Higher education and research and development activities in the field of ICT in 2022

This report is compiled by Education and Youth Board and translated into English by Scriba OÜ. The translation does not include the chapter about vocational education.

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Overview

This analysis provides an overview of the quantitative data related to the field of information and communication technology (ICT) in Estonia. The focus is on ICT research and development, which is analysed in retrospect until the year 2013 (the period observed includes 2013–2022).

Higher education

In higher education, the number of students in the field of ICT has increased, as well as the proportion among the total number of students that has increased from approximately 7% to 11%. The proportion of the students of ICT among the admittees has remained at the same level for the previous three academic years; the proportion of graduates has remained the same for two academic years – similarly to vocational education, fewer students, compared to other fields of study, reach graduation in the ICT field of study. At the same time, graduation efficiency has consistently increased during the period observed.

Compared to other fields of study, the ratio of graduates and admitted students is lower in the field of ICT, indicating that students discontinue studies more often in the field of ICT compared to other fields of study. In general, it could be said that the lower the level of higher education, the higher the number of students discontinuing their studies.

Besides the ICT field of study, other fields of study also provide ICT-related study programmes: education; arts and humanities; ICT; engineering, manufacturing and construction; business, administration and law. While the proportion of women in the ICT field of study has increased from 23% to 30% during the period, the proportion of women in other fields of study varies from 18% (engineering, manufacturing and construction) to 74% (education).

During the period, 10 institutions have provided ICT-related studies, the number of respective institutions has been six over the last three years. These institutions are: Estonian Entrepreneurship University of Applied Sciences (Mainor), Estonian Academy of Arts, Tallinn University (TU), TTK University of Applied Sciences, Tallinn University of Technology (TalTech) and the University of Tartu (UT). 81 study programmes have been included in the analysis (3 in the field of study of education; 4 in the field of study of arts and humanities; 53 in the field of study of ICT; 12 in the field of study of engineering, manufacturing and construction; 6 in the field of study of business, administration and law). The largest number of study programmes are available in TalTech, the smallest in Mainor.

During the period, the number of students has increased in the three largest universities (TU, TalTech, UT), while the growth has been the most considerable at UT (in relative terms). The distribution of admittees among the three educational institutions has changed significantly during the period: the proportion of UT has increased while that of TalTech has decreased. The distribution of graduates has varied without a clear trend during the period observed.

The proportion of women has varied considerably in the field of study of ICT during the period observed, fluctuating between ca 10% and ca 68% in different categories. The proportion of women has increased in all groups of study programmes during the period; however, the level depends on the level of education – the proportion of women is the highest at the Master's level. The proportion of women has increased overall among the admittees from 27% to 32%.

The number of foreign students has increased almost 2.5-fold and their proportion nearly fivefold during the period, the increase has been the most considerable at the level of doctoral studies. The

proportion of foreign students has been more than 50% in doctoral studies since the academic year of 2019/20. Comparing universities, the proportion of foreign students has increased the most at Tallinn University.

In terms of income, among the 2020 graduates of the ICT field of study, the graduates of TalTech's study programme group of databases had the highest income (ca 2,800 euros per month), and graduates of the Tallinn University software study programme group had the lowest income in 2021. The employment level was the highest among the graduates of TalTech's study programme group of ICT not elsewhere classified, and the lowest among the graduates of Tallinn University's software study programme group.

71% of the students who graduated from the ICT field of study in 2020 worked in the ICT sector and 29% in other sectors. The proportion of people employed in ICT-related positions was the highest among the graduates of the University of Tartu (83%), and the lowest among the graduates of Tallinn University (ca 57%).

Research and development activity

The funding of research and development (R&D) in the field of ICT is mostly project-based, similarly to the rest of Estonian research. Project reports are available to the public via the Estonian Research Information System (ETIS), where submitting data regarding projects is not consistent and uniform across institutions. Thus, the parameters included in this chapter may not reflect the situation of R&D to the full extent.

A substantial part of ICT-related R&D in the public sector is performed mainly in the three largest universities: Tallinn University of Technology, Tallinn University, and the University of Tartu. The analysis examines the indicators related to the funding of research projects, academic staff, and publications in detail.

The volume of ICT-related research projects has increased more than threefold compared to the beginning of the period (5.3 -> 17.9 million euros), 2016 was a low point for funding. The proportion of ICT among all research projects funded has increased consistently during the period, reaching a record high of 11% in 2021. Among the universities, the proportion of funding attributed to ICT was the largest at TalTech, reaching approximately 18–20% in the past few years. The proportion of funding attributed to the field of ICT at the University of Tartu has increased nearly threefold during the period (3% -> 11%). The proportion of the field of ICT at Tallinn University has fluctuated between *ca* 4 to14%. No trends emerge from the fluctuations of the period.

The volume of foreign funding has increased significantly during the past two years; while it was in the range of 1.3–2.4 million euros per year before, it amounted to 6.4 million euros in 2021. This considerable growth can be attributed to an increase in the volume of the University of Tartu's funding.

The volume of ICT projects funded by businesses has increased tens of times during the period: the volume was the smallest in the years 2014–2015 (approximately 50,000 euros), and the largest in 2021 (approximately 2.7 million euros).

The numbers concerning the academic staff directly involved in ICT-related research, were submitted by respective units of the universities in 2021. In total, 683 people were employed as academic staff in the field of ICT, the majority were doctoral students (326), followed by research fellows (105), and lecturers (98). TalTech had the largest academic staff in the field of ICT. Compared to last year, both the number of employees and fulltime equivalent have increased in all three universities.

In the current analysis, publications are divided into proceedings papers and articles. Their number and impact factor (ranking among the 10% of the world's most impactful publications based on the number of citations) is examined. The number of publications has varied to a great extent during the period observed, while it has increased compared to the beginning of the period. Comparing the universities, TalTech's researchers have published the largest number of proceedings papers during the period observed, while the proportion of the most impactful proceedings papers was the largest at the University of Tartu. Fewer articles were published compared to proceedings papers, the University of Tartu was the most successful considering both the number and impact.

I Studies in higher education

Summary

This chapter provides a brief overview of the main quantitative indicators of ICT studies at the level of higher education in the period of 2013–2022. It focuses on the examination of the proportion of the field of ICT compared to other fields of study, which educational institutions and which curricula it is possible to acquire ICT higher education; dynamics of admitted students and graduates across educational institutions and levels of education, the proportion of women in higher education in the field of ICT, and the labour market outcomes for higher education graduates. The source of data is the Estonian Education Information System (EHIS) and the employment register, the methodology has been described in more detail in Annex 1.

To a large extent, universities are entitled to specify the fields of study of their study programmes themselves, thus there are study programmes closely connected to ICT studies also in other fields of study beside the field of ICT: education 3; arts and humanities 4; engineering, manufacturing and construction 11; business, administration and law 6 (a list of study programmes has been provided in Annex 2). This is why the category of "Study programmes offering ICT studies", not "ICT field of study" has been used in exploring some of the features.

- The number of people studying at the level of higher education has decreased *ca* 30% over the period of 2013–2022, but increased in the field of ICT. The proportion of ICT students among all students has increased from *ca* 7% to nearly 11%. The increase in the number of ICT students is partly due to the increase in the number of foreign students.
- The ratio of graduates and admitted students is lower in the field of ICT compared to other fields of study, indicating that students discontinue studies more often in the field of ICT than in other fields of study. In general, it may be said that the lower the level of higher education, the higher the number of students discontinuing their studies. The proportion of students who discontinue their studies has decreased in the period observed, however, it remains higher compared to other fields of study.
- During the observed period, 10 educational institutions offered ICT-related education. Tallinn University of Technology (TalTech), the University of Tartu and Tallinn University being the largest in terms of the number of students. The number of students has increased in all three universities; the proportion of students admitted to the universities has changed during the period – the proportion of the University of Tartu and Tallinn University has increased, while TalTech's proportion has decreased (the proportions in the academic year of 2022/23 were 32%, 12%, and 56%, respectively); the proportion of graduates has not changed significantly (in conclusion, this demonstrates that the University of Tartu and Tallinn University have more students who discontinue their studies than TalTech).

- The proportion of women has varied greatly during the period observed, fluctuating between *ca* 10% and *ca* 68% in different categories. The proportion of women has increased in all groups of study programmes during the period, however, the level depends on the level of education – the proportion of women is the highest at the Master's level. The number of admitted students was analysed to specify how many women choose the ICT field of study. The proportion of women among students admitted at the level of higher education who pursue the ICT field of study has increased from *ca* 27% to 32%, while the proportion has decreased, for example in the fields of study of arts and humanities; health and welfare; business, administration and law.
- During the period, the proportion of foreign students has increased nearly fourfold, from *ca* 3% to 11 %; the proportion has increased the most at the level of doctoral studies. In comparison of the three largest educational institutions, the proportion of foreign students has increased the most at Tallinn University.
- The number of doctoral students has fluctuated during the period observed, while it has still increased during the past four academic years. The division of doctoral students between institutions has changed during the period; the share of TalTech has decreased (70% -> 45%), while the share of the University of Tartu and Tallinn University has increased (21% -> 38% and 9% -> 17%, respectively).
- In terms of income, among the 2020 graduates of the ICT field of study, graduates of TalTech's study programme group of databases had the highest income (*ca* 2,800 euros per month), and graduates of the Tallinn University software group had the lowest income in 2021. The employment level was the highest among the graduates of TalTech's study programme group of ICT not elsewhere classified, and the lowest among the graduates of the software group of Tallinn University.
- 71% of the students who graduated from the ICT field of study in 2020 worked in the ICT sector and 29% in other sectors. The proportion of people employed in ICT-related positions was the highest among the graduates of the University of Tartu (83%), and the lowest among the graduates of Tallinn University (*ca* 57%).

It is important to keep in mind general population dynamics when analysing the number of students. In the past five years, the number of 20–24-year-olds has been the lowest in the recent history of Estonia (Figure 3.1), and the downturn in also reflected in the number of students. The population pyramid also shows that the number of 20–24-year-olds will increase in the following ten years (age groups who are currently 15–19 and 10–14 will reach that age).

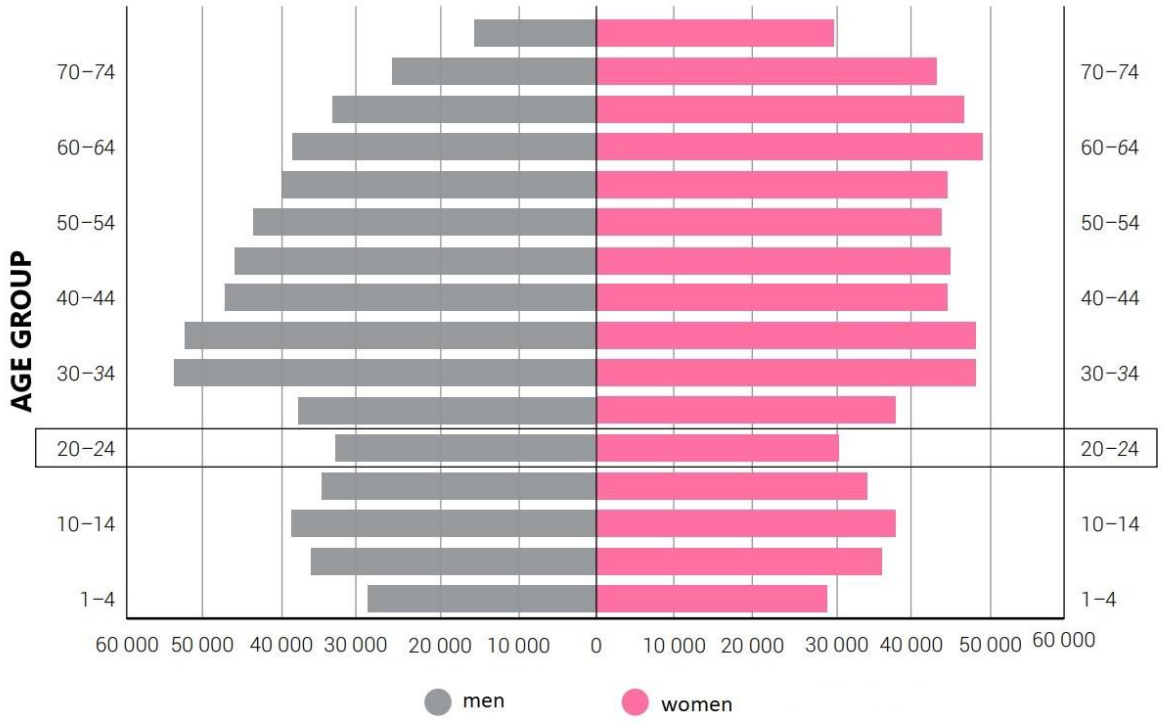


Figure 3.1. Estonia's population pyramid by age group in 2022. Source: Statistics Estonia, https://www.stat.ee/rahvastikupyramiid/

The five largest fields of study

In the chapter on applied higher education, the four largest fields of study were examined, since ICT ranks fourth in terms of the number of students (total figures during the period observed: engineering, manufacturing and construction: *ca* 94,500; services *ca* 54,800; business, administration and law *ca* 28,300; ICT *ca* 24,000).

At the level of higher education, however, **the ICT field of study ranks fifth in terms of the number of students** (total figures during the period observed: business, administration and law *ca* 107,400; engineering, manufacturing and construction: *ca* 75,600; arts and humanities *ca* 63,700; health and welfare *ca* 58,000; ICT *ca* 44,200). The field of study of arts and humanities ranks only sixth at the level of applied higher education, while the field of health and welfare ranks seventh. The field of study of services ranks ninth at the level of higher education.

The dynamics of the **number of students accepted differ** by field of study (Figure 3.2). During the period, the number of students accepted has decreased in the fields of study of engineering, manufacturing and construction, as well as business, administration and law. The number of students accepted has varied on a random basis in the fields of study of arts and humanities, and health and welfare. The indicator has been trending upwards in the ICT field of study during the period, but that tendency has not been consistent.

The dynamics of the **number of graduates** has been similar to the dynamics of the number of students admitted over the years, the academic years of 2017/18–2018/19 were a low period for nearly all fields of study (Figure 3.3). The number of graduates has been constantly increasing in the ICT field of study.

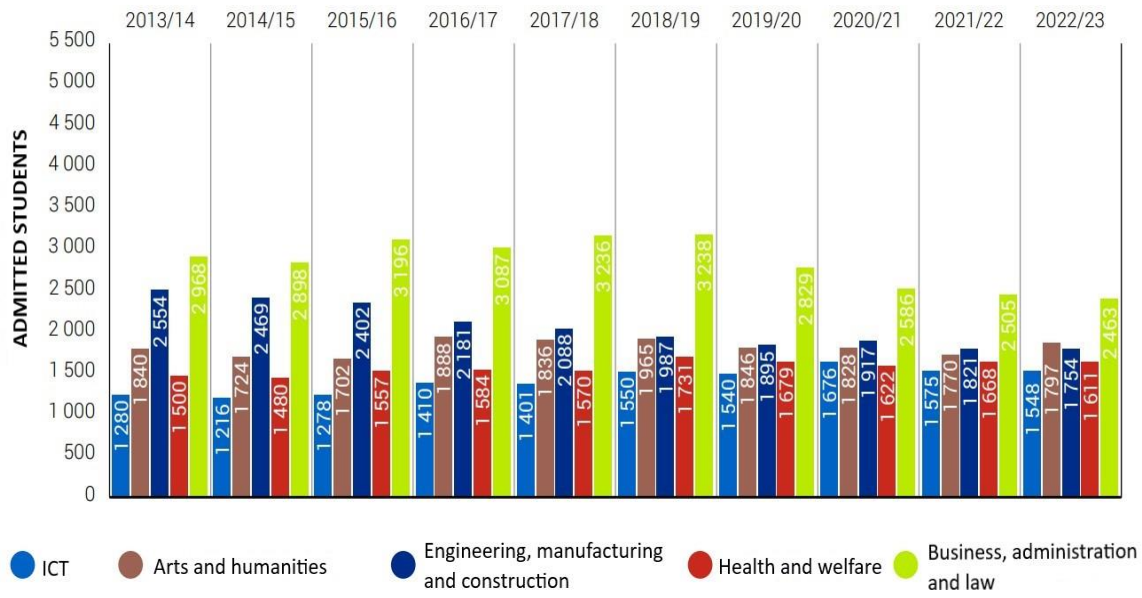


Figure 3.2. The number of students admitted in the five largest fields of study by academic years.

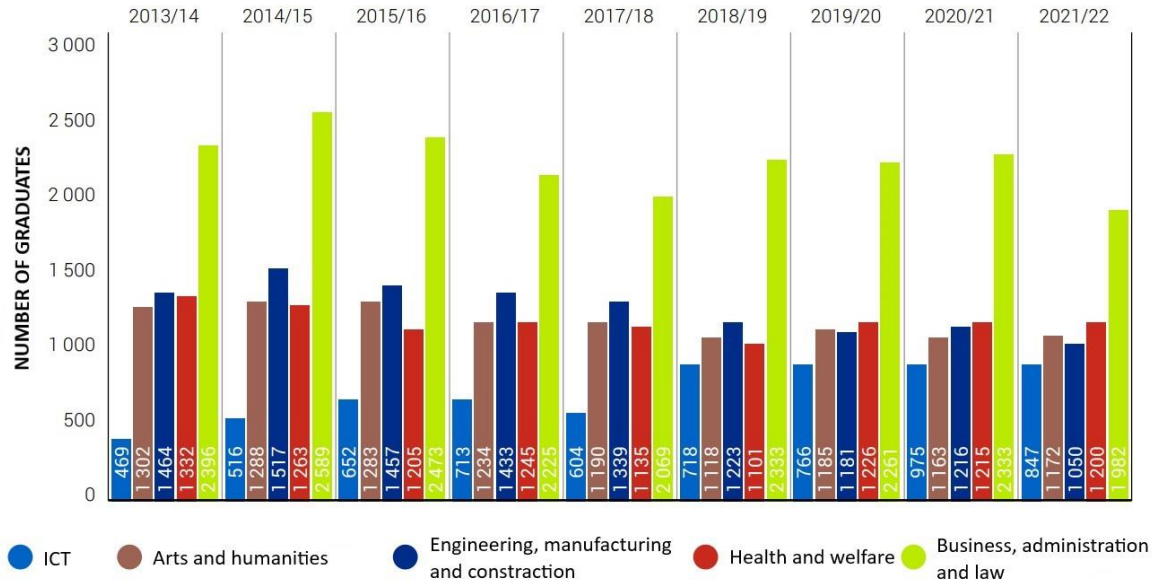


Figure 3.3. The number of graduates in the five largest fields of study by academic years.

The share of the ICT field of study in higher education

During the period, the **number of students enrolled at the level of higher education** has been consistently decreasing (Figure 3.4), the difference between the largest (*ca* 60,000, academic year of 2013/14) and smallest (*ca* 44,000, academic year of 2022/23) number is *ca* 27%. Such a decrease correlates with general population dynamics. The number of students in the ICT field of study decreased until the academic year of 2017/18, and has been increasing thereafter, having remained at the same level for the past two academic years. **The proportion of ICT students** among students of all fields of study has been consistently increasing during the period: the proportion was 7.1% in the

academic year of 2013/14, and 10.9% in the academic year of 2022/23. The proportion, as well as the number of students, has remained at the same level during the past three academic years, which gives reason to presume that the indicators have peaked, i.e., the proportion of the ICT field of study will not increase any further.

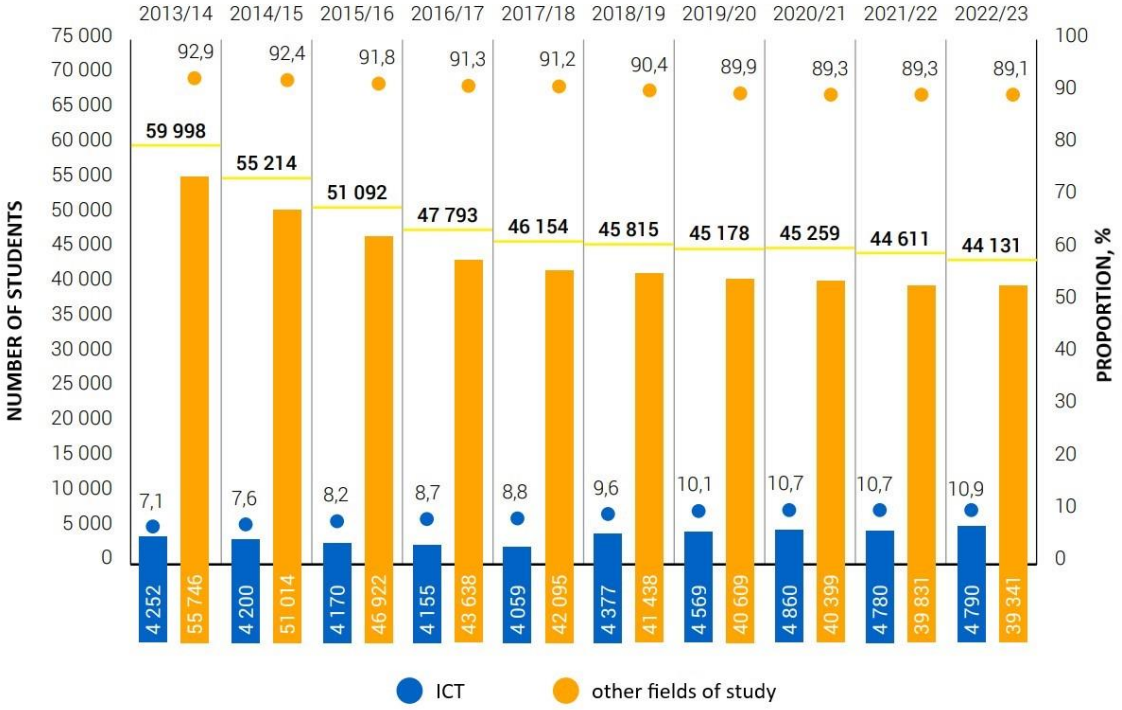


Figure 3.4. The number (columns) and proportion (dots) of students in the ICT field of study, and other fields of study by academic year. The total number per year has been marked with a yellow line.

The number of students admitted at the level of higher education in general has also decreased during the period, however, the corresponding figure has increased in the ICT field of study since the academic year of 2015/16 (Figure 3.5). **The proportion of the ICT field of study among the students admitted** has been consistently increasing during the period, while it has remained at the same level for the past two years. The dynamics of the number of graduates varies to a greater degree (Figure 3.6) – the number of graduates at the level of higher education was the lowest in the academic year of 2021/22, the indicator has been consistently decreasing during the period. The number of graduates has been trending upwards for nearly the entire period observed in the ICT field of study, having doubled by the academic year of 2020/21 compared to the beginning of the period. **The proportion of ICT graduates among the graduates in general** has also doubled during the period – 4.6% compared to 10%.

The proportion of ICT students among all students admitted has fluctuated in the range of *ca* 9–12%, while the proportion of graduates in the range of *ca* 5–10%, indicating that, compared to other fields of study, fewer students reach graduation in the field of ICT.

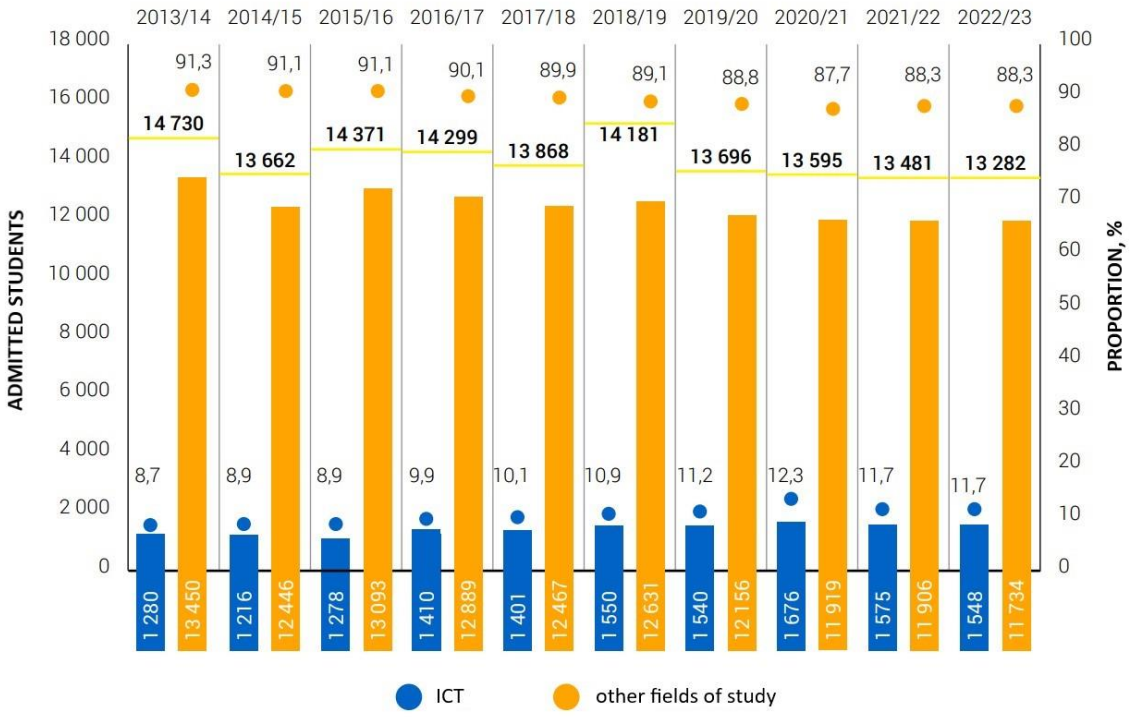


Figure 3.5. The number (columns) and proportion (dots) of students admitted in the ICT field of study, and other fields of study by academic year. The total number per year has been marked with a yellow line.

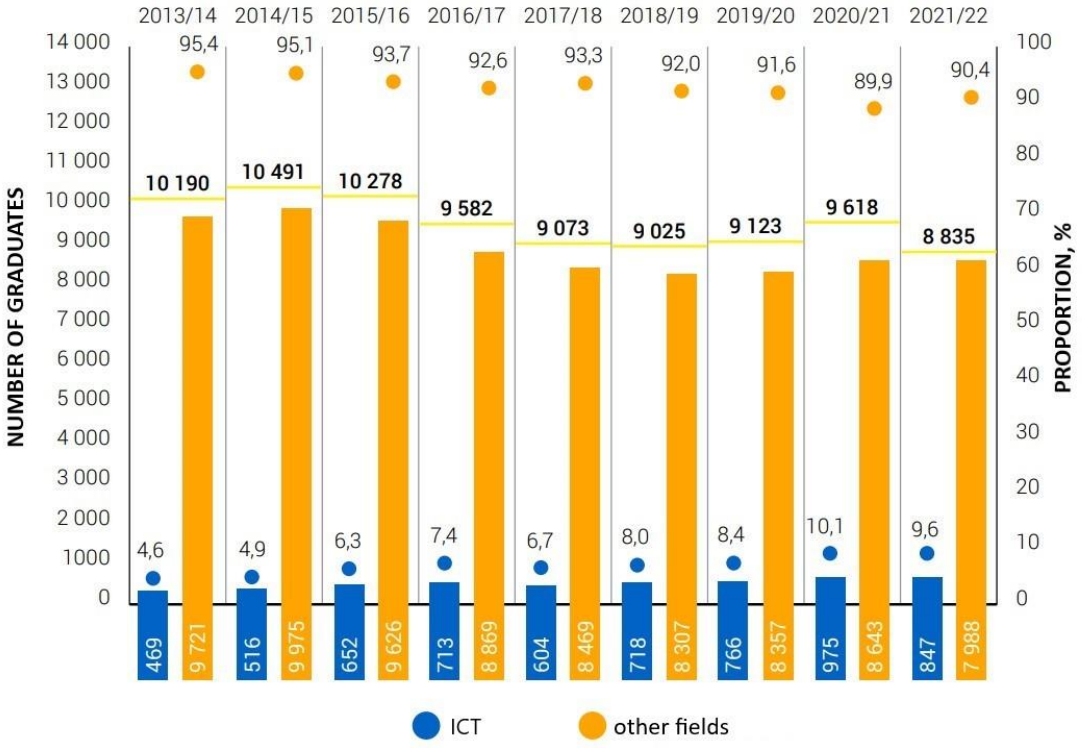


Figure 3.6. The number (columns) and proportion (dots) of graduates in the ICT field of study, and other fields of study by academic year. The total number per year has been marked with a yellow line.

Study programme groups in the ICT field of study

Study programmes in the ICT field of study are divided into five groups of study programmes: database and network design and administration (hereinafter 'databases'); software and applications development and analysis (hereinafter 'software'); 'computer use'; 'information and communications technology' (hereinafter 'interdisciplinary ICT') and communications technologies not elsewhere classified (hereinafter 'ICT not elsewhere classified').

The number of students has fluctuated in all study programme groups (Figure 3.7, rhombi). The number of students enrolled in the study programmes of databases and computer use has decreased during the period. The number of students enrolled in ICT study programmes not elsewhere classified has remained on a similar level. In terms of proportions, interdisciplinary ICT study programmes have undergone the greatest leap in view of the number of students – the growth has been approximately eightfold. In software study programmes that have the largest number of students enrolled compared to other study programmes, the number of students surged up in the academic year of 2018/19 and has been increasing thereafter.

The **proportion of women** among the students has varied greatly during the period observed, fluctuating between *ca* 10% and *ca* 68%. The proportion of women has increased in all groups of study programmes during the period; however, it greatly depends on the level of education (see next chapter). The proportion of women has been the largest in the study programme group of computer use and the lowest in the study programme group of databases during the entire period.

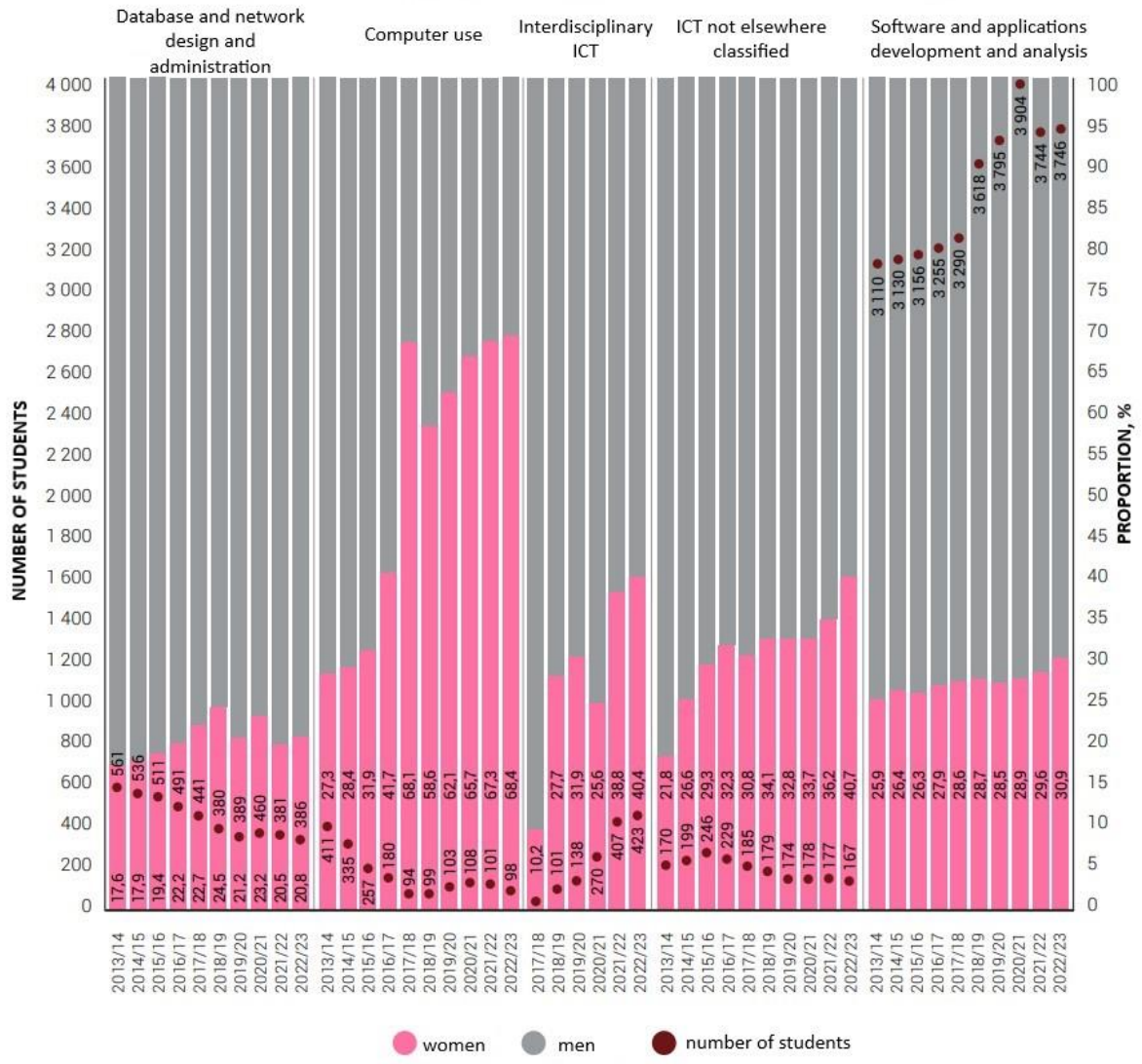


Figure 3.7. Number of students (rhombi) and distribution by gender (columns) in different study programme groups by academic years.

The number of students admitted was analysed to determine **how many women choose the ICT field of study.** The proportion of women among students admitted in the ICT field of study has increased from *ca* 27% to 32%, while the proportion has decreased for example in the fields of study of arts and humanities; health and welfare; business, administration and law (Figure 3.8). The proportion of women has increased in some study programme groups in the ICT field of study (Figure 3.9). A great increase in the proportion of women has occurred in the study programmes categorised under the study programme group of ICT not elsewhere classified – at the beginning of the period, *ca* 25% of the students admitted were women, while the corresponding figure was 60% at the end of the period. The proportion of women has also increased in the software and interdisciplinary ICT study programme group.

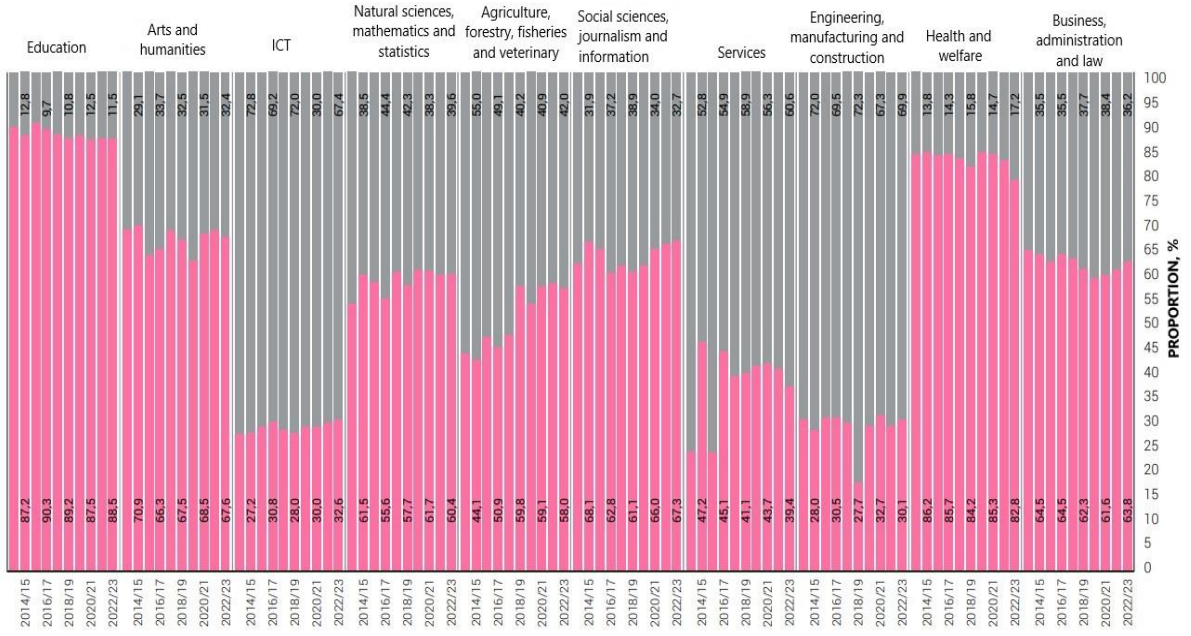


Figure 3.8. The gender distribution of students admitted in different fields of study by academic year

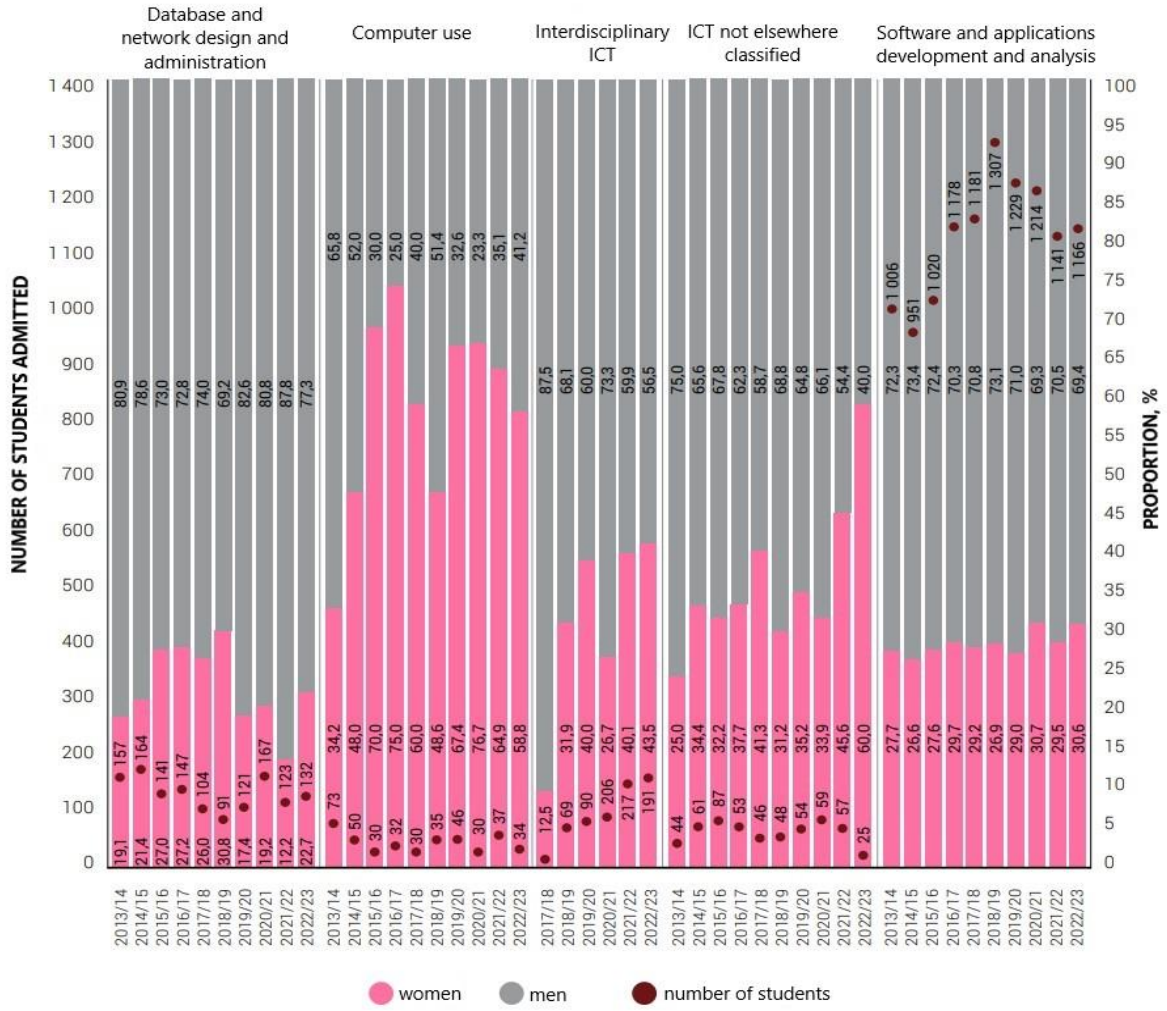


Figure 3.9. Number of students admitted (rhombi) and distribution by gender (columns) in different ICT study programme groups by academic year.

In order to compare indicators with studies in applied higher education, we will examine the **students admitted to and graduates of two study programme groups**, which were also analysed in the previous chapter.

The number of students admitted to the study programme of databases has fluctuated during the period, but no clear trend has emerged (Figure 3.10). The number of students admitted to the study programme of software increased until the academic year of 2018/19, thereafter, the figure has remained on the same level and declined slightly. The number of graduates correlates with the changes in the number of students admitted over time.

At the level of applied higher education, the number of students admitted to the study programme of databases has increased in the previous academic years and decreased in the study programme of software (Figure 2.8).

Compared to the level of higher education, the number of both admittees and graduates are in reverse – in applied higher education, more people are enrolled in the study programmes of databases, while there are more people enrolled in the study programmes of software at the level of higher education.

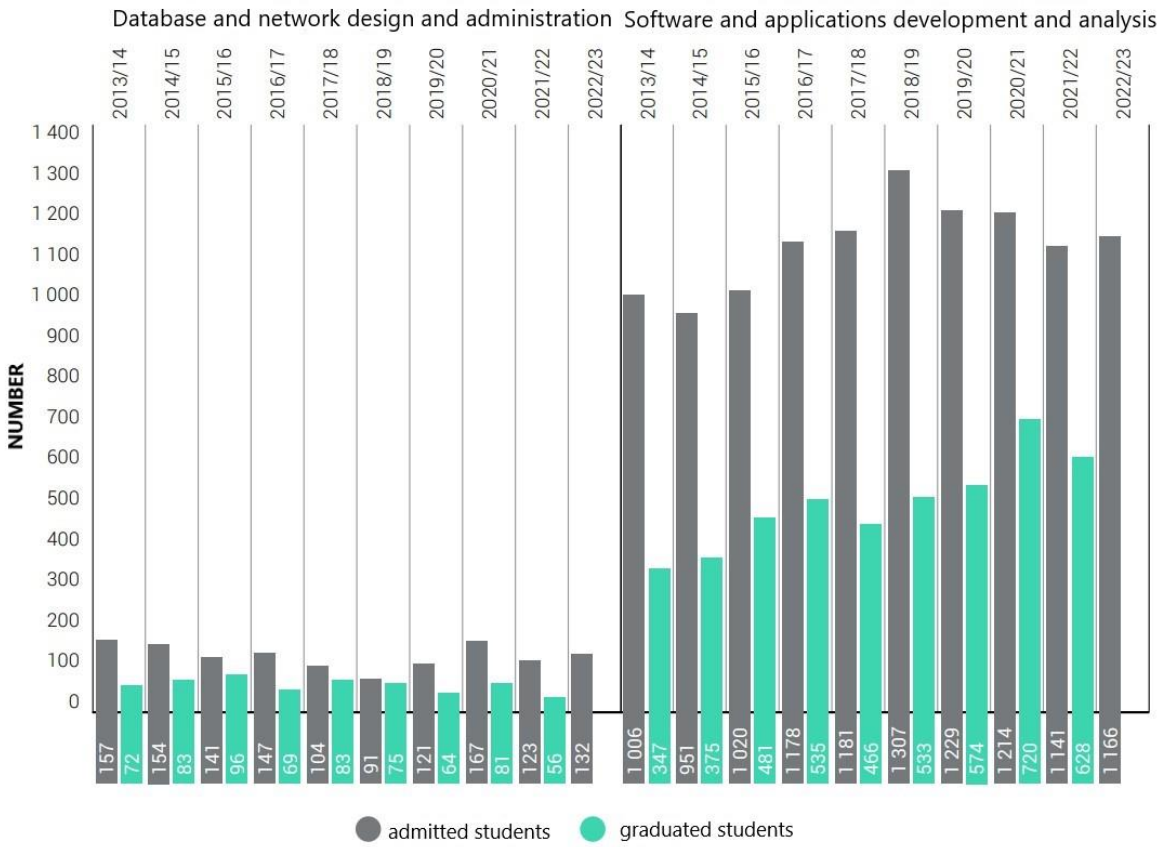


Figure 3.10. Comparison of the number of admittees and graduates in different groups of study programmes by academic year

Levels of education in the ICT field of study

All four levels of higher education are represented in the ICT field of study only in the software study programme group (Table 3.1). When we examine all the study programme groups together and look at the **number of students** across levels of education, the number has increased the most at the Master's and Bachelor's level, while it has decreased drastically (more than threefold) at the level of applied higher education and remained at the same level in doctoral studies.

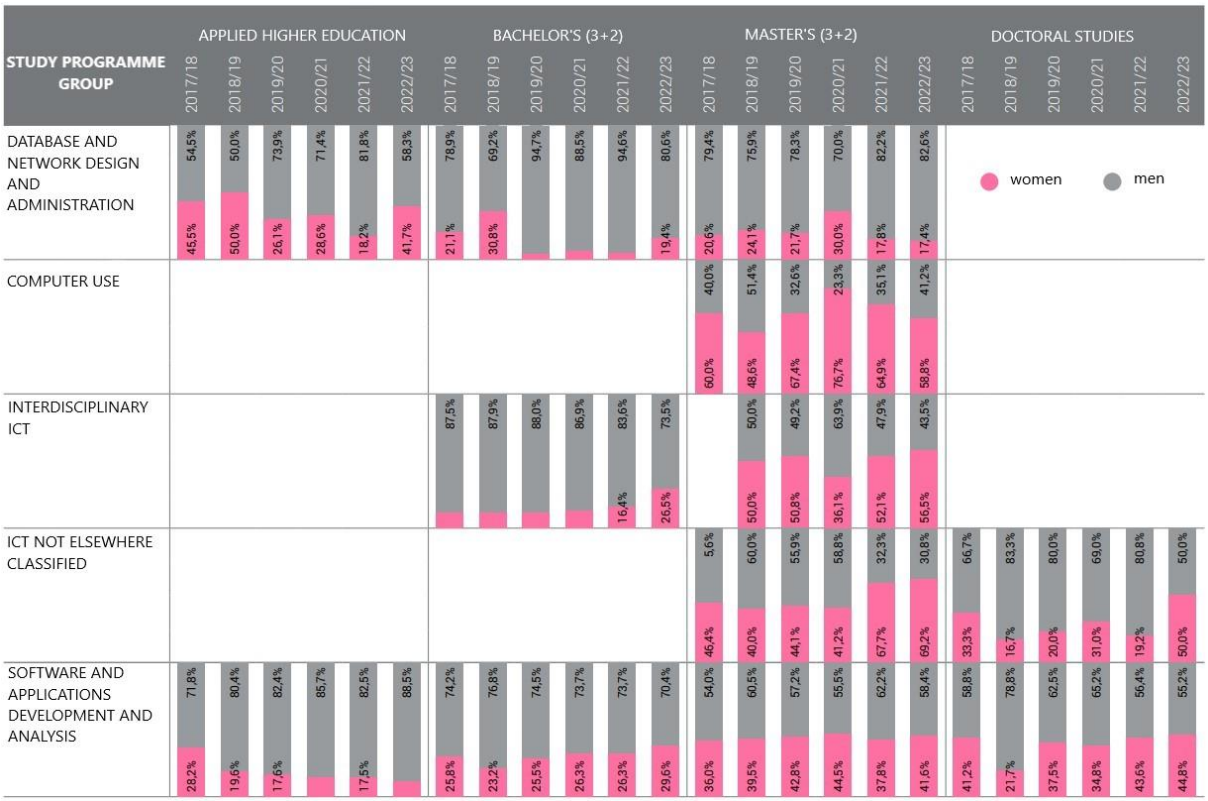
Table 3.1. The number of students at different levels of education in various study programme groups by academic year

STUDY PROGRAMME GROUP	LEVEL OF EDUCATION	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
DATABASE AND NETWORK DESIGN AND ADMINISTRATION	APPLIED HIGHER EDUCATION	428	368	303	287	216	157	119	96	73	75
	BACHELOR'S (3+2)					21	27	59	136	140	144
	MASTER'S (3+2)	133	168	208	204	204	196	181	168	138	137
	TOTAL	**561**	**536**	**511**	**491**	**441**	**380**	**359**	**400**	**351**	**356**
COMPUTER USE	APPLIED HIGHER EDUCATION	371	294	205	107	4	2				
	MASTER'S (3+2)	40	41	52	73	90	97	103	108	101	98
	TOTAL	**411**	**335**	**257**	**180**	**94**	**99**	**103**	**108**	**101**	**98**
INTERDISCIPLINARY ICT	BACHELOR'S (3+2)					49	65	73	138	148	172
	MASTER'S (3+2)						36	65	132	259	251
	TOTAL					**49**	**101**	**138**	**270**	**407**	**423**
ICT NOT ELSEWHERE CLASSIFIED	APPLIED HIGHER EDUCATION			34	38	24	20	11	6	6	
	MASTER'S (3+2)	24	54	77	76	62	71	76	63	55	55
	DOCTORAL STUDIES	146	145	135	115	99	88	87	109	116	112
	TOTAL	**170**	**199**	**246**	**229**	**185**	**179**	**174**	**178**	**177**	**167**
SOFTWARE AND APPLICATIONS DEVELOPMENT AND ANALYSIS	APPLIED HIGHER EDUCATION	790	798	831	903	739	718	650	586	410	372
	BACHELOR'S (3+2)	1 660	1 667	1 652	1 623	1 708	1 960	2 147	2 238	2 209	2 344
	MASTER'S (3+2)	596	585	589	638	751	844	897	975	991	893
	DOCTORAL STUDIES	64	80	84	91	92	96	101	105	134	137
	TOTAL	**3 110**	**3 130**	**3 156**	**3 255**	**3 290**	**3 618**	**3 795**	**3 904**	**3 744**	**3 746**
TOTAL		**4 252**	**4 200**	**4 170**	**4 155**	**4 059**	**4 377**	**4 569**	**4 860**	**4 780**	**4 790**

The proportion of women among the students admitted is the highest at the level of Master's studies (table 3.2), where the proportion of women among the admittees of the computer use study programme group has fluctuated in the range of *ca* 50–77% and in the range of *ca* 40–69% in the study programme group of ICT not elsewhere classified.

When we examine all the study programme groups together, the proportion of women among the admittees of the past six years has significantly increased at the level of Master's studies (36%->45%) and doctoral studies (20%->46%); it has decreased in applied higher education (31%->17%) and remained the same at the level of Bachelor's studies (23%->28%).

Table 3.2. The gender distribution of admittees at different levels of education by study programme group (in the academic years of 2017/18–2022/23).



Educational institutions and study programmes

Besides study programmes offering ICT studies, other fields of study also provide ICT study programmes (education 3; arts and humanities 4; engineering, manufacturing and construction 11; business, administration and law 6. A list of study programmes is available in Annex 2), therefore, the category of "Study programmes offering ICT studies", not "Field of ICT" has been used in exploring some of the features. To a large extent, universities are entitled to specify the fields of study of their study programmes themselves, thus there are study programmes closely connected to ICT studies in different fields.

During the period observed, **10 educational institutions that provide higher education** have offered ICT studies (in the corresponding study programmes of five fields of study) (Table 3.3), Tallinn University of Technology (TalTech) being the largest in terms of the number of students.

Table 3.3. Educational institutions providing higher education in the field of ICT. The total number of students at different levels of education in the academic years of 2013/14–2022/23.

INSTITUTION	LEVEL OF EDUCATION				
	APPLIED HIGHER EDUCATION	BACHELOR'S (3+2)	MASTER'S (3+2)	DOCTORAL STUDIES	TOTAL
Computer College	291				**291**
Estonian Entrepreneurship University of Applied Sciences (Mainor)	1 644		5		**1 644**
IT College	3 562				**3 562**
Estonian Academy of Arts		413	189		**602**
Lääne-Viru University of Applied Sciences	296				**296**
TTK University of Applied Sciences	389				**389**
Tallinn University	675	2 494	2 243	326	**5 7381**
TalTech	3 593	15 022	9 199	1 152	**28 966**
University of Tartu	540	6 602	4 623	663	**12 428**
Võru County Vocational Training Centre	130				**130**
TOTAL	**11 120**	**24 531**	**16 254**	**2 141**	**54 046**

The total **number of students** in **the three largest educational institutions** – TalTech, Tallinn University and the University of Tartu – has increased during the period observed (Figure 3.11). The number of students at TalTech increased significantly during the academic year of 2017/18 owing to the fact that the Estonian Information Technology College merged with the university. At the University of Tartu, the number of students has doubled during the period, and the corresponding figure has increased by half at Tallinn University. The proportions held by the universities relative to one another have changed during the period: TalTech's proportion has decreased by nearly 10 percentage points, the University of Tartu's proportion has increased by nearly 10 percentage points.

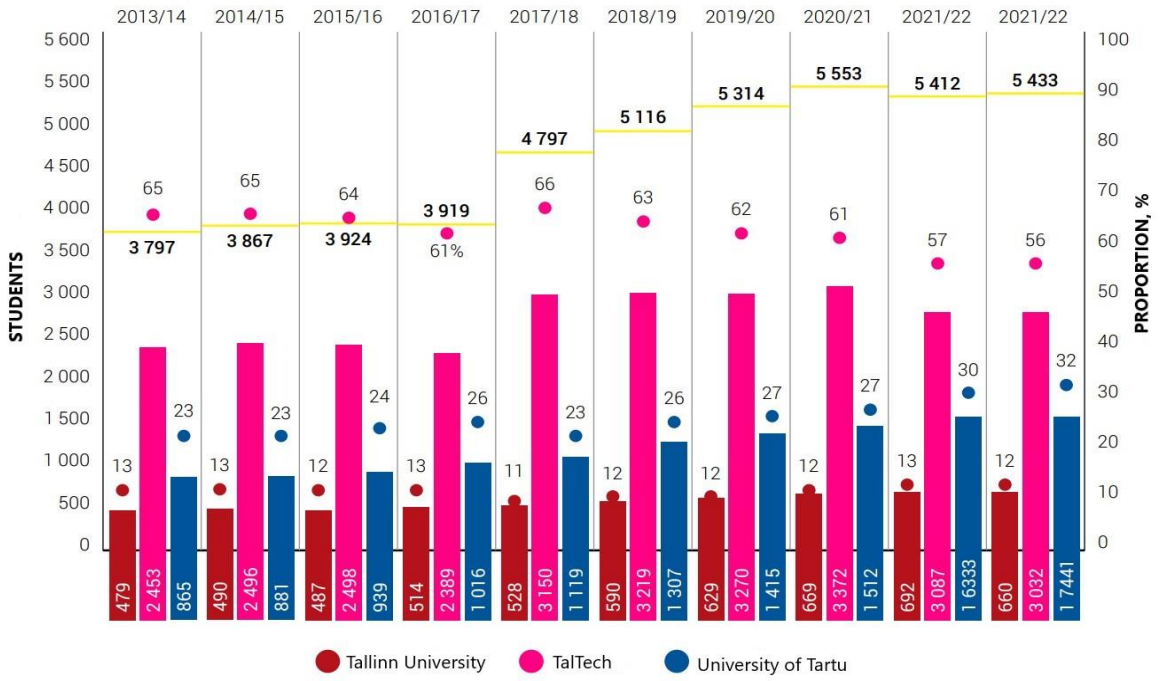


Figure 3.11. The number of students (columns) and proportions (dots) at the three largest educational institutions by academic year.

The number of students admitted has increased consistently at the University of Tartu; the number of admittees has been fluctuating at TalTech but it has still increased over the period; the indicator has also fluctuated at Tallinn University, but no clear trend has emerged from the period (Figure 3.12). The distribution of admittees between the universities has changed during the period – TalTech's proportion has decreased, Tallinn University's proportion has remained more or less the same and the University of Tartu's proportion has increased.

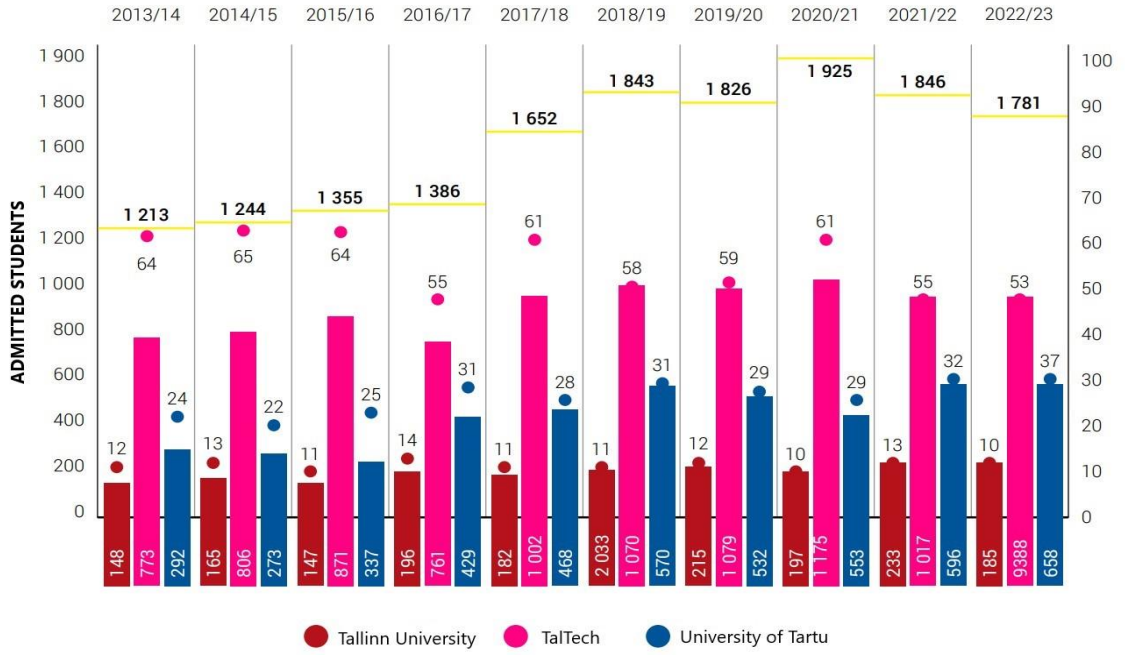


Figure 3.12. The number of students (columns) and proportions (dots) at the three largest educational institutions by academic year. The total number per academic year has been marked with a yellow line.

The distribution of admittees between universities in across different levels of education has varied during the past five academic years (Figure 3.13). The largest number of students at the level of applied higher education have been admitted at TalTech, however, TalTech's proportion at this level of education has been consistently decreasing. No significant changes have occurred in the distribution of students between institutions at the Bachelor's level. At the Master's level, TalTech's share has also decreased, while the share of the rest of the universities increased. At the level of doctoral studies, TalTech's share is also decreasing, while the University of Tartu's share is increasing.

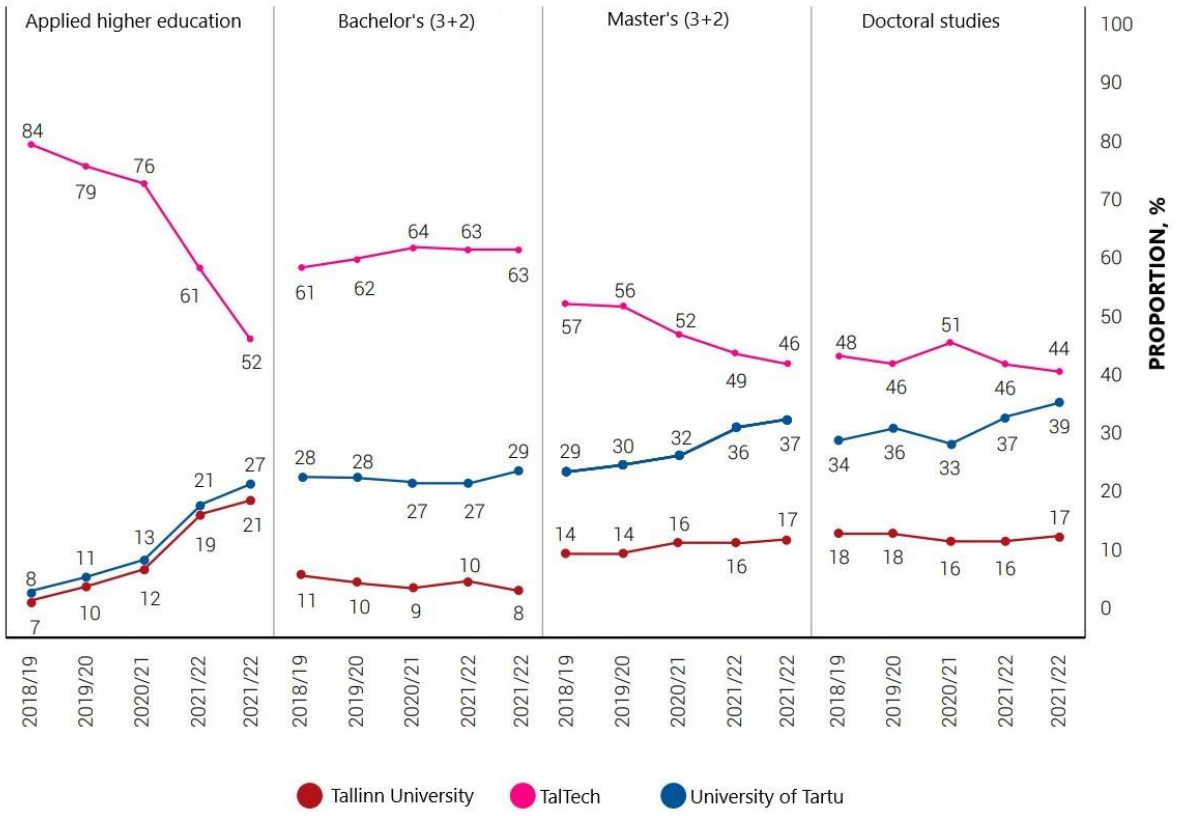


Figure 3.13. Distribution of admittees between the three largest educational institutions at different levels of education during the past five academic years.

The total number of graduates has been consistently increasing at the three largest educational institutions (Figure 3.14), the difference between the smallest (456, academic year of 2013/14) and the largest number (1,143, academic year of 2020/21) during the period is *ca* 2.5-fold. Tallinn University has also undergone the greatest relative growth, while it has been the smallest at TalTech. The distribution of graduates between universities has varied during the period, however, in general the proportions have remained more or less the same.

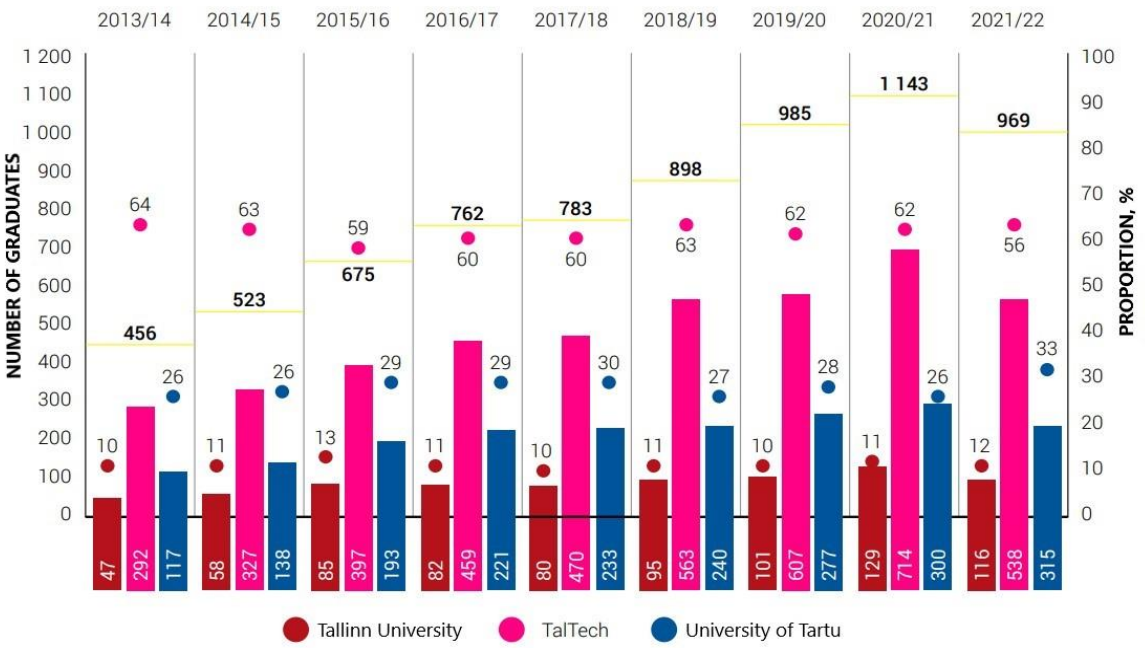


Figure 3.14. The number (columns) and proportion (dots) of graduates at the three largest educational institutions by academic year. The total number per academic year has been marked with a yellow line.

If we analyse the **ratio of graduates to admittees** (Figure 3.15) in total during the previous six academic years, it becomes clear that the greatest number of admittees reached graduation in TalTech at the level of applied higher education in view of the levels of education (excluding doctoral studies, since that level is explored separately below) and educational institutions. The smallest number of admittees in all the universities reaches graduation at the Bachelor's level.

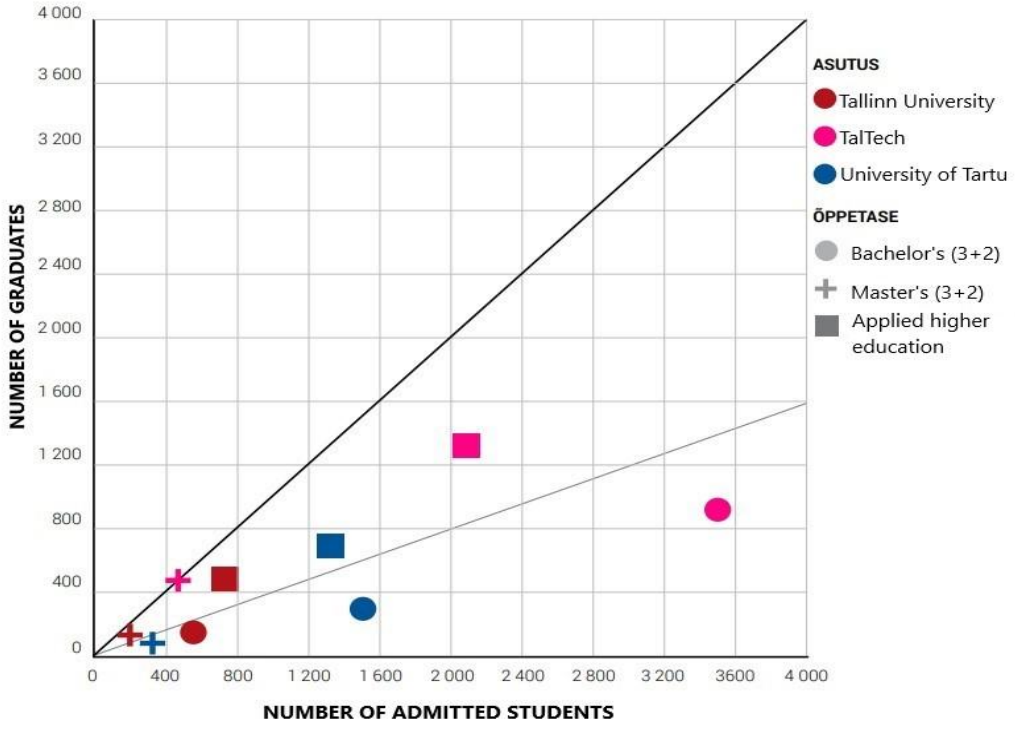


Figure 3.15. The ratio of the total number of admittees to graduates by levels of education and institutions in the academic years of 2017/18–2022/23. The dark grey line represents the hypothetical

situation where all admittees would graduate. The light grey line reflects actual data (it is a fitted model line that is positioned so that the distance between the line and all data points would be as small as possible).

81 study programmes, in which students have been enrolled in the period from 2013 to 2022 (students have not been enrolled in all study programmes each year), have been included in this analysis. Besides the *study programmes offering ICT studies*, other fields of study also provide ICT study programmes: education (number of study programmes: 3); arts and humanities (4); engineering, manufacturing and construction (12); business, administration and law (6). A list of the study programmes is available in Annex 2.

The total **number of study programmes** in all educational institutions during the period observed has fluctuated between 44–60 per academic year (Table 3.4). The number of study programmes has increased on all levels of education. The number of study programmes has increased at all educational institutions where students are enrolled in study programmes, however, at TalTech, the number of study programmes decreased in the academic year of 2021/22 (mainly at the level of Bachelor's studies and applied higher education).

Table 3.4. The number of study programmes at different levels of education by academic year.

STUDY PROGRAMME GROUP	LEVEL OF EDUCATION	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
EDUCATION	MASTER'S (3+2)	1 1	1 1	1 1	1 1	1 2	1 2	1 2	1 2	1 2	1 2
ARTS AND HUMANITIES	APPLIED HIGHER EDUCATION				1	2	2	2	2	2	2
	BACHELOR'S (3+2)	1	1	1	1	1	1	1	1	1	1
	MASTER'S (3+2)				1	1	1	1	1	1	1
ICT	APPLIED HIGHER EDUCATION	2 2 4	2 2 4	2 2 5 1 2	2 2 5	2 1 7 1	3 1 7 1	2 1 7 1	2 1 7 1	2 1 3 1	2 1 1 1
	BACHELOR'S (3+2)	1 2 2	1 2 2	1 2 2	1 2 1	1 8 1	1 8 1	1 8 1	1 8 1	1 6 1	1 6 1
	MASTER'S (3+2)	3 4 3	3 4 3	3 4 4	3 4 4	3 5 4	3 6 3	4 6 3	5 7 4	5 8 4	5 7 4
	DOCTORAL STUDIES	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 2 2
ENGINEERING, MANUFACTURING AND CONSTRUCTION	BACHELOR'S (3+2)	3 1	3 1	3 1	3 1	4 1	3 1	3 1	3 1	1 1	1 1
	MASTER'S (3+2)	4 1	4 1	4 2	4 2	4 2	4 1	4 1	4 1	2 1	2 1
	DOCTORAL STUDIES										1
BUSINESS, ADMINISTRATION AND LAW	APPLIED HIGHER EDUCATION	1	1	1	1	1	1	2	2	2	2
	MASTER'S (3+2)	1 1	1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1	1 1 1

Computer College
Estonian Entrepreneurship University of Applied Sciences (Mainor)
IT College
Estonian Academy of Arts
Lääne-Viru University of Applied Sciences
TTK University of Applied Sciences
Tallinn University
TalTech
University of Tartu
Võru County Vocational Training Centre

Foreign students

The number of foreign students enrolled in studies of higher education in Estonia has increased nearly 2.5 times during the period observed (*ca* 2,200 -> 5,500) and the corresponding proportion has increased nearly fivefold (Figure 3.16). In the ICT field of study, the proportion of foreign students has been greater than in other fields of study on average during the entire period (the proportion has been the greatest in the field of study of business, administration and law). The proportion has increased more in the ICT field of study compared to other fields of study – at the beginning of the period, foreign students amounted to *ca* 3%, while the corresponding figure is currently *ca* 14% .

In **the ICT field of study,** the **proportion of foreign students** is the highest in doctoral studies if we compare all levels of education (Figure 3.17). The level of doctoral studies and applied higher education have seen the greatest growth, as the proportion of foreign students started to increase significantly at these levels in the academic years of 2017/18–2018/19.

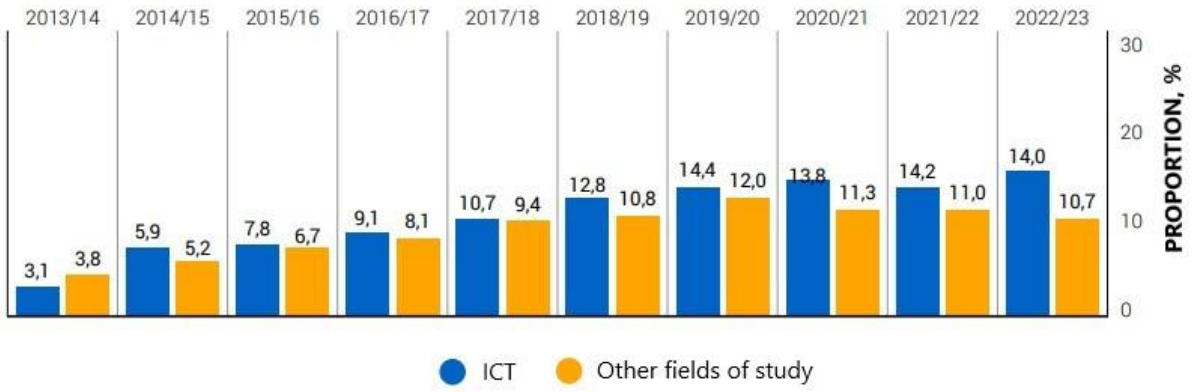


Figure 3.16. The proportion of foreign students in different fields of study by academic year.

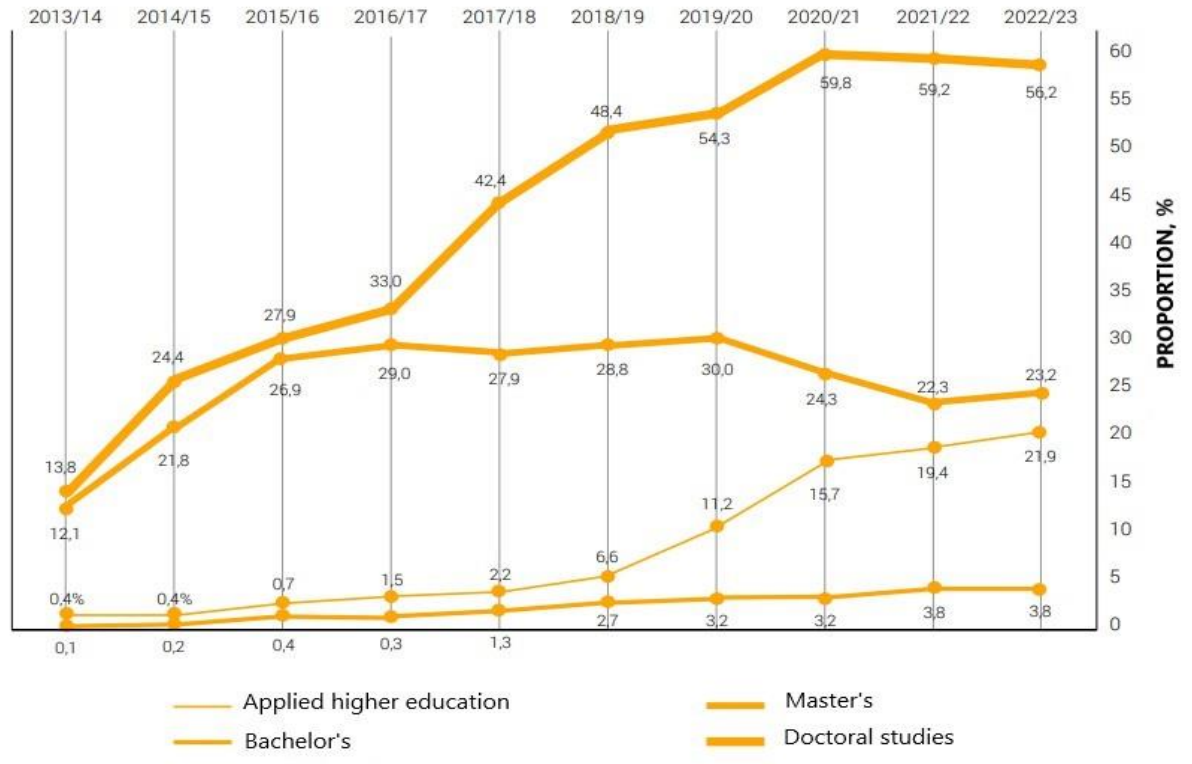


Figure 3.17. The proportion of foreign students at different levels of education in the ICT field of study by academic year.

In study programmes providing ICT studies, the proportion of foreign students has been the highest in the field of study of education; arts and humanities; business, administration and law, and the lowest in the ICT field of study (Figure 3.18). The proportion of foreign students enrolled in the study programmes of engineering, manufacturing and construction has significantly decreased in the past five academic years.

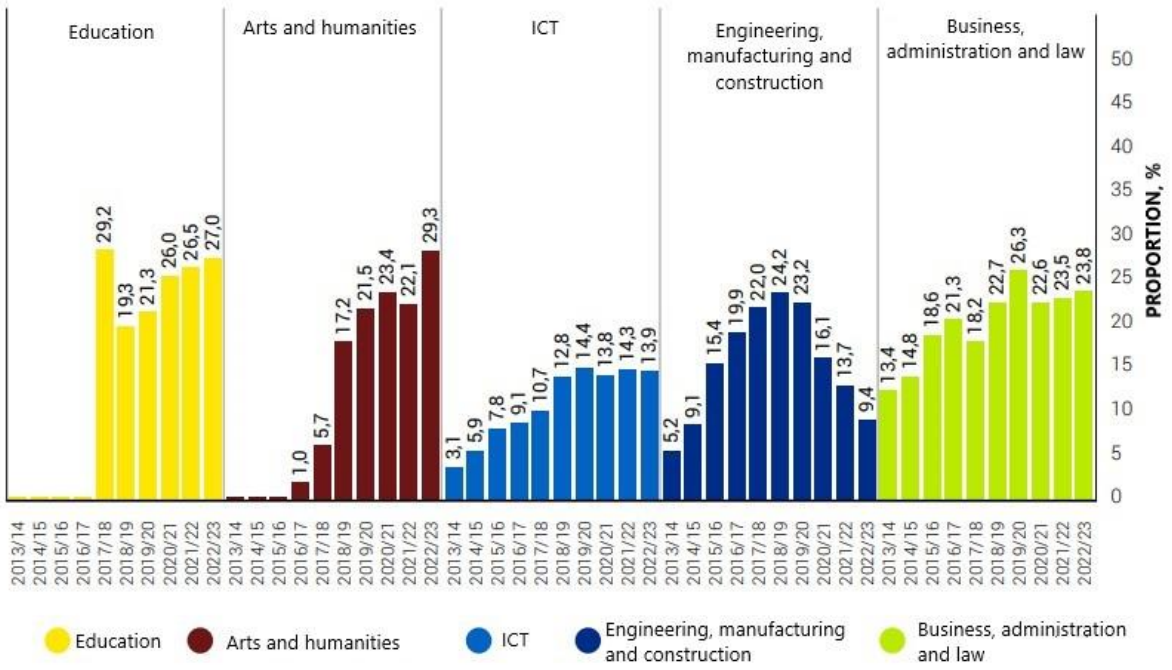


Figure 3.18. The proportion of foreign students in different fields of study providing ICT studies by academic year.

Comparing the **three largest educational institutions,** the **number of foreign students** enrolled in study programmes offering ICT studies has increased at the University of Tartu and Tallinn University during the entire period, while the corresponding number has decreased in TalTech during the past three academic years (Figure 3.19).

The proportion of foreign students enrolled in study programmes offering ICT studies has increased the most at Tallinn University during the period. The proportion has remained more or less at the same level at TalTech, while the proportion increased at the University of Tartu until the academic year of 2018/19 and has remained at the same level since then.

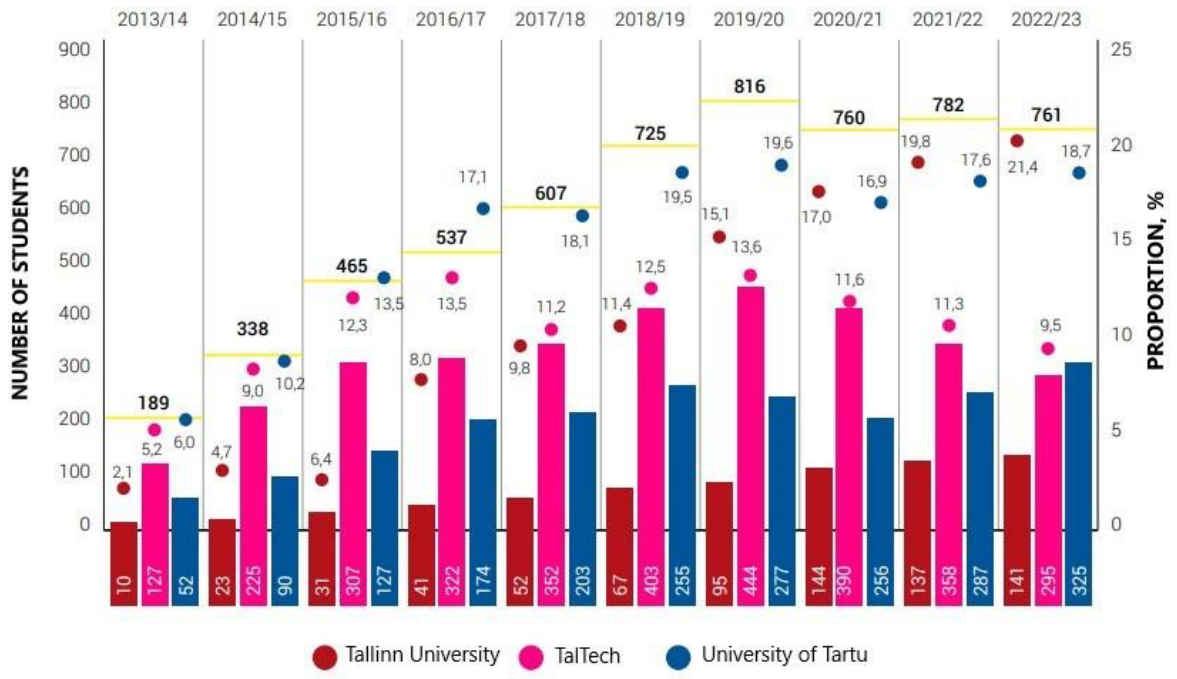


Figure 3.19. The number (columns) and proportions (dots) of foreign students enrolled in study programmes providing ICT studies at the three largest educational institutions by academic year. The total number per academic year has been marked with a yellow line.

Doctoral studies

When calculating the duration of doctoral studies, numbers of graduates as external students are excluded, as their study time may be short, for example 1 month, which significantly affects the calculation of the average.

A PhD can be acquired in the ICT field of study in three universities in Estonia. **The number of doctoral students** has fluctuated during the period observed, while it has still consistently increased during the past four academic years (Figure 3.20). The division of doctoral students between institutions has changed during the period; the share of TalTech has decreased (70% -> 45%), while the share of the University of Tartu and Tallinn University has increased (21% -> 38% and 9% -> 17%, respectively).

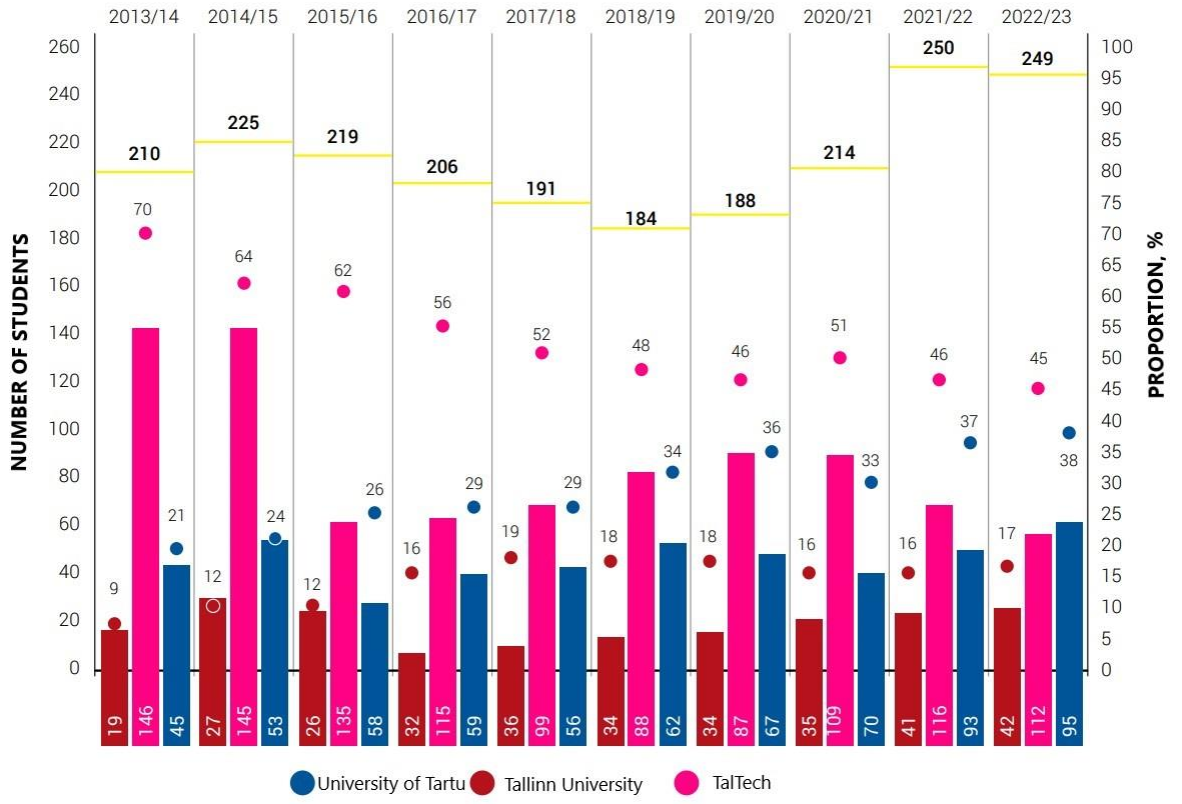


Figure 3.20. The number (columns) and proportion (dots) of doctoral students at the three educational institutions by academic year.

The average **duration of doctoral studies** in the ICT field of study fluctuated and was more similar to the average of other fields of study up to the academic year of 2017/18, thereafter, it has been shorter (Figure 3.21).

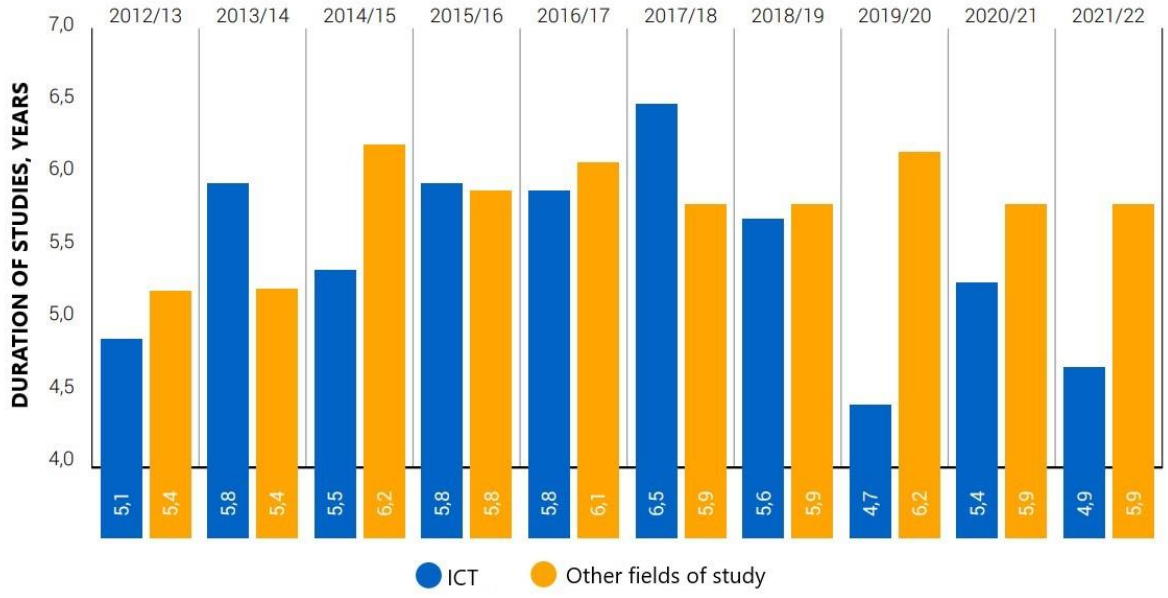


Figure 3.21. The duration of doctoral studies in the ICT field and other fields of study by academic year.

The analysis of the duration of doctoral studies in the three educational institutions has been divided into groups of three academic years due to the small amount of data. The University of Tartu clearly stands out since the average duration of studies there is shorter than in other institutions (Table 3.5). There is a temporal trend towards the shortening of studies as well at the University of Tartu.

Table 3.5. The number of graduates of doctoral studies and the average duration of doctoral studies.

INSTITUTION	PERIOD	PHD GRADUATES	AVERAGE DURATION OF DOCTORAL STUDIES
TalTech	2013/14 – 2015/16	31,00	6,00
	2016/17 – 2018/19	37,00	6,90
	2019/20 – 2021/22	32,00	5,20
	PERIOD KOKKU	**100,00**	**6,00**
TALLINN UNIVERSITY	2013/14 – 2015/16		
	2016/17 – 2018/19	10,00	5,00
	2019/20 – 2021/22	5,00	5,60
	PERIOD KOKKU	**15,00**	**5,20**
UNIVERSITY OF TARTU	2013/14 – 2015/16	9,00	4,80
	2016/17 – 2018/19	16,00	4,70
	2019/20 – 2021/22	15,00	4,50
	PERIOD KOKKU	**40,00**	**4,70**

The **age distribution** of students who completed a PhD has changed during the period (Figure 3.22). The share of the youngest age group (25–29 years) has been gradually decreasing, while no clear trend emerges with regard to the proportions of the other age groups.

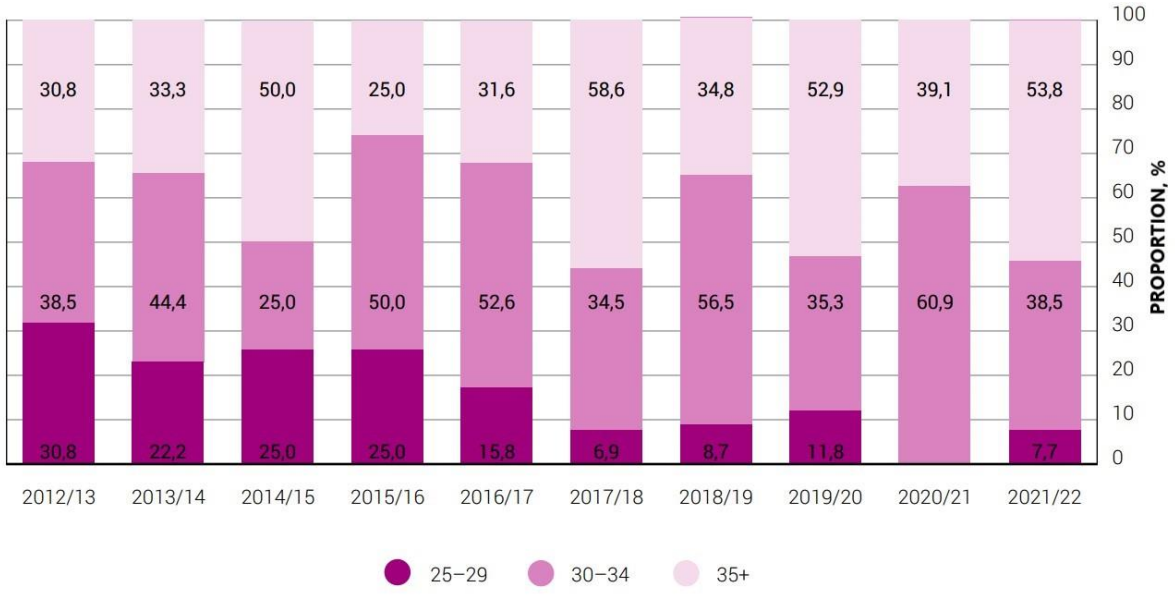


Figure 3.22. The distribution of PhD graduates between age groups by academic year.

The **gender distribution** of PhD graduates has changed significantly during the period, since the number of women is small (Figure 3.23). The proportion of women has increased but not uniformly so. The proportion of women among the students admitted to doctoral studies varies to a great extent from university to university (Figure 3.24), only at TalTech have there been women among the admittees in every academic year during the period.

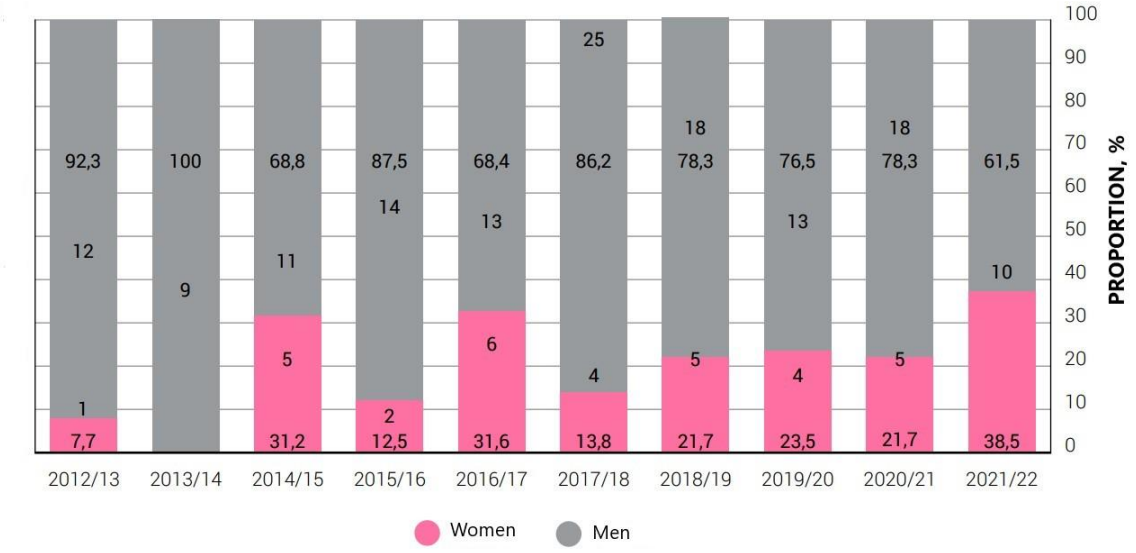


Figure 3.23. The gender distribution of PhD graduates by academic year.

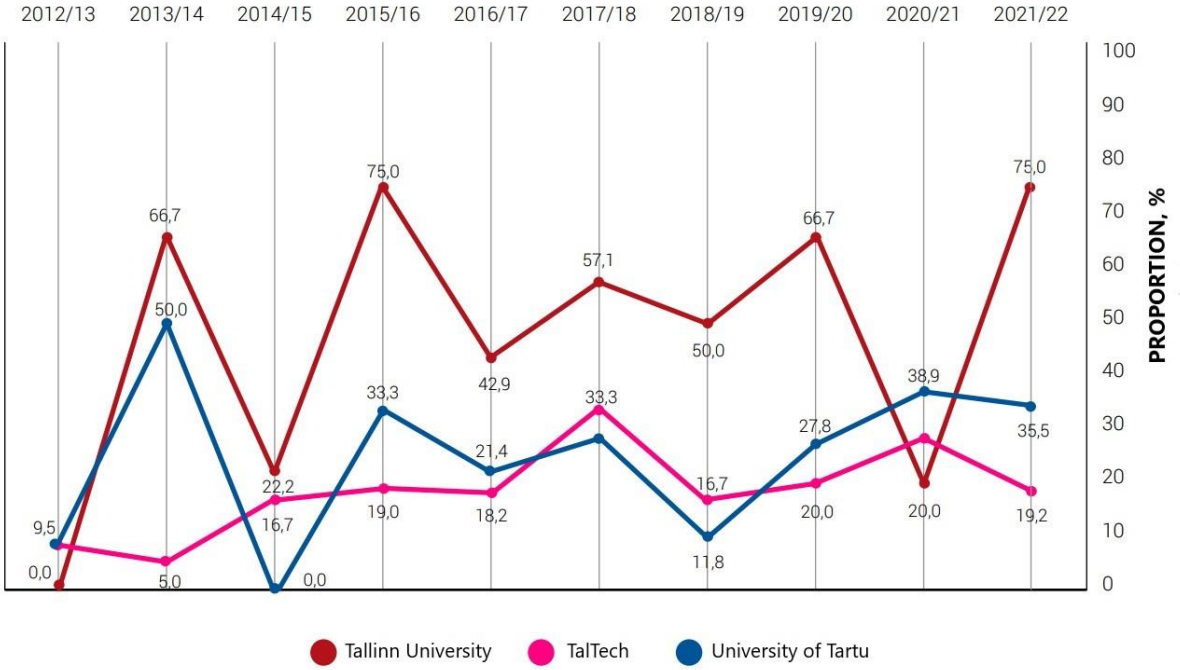


Figure 3.24. The gender distribution of students admitted to doctoral studies in different educational institutions by academic year.

Discontinuing and further studies

The **proportion of students who discontinue their studies** has been always higher in the ICT field of studies compared to all the other fields of study in total[1] (Figure 3.25). The people who are admitted to a study programme but who actually do not start their studies are also considered to have discontinued their studies. The proportion of students discontinuing their studies has decreased in all fields of study during the period.

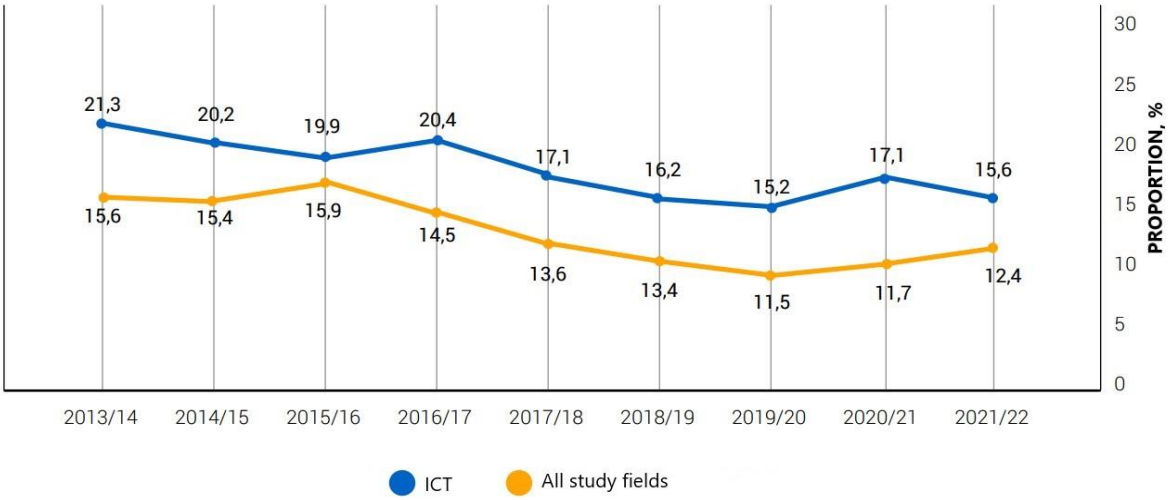


Figure 3.25. The proportion of students who discontinue their studies by academic year.

The **proportion of students who discontinue their studies during the first year** has been systematically higher in the ICT field of studies compared to all the other fields of study in total (Figure 3.26). With this this indicator, it is also apparent that the proportion has decreased in all the fields of study during the period. A larger proportion of students discontinue their studies during the first year compared to the rest of their years of study.

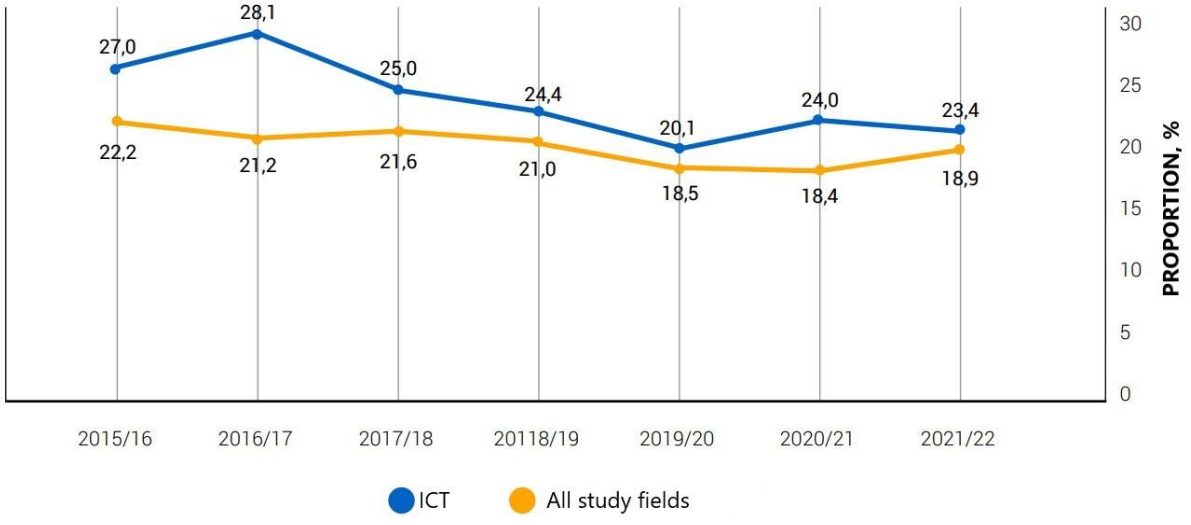


Figure 3.26. The proportion of students who discontinue their studies during the first year of studies broken down by academic year.

[1] The "total" category also includes the ICT field of study.

If **we compare the three universities,** the proportion of students discontinuing their studies has been the lowest at the University of Tartu and the highest at TalTech during the period (Figure 3.27). The proportion of students discontinuing their studies is rather trending downwards at the University of Tartu and Tallinn University, no clear trend emerges at TalTech.

The proportion of students who discontinue their studies during the first year is significantly higher at TalTech (Figure 3.28). Depending on the academic year, the proportion is the lowest either at Tallinn University or the University of Tartu. The proportion trended downwards at Tallinn University during the period, while no clear trend emerged in the other institutions.

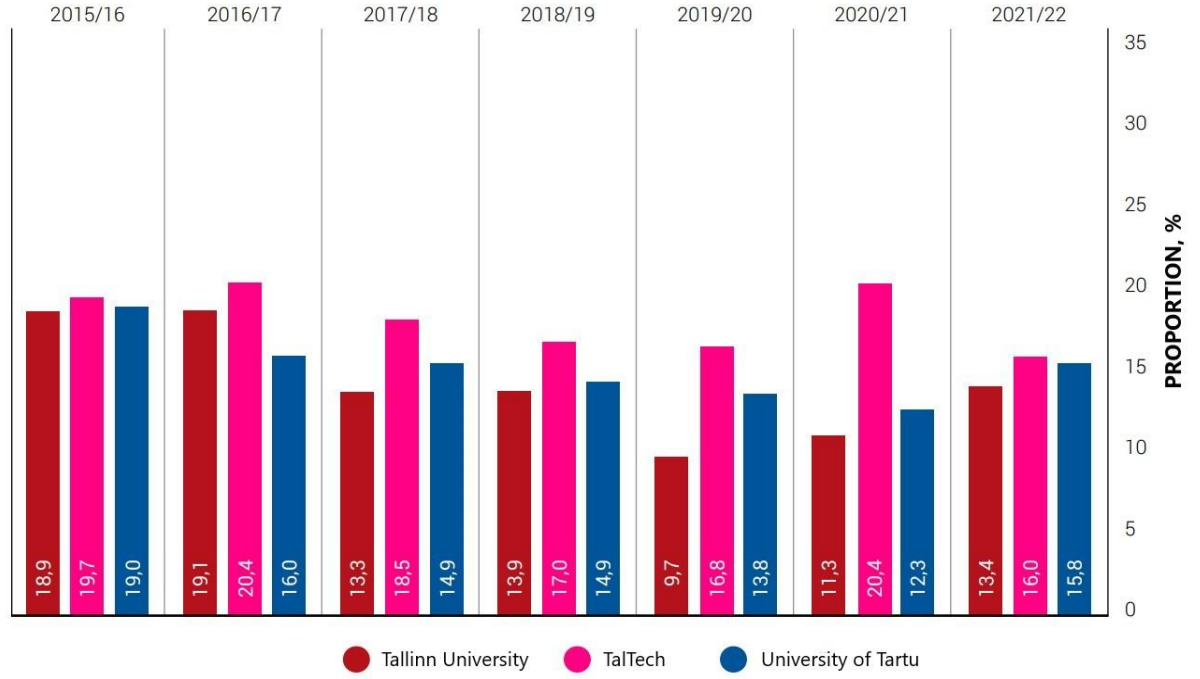


Figure 3.27. The proportion of students who discontinue their studies in the ICT field of studies in different institutions by year.

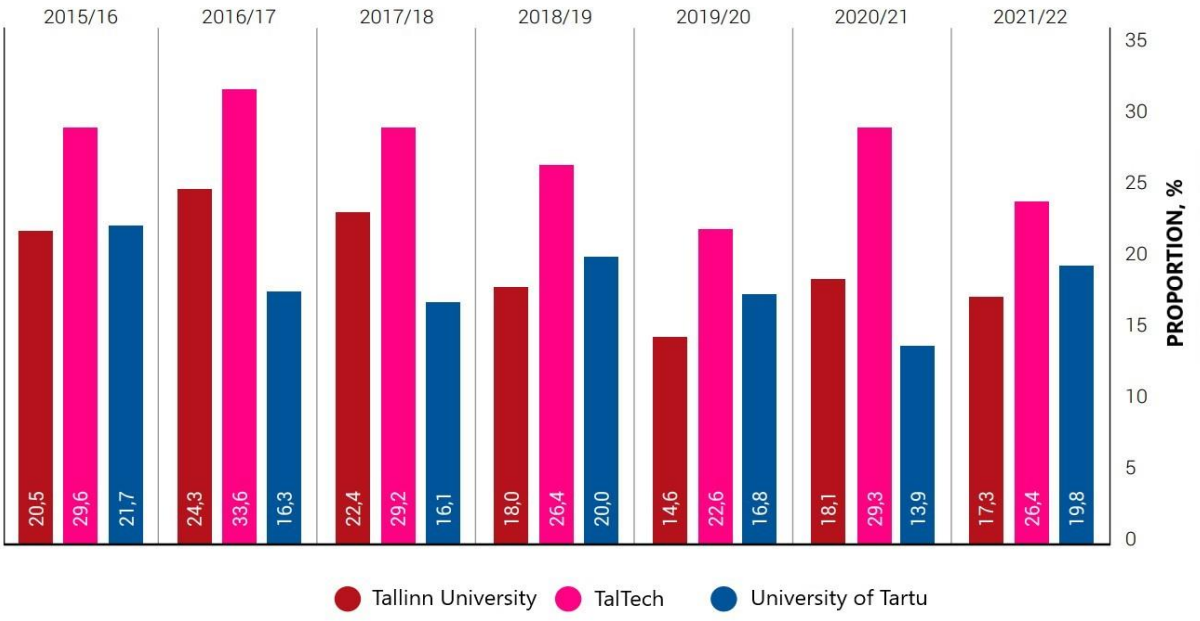


Figure 3.28. The proportion of students who discontinue their studies in the ICT field of studies during the first year in different institutions by year.

If **we compare levels of education,** the proportion of students discontinuing their studies both during all the years of study (Figure 3.29) as well as the first year (Figure 3.30) has been the lowest at the level of doctoral studies and the highest at the level of applied higher education. In general, it may be said that the lower the level of higher education, the higher the number of students discontinuing their studies.

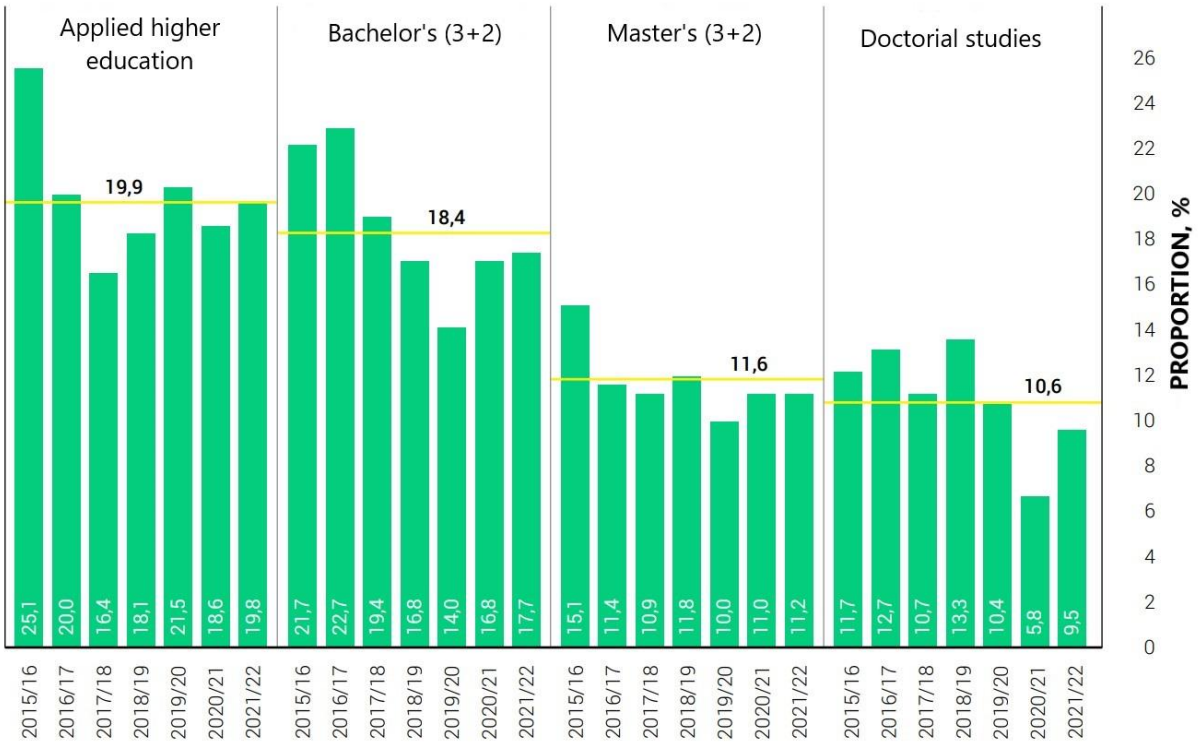


Figure 3.29. The proportion of students who discontinue their studies in the ICT field of studies at different levels of education by year. The average across academic years has been marked with a yellow line.

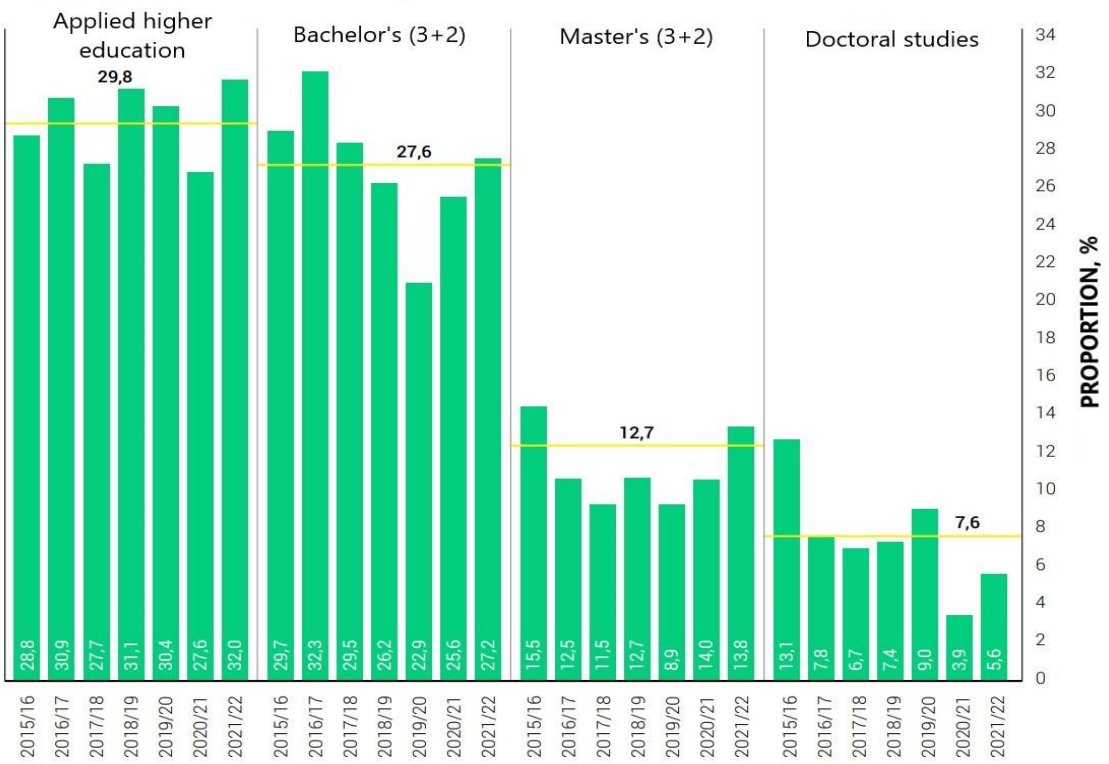


Figure 3.30. The proportion of students who discontinue their studies in the ICT field of studies during their first year at different levels of education by year. The average across academic years has been marked with a yellow line.

To consider the **number of graduates who continue their studies on the next level of education** (not necessarily the next academic year), the greatest gap emerges between graduates of the Master's level and students admitted to doctoral studies (Figure 3.31), as could be expected. It is noteworthy that although the number of Bachelor's level graduates has not been consistently increasing (there was a decrease during the academic years of 2017/18–2018/19), the number of students admitted to Master's level studies has been growing during the entire period. Up to the academic year of 2021/22 the number of students admitted to doctoral studies was trending upwards, but it has yet again decreased significantly during the last academic year.

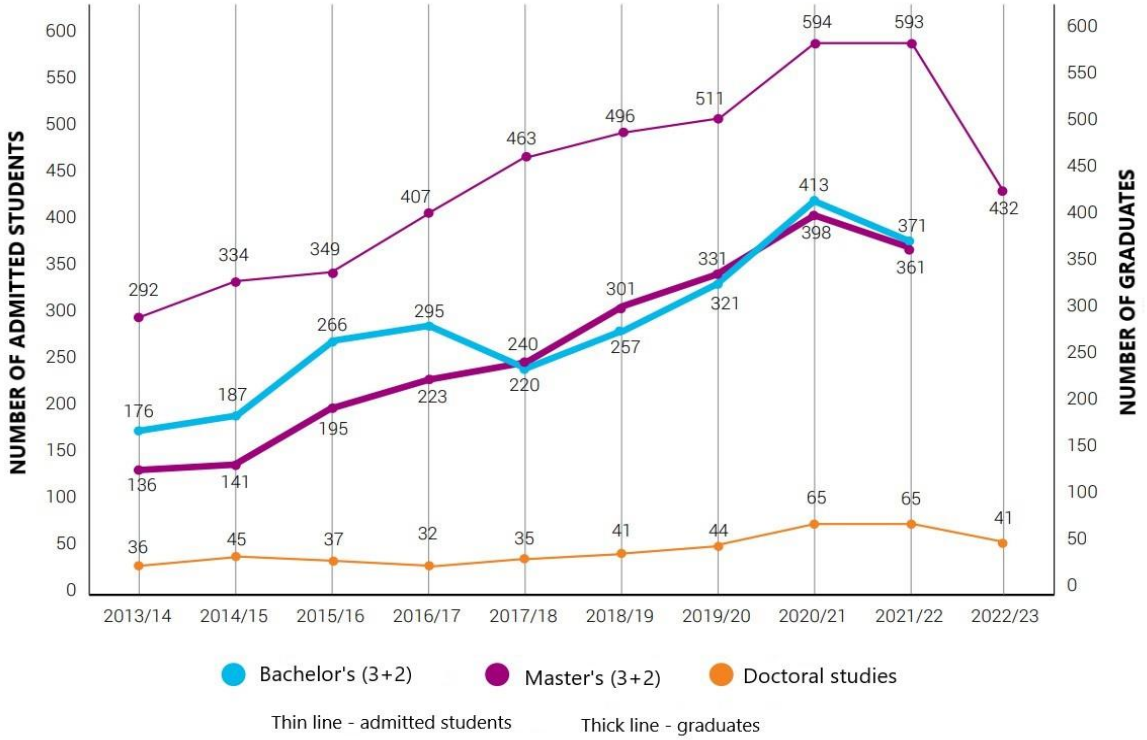


Figure 3.31. Trends of the numbers of students admitted to and graduating from different levels of education during the period.

Labour market outcomes

If we compare **universities** and **levels of education** within the ICT field of study in the year 2021, graduates of TalTech who had completed a PhD **had the highest income** (gross income of nearly 3,000 euros), and graduates of the University of Tartu who had acquired applied higher education had the lowest income (Figure 3.32). **The proportion of employed** graduates was high among all graduates, the indicator was 100% for graduates of TalTech who had completed a PhD and graduates of Tallinn University who had acquired applied higher education; the proportion of employed graduates was the lowest among graduates of the University of Tartu who had acquired applied higher education and completed a PhD (*ca* 67%).

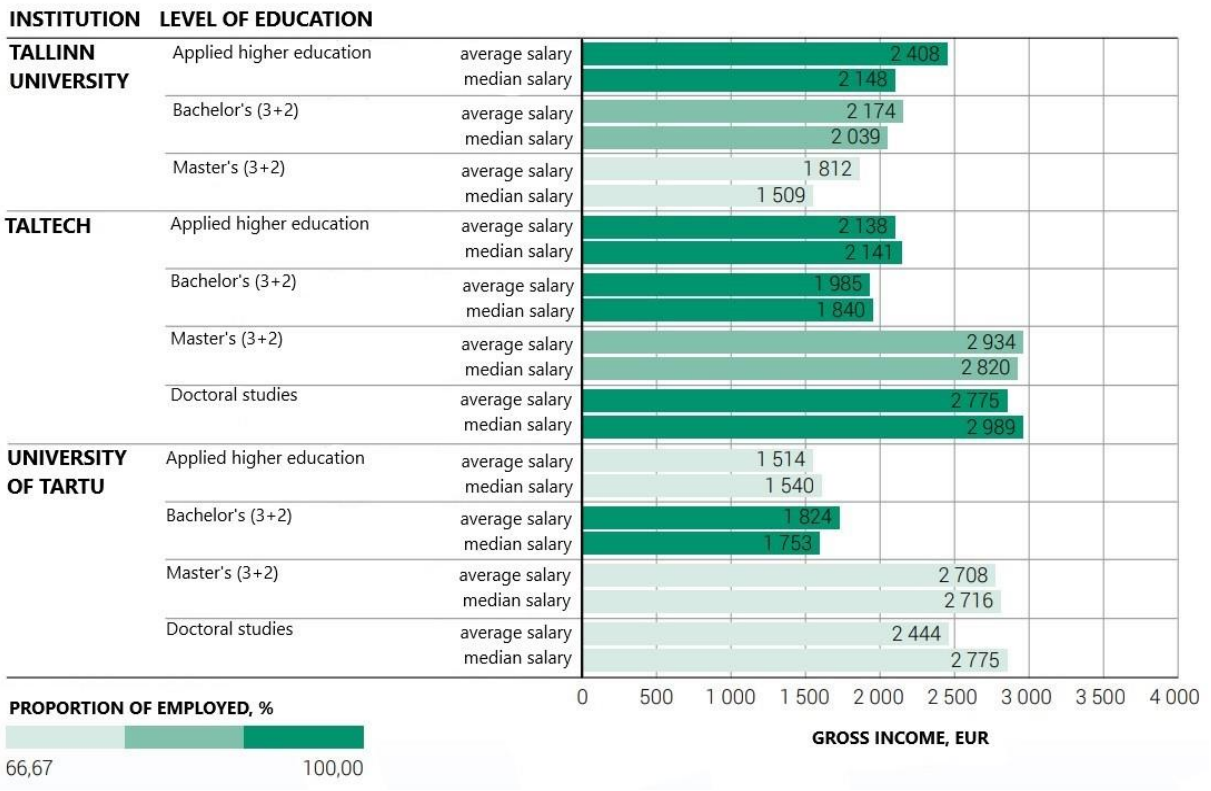


Figure 3.32. The average and median income in 2021 of ICT graduates of the 2020 of the three largest universities. The colour of the column reflects the proportion of graduates employed in 2021.

To compare **study programme groups**, the graduates of TalTech's databases study programme group had the highest income (gross income of *ca* 2,800 euros), while graduates of Tallinn University's software study programme group had the lowest income (Figure 3.33). The proportion of employed graduates was generally high among the graduates of all study programme groups (more than 74%). 100% of the graduates of Tallinn University's databases study programme group were employed. The proportion of employed graduates was the lowest among Tallinn University's software study programme group.

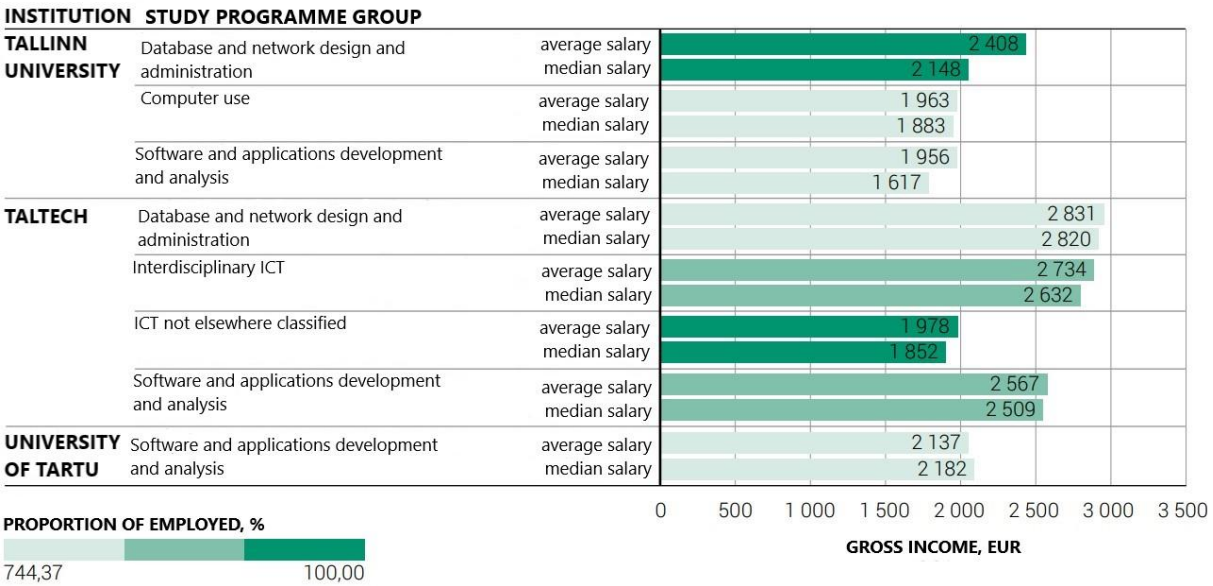


Figure 3.33. Average and median income in 2021 for graduates of the ICT study programme group of 2020 of the three major universities. The colour of the column reflects the proportion of graduates employed in 2021.

Employment in the field studied is explored for the first time in this analysis. Due to a delay in data collection, it is possible to analyse the students who graduated from an educational institution in 2020 and have been employed in 2021. A list of positions in the ICT sector is included in Annex 2.

71% of the people who graduated from the ICT field of study worked in the ICT sector and 29% in other sectors (Table 3.6). The proportion of people employed in ICT-related positions was the highest among the graduates of the University of Tartu (83%), and the lowest among the graduates of Tallinn University (*ca* 57%).

Table 3.6. Positions held as a main job in 2021 by the graduates of the ICT field of study of 2020. In the case of fewer than three people, data may not be displayed due to data protection restrictions.

Educational institutions	**Other position**		**ICT position**		**Total**
	Number of people employed	**Proportion**	**Number of people employed**	**Proportion**	
Tallinn University	27	44%	35	56.5%	62
TalTech	140	32%	302	68.3%	442
University of Tartu	28	17%	137	83%	165
Total	**195**	**29%**	**474**	**71%**	**669**

There were 37 different positions, 28 of which belonged to the ICT sector and 9 to other sectors. The greatest number of people were employed as software developers and software engineers (184 and 39 people, respectively; Figure 3.34).

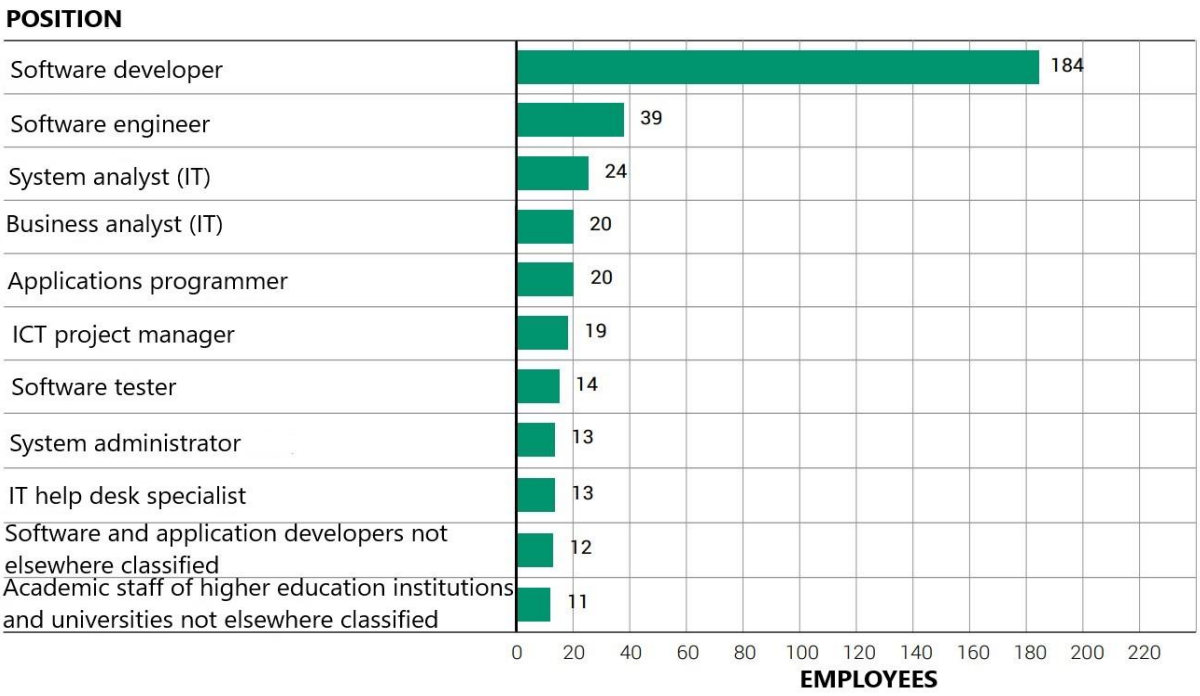


Figure 3.34. Positions where the 2020 graduates of the ICT field of study worked in the year 2021. Positions held by more than 9 people are displayed.

IV Research and development connected to ICT

This chapter provides an overview of research and development activity connected with ICT in the period from 2012 to 2021, the main focus is on the Tallinn University of Technology (TalTech), Tallinn University and the University of Tartu. This is a quantitative analysis where indicators concerning various publications, research funding and personnel are explored. The data sources include the Estonian Research Information System (ETIS) and the database of Web of Science/InCites (the extracts were obtained by the Estonian Research Council ETAG), the personnel information of the universities is based on the data submitted by the universities. The methodology has been described in more detail in Annex 1.

- The project-based funding of all research fields amounted to *ca* 167.5 million euros in 2021, which is nearly twice as much as the smallest amount in the observed period, i.e., 84.9 million euros in 2016.
- The proportion of funding for the field of ICT among the funding of all the fields during the period has been 5–11% and has been increasing consistently. Among the universities, the proportion of ICT is the largest mainly in TalTech.
- During the observed period, the funding of the field of ICT has been 5.3–17.9 million euros. Among the universities, in the period of 2012–2015, TalTech's projects received the most funding, while in the period 2016–2021, it was the University of Tartu's projects that were funded the most.
- Foreign funding has increased during the period, it has been especially notable in the past three years. Among the universities, in the period of 2012–2017, TalTech received the most foreign funding, while in the period 2018–2021, it was the University of Tartu.
- The volume of projects funded by companies increased drastically in 2018 and has remained at the level of 1.4–2.7 million euros after that, which is tens of times higher than the lowest level in 2014

(*ca* 50,000 euros). Among the universities, the project volumes are the largest in TalTech and the University of Tartu, while no clear temporal trends emerge in comparison of the institutions.

- In the year 2022, TalTech had the greatest number of academic personnel involved in ICT studies (414 persons, 306.7 full time equivalent). Compared to the year before, the number of employees has increased in nearly all universities and for all positions.
- When analysing publications, proceedings papers and articles are viewed separately, as well as their position among the 10% of the world's most impactful publications, which are evaluated based on citations . During the period, the academic personnel of TalTech published the largest number of proceedings papers (*ca* 690), while the academic personnel of the University of Tartu published the largest number of articles (340). The annual proportion of the most impactful proceedings papers and articles has mostly been the largest at the University of Tartu but in some years, the proportion of Tallinn University is equal or even larger.

Funding

Research funding is divided into two: baseline funding that guarantees stability, and competitive- or project-based funding. In Estonia, research funding is mainly project-based, baseline research funding makes up a small part of the research and development (R&D conducted in the public sector. Over the years, the proportion has varied, fluctuating between *ca* 5% to *ca* 20% (2015 and 2021) of the public sector's R&D expenditure (Rahastamise üldpilt – Eesti Teadusagentuur; https://etag.ee/en/activities/analysis/statistics-rd-funding-estonia/). Based on the data from The Estonian Research Information System (ETIS), the volume of project-based funding reflects the competitive edge of institutions – since resources are limited, the stronger projects receive funding. Although nowadays most fields and walks of life are connected to ICT, all specialities cannot be included in a single analysis, and it would not be reasonable – the volume of the analysis would be unreasonably large and the result would be too general and vague. Thus, the analysis focuses specifically on ICT development, not fields of research connected to applying ICT. Basic ICT competencies (as opposed to integrated fields of study, such as web design, IT law, IT management etc.) are explored, i.e., projects classified within the Estonian research information system fields of research classifier (ETIS classifier) under the fields of 4.6 Computer Sciences, and 4.7 Telecommunications. Only institutions from the public sector will be considered, since information concerning the private sector is incomplete in ETIS (private-sector institutions are not required to enter information into ETIS).

The project-based funding of all research fields was the smallest in 2016 (*ca* 84.9 million euros), and the largest in 2021 (*ca* 167.5 million euros), the difference was nearly twofold (Figure 4.1). Since 2016, the volume of the funding has been trending upwards in all three universities. Among the institutions, the projects of the University of Tartu have received the most funding the during the entire period.

The proportion of funding provided to the ICT field among all fields (Figure 4.2) has fluctuated between 5–11%, the proportion has increased during the period. The dynamics of the proportion differ by institution and has varied the most at Tallinn University (more than threefold), at the University of Tartu it is clearly trending upwards. During the entire period, the proportion has been the largest at TalTech, except in the years 2016 and 2017, when it was the largest at Tallinn University. When the funding of projects in all fields in the rest of Estonia's public-sector institutions (ca 20 institutions, the list can be found in Annex 2), was at a similar level to TalTech's funding the proportion of funding of the ICT field is very small in the rest of Estonia's public-sector institutions compared to the universities. This indicates how large a proportion of Estonian ICT research is conducted at the three largest universities.

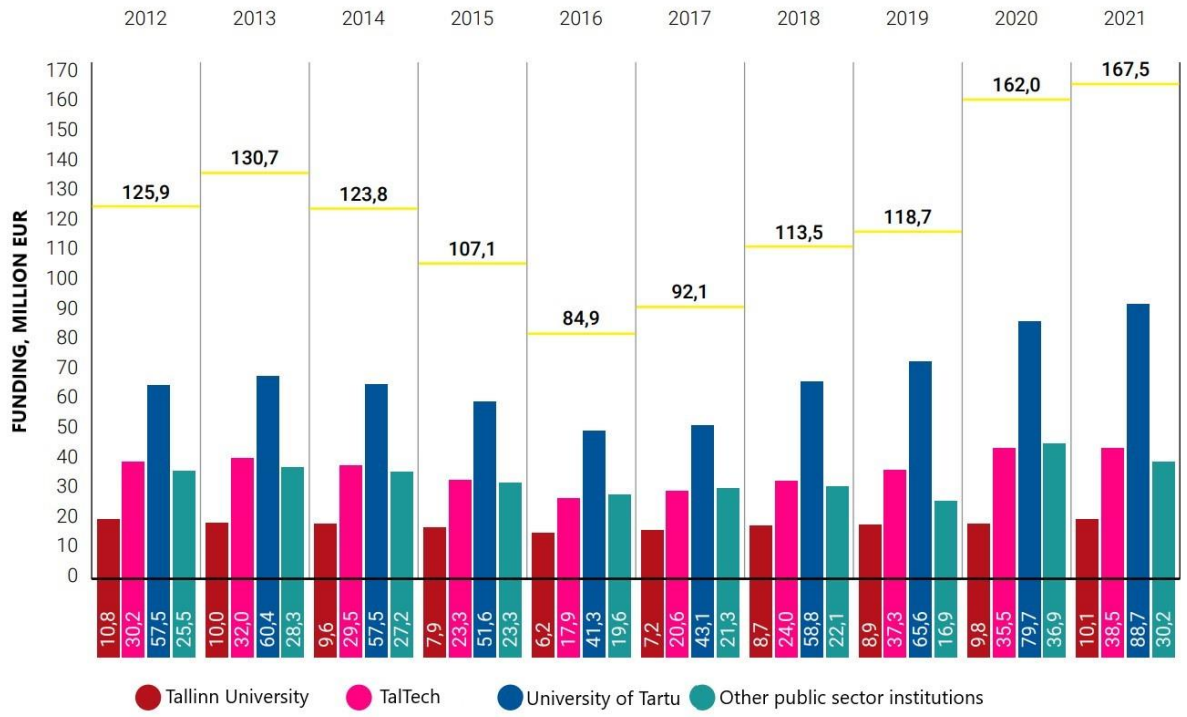


Figure 4.1. Annual funding of all fields. Total funding per year has been marked in yellow.

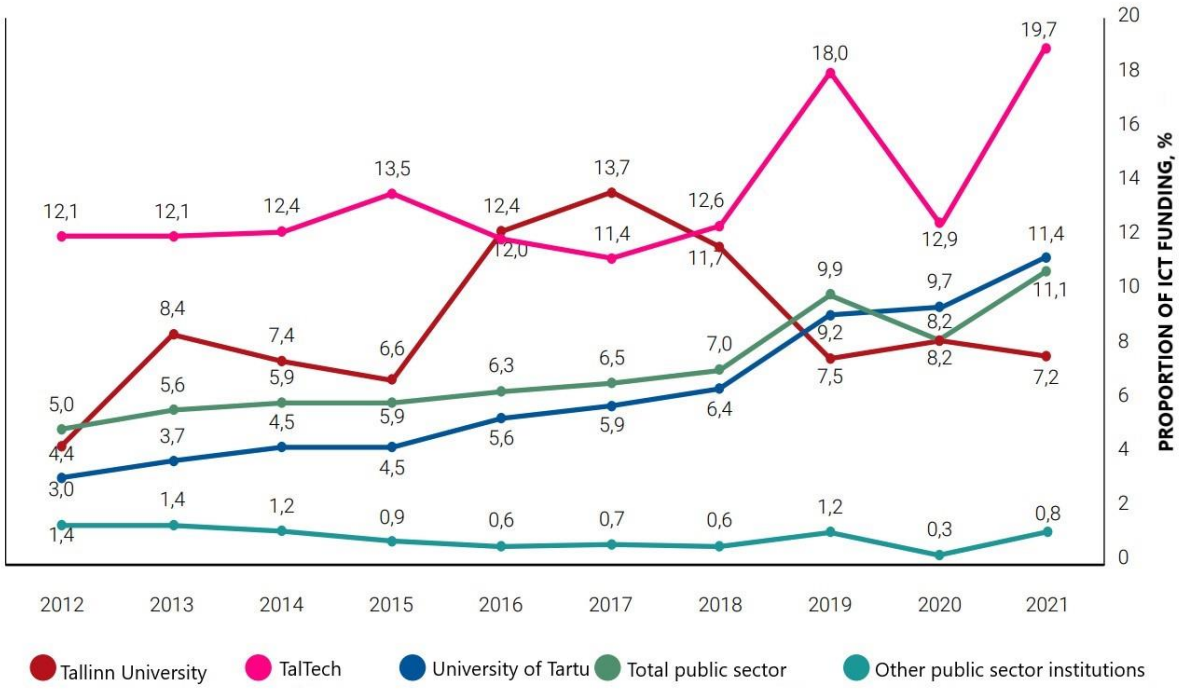


Figure 4.2. Annual proportion of funding the ICT field among the funding of all fields.

The funding of the ICT field in the public sector during the observed period was the lowest in 2016 (*ca* 5.3 million euros) but has increased nearly threefold by 2021 (*ca* 17.9 million euros). During the entire period, the projects of the computer sciences subfield have received the most funding (Figure 4.3).

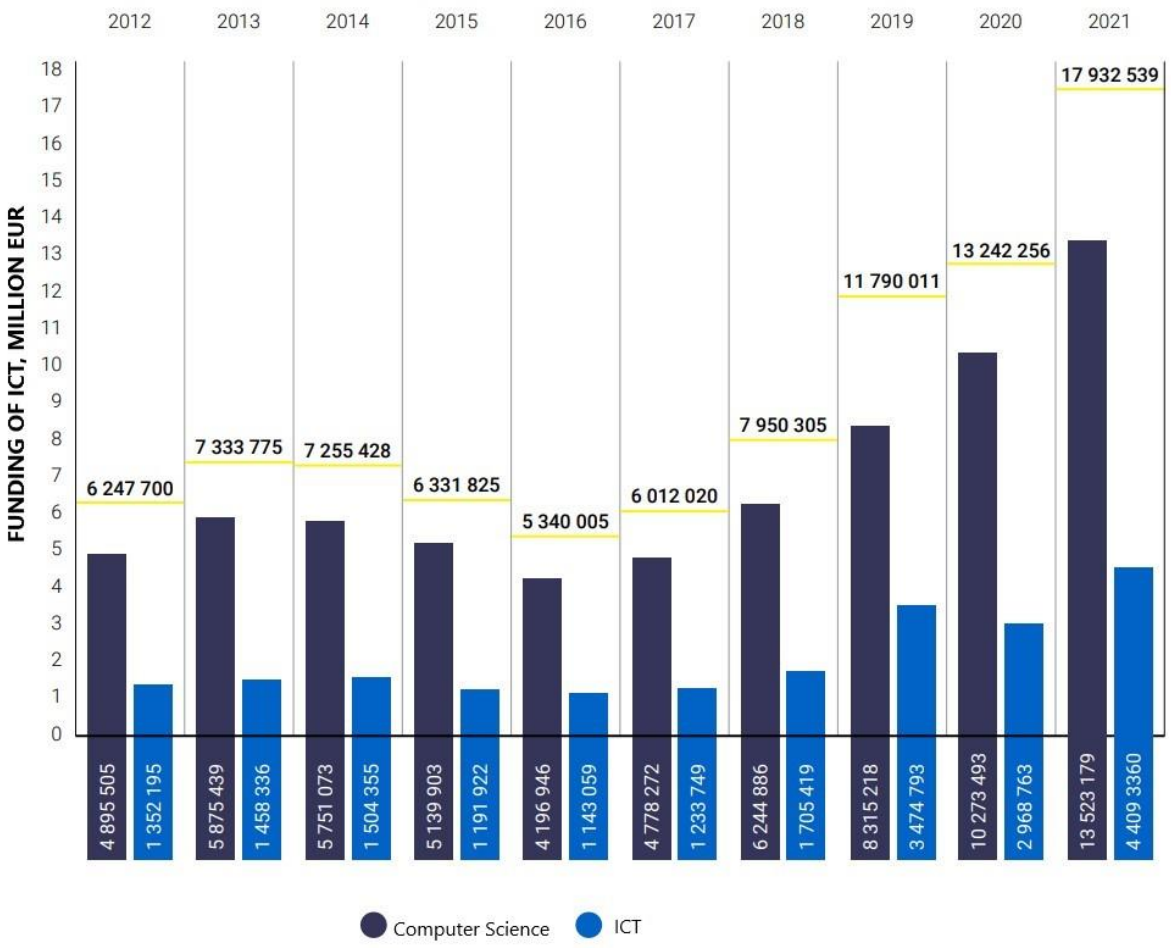


Figure 4.3. Annual funding of the ICT field in the public sector. Total funding per year has been marked in yellow.

The project volumes of the **three largest institutions** that conduct ICT research are vastly different (Figure 4.4). TalTech (in the years 2012–2015) and the University of Tartu (2016–2021) have received the most funding. Comparing the proportions of the universities, the University of Tartu has nearly doubled its proportion during the period.

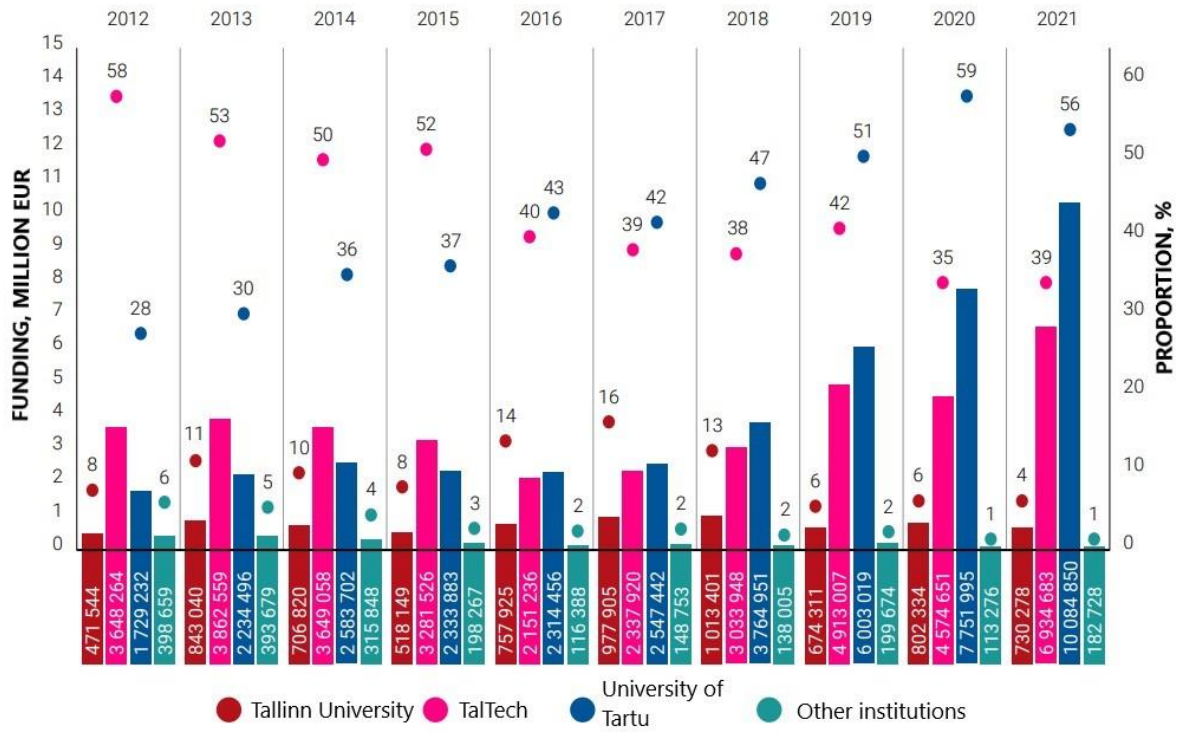


Figure 4.4. Annual division of the funding of the ICT field among public-sector institutions.

During the observed period, **foreign funding** made up 18–45% of the total funding (in 2013 and 2016, correspondingly), and *ca* 26–36% of the total funding in the past three years. The dynamics of the volume of projects that received foreign funding follows the general dynamics of funding (Figure 4.5). While the University of Tartu has had the largest funding volumes in the past six years, it has ranked first in terms of foreign funding for the past four years; before that, the volume of foreign funding was the largest at TalTech.

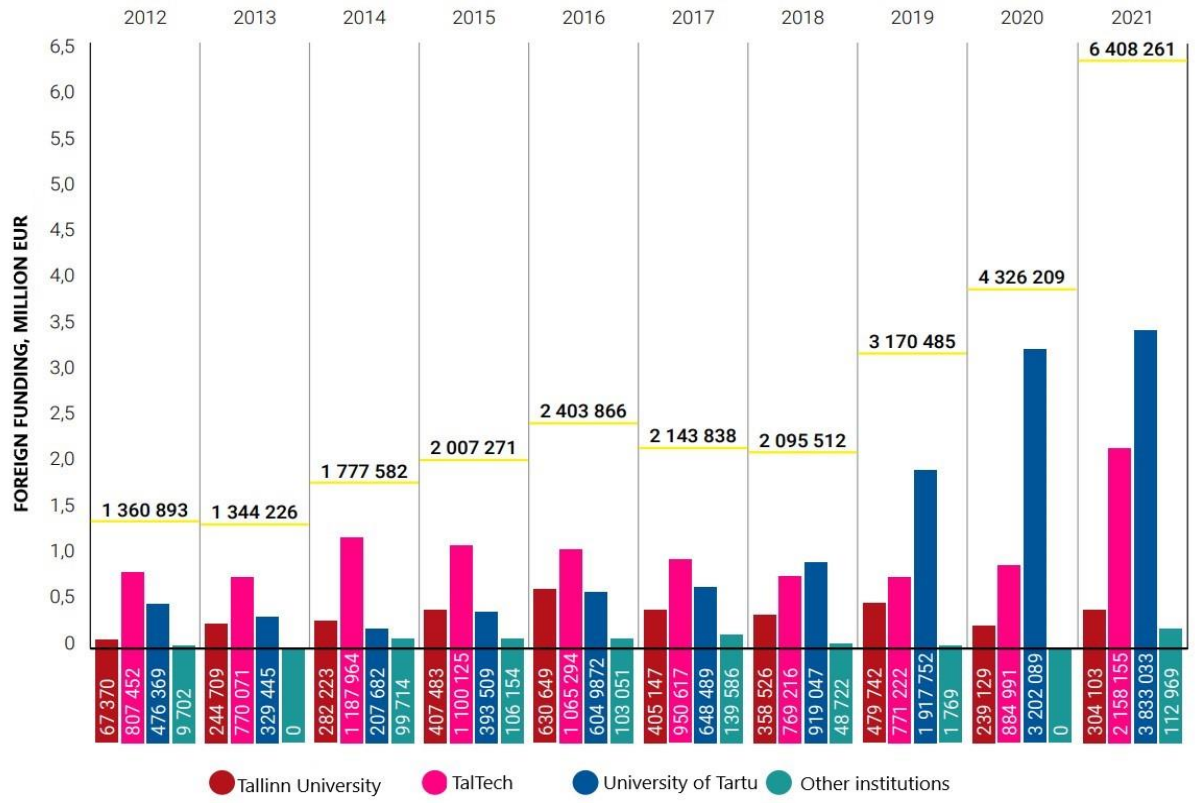


Figure 4.5. Annual division of foreign funding among institutions. Total funding per year has been marked in yellow.

The total volume of business contracts has increased considerably in the past years (Figure 4.6), facilitated by the active use of state support by companies (e.g., support measure for applied research in smart specialisation). The collaboration between research institutions and companies is reflected, among other things, in the volumes of projects funded by companies.

During the period, the total volume of business contracts has been the largest at the University of Tartu (*ca* 4.8 million euros), while business collaborations have not been undertaken every year at Tallinn University.

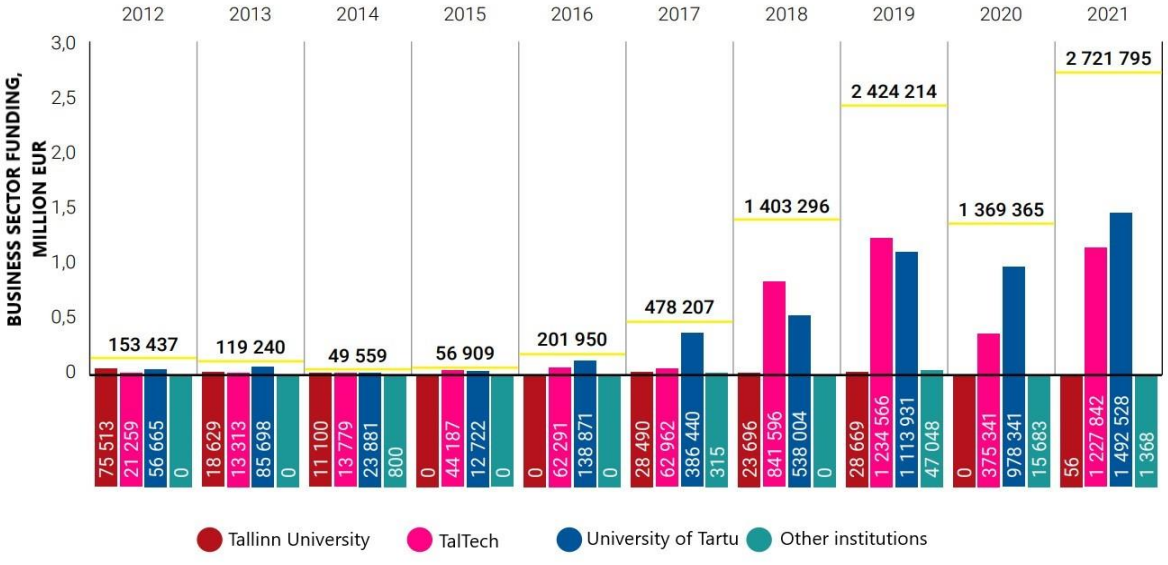


Figure 4.6. Annual distribution of the volume of business contracts by institution. Total yearly funding has been marked in yellow.

Academic personnel

In the 2017 analysis, the number of academic personnel was based on the universities' self-assessment performed during the 2015 ICT targeted evaluation. No personnel information has been collected regarding the period of 2015–2018. Starting from 2019, an overview is submitted regarding research groups that are directly involved with research connected to ICT (i.e., not application of ICT). TalTech and Tallinn University also submitted data about the people who worked outside the university's main structural units that focus on ICT (school of business and governance, school of engineering, school of science, and Baltic Film, Media and Arts School and Marketing and Communication Office). Detailed databases that include information of the structural units are available in Annex 2.

As in the years 2020 and 2021, in 2022 TalTech had **the highest number of academic personnel**, followed by University of Tartu and Tallinn University (Table 4.1). Compared to 2021, the number of academic staff and the full time equivalent have increased in all universities and for all positions, except for:

- At TalTech in case of professors and associate professors
- At the University of Tartu in case of teachers and research fellows
- At Tallinn University in case of associate professors, lecturers and senior research fellows. The same trend emerged from the comparison of the previous years.

It is also interesting to note that while the number of doctoral students increased at Tallinn University, their full time equivalent decreased, which means that the workload of the doctoral students was reduced. Likewise, the full time equivalent decreased in the university as a whole, although the number of employees increased.

Table 4.1. Number of academic personnel by position and university in 2022. The arrows signify the changes compared to 2021 (↑ – the number is bigger compared to 2021 ↓ – the number is smaller compared to 2021 * – the number has remained the same, X – this category is absent from the institution). In 2020, the classification of academic personnel changed, senior research fellows (vanemteadurid) and docents (dotsendid) are now associate professors (kaasprofessorid). Doctoral students include junior research fellows (nooremteadurid), industrial doctorates (tööstusdoktorid, Tallinn University), junior lecturers (nooremlektorid, University of Tartu).

	TalTech		Tallinn University		University of Tartu		Total	
	No. of people	Full time equivalent (FTE)	No. of people	Full time equivalent (FTE)	No. of people	Full time equivalent (FTE)	No. of people	Full time equivalent (FTE)
Professor	50 ↓	44.25 ↓	9 ↑	8 ↑	17 ↑	15.05 ↑	76 ↓	67.3 ↓
Docent/Associate professor	18 ↓	14.75 ↓	7 ↑	5.35 ↑	36 ↑	32.15 ↑	61 ↑	52.25 ↑
Lecturer	31 ↑	24 ↑	14 ↑	11.5 ↑	53 ↑	50.1 ↑	98 ↑	85.6 ↑
Teacher	-	-	-	-	4 ↓	3.2 *	4 ↓	3.2 *
Senior research fellow	62 ↑	46.34 ↑	8 *	7.5 ↑	-	-	70↑	53.84 ↑
Research fellow	76 ↑	63.4 ↑	4 *	3.1 *	25 ↓	23.2 ↓	105 ↑	89.7 ↑
Doctoral student	177 ↑	114 ↑	26 ↑	13.7 ↑	123 ↑	102.22 ↓	326 ↑	229.92 ↑
TOTAL	414 ↑	306.7 ↑	68 ↑	49.15 ↑	201 ↓	169.97 ↓	683 ↑	525.82 ↓

Publications

ETAG used the Web of Science/InCites database as a source for ICT-related bibliometrics. The analysis focuses on the so-called core-competencies of ICT research, i.e., Computer Science and Information and Communication Technology. Traditionally, the number of publications is used to evaluate the volume of research results. Publishing practices vary across research fields, hence owing to the historical characteristics of ICT research it is appropriate to view proceedings papers and articles separately.

The impact factor of publications is based on how many times they have been cited. This overview considers the proportion of publications that are among the 10% of the world's most impactful publications in their respective field. As other researchers cite the publications with a considerable delay, the impact factors of publications may increase years after they have been published.

The dynamics of the number of proceedings papers is highly variable (Figure 4.7), and it is difficult to outline a clear trend. One can conclude that the number of publications increased up until the year 2019 but in 2020 all the universities published a considerably smaller number of proceedings papers. Compared to other universities, TalTech published the highest number of proceedings papers during the observed period. For all the public-sector institutions, 2019 was the most successful year in terms of publishing proceedings papers but the **proportion of papers among the 10% of the world's most impactful proceedings papers** was not the highest that year (Figure 4.8), probably due to the long citation delay.

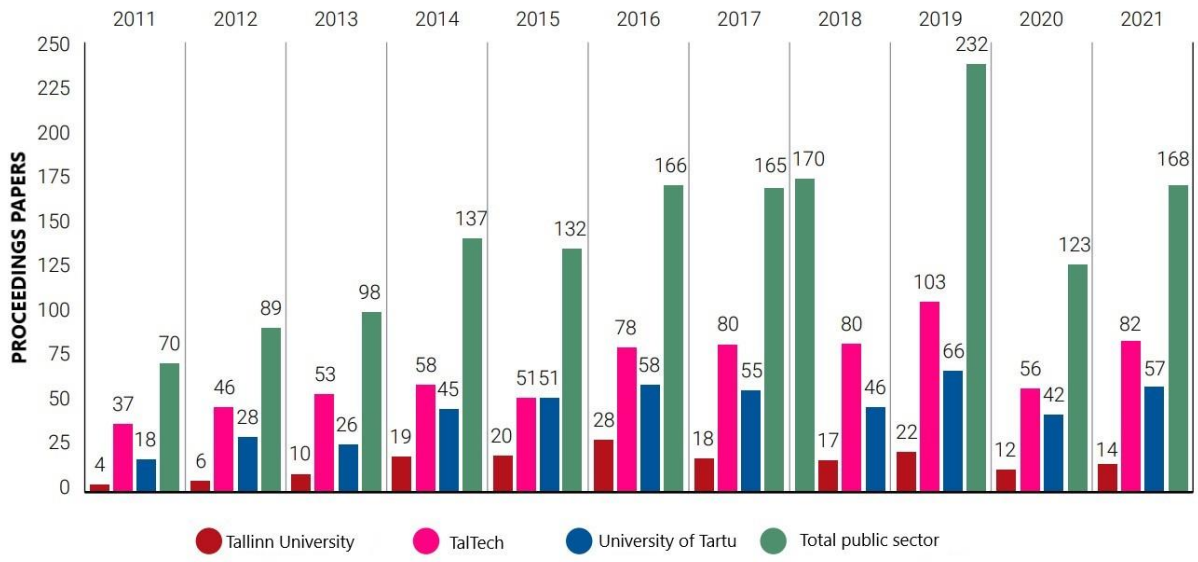


Figure 4.7. Annual number of proceedings papers related to ICT research.

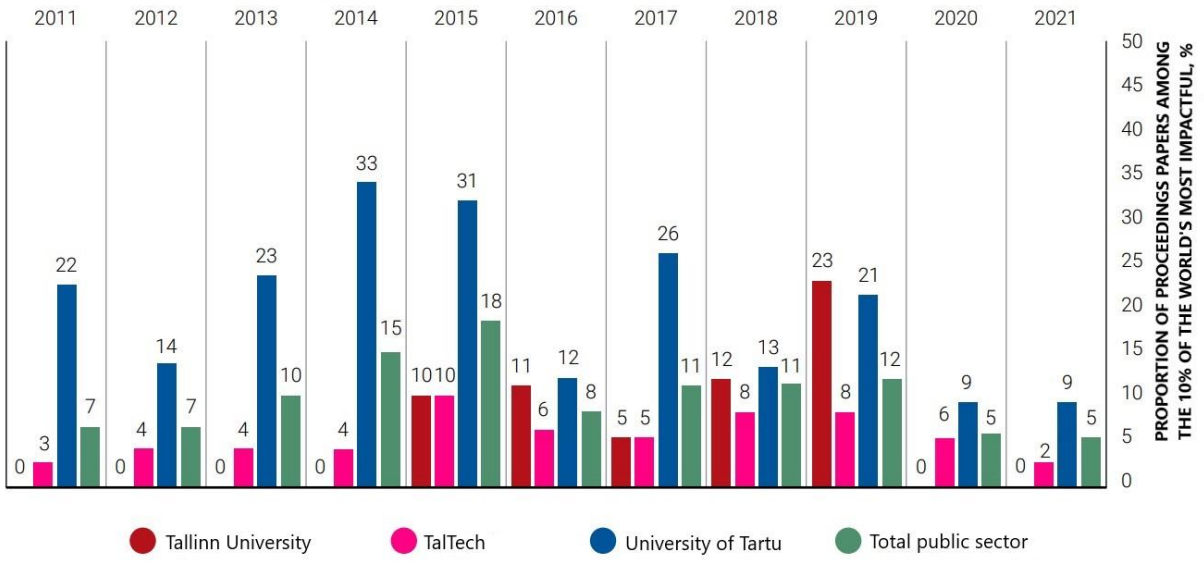


Figure 4.8. Annual proportion of proceedings papers related to ICT research among the 10% of the world's most impactful proceedings papers.

Compared to proceedings papers, a **smaller number of articles related to ICT research** have been published but in 2021 the number of articles increased considerably (Figure 4.9). The dynamics of articles differs from the dynamics of proceedings papers – it may be said that during the past four years, the number of articles has increased in nearly all of the universities. Compared to other universities, the University of Tartu published the highest number of articles during the observed period.

Similarly, to proceedings papers, the **proportion** of articles among **the 10% of the world's most impactful articles** varies to a large degree annually, yet it has remained more or less at the same level in the past five years (Figure 4.10). During the observed period, the University of Tartu had the largest proportion of the most impactful articles, while articles by Tallinn University reached among the 10% of the world's most impactful articles only in 2021.

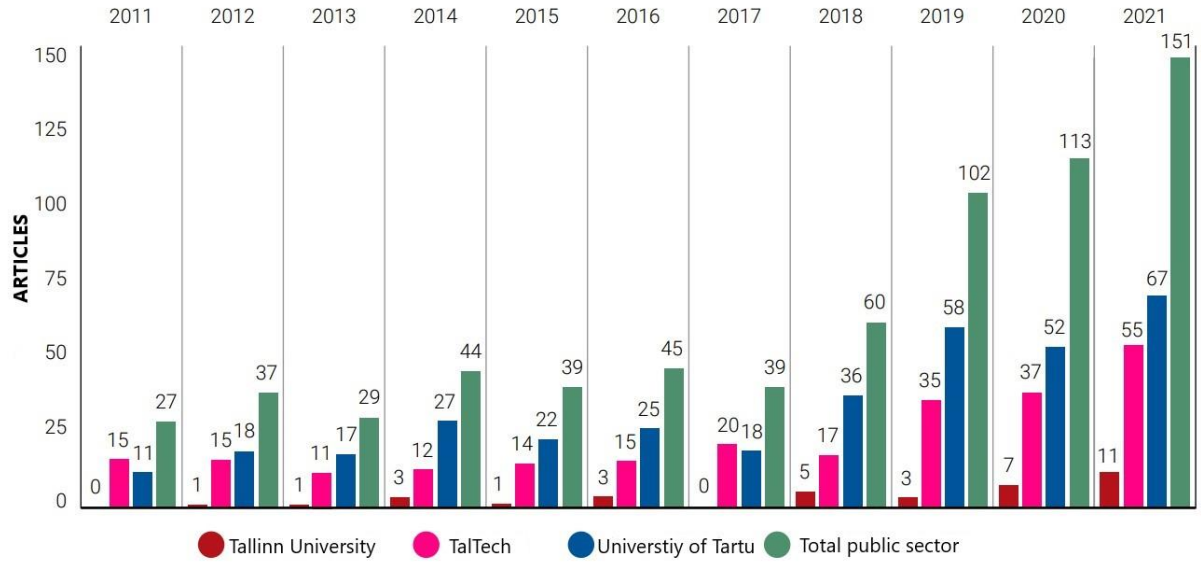


Figure 4.9. Annual number of articles related to ICT research.

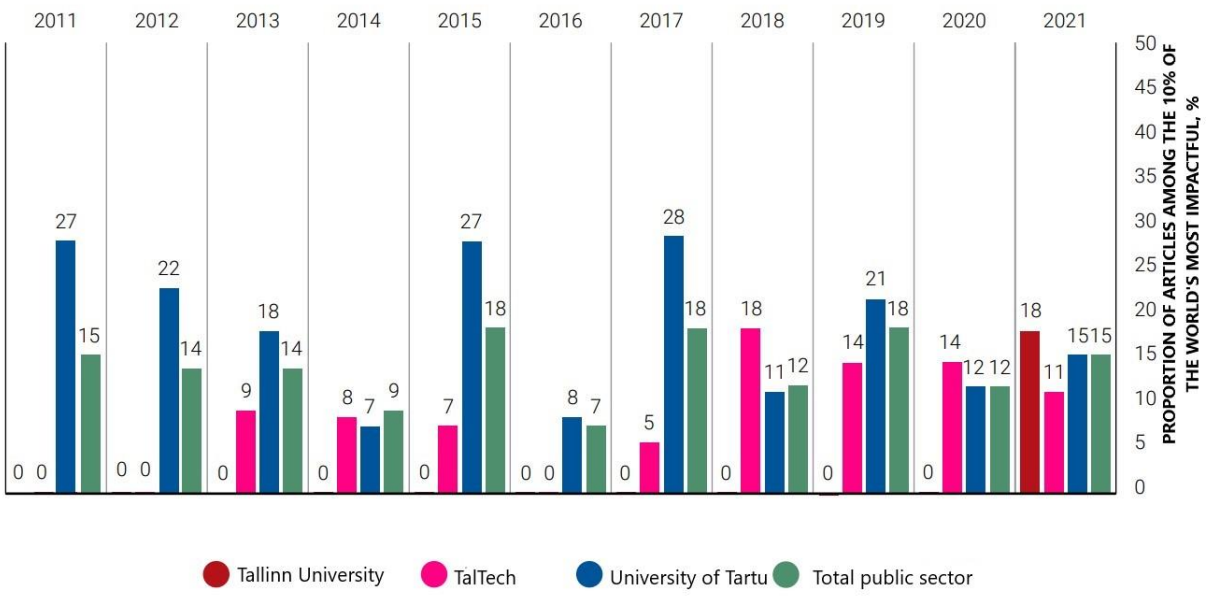


Figure 4.10. Annual proportion of articles related to ICT research among the 10% of the world's most impactful articles.