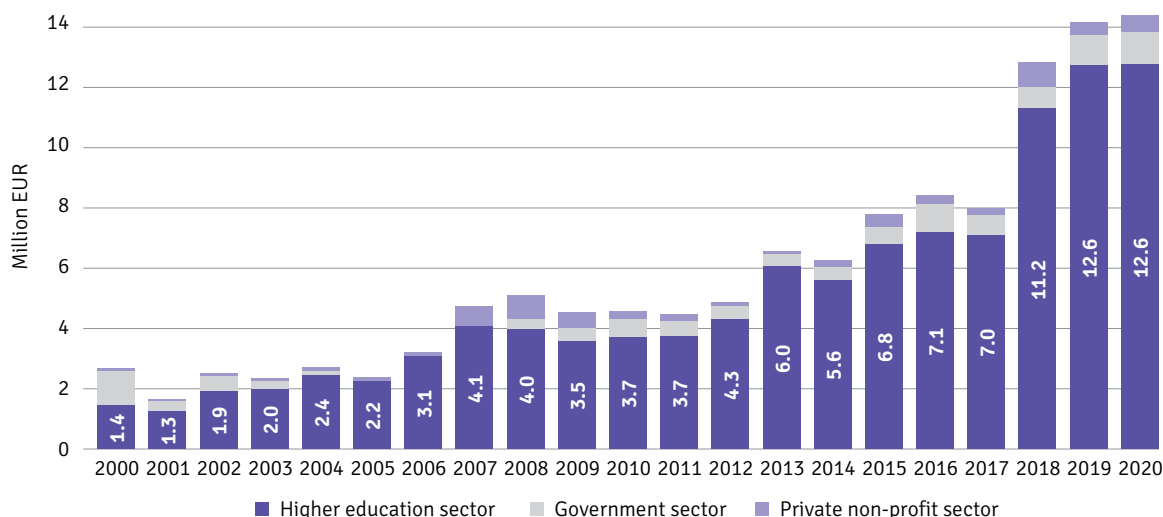


Figure 4.8. R&D expenditure in non-profit sectors financed by the business sector in 2000–2020 (million EUR)

Source: Statistics Estonia.¹⁹⁵

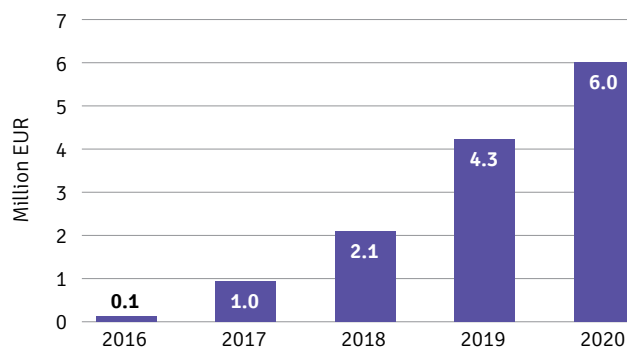


Figure 4.9. Total funding from NUTIKAS programme supporting applied research in smart specialisation growth areas 2016–2020 (million EUR)

Source: The State Shared Service Centre.¹⁹⁶

¹⁹⁵ Statistics Estonia. www.stat.ee (28.06.2021).

¹⁹⁶ The State Shared Service Centre. www.rtk.ee (data extracted 05.06.2021).

Looking at the development of cooperation between companies and universities in terms of the share of the business sector financing of research and development in the higher education sector, the share is around 7–8% (Figures 4.10 and 4.11), which in comparison with other countries is quite good. However, given the high concentration of R&D

in enterprises (see below) and the small share of applied research, this figure is probably still due to a relatively small number of larger companies outsourcing substantive development projects along with a large number of small orders for small businesses, such as training, consulting or conformity assessment services.

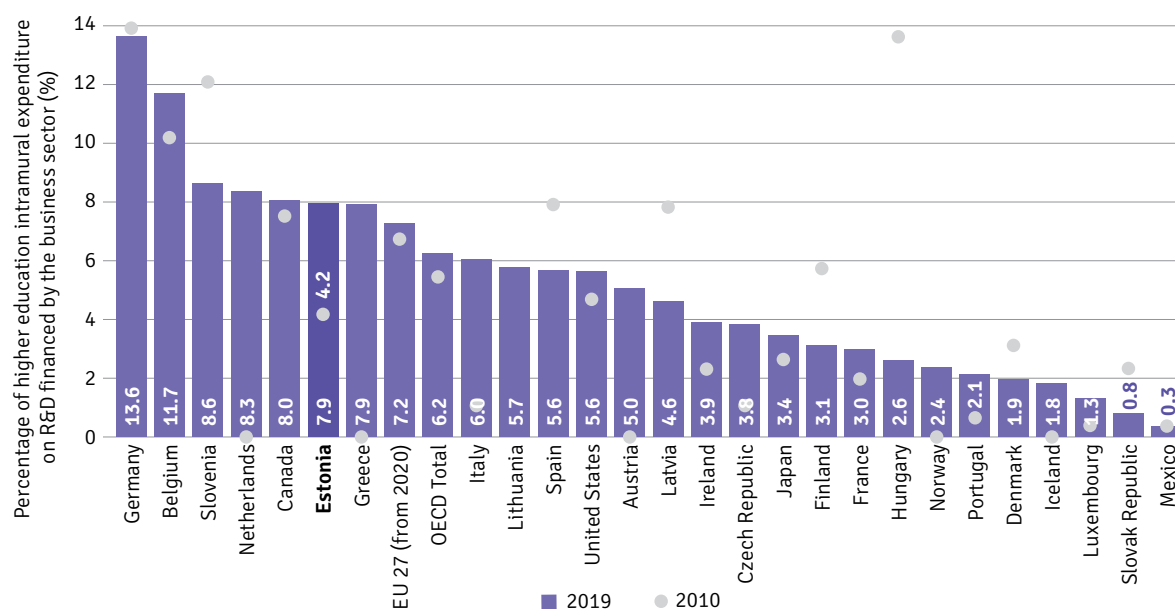


Figure 4.10. Percentage of higher education intramural expenditure on R&D financed by the business sector in 2019 (or last available year) compared to 2010

Source: OECD.¹⁹⁷

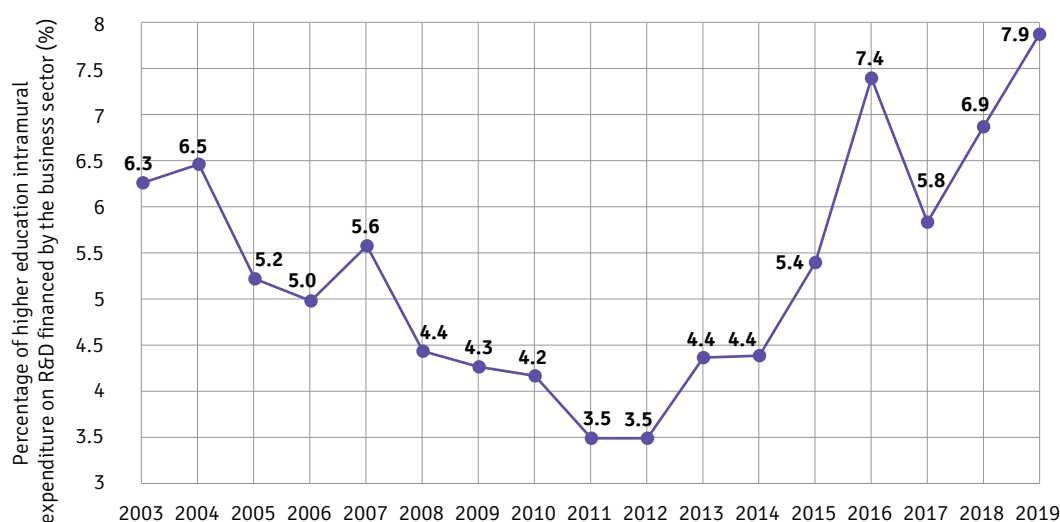


Figure 4.11. Percentage of higher education intramural expenditure on R&D financed by the Estonian business sector in 2003–2019

Source: OECD.¹⁹⁸

197 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (03.12.2021).

198 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (03.12.2021).

In order for Estonian companies to be able to place significant emphasis on research and development in their business strategies, the **existence of the corresponding human capital** as well as the transfer of researchers from universities to companies is needed. In 2017, Urmas Varblane and Kadri Ukrainski¹⁹⁹ wrote that the small ratio of R&D personnel and the very modest number of doctoral employees in the Estonian economy are clear evidence that the economy and society as a whole are unable to employ highly educated specialists. This, in turn, is reflected in the poor productivity performance of our companies, or their moderate ability to create new value. They pointed out that the ratio of R&D personnel in the economy is even more strongly correlated with productivity than the level of R&D investment.

In 2019, Erkki Karo²⁰⁰ wrote that the small number of R&D personnel in business indicates a structural crisis. After all, it is people – not money – that are the real bridge between

science and business, which turns new knowledge into business.

A look at the developments that have taken place in the meantime (Figures 4.12, 4.13, 4.14 and 4.15) is moderately encouraging. In 2011–2015, there was a downward trend in the number of researchers per thousand employees in the manufacturing industry, which turned upwards in 2016. In 2019, there were 3.9 researchers per thousand employees in the Estonian manufacturing industry (2.5 in 2015). However, the difference with regard to Sweden, for example, is four times, with Finland and Denmark three times, and with Germany two times. If we look at the total number of researchers per thousand employees in these countries, the differences are smaller (Figure 4.14), and if we compare ourselves with the model countries, Estonia has relatively more researchers in the public sector and less in the private sector.

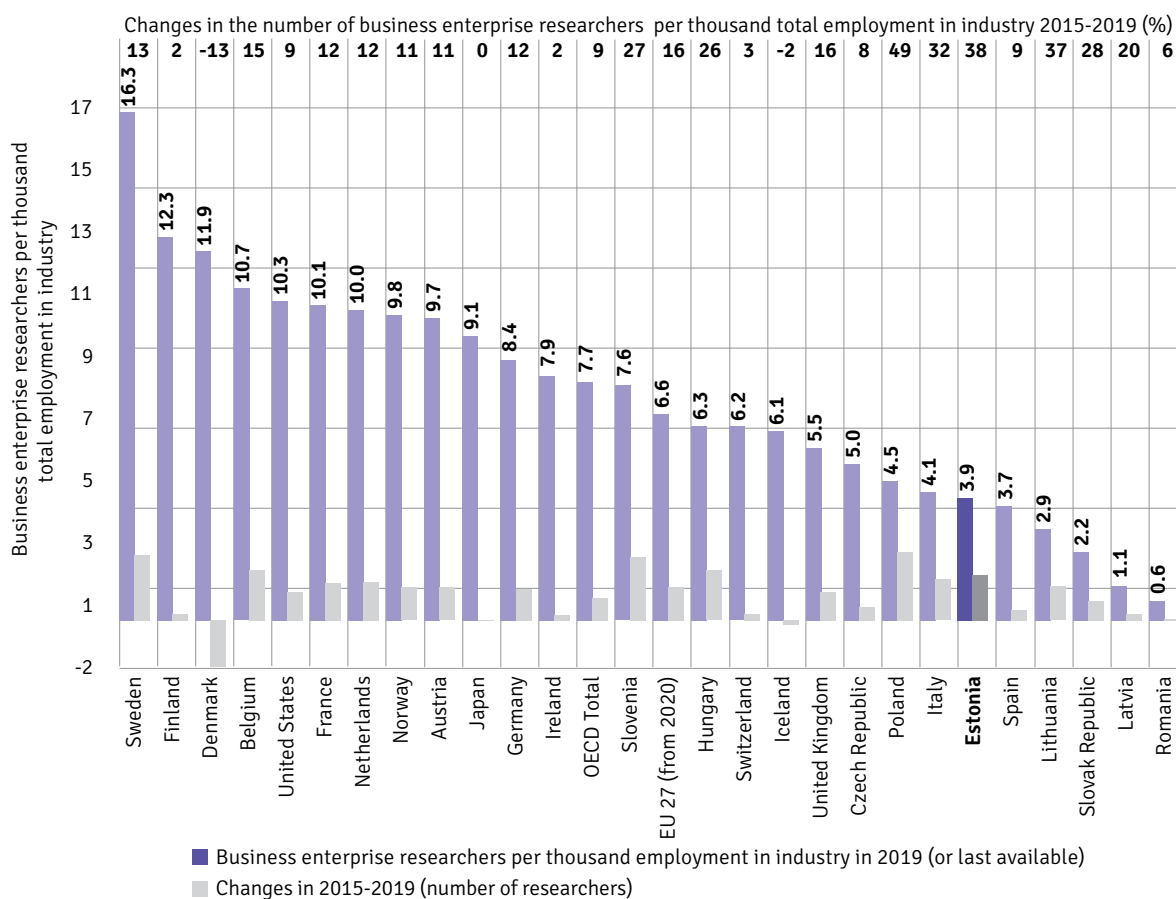


Figure 4.12. Number of researchers per thousand employment in industry in 2019 and changes therein in 2015–2019

Source: OECD,²⁰¹ calculations by the Estonian Research Council.

199 Varblane, U., Ukrainski, K. (2016). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33–43, Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0002>

200 Karo, E. (2019). The future and societal importance of Estonian research and development. – Estonian Research 2019 (ed. K. Raudvere), pp. 47–60, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>

201 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (09.06.2021).

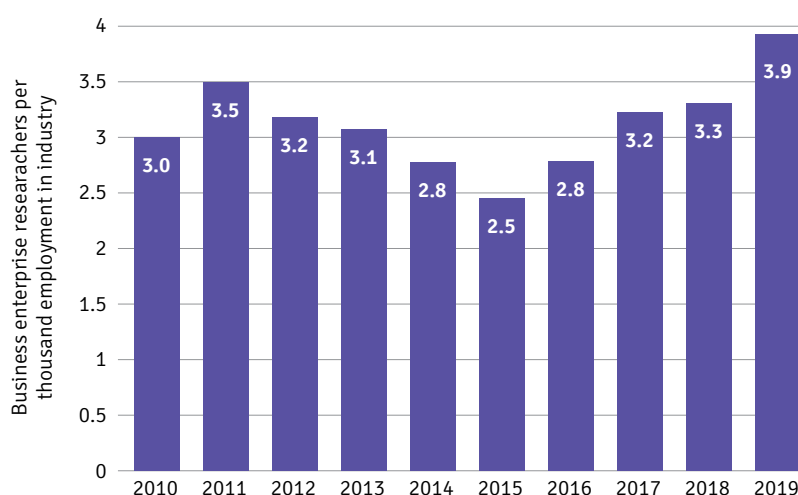


Figure 4.13. Number of researchers in Estonia per thousand employment in industry in 2010–2019

Source: OECD,²⁰² calculations by Estonian Research Council.

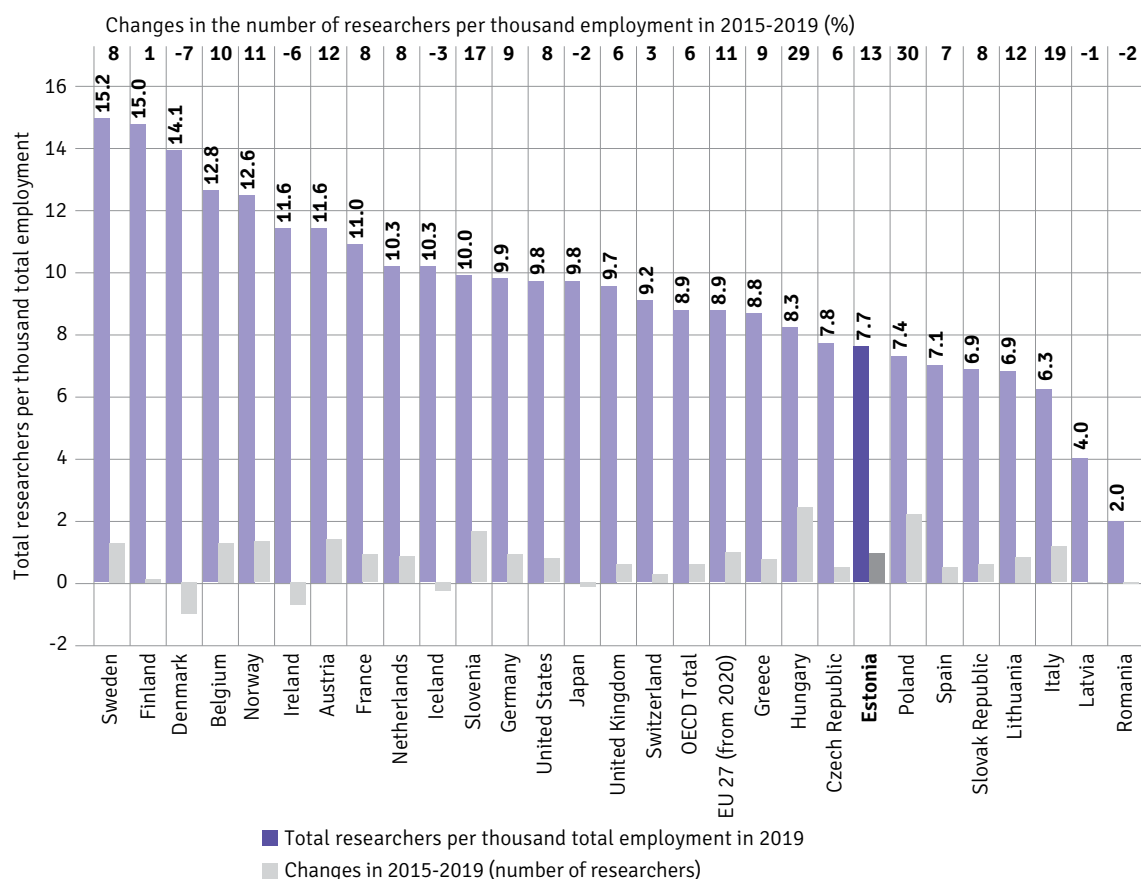


Figure 4.14. Number of researchers per thousand employment in 2019 and changes therein in 2015–2019

Source: OECD,²⁰³ calculations by Estonian Research Council.

202 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (09.06.2021).

203 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (09.06.2021).

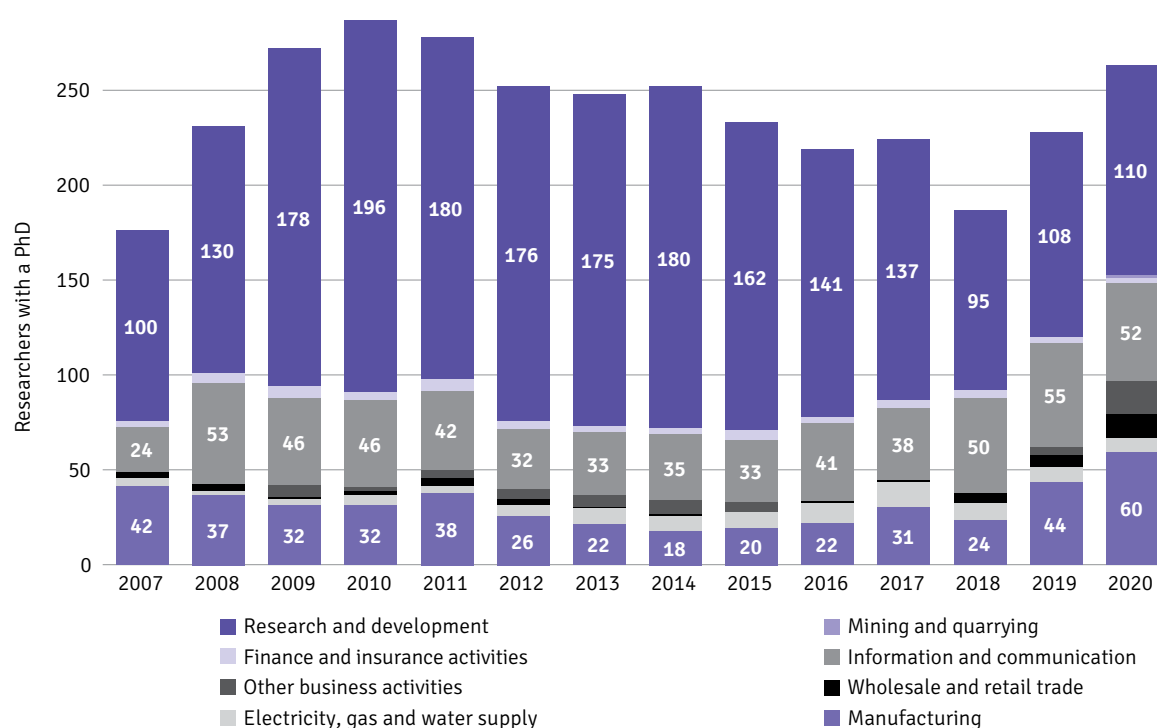


Figure 4.15. Researchers with a PhD in the various parts of the Estonian business sector in 2007–2020

Source: Statistics Estonia.²⁰⁴

In conclusion to the above-mentioned observations, the strengthening of the links between research and business unfortunately takes time. There are many reasons for this. Although perhaps to a lesser extent, the statement of Varblane and Ukrainski (2017)²⁰⁵ still applies today: “So far, neither the Estonian research funding system nor the careers of researchers have been strongly oriented towards cooper-

ation with business, and changes in this direction are essential to increase the knowledge intensity of the economy.” On the other hand, push factors alone are not sufficient to increase the knowledge intensity of the economy, as cited above, for business sector partners with R&D capacity are needed as well. In the following, we will take a closer look at them.

A VERY SMALL NUMBER OF COMPANIES IN ESTONIA INVEST IN RESEARCH AND DEVELOPMENT

Taking a closer look at research and development investments in the Estonian private sector, it is gratifying that, in 2019, private sector R&D investments increased after a long period of time, and the growth continued in 2020 as well (Figure 4.2), reaching 1.01% of GDP. In absolute terms, the investments amounted to 272 million euros, which exceeds the result of the record year 2011 (246 million euros), when Eesti Energia made large investments in the Enefit Technology. As we have already seen, the number of companies investing in research and development has been on an upward trend since 2015, although 286 companies with

R&D expenditure are, of course, only a tiny drop in the ocean of the Estonian economy, with about 50,000 economically active companies.

In addition to very few companies investing in R&D, these investments are also highly concentrated and the concentration has increased over the last ten years. 75% of the total investment in 2019 was made by only 9.1% of all enterprises with R&D expenditure (14.2% of enterprises in 2008) and 90% of the total investment by only 25.2% of enterprises (32.2% of enterprises in 2008) (Figure 4.16).

²⁰⁴ Statistics Estonia. www.stat.ee (02.12.2021).

²⁰⁵ Varblane, U., Ukrainski, K. (2016). Research, development and productivity compared internationally. – Estonian Research 2016 (ed. K. Raudvere), pp. 33–43, Estonian Research Council, Tartu. <http://dx.doi.org/10.15158/DISS/0002>

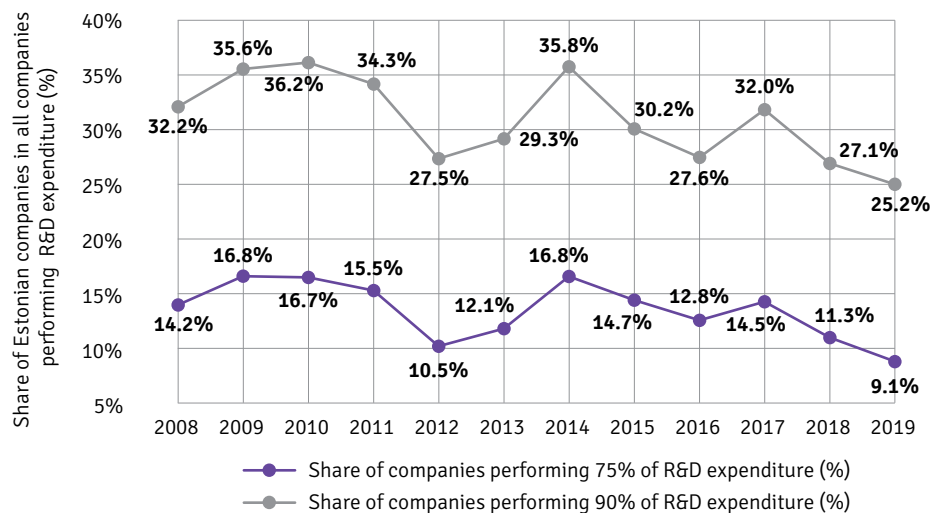


Figure 4.16. Share of Estonian companies in all companies performing R&D expenditure, which accounted for 75% and 90% of all business R&D expenditure in 2008–2019

Source: Statistics Estonia.²⁰⁶

As expected, larger companies are also the largest R&D investors: In 2019, 65% of investments were made by companies with more than 100 employees (57 companies),

including 45% of expenditures by companies with more than 250 employees (28 companies) (Figure 4.17).

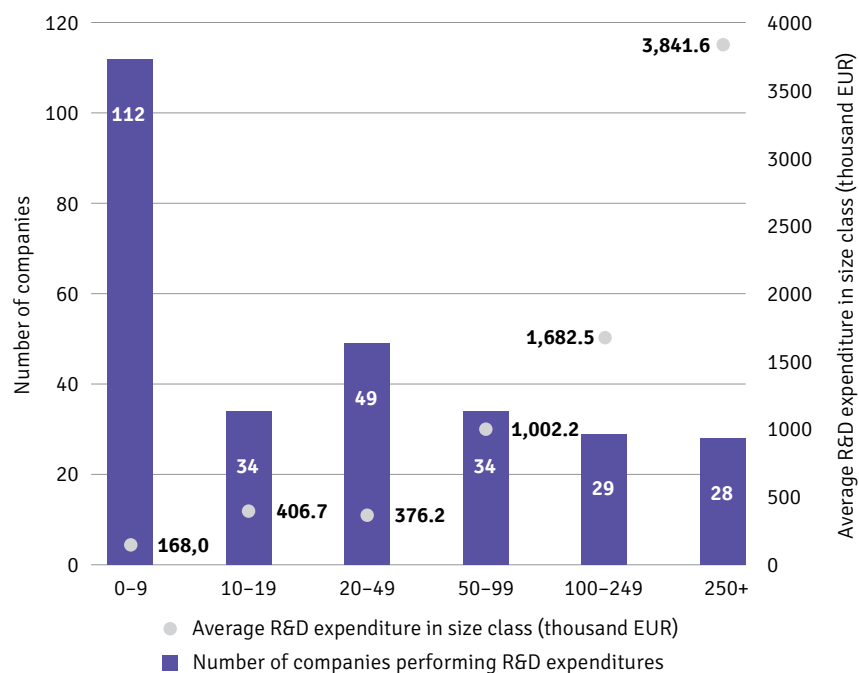


Figure 4.17. Estonian companies performing R&D expenditures by size classes in 2019

Source: Statistics Estonia.²⁰⁷

R&D is a highly concentrated field in other parts of the world as well. The European Commission estimates that 2,500 companies account for around 90% of global R&D investment. But the situation is even more biased. Half of the R&D investments of these 2,500 top-ranked compa-

nies are made by only 100 of the largest companies. Thus, around 120 companies make almost half of the world's R&D investment. About a quarter of them are in Europe, a tenth in China, a third in the United States and the remainder in the rest of the world.²⁰⁸

²⁰⁶ Statistics Estonia. Data order by Estonian Research Council (July 2021).

²⁰⁷ Statistics Estonia. Data order by Estonian Research Council (July 2021).

²⁰⁸ European Commission. (2019). The 2019 EU Industrial R&D Investment Scoreboard. <https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard> (23.09.2021).

Let us also look at how the activity of various economic sectors in research and development has changed over the last decade. Ten years ago (2009), 50% of private sector research and development took place in the field of information and communication, the financial sector and trade, and the sectors investing in research and development were quite different from Estonia's main export sectors (Figure 4.18).

Looking at the period of 2009–2020, it is gratifying to note that, although the information and communication sector has further increased its lead as the reigning champion, the manufacturing industry, and in particular the energy sector, has increased its investment in R&D faster than other sectors, and the share of these sectors in the general distribution has increased. The very small share of R&D in construction (0.1% both in 2009 and 2020) is a cause for concern. Like industry and energy, the construction sector has to cope with major changes in the regulatory environment and consumer demand as a result of the green transition.

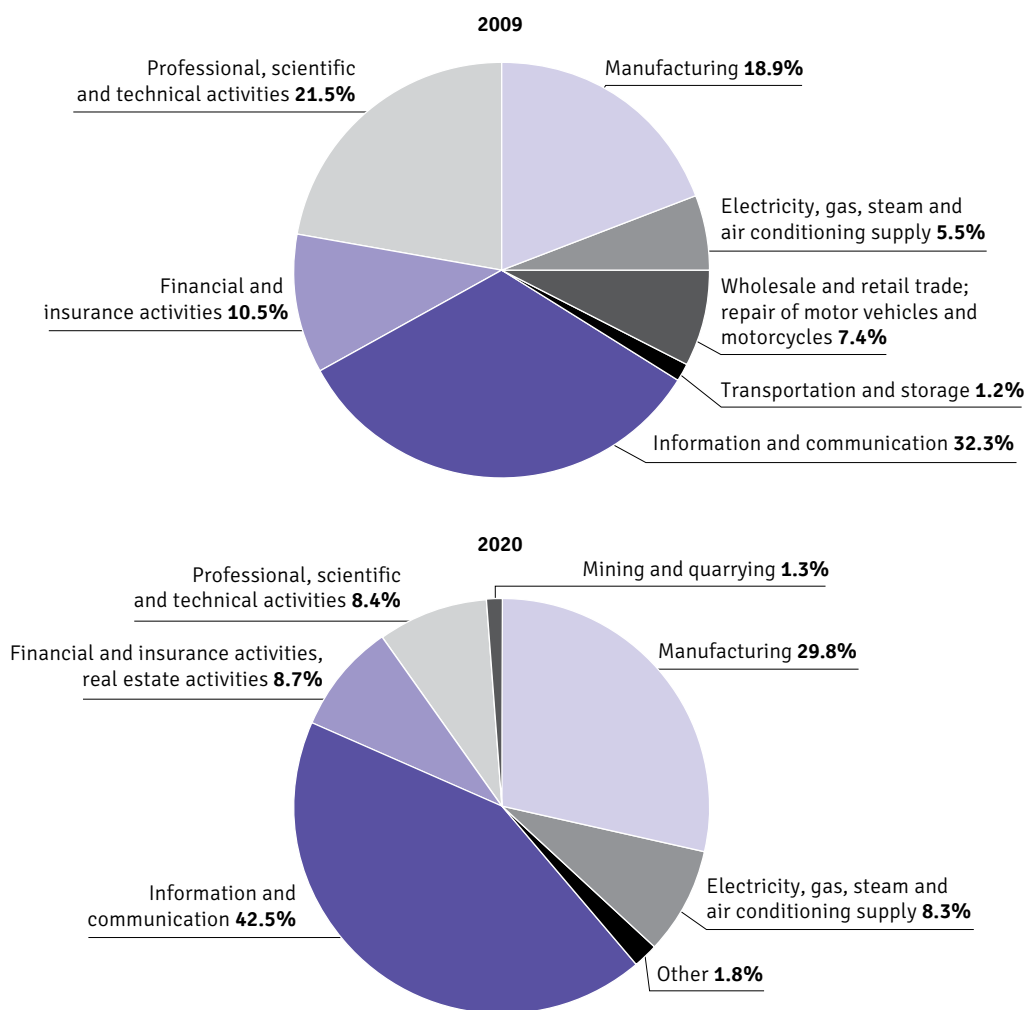


Figure 4.18. Percentages of R&D expenditure of Estonian companies by economic activity (intramural and extramural R&D expenditure summarised) in 2009 and 2020. In the figure for 2020, the category “Other” includes wholesale and retail trade, repair of motor vehicles and motorcycles, transport and storage, construction, health and agriculture, forestry and fishing (the share for each of them less than 1%)

Source: Statistics Estonia.²⁰⁹

At this point, of course, the reader may already ask – why is it necessary to pay so much attention to such a small number of companies in terms of the size of the Estonian economy? In the following, we will reach a much larger number of companies – namely, those who can be considered as innovative companies and can therefore be considered as

the natural breeding ground for R&D-intensive companies. First of all, however, it is important to emphasise that the small number of companies investing in R&D in Estonia is a big problem, the reasons for which need to be carefully explained in order to be able to offer a good solution.

WHAT IS THE BREEDING GROUND FOR R&D-INTENSIVE COMPANIES IN ESTONIA?

At the beginning of this year, Eurostat came out with the news that Estonia holds the European Union record for the share of innovative companies: namely, 73% of all companies in Estonia with more than ten employees being innova-

tive (Figure 4.19). Estonia has also shown quite good results in previous years: the corresponding share has remained close to 50%.

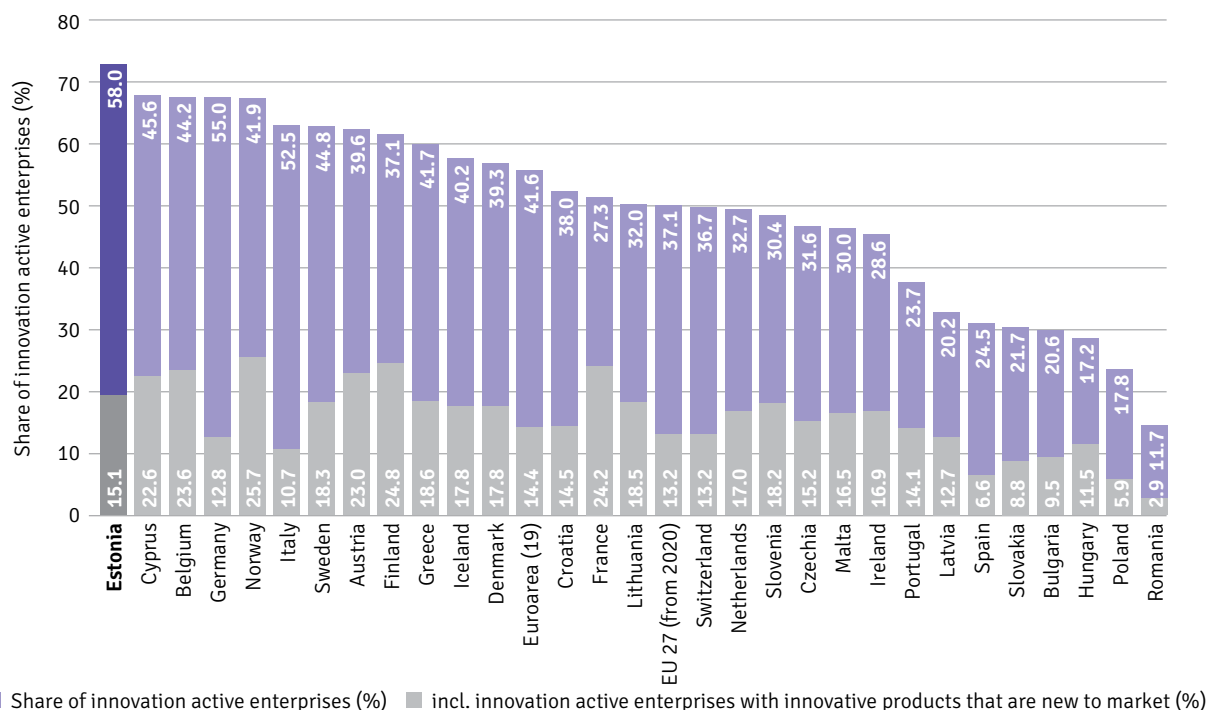


Figure 4.19. Share of innovation active companies in Europe (2018)

Source: Eurostat.²¹⁰

The following types of enterprise activity are considered to be innovation in this Community Innovation Survey (CIS): 1) process innovations, including innovations in the main process, logistics, information technology, administrative and business processes, work organisation and marketing; 2) product innovations, including new and improved products and new and improved services. Expenditure on innovation includes investment in research and development, machinery and equipment, design, marketing, staff training, software and databases, and the protection of intellectual property.

How do we explain the paradox that although there are so many innovative companies in Estonia, we have so few companies investing in research and development?

One of the reasons may lie in the specifics of our tax system and how it affects the statistics. The investment activity of Estonian companies has remained high due to the Estonian income tax system, which does not tax reinvested earnings. As a company investing in fixed assets is considered to be innovative, the Estonian income tax benefit has helped us to stand out positively in the innovation survey.

On the other hand, Estonia is one of the very few OECD countries that does not have tax exemptions that favour R&D. Karo (2019) notes that since statistics on R&D expend-

iture are collected as companies' own estimates, companies often do not understand the importance of collecting R&D statistics, consider reporting too complicated and provide the requested information quite randomly.²¹¹ It is logical to conclude from this that a tax incentive would motivate the companies to report the R&D investments more carefully, thus hopefully encouraging even those who have so far been rather lenient about this obligation.

However, an even more important reason than tax incentives or their absence is the profile of innovative activities of Estonian companies, which is inclined towards process innovations. More than a decade ago, it was already striking to see that the structure of innovation expenditure was dominated by investments in machinery and equipment, while other investments – such as on consulting and training or design and marketing – accounted for a very small share (Figure 4.20).

Although the methodology of the survey has changed and this has led to a change in the names of the cost categories, it is safe to say that the cost structure has remained broadly the same. The introduction of new machinery and equipment was the main innovative activity in Estonian companies in 2018 as well.

²¹⁰ Eurostat. <https://ec.europa.eu/eurostat/data/database> (23.09.2021).

²¹¹ Karo, E. (2019). The future and societal importance of Estonian research and development. – Estonian Science 2019 (ed. K. Raudvere), pp. 47–60, Estonian Research Council, Tartu. <https://dx.doi.org/10.15158/DISS/0003>.

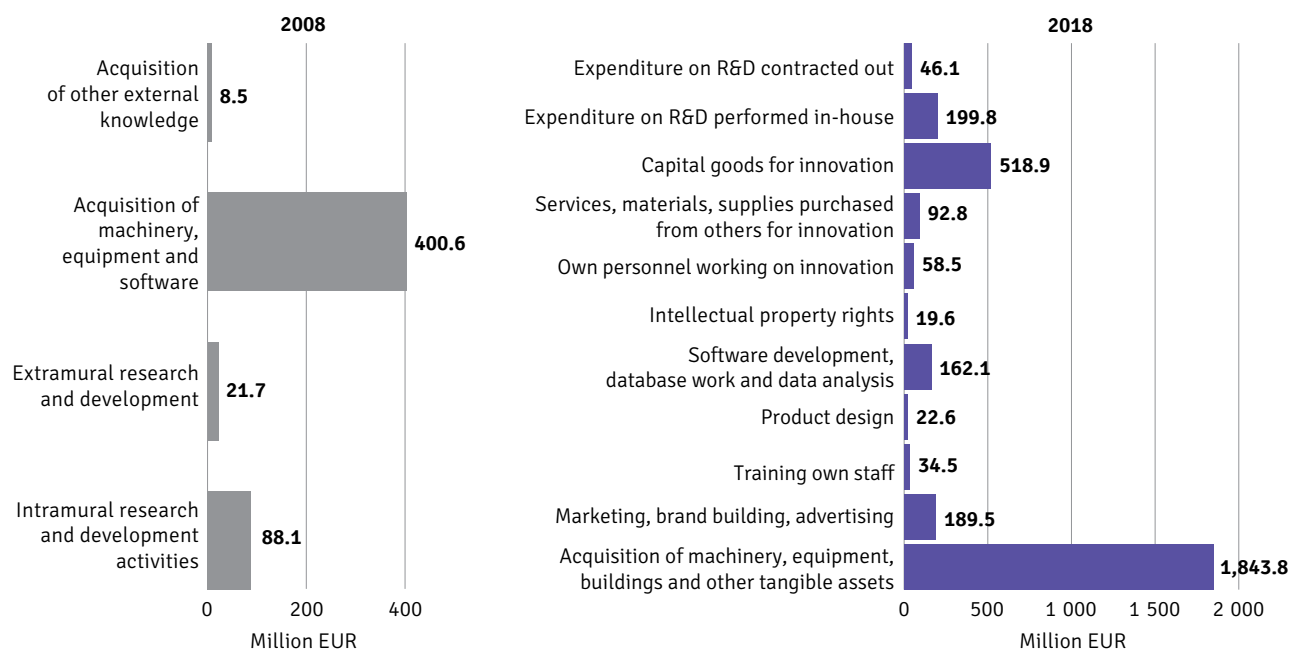


Figure 4.20. Innovation expenditure of technologically innovative enterprises in 2008 and 2018 (million EUR)

Source: Statistics Estonia.²¹²

The lack of ambitious innovation plans is also reflected in the fact that although the share of revenue from competing products (new-to-company but not new to the market) in total sales has increased over the last ten years, the share of revenue from non-competitive products (new-to-market)

has declined (Figures 4.21 and 4.22). At the same time, it is the latter category that measures what we consider to be innovation in the conventional sense – providing the market with something that does not yet exist there.

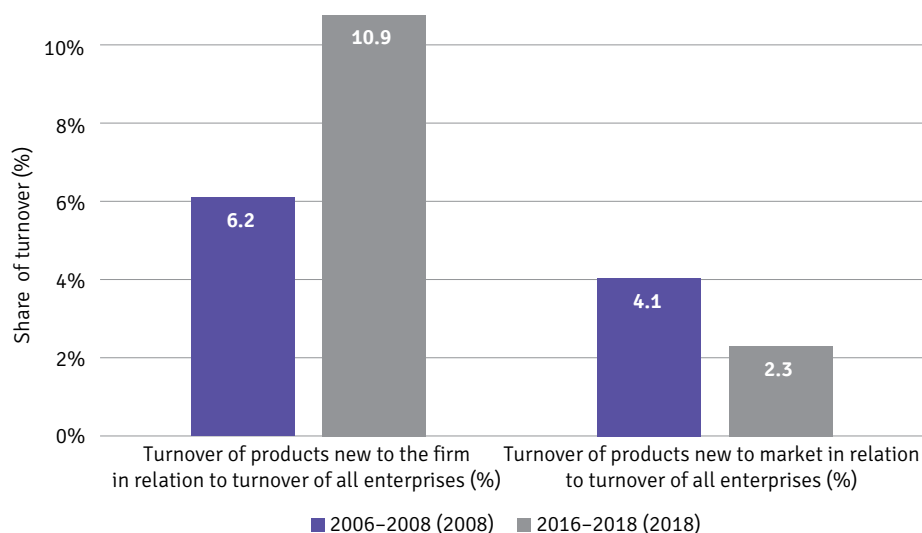


Figure 4.21. Turnover of new-to-market and new-to-company products as percentage of total turnover for Estonian enterprises in 2008 and 2018

Source: Statistics Estonia.²¹³

²¹² Statistics Estonia. www.stat.ee (23.09.2021).

²¹³ Statistics Estonia. www.stat.ee (10.06.2021).

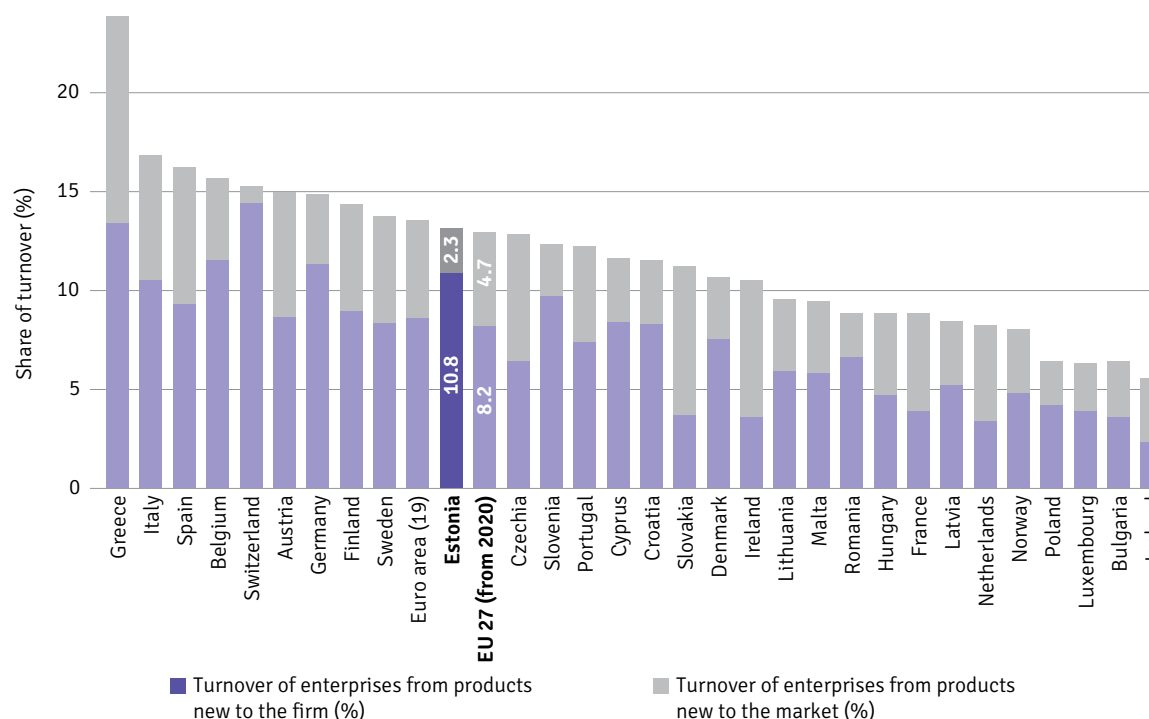


Figure 4.22. Turnover of new-to-market and new-to-company products as percentage of enterprise turnover in 2018 (%)

Source: Eurostat.²¹⁴

The 2015 study “Innovativeness of Estonian companies and opportunities to support it”²¹⁵ commissioned by the Ministry of Economic Affairs and Communications attributed the current situation to the most common business model in Estonian industry – custom manufacture or outsourcing in the vernacular. (In the service sector, this is typical of the functional units of groups, such as accounting units, asset management units, etc.). A company operating as a custom manufacturer usually achieves good results in innovation metrics, but this is mostly due to process innovation and related cooperation with customers or other parties in the group. Such a company has no contact with the final product, and the development of the company mainly consists of the diversification of production opportunities, increase in quality and volumes. At the same time, indicators such as product innovation and new product turnover are rather modest, as issues of product development, supply chain management, marketing and sales are addressed elsewhere.

The study referred to above lists the obstacles that hinder Estonian entrepreneurs. A short selection of them will now be given.

- **Identification and validation of market signals.** Entrepreneurs often see only a limited number of market opportunities, usually only in neighbouring markets or within their own group. They do not know how to test market signals or do not have the necessary tools (networks, funding, technology).

- **Design and development competence.** Companies lack the knowledge and skills to develop new products and services, nor do they have potential partners willing to share them.
- **Marketing and distribution.** There is a lack of knowledge and experience and an inability to find partners to help with marketing and building the supply chain.
- **Failure to scale your business.**²¹⁶ It is also related to a lack of skills and experience, but the reason may often lie in the fact that the core business is not profitable enough to invest in growth or innovation projects.
- **Feedback from users.** Entrepreneurs and innovators do not receive enough feedback from users to make decisions about (further) product development. One reason for this may be selling through intermediaries, which does not allow direct contact with the final consumer.

It must be acknowledged that foreign capital, which has great merits in importing know-how and technology into the Estonian economy, does have its cost – insufficient product innovation. From the point of view of innovation policy, it is important to understand that in order for a company with a production order business model to start developing and selling its products, only making R&D support available is usually not sufficient, as the company does not have the preconditions for launching product development, its implementation and finally selling it on foreign markets. Assistance is also needed to first create these preconditions.²¹⁷

²¹⁴ Eurostat. <https://ec.europa.eu/eurostat/data/database> (10.06.2021).

²¹⁵ Kaarna, K., Ojamäe, K., Lember, K., prof Welch, E., Fisher, B. (2015). Innovativeness of Estonian companies and opportunities to support it. Tallinn: Ministry of Economic Affairs and Communications of the Republic of Estonia. https://www.mkm.ee/sites/default/files/inno_24.pdf (23.09.2021).

²¹⁶ In a broader sense, scaling is understood as the accelerating growth of a company over time. In a narrower sense, this means the company's ability to increase sales and production volumes so that production and sales costs grow at a significantly slower pace. As a result, economies of scale are created and the company's profitability increases.

²¹⁷ Danilov, T. (2016). Insights: the state and background of innovation and exports. – Riigikogu toimetised, No. 33, pp. 22–28. <https://rito.riigikogu.ee/wordpress/wp-content/uploads/2016/06/Danilov.pdf> (30.09.2021).

When looking at the breeding ground of R&D-intensive companies, one cannot overlook the **sector of start-ups**, which has gained considerable strength in Estonia in recent years. Many start-up companies have started working with universities to solve ambitious problems, some examples being Bolt, Milrem, Click & Grow, Roofit Solar, along with many others.

As of the end of 2019, a total of 5,944 people worked in Estonian start-ups and 77 million euros in labour taxes were paid during the year. In the period of 2011–2019, the sector has grown by an average of 30% per year. In the first half of 2020, the average salary in Estonian start-ups was 2,508

euros – 1.8 times higher than the Estonian average.²¹⁸ The sector has favourable prospects for further growth, as, due to negative interest rates, investors are looking for more productive investment opportunities and are willing to take more risks, and the Estonian start-up ecosystem is also attractive to investors.

Estonian start-ups are attracting investments at an ever-increasing pace. 2020 was a record year, yet has already been greatly exceeded this year (Figure 4.23). However, the vast majority of the investments involved have been received across borders, not from the Estonian capital market.

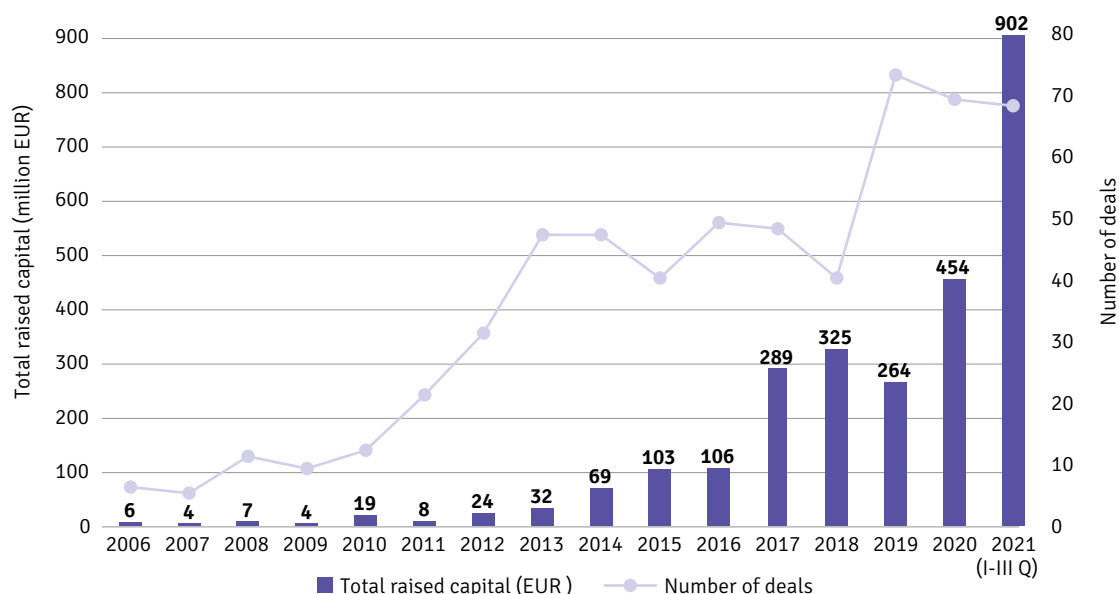


Figure 4.23. Venture capital investments by Estonian enterprises in 2006–2021 (Q1–Q3)

Source: EstVCA.²¹⁹

Maria Demertzis and Nicola Viegi from the thinktank Bruegel attribute the slow development of European productivity to a lack of local venture capital,²²⁰ arguing that bank-based financing of businesses is too conservative for innovative businesses and thus many good ideas remain unfunded. To get a loan from a bank, you need physical capital as a guarantee, which a start-up company does not have.

Being able to fund development can be equally difficult for a company based on intangible assets – such as intellectual property, trademarks, distinctive designs, innovative business models – that does not have the necessary equipment to produce or provide services itself, but rents them where necessary. However, intangible assets are not as liquid as physical assets, and thus not suitable as a loan guarantee.

At the same time, the lack of focus on the accumulation of intangible assets is one of the weak points in the innovation pattern of Estonian companies.²²¹

A diversified capital market that allows money to be raised in exchange for involvement helps to overcome these bottlenecks. Fortunately, the supply of venture capital in the Estonian market has improved considerably over the last ten years – there are more and more venture capital investments by local funds and investors (Figure 4.24). However, these investments are still relatively small, reaching a record 40 million euros in 2019 and 25 million euros in 2020. For comparison: According to Eesti Pank, in 2020, commercial banks issued loans to non-financial corporations worth more than 2 billion euros.²²²

²¹⁸ Start-up sector. The Foresight Centre. https://arenguseire.ee/wp-content/uploads/2021/03/2020_covid-19_iduettevotlus_faktileht.pdf (19.10.2021).

²¹⁹ Estonian Private Equity & Venture Capital Association (EstVCA), www.estvca.ee (data extracted 04.10.2021).

²²⁰ Demertzis, M., Viegi, N. (2021). Low interest rates in Europe and the US: one trend, two stories. – Policy Contribution Issue n 07/2021, Bruegel. <https://www.bruegel.org/2021/03/low-interest-rates-in-europe-and-the-us-one-trend-two-stories/> (01.10.2021).

²²¹ Männasoo, K., Rungi, M., Hein, H., Hazak, A., Tasane, H. (2018). Do companies' investments reach productivity? Survey commissioned by the Foresight Centre of the Riigikogu. Tallinn University of Technology, Tallinn. https://www.riigikogu.ee/wpcms/wp-content/uploads/2017/09/Uuringuaruanne_Tootlikkus_ja_investeeringud_30052018.pdf (01.10.2021).

²²² Statistics. Eesti Pank. <https://statistika.eestipank.ee/#/et/p/650/r/1059/908> (22.10.2021).

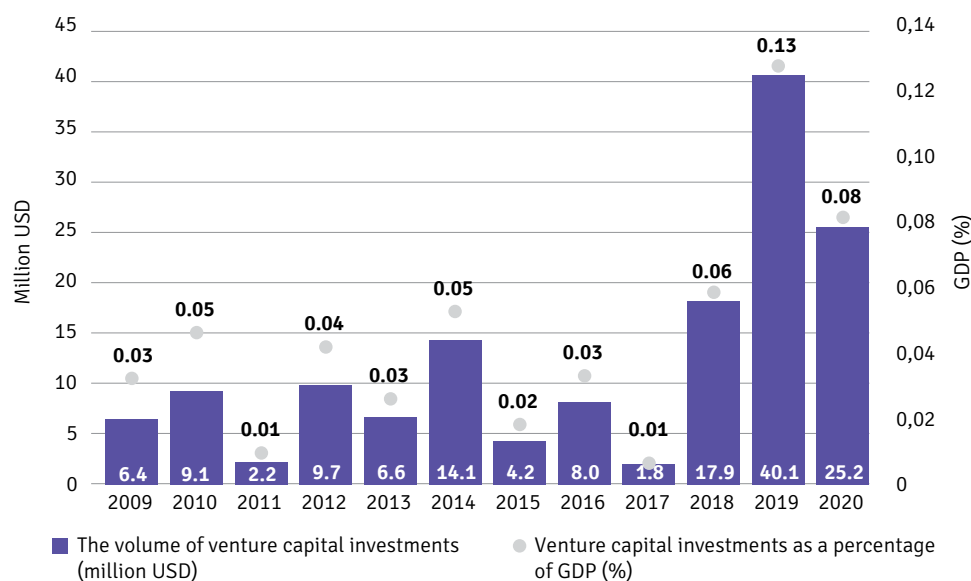


Figure 4.24. The volume of venture capital investments in Estonia (million USD) and its percentage of GDP (%) in 2009 to 2020

Source: OECD.²²³

INNOVATION SUPPORT POLICY IN ESTONIA: DO LESS, BUT DO BETTER?

Estonia is one of the few OECD countries that does not have tax exemptions conducive to research and development. We have chosen to promote business R&D and innovation through subsidy programmes, which allows the possibility for better targeting of the support. On the other hand, tax incentives have a greater impact on the wider spread of R&D among companies than subsidies. Therefore, developed countries use both measures.

OECD countries support R&D in the business sector at an average rate of 0.2% of GDP (as of 2018, see Figure 1.3 in the first chapter of this collection), which is more or less evenly distributed between subsidies and tax incentives. In Estonia, state support for corporate R&D amounted to only

0.03% of GDP (9 million euros) in 2018, more than five times below the OECD average. The OECD average would be 50 million euros per year.²²⁴

As innovation is a risky and time-consuming process, it is important to support private sector R&D consistently and over a longer period of time. Tax incentives are generally more stable and provide companies with more certainty than subsidy programmes. In Estonia, the support for companies' R&D has been rather inconsistent, with the share of support being in the range of 4–11% of companies' R&D investments. The annual amount of subsidies has ranged from 6–7 million euros (in 2008, 2016, 2017) to 20 million euros in 2012 (Figure 4.25).

²²³ OECD. Industry and Services, Enterprise Statistics (11.06.2021).

²²⁴ The Foresight Centre. Use of research and development incentives in the tax system. Short Report, September 2021. https://www.riigikogu.ee/wpcms/wp-content/uploads/2021/09/Lyhiraport_TA_A4_CMYK.pdf (30.09.2021).

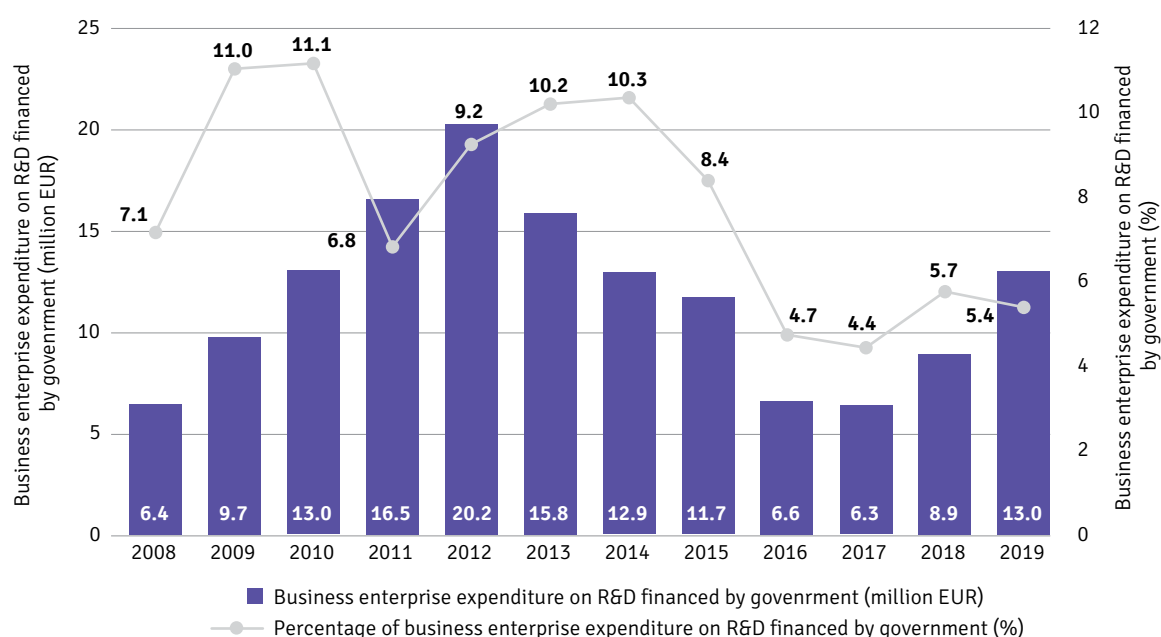


Figure 4.25. Business enterprise expenditure on R&D financed by the Estonian government (million EUR and %) in 2008–2019

Sources: OECD²²⁵ and Statistics Estonia,²²⁶ calculations by Estonian Research Council and the Foresight Centre.

Since the early 2000s, research and development and innovation subsidy programmes for companies have undergone significant development in Estonia. It started with the sharing of R&D risks of individual companies (R&D project support programme), then the focus shifted to cooperation between companies and universities (SPINNO programme, innovation share programme), followed by R&D cooperation between companies themselves (technology development centres), solving social bottlenecks (national R&D programmes), growth platform development (clusters, technology investments, support for the recruitment of development staff, Start-up Estonia) and the use of public sector orders to boost innovation (innovative public procurement programme).

Many of these programmes have now ended, although some have continued in other forms. For example, the former R&D project support programme has successors in the form of programmes for applied research and product development, although they arose significantly later after the end of the R&D project support programme.

An important step forward was the enterprise development programme launched in 2016, which addresses the company as a whole and provides combined support to promote research and development along with exports, design development, etc. In recent years, support policies have been complemented by digitalisation support and intellectual property services.

Already by 2007, an international group of experts under the auspices of the European Commission²²⁷ found that although Estonia's innovation policy is one of the most advanced among the new Member States, with a well-structured and diverse range of measures, administrative capacity needs to be strengthened to implement this complex package effectively. Fourteen years later, this conclusion is still valid today.

There are and have been many different subsidy programmes, often emerging and disappearing quickly, and without achieving the necessary consistency to have a long-term impact. Their monetary volume, taken in isolation, is generally not sufficient to bring about visible changes in economic statistics, so they should be both targeted and measured as a whole, but this is usually not the case.

According to the new Research and Development and Innovation Strategy, the scope of innovation policy in 2021–2035 will be further-reaching than ever before. In addition to developing the knowledge intensity and innovation of companies, the focus is on the digital and green transitions. Furthermore, the areas of so-called smart specialisation are still priorities: digital solutions, value enhancement of resources, health technologies and services, smart and sustainable energy solutions, Estonian language and culture. Given the current level of emphasis and focus, the issue of policy implementation capacity becomes even more pressing.

225 OECD. Main Science and Technology Indicators Database. www.oecd.org/sti/msti.htm (07.06.2021).

226 Statistics Estonia. www.stat.ee (21.09.2021).

227 European Commission. (2007). OMC Policy Mix Review Report. Country Report Estonia. https://ec.europa.eu/invest-in-research/pdf/download_en/omc_ee_review_report.pdf (01.10.2021).

The areas of smart specialisation, i.e. the focus areas selected in 2011–2012, have so far not been at the centre of innovation policy, as might have been expected in setting priorities. The areas have not had a budget to plan and implement according to the needs of the field. Priorities have mostly been applied as a filter in several support programmes. For example, companies outside these fields have not been involved in the Estonian Research Council's programme NUTIKAS for applied research or the support programmes for technology development centres and clusters of Estonian Business and Innovation Agency.

Thus, the development of priorities in the previous strategy period (2014–2020) has been a technical rather than a substantive activity – a certain amount of subsidies have been granted for projects in focus areas, while other subsidy programmes have simply been accounted for without any special effort.

It is hoped that the situation will improve in the future, as several focus area managers have recently been hired, whose task is to plan the development of the field and organise its implementation. However, they may run into

difficulties if they do not have their own budget to plan and implement according to the needs of the sector.

All in all, Estonia's innovation policy has been very innovative, quickly reacting to global developments in innovation policy. Unfortunately, with the addition of new initiatives, the previous ones have often lost focus, as the resources needed for implementation have not been sufficient for all. The development of smart specialisation areas has so far only been formal, but it can be hoped that substantive activities will be implemented during the new strategic period that recently began.

The dogma of avoiding tax incentives should be abandoned, especially given that the Estonian corporate tax system has come under pressure due to international agreements being concluded at G7 and OECD level. If it proves necessary for Estonia to restore the classic corporate income tax, i.e. the taxation of profits for the entire financial year, the tax incentive for research and development could be used to leave the profits invested in R&D tax-free. This might give a significant additional impetus to the research and development activities of Estonian companies.



GREY SEAL PUP ○ Jaan Minakov

TOPICAL ISSUES



SCIENCE BAROMETER²²⁸

Out of all Estonian residents:



THE FIRST TEN YEARS OF THE ESTONIAN RESEARCH COUNCIL

ANDRES KOPPEL

Director General of Estonian Research Council between 2012–2020

ANU NOORMA

Director General of Estonian Research Council since April 2021

KARIN JAANSON

Executive Director of Estonian Research Council since 2015

The Estonian Research Council started operations on 1 March 2012. Although ten years may seem like a short period of time, the impact of Estonian Research Council on the development of Estonian research is long term.

WHY WAS THE ESTONIAN RESEARCH COUNCIL ESTABLISHED?

The scientific progress of re-independent Estonia can be considered a sort of miracle story compared to other post-Soviet countries. An article²²⁹ published in the journal *Nature* in 2015 considers good organisation of research as one of the main factors that contributed to the success of scientific research in Estonia. Our organisation of research was established in the 1990s on the basis of a system of values created by researchers themselves, which emphasised the quality of research and the open attitude towards international co-operation. During the first years of the transitional period when the state had very limited resources, the main objective was ensuring the survival of as many strong research teams as possible. After the so-called Swedish evaluation in 1992²³⁰, the network of research institutions was organised and transformed to be predominantly university-centric. As social wealth increased, international co-operation strengthened and foreign funding methods became available, the organisation of research also needed to be changed.²³¹ Up until the beginning of the 2000s, societal development flourished, resulting in the support system of the organisation of research becoming more and more dispersed between different institutions over time.

The greater part of domestic research funding, the largest instrument of which was targeted financing for research groups, was organised by the Ministry of Education (renamed the Estonian Ministry of Education and Research or MER in 2003), following the recommendations made by the Estonian Scientific Competence Council. Competitive grants were awarded by an independent foundation, the Estonian Science Foundation.

Research institutions were dissatisfied with the fact that almost all decisions on research funding were made without any input from them, making it impossible for institutions to guide and direct the development of their scientific research. Although a baseline funding instrument was created once again as a result of heated discussions on tar-

geted financing in 2003–2004, its budget was very small. Researchers were also not satisfied with the funding system. Research funding was obviously lacking in terms of money but also in terms of organisation. The two primary funding instruments – targeted financing and baseline funding – grew closer to one another over time because the Scientific Competence Council started to increasingly take into account quality assessments when deciding on targeted financing, moreover, decision making on funding was slow as it took place at the highest, ministerial level.

As a result, discussions about changing the organisation of research were entered into. The memorandum sent to the Minister of Education and Research by Martin Zobel, Chairman of the Scientific Competence Council, and Jüri Allik, Chairman of the Supervisory Board of Estonian Science Foundation, on 6 January 2008 provided a clear basis for these discussions. They proposed transforming the existing core funding system into a common grant system and bringing the processing of grants under one organisation to reduce fragmentation. This memorandum provided major impetus in amending the Research Organisation Act, which resulted in the establishment of the Estonian Research Council among other things.

In addition to the need to reform the research funding system, another important reason for establishing the Estonian Research Council was the need to restructure how other research organisation related activities, which had become scattered between different institutions over time, were supported. Estonian researchers actively participated in the European Union framework programmes for research and development, in regard to which the Archimedes Foundation provided relevant assistance. The Estonian Science Foundation was also involved with many international forms of co-operation (also including for example the ERA-Net part of Framework Programmes and Estonia's bilateral research co-operation agreements). The Estonian Science

229 May, M., Brody, H. Nature Index 2015 Global. *Nature* 522, S1. (2015). <https://doi.org/10.1038/522S1a>

230 Evaluation 1991–1992. Estonian Research Council. <https://www.etag.ee/tegevused/evalveerimine/varasemad-evalveerimised/evalveerimine-1991/> (22.11.2021).

231 Koppel, A., Reimand, I., Jaanson, K., Raud, T. (2016). Scientific research in Estonia: a temporal perspective. – *Riigikogu toimetised*, 33, pp. 64–80. <https://rito.riigikogu.ee/wordpress/wp-content/uploads/2016/06/Koppel-Reimand-Raud-Jaanson.pdf> (09.12.2021).

Foundation represented Estonia in several international organisations (e.g. European Science Foundation, Science Europe). The Archimedes Foundation was also engaged in organising the funding of research programmes and centres of excellence funded by the Structural Funds as well as popularising and promoting science and research, and managing the Estonian Research Information System. The initiatives of the European Research Area (ERA) brought the topics of open science and ethics in science into Estonian research policy, which were completely new and not previously being addressed anywhere.

Therefore, the establishment of the Estonian Research Council as an authoritative research institution was a logical step in the development of the organisation of Estonian research.

A working group was set up at the Estonian Ministry of Education and Research for that purpose, and, as a result of lengthy discussions, a package of amendments to the Organisation of Research and Development Act was completed by the end of 2011, the main objective of which was to restructure funding instruments: to replace targeted financing with institutional research funding and Estonian Science Foundation's grants with personal research funding. Another important objective was the establishment of the Estonian Research Council, for which the legislative amendments adopted by Riigikogu on 23 February 2011 provided a legal basis.

HOW WAS THE ESTONIAN RESEARCH COUNCIL ESTABLISHED?

On 16 May 2011, the Minister of Education and Research Jaak Aaviksoo tasked the six-member working group (Deputy Secretary General A. Koppel, Chairman of the Supervisory Board of Estonian Science Foundation T. Maimets, Head of department at MER I. Reimand, Chair of Archimedes Foundation R. Toompere, Adviser at MER S. Uusna, and Financial Expert at MER H. Lepp) with making preparations for the establishment and launch of operations of Estonian Research Council on the basis of the Estonian Science Foundation and developing the necessary draft documents.

At the same time, a search committee set up by the minister (A. Koppel, President of Estonian Academy of Sciences R. Villem, and political advisor of the minister A. Kaarmann) started seeking candidates for the position of Director General of the Estonian Research Council. The objective was to follow the example of other heads of European research funding agencies and find a person who has excellent characteristics, previous senior management experience in a research institution, impeccable credentials and who is also a valued member of society. The search committee submitted a list of possible candidates to the minister where the preferred candidate was Volli Kalm, Chairman of the Scientific Competence Council and Geology Professor at the University of Tartu. The minister approved his nomination and convinced him to take this job. Volli Kalm was included in the preparatory working group and, in the beginning of September, he started forming the Estonian Research Council. The public was notified of the establishment of the Estonian Research Council from the outset. On 9 September, a press conference was held in Tartu where minister J. Aaviksoo and V. Kalm introduced the plan for establishing the Estonian Research Council.

V. Kalm was the manager of the Estonian Research Council formation project until its legal entity was established. His duties included the preparation of organisational documentation with MER and solving technical issues, from finding suitable premises to fitting-out the premises with appropriate equipment.

The research community and the public were informed of the progress of forming the Estonian Research Council on a regular basis – a number of press releases were published and monthly information days were held alternately in Tallinn and Tartu from November to February. The last information day was held on 29 February 2012, which was also the day the Estonian Science Foundation ceased its activity.

The Estonian Research Council was legally formed after the Supervisory Board of Estonian Science Foundation approved the new Statutes which amended the name and objectives of the Foundation. The staff mainly comprised people who had previously worked for the Archimedes Foundation or the Estonian Science Foundation, there were only eight brand new employees. At the first meeting, the Board elected V. Kalm as Director General of Estonian Research Council. However, at the end of May he had already been elected rector of the University of Tartu and his term of office in Estonian Research Council only lasted until the end of June. In the second half of August, Deputy Secretary General A. Koppel assumed the role of Director General after the Minister of Education and Research convinced him to apply to this position and the Board appointed him. A. Koppel headed the Estonian Research Council for over eight years. At the end of February 2021, Anu Noorma, Research Professor in Applied Remote Sensing, was elected the new Director General of Estonian Research Council and she assumed her duties on 1 April.

WHAT HAS THE ESTONIAN RESEARCH COUNCIL ACCOMPLISHED?

The Estonian Research Council has fulfilled the expectations set out at the time of its establishment. This was confirmed by the assessment of the implementation of the 2014–2020 development plan by the Board at the end of 2020. More importantly, researchers and other partners have praised the work of Estonian Research Council in numerous feedback surveys.

The starting years were not easy, as a great deal of frustration was aimed at the newly established Estonian Research Council due to shortcomings in the organisation of research or lack of research funding.

Over time, the Estonian Research Council has proven itself to be a professional and dynamic institution, the employees of which are devoted to promoting research and thus also

improving the well-being of Estonian society. The first half of 2020 was a type of matriculation exam for the Estonian Research Council. When the Covid-19 pandemic started, the Estonian Research Council acted promptly to ensure that researchers could contribute to curbing the epidemic and mitigating its impacts.

The Research Council has carried out its operations in a systematic manner, at first following the development plan prepared for the years 2016–2020²³² and from 2021 the development plan for 2021–2027²³³. It is impossible to briefly summarise our activities over the past ten years, which is why only the most important ones are being highlighted.

Restructuring of research funding

Research funding in Estonia has experienced a major transformation. On the initiative of the Estonian Research Council, a logical and functioning research funding system was developed and the principles for comprehensive and coherent research funding were established. The research funding system has become more stable over time. New types of grants and programmatic measures (thematic programmes and grants, proof-of-concept grants, target grants) have been implemented. In the allocation of research grants, greater attention is paid to the social impacts of the projects and their significance for Estonian culture, society and/or economy.

- In 2014, we analysed the research funding system and made proposals for its restructuring, which served as a basis for the fundamental recommendations given to the working group formed by the Minister of Education and Research.
- In 2016, the new framework for research grants and baseline funding in the Estonian research and development (R&D) funding system²³⁴ was completed in co-operation with our partners.
- The framework was used to update the research funding system in the following years in a planned way.
- In 2017, we successfully conducted a call for applications for new personal research grants: post-doctoral grants, starting grants, and team grants.

- In 2018, the last phase of the grant application and reporting simplification process was implemented, as a result of which the application and reporting burden of researchers was significantly reduced, leaving them more time to focus on achieving project targets. Moreover, the criteria of potential societal impact and feasibility of project results and significance for Estonian culture, society and/or the economy was integrated into the assessment process of applications and reports.
- In 2019, the first call for experimental development proof-of-concept grants was opened.
- In 2020, a target grant was developed in just a few months and implemented straight away to match the services of researchers and the needs of the state in conducting Covid-19 related research.
- We launched the research and development adviser system in ministries and professional associations.
- We implemented the Structural Funds programmes TerVe, KESTA, TeRaS, TeaMe, Mobilitas. We continued and launched new programmes RITA, TeaMe+, MobilitasPluss, ResTA.
- In 2021, we analysed the implementation of the framework for research funding (2016) to make recommendations for the future development of the coherent system of funding instruments.

Enhancing international scientific cooperation

Estonian researchers have successfully participated in the EU Framework Programme Horizon 2020. As of 2021, nearly a quarter of a billion euros²³⁵ were provided to Estonia, which is 2.5 times more than the funding received under the previous framework programme. We have provided advice to researchers regarding participation in the framework programme as well as other forms of international co-operation, supported them financially, organised training, and created new opportunities for international cooperation.

- The Estonian Liaison Office for EU RTD was established in Brussels to support researchers and research institutions.

- Co-operation with the Nordic funding organisation NordForsk has increased – the Estonian Research Council is involved in the preparation for calls and the provision of funding for successful research projects.
- We launched the initiative Research in Estonia, the main aim of which is to introduce Estonian research on an international level and for an international audience.
- We have introduced the image of Estonia as a research country in the world through Science Europe, an association representing major public organisations that fund research in Europe, and through direct contacts.

232 Estonian Research Council Development Plan 2020. Estonian Research Council. <https://www.etag.ee/teadusagenduur/dokumendid/arengukava-2016-2020> (22.11.2021).

233 Estonian Research Council Development Plan 2027. Estonian Research Council. https://www.etag.ee/wp-content/uploads/2021/01/ETAG-arengukava-2027_est.pdf (22.11.2021).

234 A New Framework of Research Grants and Baseline Funding in the Estonian Research and Development Funding System. Estonian Research Council. https://www.etag.ee/wp-content/uploads/2016/10/Uurimistoetuste_ja_tegevustoetuse_uus_s%C3%BCsteem_ETAg_2016.pdf (22.11.2021).

235 Estonian participation in the Framework Programme for Research and Innovation in the European Union Horizon 2020. Estonian Research Council. https://www.etag.ee/wp-content/uploads/2021/06/ETAG_Horisont-2020.pdf (22.11.2021).

Partnerships in Estonian R&D and innovation policy formulation

We have initiated discussions and provided advice which was heard and implemented.

- In 2014, in co-operation with partners, we organised the annual series of research policy conferences entitled 'Research as the powerhouse of Estonia'.
- In 2016, in collaboration with researchers, we launched the discussion forum TeadusEST which focuses on current topics.
- We discuss issues related to the research system with the heads of research institutions on a regular basis.
- We initiated discussions on the topic of ethics in research which resulted in the completion of the Estonian Code of Conduct for Research Integrity in 2017. We compiled an overview of the principles of European research ethics and their implementation guidelines.

- The Open Science Expert Group of Estonian Research Council established the principles and issued recommendations on forming the national open science policy.
- We compile and analyse research system data on a continuous basis and publish topic sheets and studies on statistics. Every three years we compile an overview of Estonian research (previously published 'Estonian Research 2016' and 'Estonian Research 2019').
- In 2019, we coordinated the preparation of the plan for increasing the public funding of R&D to 1% of the GDP pursuant to the Estonian Research Agreement. It can be argued that without the preparatory work and analyses of Estonian Research Council the Estonian Research Agreement would most likely not have been prepared.

Valuing research and knowledge in society

The popularisation of research has resulted in systematic research communication activities and a network of organisers.

- We organised a number of successful research-oriented television shows, such as *Rakett 69*, *Uudishimu tippkeskus*, *TeadusEst*.
- In 2016, we established a research communication task force to increase co-operation between various people working in this field and enhance their competence.
- We launched the National Contest of Young Inventors.

- We started the tradition of the students' science festival to create research interest in students and promote a research-based mindset.
- In co-operation with our partners, we developed the Estonian Science Communication Strategy 2020–2035 'Estonia knows'.²³⁶
- We also started introducing the results of Estonian Research Council funded research projects to the wider public. Since 2018, an online publication *Teadusriikas Eesti. Grandiprojektide tulemuste kogumik* (literally 'Research-rich Estonia: an overview of grant project results') has been published annually.

ETAg 10+. The future role and tasks of the Estonian Research Council

The Estonian Research Council Development Plan 2027, which was approved by the Board in 2020 and prepared collaboratively by the employees, partners and the Board of Estonian Research Council, offers a good indication of our future. The new vision of the development plan provides that the Estonian Research Council is the best support, partner and competence center. The development plan is based on the national long-term development strategy 'Estonia 2035' and the Estonian Research and Development, Innovation and Entrepreneurship Development Plan 2021–2035, while also keeping in mind other political trends, the priorities of ERA, and the Sustainable Development Goals of the UN. The role of research and knowledge in these areas cannot be underestimated.

Fulfilling the objectives of the Estonian Research and Development, Innovation and Entrepreneurship Development Plan²³⁷ in its three fields (research system, knowledge transfer, and business environment) will contribute to meeting the development needs of Estonia, increase the societal influence of research and researchers, and result in a more knowledge-intensive business sector. The Estonian Research Council has contributed to this development plan

by setting the following strategic objectives.

1. Estonian research funding system is comprehensive and coherent, and supports the growth of Estonian social welfare.
2. Estonia is active in international scientific cooperation and has a prominent place in the Baltic and Nordic research area.
3. In Estonia, science is visible and valued.
4. Estonian policy is based on science and evidence.
5. The Estonian Research Council is an efficient organization with a smart and dedicated team.

The first ten years of the Estonian Research Council confirm that we have managed to achieve our objectives effectively and beyond the necessary level. Estonia as a small country with limited human resources should use the existing competences to the largest extent possible. Thanks to the extensive knowledge and skills of its staff, the Estonian Research Council is a capable competence center which can be relied on now and in the future to transform our lives for the better.

236 Science Communication Strategy 2020–2035. Estonian Research Council. https://www.etag.ee/wp-content/uploads/2019/12/ETAG_Eesti-teab_strateegia-web_dets19.pdf (22.11.2021).

237 Estonian Research and Development, Innovation and Entrepreneurship Development Plan 2021–2035. Estonian Ministry of Education and Research. <https://www.hm.ee/et/TAIE-2035> (22.11.2021).

AN ENTREPRENEUR'S VIEW ON SCIENCE

AAVO SÕRMUS

Chairman of the Council of Center of Food and Fermentation Technologies and Chairman of the Board of Bioexpert OÜ

If you were to ask someone whether science is necessary, the answer would most likely be yes. However, if you were to dig deeper and ask why and for whom science is necessary, you would receive some fairly hesitant answers, and if you were to mention funding, the answers would be even more vague.

Why is science essential? Who needs it? What kind of a role does the state play in structuring cooperation between research and business sectors?

Entrepreneurs are mainly interested in science, the results of which can be implemented within a specific measurable timeframe and can be used for business development. Applied research relies on the results generated through basic science which, in turn, involves a great deal of uncertainty. At the same time, without basic science, it is difficult to reach a stage that would interest entrepreneurs. Therefore, years of hard work are often required to get the real economy interested in scientific developments. All this forms a whole, but unfortunately funding channels are often unstable and inconsistent. This is exactly where close cooperation between the state and entrepreneurs is essential to ensure that everything from basic and applied science to experimental development is organised in a coordinated way. Thematic focuses which support the sustainable development of society should be set out in more detail. Conflicts of interests will definitely arise, but this is no cause for concern.

The current circumstances mainly encourage thinking small and tackling minor problems. Often, only a sprinkling of funds is distributed, the entire process of which involves a significant loss of time and resources with regard to administration, assessment, and other such activities. It makes sense for high-risk activities to receive state support, even if it is clear that many of these activities will never be realised as intended. Nevertheless, they will result in new knowledge and potential new products, services or solutions which can be the basis for future initiatives. A positive sign is that entrepreneurs are increasingly being involved in processes concerning base research and its funding, also including introducing economic indicators. In the organisation of research projects, it is essential that the purpose and intentions of the project are defined from the outset. Naturally, it is not always possible to predict the end result and make economic calculations, but the initial, economically meaningful, plan must be there, although it may change in the course of the work.

At present, there is still a huge chasm between research institutions and enterprises due to discrepancies between objectives and the measurement of results. Entrepreneurs are committed to providing cost-effective products and services that meet market demand, while the main interest of research institutions and researchers is something entirely different – the number of publications and patents. These

may hold no economic value at all, but they are the basis for receiving state grants. Thus, conflict is already there at the outset. For entrepreneurs, the speed of bringing products to market and their likelihood of success are of key importance, whereas in research institutions, plans are much more far-reaching and funding is required for more than just the one to two years that it takes to publish their work. This may not be acceptable for entrepreneurs, as the maximum time for launching a product is often two years. All these factors – time, efficiency, and confidentiality – create a gap between different viewpoints. Unfortunately, various measures and regulations contribute to delays and decreased efficiency.

We cannot speak of reasonable and efficient administration if the application and decision-making period for grants is half a year or more, while the amounts barely make it possible to hire at most up to three people. Moreover, the majority of these types of grants are rounds-based. The funding system for such smaller-scale research grants should be flexible and swift. There is clearly something amiss if the funding for implementing an idea is 100,000 euros and it also comes with an expectation that this amount should solve all the problems in the world, meanwhile everything must also be documented in great detail, taking up a significant part of working time. Such funding systems should be open-round and run like clockwork: when you have an idea, you submit the documents for it, the next day you receive a reply as to whether something else is required, and the final decision is then made on the third or fourth day. One of the conditions for receiving a grant should be the involvement of an interested business partner, as this would make the involvement of enterprises in projects much more attractive and active from the very beginning. As a result, relationships between research institutions and enterprises already form at an early stage, making it possible to find common ground. Time will then tell whether this will lead to long-term cooperative relations or not.

It is essential that we experiment and are prepared to change the current funding system. We hear all the time that the state should invest 1% of GDP in research and development activities. This is reluctantly being done at the moment, but we cannot just stop here. At least 3–5% of GDP should be invested in research to make the economy smarter and more knowledge-exporting; this, however, is only possible if the additional 2–4% comes from business. Entrepreneurs only contribute if they can see and know where the money is going and what the outcome will be. If such reliable partnerships were to emerge, I do not see a reason why the state would not increase its contribution where necessary.

A very close cooperation between the state, research institutions and enterprises is the basis for all of this. Such tri-lateral cooperation should be supported by accessible and convenient state funding mechanisms that do not change

every year – there is no time to even get used to one before a new and different mechanism is put in place. For this to happen, coordinated cooperation between different agencies is required.

At state level, there is also a lack of ambition and thinking big. The aforementioned sprinkling of funds greatly restricts innovation. Where does the innovation of the state lie? What does it entail? There has not been any substantive innovation for decades. At the time, it mostly concerned the IT sector and the development of e-government solutions – something which we have not been at the forefront of for quite some time now, although we like to reminisce and make ourselves out to be better than we are. We have not realised the full potential of our skills and opportunities in combating COVID-19, for example, by not utilising an ID-card-based COVID-19 certificate. In terms of the green transition, there are no high-resolution mapping models for CO₂ emissions and sequestration or any associated reorganisation of activities which would set an example for other countries. This, in turn, would open up new opportunities for research institutions and private enterprises. Innovation can only flourish when all parties think together to achieve a common goal.

From time to time, the media reports that another wage race is starting. These reports usually have a rather negative undertone. In reality, there is nothing unnatural or bad about the fact that people want more pay for their work, which would also increase our standard of living. We should take pride in our success. We should rather be displeased when we cannot achieve this with our business because the price paid for products does not allow us to pay higher wages. For this, we cannot blame our employees, who would like to create smart and impressive things. Rather than talking about the wage race, it would be more appropriate to talk about how we could enhance cooperation between researchers and entrepreneurs and which measures the state could implement to act as both a catalyst and risk mitigator in this process. There has been a noticeable change in the parties' willingness to cooperate in recent years. This offers some hope that we will reach a position where problems will be tackled from the outset, instead of just using band-aid solutions that do not address the underlying cause of the problem.

Speaking of innovative future plans, I should like to hope that our future will be a friendly human and robot society that ensures the competitiveness of Estonia and the survival of the Estonian people, as well as clean nature and sustainable cooperation between researchers and entrepreneurs.

THE LANGUAGE OF SCIENCE AND THE SCIENCE OF LANGUAGE

ARVI TAVAST

Institute of the Estonian Language, Director

Estonian is one of the 50 or so languages in the world, in which it is possible to conduct research in at least some areas, for example, defend a doctoral thesis or publish an article classified as Category 1.1 according to the Estonian Research Information System. Thus, the answer to the common question as to whether the Estonian language is a language of science would be yes. Unlike most of the languages in the world, Estonian is a language of science and we can justly be proud of that.

The science of language, however, is concerned with another issue: what is the language of science like as one of the varieties of Estonian, i.e., what is the language like in which research is conducted in Estonian, or what would it ideally be like if the conscious development of language was possible? The positive answer to the previous question indicates that the Estonian language of science should be able to fulfil the requirements of a language of science, at least in the long term. The objective of this article is to demonstrate that even the fulfilment of all the requirements may be problematic from the perspective of linguistics.

CONDUCTING RESEARCH

The most obvious function of a language of science is communication (which will be discussed in more detail below), which is preceded by cognitive function, i.e., research as the process of thinking. These functions sometimes set mutually exclusive expectations for language. In other words, when we think consciously and verbally – as we usually do in science and research – then, in addition to inventing new things and ideas, we should also have the linguistic skills to name these inventions. Thanks to prolific word-formation processes such as compounding and derivation, the nom-

inative vs. genitive opposition, and other characteristics of the language, Estonian is actually better equipped for such purposes than, for example, the English language. What we need to work on, is the expectation of comprehensibility and unambiguousness. A newly coined term to denote an invention or phenomenon cannot be understood by others without further explanation. It is therefore essential to provide these explanations and do everything else necessary for the new term to become part of linguistic convention.

SIZE OF THE RESEARCH COMMUNITY

The immediate circle of participants in the convention includes the researchers in the same field who conduct their research in Estonian. However, due to increasing hyperspecialisation, there may be very few or even none of them, significantly reducing the motivation of researchers to make efforts to develop linguistic conventions and the language of science in Estonian.

The greatest difficulty lies in the inevitability that the vast majority of research in the world is carried out in other languages. Thus, maintaining the Estonian language of science at an adequate level would require continuous and substantial effort from Estonian researchers in translating research

papers published in other languages into Estonian. On the one hand, it would be necessary for conducting research in Estonian, as we cannot ignore what has been expressed in other languages. On the other hand, there is no incentive to make such efforts. In a worst-case and sadly the most common scenario, the number of potential readers of the translation would be exactly one – the translator themselves.

When there are no other researchers with whom it would be possible to discuss the topic in Estonian, talking to Estonians who are not researchers and other non-Estonian researchers takes priority.

INTERDISCIPLINARY COMMUNICATION

Just as researchers are not separated from the rest of society, the language of science cannot clearly be distinguished from general language and specialised language. The smooth transition from one to the other is due to the practical implementation of research findings, teaching and popularisation. The most recent and much talked about example is the introduction of epidemiological terminology into general language in March 2020. We are all well aware

of the difficulties of distinguishing the scientific language of other medical fields, IT and law from both the general language and the specialised language of the respective field (e.g., legislative language in the case of law).

Despite that, a smooth transition does not imply that there are no differences between language varieties – the above areas are also notorious for being difficult to understand

and for having negative language attitudes. For instance, the deliberate attempt to keep the language of consumer software in line with the specialised language of IT, which is only used by a narrow circle of experts, is one of the reasons why some Estonian consumers find the English version of the software much easier to understand than the Estonian version.

In some cases, the differences may actually be counter-intuitive. For example, legal language is easier to understand than legislative language according to research, that is to say, lawyers use simpler language with their colleagues than they do with the rest of the society. There are both

objective and subjective reasons for this which cannot be removed upon decision, even if achieving better understanding between parties is the common objective.

In any case, it is unreasonable to expect that research results should be communicated in a simple and clear language which can easily be understood by lay persons, but at the same time, not contain any compromises in accuracy. The readability of the text may, to some extent, depend on linguistic parameters such as sentence length and structure, however, comprehensibility primarily depends on the complexity of the content, not the language variety used to express it.

INTERNATIONAL COMMUNICATION

Estonian researchers also have contact with non-Estonian researchers. Although machine translation is evolving, it is currently not good enough to remove the language barrier in the rapidly changing field of research where communication is of the essence. Thus, the simplest way to communicate with other researchers is to use a language that both parties can understand to some extent.

We can see the effectiveness of publishing in Estonian when we look at citation data in those fields where Estonian articles can be published – if someone cites an article, they either have an Estonian name or a research object related to Estonia. Since the exchange of information is a two-way process, the following thought experiment may be beneficial: how many Estonian researchers are familiar

with research results published in their field in Latvian, a language close to Estonia and quite widely spoken among Estonians, or in Greek, a language associated with culture since ancient times, or in Chinese, a language with a huge and excellent research community? There is no reason to believe that other researchers read research in Estonian any more than we read in their languages.

Therefore, publishing research in Estonian contributes (or, depending on the discipline, would contribute) to the development of the Estonian language of science, but when it comes to the actual communicative function of the language of science – to communicate research results to colleagues – it is absolutely useless.

CONCLUSION

In the classical sense of the term, the language of science or the language in which research is conducted and its results are published may not be realistic in the case of the Estonian language due to the conflicting and challenging expectations that it entails. Instead of worrying about this, we should focus more on developing the general and specialised registers of Estonian which would allow researchers to distribute their own research results as well as those of other non-Estonian researchers more widely. It is also worth

noting that thinking in Estonian rather than in another language more widely used for research may present researchers who are native speakers of Estonian a certain advantage, allowing for more flexibility. However, in this case, the assumption that what is conceived in the Estonian language should be published in the Estonian language does not hold true, as comprehensibility is more important than flexibility in publishing.

THE ROLE OF MINISTRIES IN SECTORAL RESEARCH AND DEVELOPMENT FUNDING

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State organisation of research and development in ministries is established in section 13 of the Organisation of Research and Development Act²³⁸ in force. According to the Organisation of Research and Development Act, all ministries perform the following functions: organisation of the required research and development in their areas of government and the financing thereof, drafting national research and development programmes and organising their implementation, approval of the statutes of state research and development institutions which belong under their area of government, as well as justification and determination of the funds required for financing research and development in their area of government in the state budget. Although these functions were first laid down in the Organisation of Research and Development Act nearly 20 years ago, the capabilities and opportunities of ministries to promote sectoral research and development are still widely different. In 2021, the highest sectoral R&D expenditure was planned in the areas of government of the Ministry of Rural Affairs (13.3 million euros) and the Ministry of Social Affairs (5.8 million euros), whereas the lowest expenditure was planned in the areas of government of the Ministry of the Interior, the Ministry of Justice, and the Ministry of Foreign Affairs (0.8 million euros each).²³⁹

Taking inspiration from Finnish sectoral R&D organisation²⁴⁰, the Estonian Ministry of Education and Research launched the RITA programme²⁴¹ in 2016 to increase the capabilities and opportunities of ministries. RITA Activity 3 supports the creation of scientific adviser positions at the ministries to improve their internal capabilities. Currently, there are scientific advisers in all ministries, except the Ministry of Justice and the Government Office.²⁴² In addition to supporting the creation of scientific adviser positions, the RITA programme also provides funding for the promotion of sectoral research and development. RITA Activity 1 supports the commissioning of large-scale applied research based on the strategic directions of the state in order to strengthen cooperation between research institutions and ministries, to obtain evidence-based recommendations from research, and to apply them to tackle the socio-economic challenges faced by society. Research has been conducted, for exam-

ple, on the following topics: opportunities derived from the changing labour market and migration, opportunities for the exploitation of mineral resources, reducing the gender wage gap, use of remote sensing data for the development of public services, antibiotic resistance, along with many other related projects. RITA Activity 2 supports topical applied research commissioned by ministries intended to address issues that require speedy intervention and the results of which are used in knowledge-based policy formulation. As part of RITA Activity 2, more than 80 studies have been conducted, ranging from the risks that heavy metals in fertilisers pose to human health and the environment to the preparation of an analysis document on the long-term view on construction.

The RITA programme has given great impetus to the promotion of sectoral R&D in ministries, the cooperation between research institutions and ministries, and also the cooperation between ministries. Thanks to the RITA programme and the network of scientific advisers, it is also possible to react quickly to external forces. A good example is the SARS-CoV-2-related brainstorming event, in the course of which ministries formulated their research needs and Estonian researchers presented their research proposals. As a result of the brainstorming event, RITA Activity 1 and 2 studies were launched and the Estonian Research Council opened an exceptional call for target grants. The RITA programme and the work of scientific advisers has also had a broader impact on raising the awareness of the employees and management of the ministry in knowledge-based policy formulation, as well as on our ability to value researchers' contribution to tackling societal challenges.

The implementation of what was agreed in the Estonian Research Agreement²⁴³ (increasing the public funding of research and development to 1% of the GDP and maintaining it at least to the same level) from 2021 also contributed to the promotion of sectoral R&D in ministries. According to the decision made at the 13 February 2019 meeting of the Research and Development Council, 20% of additional resources will go to funding R&D and innovation measures supporting evidence-based sectoral policy formulation and

238 Organisation of Research and Development Act. Passed by Riigikogu on 26 March 1997. – Riigi Teataja I 1997, 30, 471. Translation published 03.06.2019. <https://www.riigiteataja.ee/en/eli/524032014005/consolide/current> (08.11.2021).

239 Research and development funding in draft state budget for 2021 and State Budget Strategy 2021–2024. Estonian Research Council. <https://www.etag.ee/wp-content/uploads/2020/10/TA-rahastamine-2021-RES-ja-RES-2021-2024.pdf> (08.11.2021).

240 Government working group for the coordination of research, foresight and assessment activities. <https://tietokayttoon.fi/en/government-working-group-for-the-coordination-of-research-foresight-and-assessment-activities> (08.11.2021).

241 RITA – Support for sectoral R&D. Estonian Research Council. <https://www.etag.ee/rahastamine/programmid/rita/> (08.11.2021).

242 Scientific advisers at the Ministries and the Government Office: RITA 3. Estonian Research Council. <https://www.etag.ee/rahastamine/programmid/rita/teadusnõunikud-ministeeriumites-ja-riigikantseleis/> (08.11.2021).

243 Estonian Research Agreement. A social agreement to ensure the further development of Estonian research and innovation. <https://www.etag.ee/wp-content/uploads/2019/05/Teaduslepe.pdf> (08.11.2021).

the implementation of sectoral objectives.²⁴⁴ The allocation of additional resources for 2021 was a one-off political decision; thus, as of 2022, the allocation of additional resources will be carried out based on the proportions and principles derived from the proposal of the Research and Development Council.²⁴⁵ Looking further ahead, it is encouraging that the Estonian Ministry of Education and Research is planning to partially continue the RITA programme, in particular, to support strategic applied research and the activities of the network of scientific advisers. Additionally, funds will be granted to the Government Office from the structural funds of the new period for the promotion of research and development. The primary objectives are to increase the capacity of public sector in implementing innovative solutions and to enhance cooperation between the public sector, private sector, and research institutions.

A fertile breeding ground has thus been created for ministries to promote sectoral research and development and to cooperate with research institutions and researchers. However, what are the needs of the ministries in this regard? Above all, two main needs must be highlighted. Firstly, sectoral R&D is needed for knowledge-based policy formulation, mainly involving the organisation of studies and analyses, on the basis of which it is possible to make policy decisions, shape the sector through the judicial area (laws and regulations), develop long-term sectoral strategies (development plans), support sectoral development (support measures), and offer new services. Secondly, sectoral R&D is needed to ensure the overall development of the sector. This may be a matter of prioritising the development of a specific, small area based on the needs of the state (e.g., e-governance services and cybersecurity) or of preparing more extensively for future challenges (e.g., developing sectoral competence for green transition and digital focus).

Based on these needs, four main forms of cooperation between ministries and researchers can be identified. The first and most common form of cooperation is the above-mentioned commissioning of applied research. The second form of cooperation is joint projects, both state- and EU-financed (e.g., Horizon 2020, Horizon Europe, LIFE), the aim of which may be knowledge-based policy formulation or the improvement of sectoral R&D capacity. The third form of cooperation is supporting researchers in international cooperation (e.g., Horizon Europe partnership or Nordic and Baltic cooperation programmes). In this case, the ministry provides financial support to researchers for participating in research projects, while frequently having control over the topics and conditions under which projects are supported. The fourth and final form of cooperation is the involvement of researchers in the preparation of development plans, strategies, roadmaps, and measures through working groups, expert committees, and advisory bodies. The fact that researchers and experts are involved is not as important as the fact that their voices are actually heard.

Looking forward, there are a few bottlenecks that must be improved in order to ensure that ministries have a distinct role to play in R&D funding and that cooperation between ministries and researchers is reinforced. The Organisation of Research and Development Act is currently being updated, and reviewing the functions of all ministries is an issue that is being considered. The most pressing issues are as follows: should the functions of ministries be set out in as much detail as they are at the moment (e.g., drafting R&D programmes), what is the division of responsibilities of the Estonian Ministry of Education and Research and other ministries in securing the diversity and continuity of sectoral R&D, and how could ministries direct sectoral R&D activities.

The future of scientific adviser positions at the ministries remains unclear. As part of the Estonian Research and Development, Innovation and Entrepreneurship (TAIE) development plan, a Coordination Committee for R&D and Innovation (TAI) was established, bringing together all officials responsible for R&D at the ministry. The RITA successor programme provides support for the network of scientific advisers. Nevertheless, most scientific adviser positions are fixed term, and, seeing as the RITA successor programme does not provide for the creation of new or the preservation of current scientific adviser positions, it is unclear whether the positions of scientific advisors will remain in all ministries or not.

The increase in R&D funding and commissioning of applied research by the ministries has introduced a new problem: there are not enough research providers and, as a result, competitions and procurements often fail or become much more expensive than planned. It is therefore vital to reflect on how to ensure a sufficient supply and make cooperation with ministries more attractive to researchers. One possible solution might be to organise long-term cooperation projects instead of one-off studies or to conclude framework agreements, which would provide all parties with greater certainty.

In conclusion, it appears that the ministries' awareness and capacity in the area of research and development has greatly improved over the past five years, knowledge-based policy formulation has increasingly been implemented, and cooperation between ministries and researchers has also increased. At the same time, this process is only at an initial stage and several other bottlenecks in cooperation between ministries and researchers need to be resolved, not to mention all the processes and development needs within ministries that also require solutions. These issues should, however, be addressed in more detail in a separate article.

²⁴⁴ Minutes of the Research and Development Council. Government Office. <https://pilv.riigikantselei.ee/index.php/s/45zBo6p2HbYfJsD#pdfviewer> (08.11.2021).

²⁴⁵ Government Office. Teadus- ja Arendusnõukogu istungi protokoll, nr 6-1/89, 31.08.2021. <https://dhs.riigikantselei.ee/avalikteave.nsf/documents/NT00388B8A/%24file/TAN21P89.pdf> (22.11.2021).

THE CORONAVIRUS CRISIS AND RESEARCH FUNDING

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In addition to the lack of personal protective equipment, available treatments and prophylactic methods, the unexpected COVID-19 pandemic revealed another problem soon after the outbreak started - our knowledge of the coronavirus and how to deal with health crises was minimal. In January 2020, all we knew was that it was a novel coronavirus similar to the SARS-CoV-1 both in its structure, genetic makeup and the disease it caused. Everything else was quite unclear and it quickly became apparent that not all knowledge gained during the SARS-CoV-1 epidemic was applicable in the current pandemic. It was no wonder that, in these circumstances, everyone turned their attention to science and scientists. Some of the most burning questions that needed answers were: how does the virus spread, how can the spread of the virus be stopped, what is the course of the disease, and who are at most risk. First and foremost, attempts were made to produce or repurpose medicinal products and vaccines.

Many national governments decided to invest in COVID-19 research and called for target grant or research funding applications. The main objective was to stop the spread of the virus as soon as possible and end the pandemic. In 2020, none of us imagined that the pandemic would last for several seasons or that, in the autumn of 2021, there would still be no signs of it waning. By the autumn of 2020, it was clear that this was a marathon, not a sprint.

Similarly to other countries, the Government of the Republic of Estonia allocated funds, more than 4.7 million euros, from additional resources to support the research of COVID-19. A total of 27 research projects were funded under five programmes (target grants, RITA-1, RITA-2, RVL NF and ERANet).²⁴⁶ First, a collection of ideas took place, in which researchers from different universities had the opportunity to brainstorm new ideas, and after that, the call for target grants was opened. The grant applications covered all aspects of COVID-19 from testing for SARS-CoV-2, the description of the clinical course and mortality risk of the disease to antiviral materials and transport robots. Funding was also provided for research which focused on the assessment of the economic and social impacts of nonpharmaceutical measures including restrictions. The funding period for most research projects was 15–18 months, therefore, the results from these projects are not yet available.

In addition to giving out grants, the Estonian government also funded various targeted studies, such as seroepidemiological, waste water monitoring and virus sequencing studies. The latter were all applied research studies, the results of which have been made available for everyone. These studies have been essential for controlling the pandemic.

During the first phase of the pandemic in the spring of 2020, everyone was curious about how widespread the pandemic would become and what the future would bring. Many epidemiological modelling groups in both Europe and the USA started actively working at the time. The initial models have been much criticised, however, they could only be as good as their inputs. The data at the time originated from the early days of the pandemic in China. In retrospect, the true extent of infection in China was underreported due to insufficient testing and the lockdown of the area, and as a result, both the mortality rate and hospitalization rate were significantly higher than what we have seen later during the pandemic. These models were still beneficial in helping us understand in which direction the epidemic was heading. Estonian researchers also started developing forecasting models in the early days of the pandemic. Similarly to other models in the world, Estonian models have become more accurate and reliable over time.

The next major step was to improve diagnostic testing. Everyone knows that it is much easier to deal with known rather than unknown things. PCR testing became widely available despite its high cost. The development and approval of reliable rapid antigen tests and at-home test kits required more time. At the moment, one and a half years after start of the pandemic, the gold standard of testing is still the PCR test, although rapid antigen tests are being used more widely, especially for self-testing. In the spring of 2020, several rapid antibody tests also reached the market, but since they do not hold any significant value in disease diagnosis, their development has subsided.

The major scientific breakthrough of this pandemic was the rapid development of vaccines. This was possible only thanks to previous basic research. Viral vector vaccines had already been used against Ebola, and additionally, the mRNA technology had been developed and researched for years and was ready to be tested in humans. Both mRNA and viral vector vaccines proved to be more effective than expected, as clinical trials showed their high efficacy in preventing severe COVID-19. The rapid development of vaccines was only possible thanks to advances in basic research, demonstrating once again that the funding of basic research should not be ignored between pandemics and epidemics. The development of COVID-19 vaccines also demonstrated that if we join our forces and resources and if both the pharmaceutical industry and national institutions cooperate with each other, the situation can promptly be improved. The development of other medicinal products could also benefit from such cooperation. At the same time, we should bear in mind all the problems associated with the rapid development of medicinal products, so that they could be avoided in the future.

²⁴⁶ Overview of COVID-19 R&D funding through the Estonian Research Council. Estonian Research Council. <https://kustsatead.ee/ulevaade-covid-19-ta-rahastamisest-est-tee-agentuuri-kaudu/> (29.09.2021).

Vaccines are the success story of this pandemic, however, the same does not apply to the development of antiviral agents. We have been in a pandemic for one and a half years, yet we still do not have any effective medicines against COVID-19. Hopefully, lessons will be learnt from the development of vaccines and the development of antiviral agents will receive the same level of investment in the future. Research into repurposing existing medicinal products for the treatment of COVID-19 has also not proven successful. Nevertheless, clinical trials have run smoothly with the implementation of new methodology (umbrella trials) and the involvement of a number of institutions, making it possible to conduct research more expeditiously. Unfortunately, the results have been disappointing as only one medicinal product – dexamethasone – has proven to be effective. Research has shown that many other medicinal products (e.g. hydroxychloroquine, azithromycin, budesonide, and zinc) do not have a clinical effect on COVID-19. Estonian researchers have also participated in several of these studies, but Estonia is too small to be the leader of international studies and the state has probably not had sufficient funds to carry out such research.

As previously mentioned, the research projects funded so far have not yet been completed, making it difficult to assess their effectiveness. At the same time, we can already see that funding based on idea collection may not be the most effective solution in a crisis situation. Speed, oper-

ability, and flexibility are of the essence in managing a crisis. For instance, the knowledge that we had about the spread of the virus in the beginning of the pandemic has now increased and developed. We now know that the virus spreads through respiratory droplets and aerosols, which is why in our fight against the virus, we primarily need to focus on blocking the respective routes of transmission. In future calls for proposals, the establishment of a committee of experts should be considered and perhaps more emphasis should be put on thematic areas important for Estonia in addressing the crisis.

As a researcher and the Head of the Scientific Advisory Board, I must say that when it was time to make research-driven decisions, we did not have sufficient results from operational research. Under normal circumstances, we can rely on research to make our lives better in the future, which is what many of the funded projects will definitely do, but in a crisis situation, research results are required immediately. It is important to continue the discussion on how research can contribute to the management of crisis situations operationally and what those funding research, i.e. the state, should do in a similar situation. Clearly, conducting basic research should be of the essence even during the period between crises. If we start placing emphasis on basic research when we are already in the middle of a crisis, we are hopelessly late.

THE COVID-19 CRISIS HAS MOBILISED TOP RESEARCHERS TO CONDUCT THE NECESSARY APPLIED RESEARCH

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In summarising the current state of Estonian research in 2021, we cannot overlook the impact that the SARS-Cov-2 global pandemic has had on research, the economy and society. At the time of writing this article, the author has not yet received sufficient data to illustrate which disciplines developed faster and which slower, and whether the productivity of researchers working from home with children has increased or decreased, or whether the impact was greater on laboratory research or other research, and so on.

Thanks to its close connections and digitalisation, Estonia as a small country has managed the coronavirus crisis relatively well so far. The situation only started to get out of hand when it became clear that the level of vaccination coverage was not going to reach the necessary threshold. The low vaccination rate mainly reflects the local social norms, the prioritisation of one's own personal views over the needs of the society, the wide-scale spread of false information and the use of it as a means to manipulate people's minds. However, the fact that, compared to other countries, we managed the crisis well in the beginning does not mean that we should not be critical and learn how to do better in the future.

As with most other countries, Estonia responded with too little, too late. Both the Health Board and researchers were not prepared for the crisis. Different parties only started coming together when the virus had already aggressively spread across Estonia. Initially, Europe as a whole was in denial, hoping that this issue will disappear on its own and not concern us. The state was forced to respond decisively only after the first quick calculations on the outbreaks of Saaremaa and other places in the spring of 2020 were completed and which showed a rapid spread of the virus. At first, even the thought that mathematicians, physicists and data scientists could comment on the virus seemed rather radical. Even though science and research are based on calculations – we decode the world around us with the help of data and mathematics.

Estonia, like many other countries, could have mobilised and involved researchers in tackling the issue much earlier. Above all, it should have been established how different parties could help, what could be done in preparation for the impending crisis, and which teams could be involved. Agencies did not have free resources in the crisis situation to organise brainstorming events, assign tasks or even call upon anyone to co-operate, let alone manage it all properly. The main cause of frustration among researchers was perhaps the fact that they and their teams were ready to

contribute in any possible way but their help was either rejected or ignored. A great deal of emphasis was placed on centralised institutions, hackathons, and spontaneous solutions to help resolve the issue. While it is true that thanks to the above an abundance of ideas and initial solutions were put forward, their potential remained largely untapped and co-operation was low, if not completely lacking. The development of coronavirus applications, symptom tracking and data management, which combined both personal data and open data approaches, remained half-finished as they were not needed. The problem was not so much people's lack of interest in contributing to this issue for free, but rather the lack of interest from the state. It seemed like researchers (and entrepreneurs alike) were just forcing their help on the state while the state had everything under control.

Better thought should have been given to figure out which disciplines could have contributed and in which aspects. First, it became clear that classical epidemiology in Estonia is a weak, almost dead discipline. As a result, the first response was largely based on virology and clinical medicine. The potential of the data-led digital world was not appreciated and data analysis, statistics and modelling were not incorporated until later, while the collection, management and analysis of data has still not been properly addressed. A psychology expert was involved later on as both the provision of information and low rate of vaccination were being influenced by mass psychology. In terms of the economy, Estonia has coped with the crisis quite well. However, the service sector and tourism were hit the hardest. The Scientific Advisory Board has an advisory role, which is why different opinions must be represented there. But how are opinions turned into scenarios and comprehensible guidelines?

The Scientific Advisory Board comprises a small group of experts whose opinions carry weight. An active and busy Board cannot have too many members. Perhaps the biggest drawback of such a solution is the fact that science cannot be conducted by a few experts in a small group that only meets occasionally and just forms opinions. Each scientific field should have had its own team led by a representative of the Scientific Advisory Board which would have been responsible for collecting input and working hard on a continuous basis. Unfortunately, the Scientific Advisory Board did not have the necessary team or resources to organise anything on their own. For instance, the collection, management and analysis of data and the development of modelling tools is hard work that requires top-level specialists who are not just managing random Excel files but are also

developing systemic work tools, workflows and analysis applications. A few dozen people have contributed to this work during the pandemic – some more, some less. Since the work was primarily voluntary in nature, much of it was left unfinished or the planned solutions were never implemented. This was due to the fact that we received no specific well-formulated questions, orders or wishes.

The co-operation between researchers and the Health Board has never been plain sailing – during the crisis, bottlenecks in communication appeared and administrative restrictions dictated what could and could not be done. The importance of ensuring proper data management in our e-government was also not acknowledged. Data on coronavirus testing was gradually being collected via the Patient Portal digigu.ee, making the data more reliable. Nevertheless, no proper analysis was carried out to obtain reliable data on transmission patterns in public spaces, workplaces, schools, kindergartens, and care homes. When working with very little information, the complexity of data modelling cannot be too high.

One of the main parameters used in the models was the mysterious R number, or reproduction number, which refers to a disease's transmission rate. In essence, it indicates the exponential value of growth rate. Data modelers who applied this kind of exponential growth several weeks in a row without taking into account the changing behaviour of people, additional restrictions and the rate of achieving the hoped-for herd immunity (i.e., reduction in the R number without changes in behaviour), were heavily criticised. There was and still really is no data on how the R number varies in different parts of the country, subsections of the population and within families, etc., and which events caused the outbreaks. Hospitals were primarily concerned with the rate of hospitalisation. Trends in the hospitalisation rate could be determined on the basis of the infection rate calculated using simple ratios. However, when the methodology changes – for example, who should be tested and to what extent – the ratios also change.

The Estonian Research Council organised an idea collection and an application round for research grants based on the topics highlighted; however, the final results of these projects have not yet been presented. The systematic monitor-

ing studies carried out for the state have been quite successful as they have helped to reveal the true state of infection. These studies include PCR testing and interviewing based on random sampling, antibody testing, and systematic waste water analysis. Random sampling allows researchers to better assess the spread of the virus in the population as it is not biased by testing strategies. Finally, viral RNA sequencing, which is acknowledged internationally as an important method for the detection of new strains and monitoring of the spread of the disease as well as for the analysis of the impact of different strains, was also launched. In the end, there has been no comprehensive data management. At the same time, it is clear that extensive monitoring studies take up a lot of the working time of researchers and their teams, thus taking away precious time from their other regular projects which yield actual new research results. As a result, researchers' opportunities to return to their previous work in the future and find funding decrease.

The areas which have been essential in the crisis situation include genetics (testing, sequencing), health data analysis, epidemiology, biostatistics, data science, immunology, and virology. Physicists, including atmospheric physicists, civil engineers (ventilation), psychologists and social scientists have also contributed to tackling this crisis. A number of pedagogical issues have arisen during the crisis, highlighting the need for computing infrastructure and proper data management. Naturally, most of the researchers in these fields were not previously working with viruses or conducting research in the field of epidemiology or on mitigating the impacts of the pandemic. Fortunately, top-level researchers are able to adapt quickly and apply their skills in new circumstances. Research is flexible by nature in its continuous search for new knowledge. It is the top scientists who have contributed the most to tackling this crisis, clearly illustrating why high-level research is essential for a small country. Generally speaking, it does not always matter which small, specific area we have expertise in. What matters, however, is that we have enough top researchers in a number of areas who advance our science and train future generations. In conclusion, top-level blue skies research, which is based on the interests of the researchers, should always be promoted, because curiosity-driven research and competence allow researchers to also contribute to applied research in new circumstances – which this global crisis undoubtedly is.

VISION FOR EUROPEAN RESEARCH AND INNOVATION IN 2022

SIGNE RATSO

Deputy Director-General for Research and Innovation at the European Commission

Just like the rest of the world, European research and innovation are continuously evolving and becoming more and more intertwined with other areas. There is a wind of change blowing in the area of European research policy. This is, above all, the result of the new European Research Area (ERA) strategy adopted in the autumn of 2020 and the Research and Innovation Framework Programme Horizon Europe launched in the summer of 2021.

The new ERA for Research and Innovation was established to bring the common European research policy more closely into line with the changed conditions, to learn from the experience gained from the implementation of the ERA since 2000, and to define a specific set of targets and provide a clear action plan for the coming years. The European Research Area fulfils an important role in bringing together research and innovation policies at a national and European level, encouraging Member States to strengthen research and innovation at both a national and regional level, and enhancing cooperation in Europe. The new ERA for Research and Innovation aims at helping our research and innovation systems to better respond to the major societal, ecological and economic challenges that lie ahead of us, as well as providing impetus for further research and innovation to find new solutions and improving cooperation between private and public sectors in the field of research and innovation. Equally important are the objectives of accelerating green and digital transition in Europe, strengthening the resilience and preparedness of Europe to deal with crises, and maintaining Europe's competitive edge in the global competition for knowledge.

The vision for the new ERA is based on the following key strategic objectives, which can only be achieved through enhanced cooperation with Member States:

1. prioritising investments and reforms, including the objective of raising overall R&D investment to 3% of GDP;
2. improving access to excellence, e.g. by supporting countries with low levels of research and innovation in order to increase the capacity of their research and innovation systems;
3. translating research and innovation results into the economy, including the development of the framework supporting European research and innovation ecosystems;
4. deepening ERA, including finding additional resources to support the career prospects of researchers and developing a roadmap of actions for creating synergies between higher education and research.

To achieve these objectives, an action plan for the new ERA has been prepared which sets out priority areas for the next three years and which will be implemented in cooperation

with Member States and stakeholders.

I believe that there is a broad overlap between many of the priorities set out in the new strategy and action plan and the priorities of Estonia in developing its research and innovation system. Emphasis is put, for example, on integrating research policies into education and business strategies, creating stronger ties between research organisations and enterprises, and promoting synergies between research funding and the use of structural funds. In view of the fact that a great deal of attention will be paid to these areas in Europe in the following years, it is crucial for Estonia to actively participate in the initiatives of the ERA, taking full advantage of them to implement its reforms, while also contributing to joint discussions and projects.

The new Research and Innovation Framework Programme Horizon Europe is one of the main joint financing instruments that contributes to the achievement of ERA strategic priorities. What are the key features of this new research and innovation programme?

First, it is the world's largest international research and innovation programme, with a seven-year budget of almost 100 billion euros. Compared to the budget of the previous programme Horizon 2020 (80 billion euros), the budget of the new programme has increased, making it one of the few programmes under EU funding, the budget of which will increase in the new financial period.

Since the majority of public research expenditure in Europe comes from national budgets, the joint European research and innovation programme enables transnational cooperation on common challenges. The list of participants is not restricted to the 27 Member States of the EU. Non-EU countries that share common values with Europe are also allowed to join Horizon Europe. Approximately 20 other countries, including both EU neighbouring countries and countries elsewhere in the world, are expected to join the programme and bring with them an additional 20 billion euros in investments. Therefore, participation in the programme provides researchers and entrepreneurs an opportunity to collaborate with partners from approximately 50 different countries for the purpose of resolving common problems.

Another important feature of Horizon Europe is its objective of tackling major societal challenges. The thematic structure of the previous programme Horizon 2020 has been amended in that similar topics have been grouped into clusters. For instance, all research in the area of climate, energy and mobility is in one cluster so that the projects can be jointly coordinated to achieve the best possible synergy between investments in different areas. The same principle has been followed in the grouping of all seven clusters which form the pillar of global challenges.

This focus on addressing major global challenges is one of the main features of Horizon Europe. The excellent science programme of the European Research Council will also be continued on a larger scale, whereas the remaining parts of Horizon Europe will primarily focus on achieving greater societal impacts. As part of multi-annual strategic planning, the objectives for the first three years as well as expected impacts will be identified.

As a new way to achieve greater impact and bring concrete solutions to some of the greatest societal challenges, EU missions, which are a novelty of the Horizon Europe research and innovation programme, have been implemented. EU missions were inspired by US President John F. Kennedy's mission of landing a man on the Moon. This approach is relatively new in research and innovation policies, emphasising that the state should have a stronger role in guiding research and innovation, and a more active role in the search for solutions. EU missions are our pilot projects for the new approach which sets out specific ten-year goals and the achievement of which involves both public and private investments.

The first five EU missions, four of which are aimed at tackling climate challenges and one at health challenges, were launched in the autumn of 2021. The Member States collectively selected the following research missions: adapting to climate change, restoring soil health, restoring oceans and waters, making cities climate-neutral, and conquering cancer. I am delighted that the representatives of Estonia were also involved in the drafting of these missions, and I sincerely hope that the state agencies and the research community of Estonia will actively participate in the implementation of these missions and the achievement of these goals in both Estonia and Europe. The cities mission aims to turn 100 European cities climate-neutral by 2030 – a competition to find suitable cities will be organised. In this respect, both Tallinn and Tartu have potential, as the former was recently awarded the title of European Green Capital, and the latter was selected as the European Capital of Culture. In the context of cancer research, Estonia has significant research potential which could be exploited to achieve mission targets. Adapting to climate change, restoring the health of soil and improving the status of the Baltic Sea are all topical issues that should be of importance to Estonia.

In addition to missions, European partnerships also have a major role to play, in which the public sector alone or in cooperation with the private sector invests in selected sectors. Under the previous framework programme, the partnership landscape consisted of nearly 120 different initiatives; however, as a result of discussions initiated during the Estonian Presidency, the new approach to partnerships has

been significantly streamlined. Approximately 50 partnerships have already been formed under the new programme, to which Estonian researchers and enterprises are also very welcome to contribute. One noteworthy example would be the Clean Hydrogen Partnership, which is crucial for green transition, especially taking into account the strengths of Estonian researchers in this area as well as the growing interest of the state and investors in its development.

The establishment of the European Innovation Council also enhances the achievement of societal impacts and introduces innovation measures to significantly increase and accelerate the transferring of research excellence into innovative products and services. Europe is the world's leading region in the production of new knowledge, however, when it comes to the application of this knowledge, we are not as successful. This is precisely what the newly established European Innovation Council should improve.

The recent review of the Estonian R&I system, which was completed in 2019 with the support of the European Commission²⁴⁷, also outlined the need to strengthen research and development efforts in Estonia and to enhance cooperation between universities and enterprises. I am pleased to see that, after the completion of the review, substantial steps have already been taken in this direction and that these recommendations have also already been expressed in the new Estonian Research and Development, Innovation and Entrepreneurship Development Plan. I believe that both the structural instruments of the new period and investments from Horizon Europe will be of great help in implementing these changes.

Estonia has been one of the most successful participants in the recent framework programmes. Compared with the investment of 76 million euros under the Seventh Framework Programme, investments in Estonian researchers and entrepreneurs tripled, reaching more than 270 million euros, under Horizon 2020. The Horizon Europe programme will certainly offer even greater opportunities and Estonia will have additional resources, especially from the private sector, which can be channelled into joint projects.

I hope that every Estonian research team, university, innovator, and entrepreneur will seriously consider contributing to European joint projects. These projects should aim at achieving a long-term impact in the best way possible for the benefit of both the Estonian R&I system, the society, and Europe. Estonia is well-placed to achieve this and headed in the right direction. I wish everyone much enthusiasm, determination, success and a little bit of luck in achieving these goals.

247 European Commission. (2019). Directorate-General for Research and Innovation. Peer Review of the Estonian R&I System. Final Report. https://www.hm.ee/sites/default/files/pr_estonia_-_final_report_.pdf (22.10.2021).

SCIENCE IN AN EVER-CHANGING WORLD

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Science has many sides and meanings, all of which are ever-changing in time and differ from one language to another and from one culture to another. It is therefore important to explain what I mean by science in this article.

The term 'science' is derived from the Latin word for knowledge – *scientia*, denoting, on the one hand, knowledge about nature and society, and, on the other, the human activities that result in the creation and organisation of such knowledge. Nevertheless, not all knowledge in the world falls under the definition of science – apparitional and religious experiences as well as artistic and other sensory expressions lie beyond the scope of science.

In respect to science as a human activity, I will proceed from an even narrower definition: science as a human activity is systematic and aimed at generating novel, creative and unpredictable knowledge, the results of which must be transferable and reproducible. This is the definition used by OECD countries, which in addition to strictly scientific activities, also includes technological developments based thereon, i.e. knowledge-based skills.

Science as such has significantly and resolutely contributed to the development of modern civilization. However, scientific advancements have also brought about all the anthropogenic existential risks that we are facing today. The power of science lies in its ability to predict the consequences of our actions, whereas, if reversed, it can be used to answer the following question: "What must be done to achieve the desired outcome?"

Like curiosity in humans, science in society is a gift of evolution over which we have no power, but which we are free to develop and use as reasonably as possible.

On this point, I draw the first conclusion: science has brought us to the present day, therefore, science will also help us to move forward. I doubt that anyone believes that without science the future would be better.

The greatest existential risk facing us today is the fact that the consumption of energy by humans has reached the Earth's threshold of tolerance. We have replaced mechanically powered machines and steam engines with internal combustion engines and electric motors which are predominantly fuelled by non-renewable resources. While we are moving towards the broader use of solar, wind and nuclear energy, there is still a lack of knowledge in the area of sustainable energy. The vast potential of controlled fusion energy remains untapped and, without a viable solution, the problem of electricity storage will remain unresolved. At the same time, global needs for energy are increasing, especially with regard to developing countries, who would also rightly like to enjoy the fruits of the progress made so far. The world is facing a resource crisis – but the key to resolving this problem is the development of new energy

production technologies. Without oversimplifying the matter, we have two options: we can either increase our military capabilities and hope that we survive the final fight for resources or, alternatively, we can contribute to the development of new technologies by enhancing global mutual trust. Without science, neither is possible.

Combating the climate crisis is directly linked to the previous problem. However, in the context of increased energy consumption, we lack suitable technological solutions to rapidly and significantly reduce greenhouse gas emissions. The naive hope of reducing global energy consumption by way of agreement is not scientifically justified. Only technologies that are based on new knowledge can provide a solution, including those related to carbon capture and storage. We need more science!

Let's now look at the lesson learned from the coronavirus crisis. Vaccination has proven to be the only effective technology in tackling the pandemic. While it is true that vaccination does not meet the idealised expectations of many, it is in line with the practical possibilities of its technology. Thus, what is important in the case of the coronavirus vaccines is the fact that mankind has been able to direct appropriate levels of funding into research and development and achieve the results several times faster than would have been possible under normal circumstances. This is the most valuable lesson of the coronavirus crisis: science is capable, but only if humans reach an agreement.

What has made such progress possible?

A turning point in modern research policy took place after the end of World War II when Vannevar Bush sent a letter to the President of the United States, noting the need to support scientific research at a national level in order to increase the competitiveness of the society and economy. It has been speculated that the letter was inspired by the effectiveness of the Manhattan Project and other such military projects. This way of thinking was further advanced by Sputnik, Laika and Yuri Gagarin, John Glenn, Neil Armstrong and other astronauts, resulting in strategic and mission-oriented collective research and innovation initiatives.

By nature, curiosity is the driving force behind scientific endeavour. The effective implementation of the resulting knowledge has led us to the development of institutionalised private and public research systems. However, new challenges are indicating an increasing need to supervise and coordinate research and development in cooperation with researchers and various institutions, as well as across countries, because even the capabilities of the largest countries may not be enough to solve the most complex of problems in a timely and efficient manner.

Horizon Europe, the new Framework Programme for Research and Innovation in the European Union, perfectly

illustrates the shift in modern research policy, as it clearly aims to encourage innovation and direct research to address (research) policy challenges. A portion of the programme's funding is, of course, still aimed at generating excellent science, thus the European Science Foundation receives 16% of the budget of €100 billion. The bulk of the programme's budget goes towards solving global problems, enhancing industrial competitiveness, and addressing the specific innovative needs of Europe, in particular, the green transition and digital transition.

In line with the above, I dare to say that when it comes to small countries like Estonia, our participation in major mission-oriented initiatives at the level of both academic research and business development will become more and more important. This, in turn, requires making clear research policy choices to bring together both people and resources and contribute to areas in which we have something to offer to our partners and which will also benefit the Estonian economy and society at large. It should also be pointed out that our practice so far has mostly been based on the interests of individual researchers with the objective of participating in as many initiatives as possible, which ultimately may not be the most effective strategy for a small country.

Another important shift in the role of science is related to the increasing complexity of today's society. More and more frequently we find ourselves in a situation where plain old common sense is no longer enough to find solutions, everything seems too complicated and interconnected, causing us to lose focus so much that relying on past experiences becomes impossible. Furthermore, common sense often prevents us from realising that the problems are worsening. It does not matter whether the challenges are facing us at a global, national, regional or business level.

Science is expected to solve all such complex socio-political issues. Of course, a scientific, causation- and evidence-based approach will allow us to make better decisions, but it is wrong to think that science is almighty.

Science has three limitations.

Firstly, complex systems are called complex because their behaviour cannot, as a matter of principle, be accurately predicted. It was not a mystery where the apple would fall even before Newton formulated the law of universal gravitation. Yet we still cannot predict the weather two days in advance, despite the fact that 400 years have passed and all the relevant formulas and laws are at our disposal. Nevertheless, this does not imply that the weather cannot be predicted at all – it is more important to know what can and cannot be done as well as how accurately and with what probability it can be done. This is the case for all complex systems, from global climate change and major wars to apartment association meetings.

It is thus appropriate to make the following conclusion: the complexity of the world means that we must learn how to deal with uncertainty and manage risks. This is a responsibility that even science cannot shoulder.

The second limitation of science lies in the fact that science has no will. Science can help us find solutions to achieve a set goal, but it cannot help us when we have lost all sight. Even in the case of achieving a set goal, science may offer us solutions that we do not like. In school, we learn the golden rule of mechanics, which expresses that whatever is lost in force, is gained in displacement. University physics further elaborates on this idea: every undertaking which increases order causes even more chaos and disorder elsewhere. In other words, everything has a price and every act causes pollution. Therefore, we must make choices, but in order to make choices, we must know what we want and how we can achieve a balance point between different values. For example, in the case of the establishment of a factory, both the economic benefits that can be generated and the impact on nature must be considered, including public health and the protection of individual freedoms in the management of the coronavirus crisis. Science cannot help us here. It is up to the individual to make the choice based on their own interests, preferences and values, while also assuming responsibility for it. Taking responsibility being the most difficult aspect of it all.

The third limitation stems from the fact that even scientists are human. In our pursuit of objective knowledge, we can never fully eliminate all our personal preferences and especially our subconscious attitudes – this inevitably affects our expert opinion. It is, therefore, not surprising that environmental researchers care more about environmental matters than economic matters, but the opposite is true for economists. And the exception proves the rule, which is to be expected. Regrettably, scientists and researchers also sometimes lose their objectivity, disrespect the standards of professional competence, and start to push forward their own personal agenda and fulfil their material goals under the guise of doing their job. In addition, the practice of involving not only lawyers but also scientists to defend one's own truth in disputes between parties is becoming increasingly popular. A local precautionary precedent was set in the debate involving the Tartu cellulose factory when some researchers started to support the ban on scientific research. This may be the greatest threat posed by science today.

As long as science fails to provide comprehensive answers, we can expect it to evolve. Insofar as science does not make our choices and set our goals, we are responsible for doing it. However, mistakes made in the name of science break our trust in science in its entirety, making it hopelessly impossible to address serious problems.

The changing role of science is also evident in the terminological shift in English, the lingua franca of science, where instead of 'science' the phrase 'research and innovation' is being used more and more to better convey its emphasis on goal-oriented problem solving and societal matters. Nonetheless, the most important aspects of science are its quality, objectivity, and reliability. Social progress and overall success can only grow out of science that is based on these values.



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