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Evaluation of the knowledge society in the Danube region (2010 – 2018)

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Acronyms – other countries	BE – Belgium; CY – Cyprus; DK – Denmark; EE – Estonia; EL – Greece; ES – Spain; FI – Finland; FR – France; CH – Switzerland; IE – Ireland; IL – Israel; IS – Iceland; IT - Italy; LT – Latvia; LU – Luxembourg; LV – Lithuania; MT – Malta, NL – Netherland; NO – Norway; PL – Poland; PT – Portugal; SE – Sweden; TR – Turkey; UK – United Kingdom
ERC	European Research Council
MSCA	Marie Skłodowska-Curie Actions
SME	Small and medium-sized enterprise

1. Introduction

The *Analysis of the Evaluation of the Knowledge Society Development in the Danube Region for the period 2010 – 2018* has been commissioned by the Ministry of Education, Science, Research and Sport of the Slovak Republic and contracted to the Slovak Centre of Scientific and Technical Information.

The aim of the study is to assess the current state and progress in the area of knowledge society in the Danube Strategy countries, as well as to make recommendations for improving the situation in the region. The analysis focuses on Priority Area 7 – Knowledge Society (Research, Education and ICT), which is jointly coordinated by Slovakia and Serbia.

The study contains four basic parts:

The chapter *Analytical evaluation of the knowledge society* is the basis of the whole evaluation and focuses on the quantitative and qualitative description and evaluation of the current state and progress that has occurred in the analysed period. It is divided into four parts that reflect the innovation process – inputs, activities, outputs and short and long-term effects.

In the chapter *Fulfilment of Objectives from 2016* we will focus on the evaluation of the set target indicators as well as the potential of their fulfilment by 2020.

The chapter *Evaluation of the Best Practice to Date and* a *SWOT Analysis of PA7* contains summaries of what has been done in the region so far and especially the evaluation of strengths, weaknesses, opportunities and threats.

The last chapter, *Recommendation to improve the current state* contains a proposal for measures that could strengthen the cooperation between countries in the region under PA7.

2. Methodology

The analysis focuses primarily on the comparison of the knowledge society (especially research and innovation) in the Danube region since 2010. The comparison was based primarily on data available in the databases of Eurostat, OECD, UNESCO, European Patent Office, WIPO, E-corda and the Web of Science Core Collection. In the evaluation, we combined quantitative and qualitative methods, focusing primarily on the countries of the Danube region. In some cases, if a better comparison required it, we also used comparisons with other European countries. The analysis itself is partly influenced by the availability of data for individual countries and regions.

The Member States of the Danube Strategy can be divided into four groups:

- **Member states** (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia and Slovenia);
- **Accession countries** (Bosnia and Herzegovina, Montenegro and Serbia);
- **Neighbouring countries** (Moldova and Ukraine);
- **Regions** (Bavaria and Baden-Württemberg).

The analysis focuses mainly on measuring the progress of individual countries. However, based on the data availability, at certain points Bavaria and Baden-Württemberg were also included in the comparison. In some comparisons, data (mostly) for non-EU countries as well as older data were not available. The Danube Region thus constitutes a mixture of countries that are at different stages of development in research and innovation. Each country gives these areas a different importance – a fact, which is reflected primarily in the amount of investment and which also partly influences the study.

3. Analytical assessment of the knowledge society in the Danube region

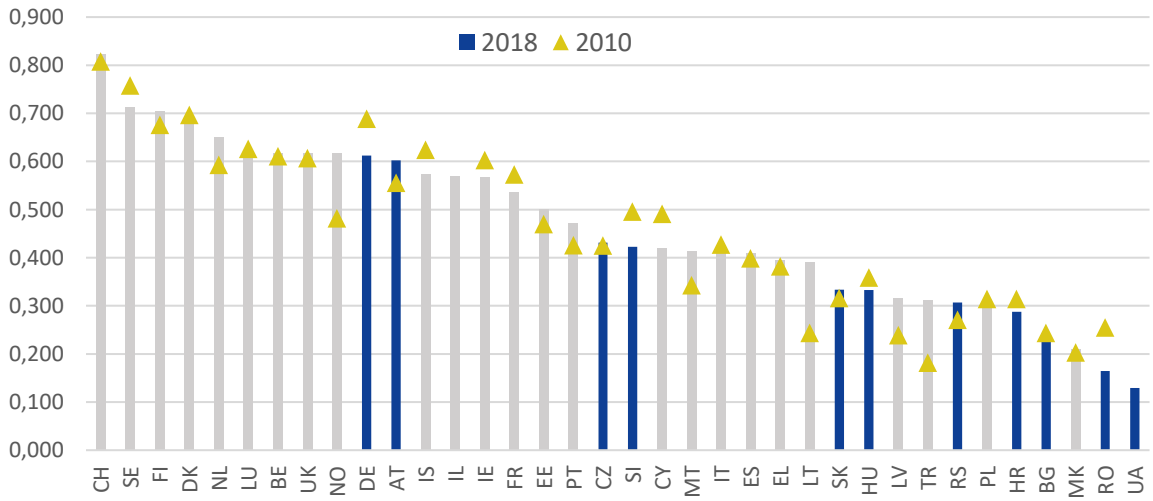
The following chapter contains an analytical assessment of the state and progress of the knowledge society in the Danube region. We focused primarily on the changes that occurred in comparison with 2010. The analysis is as structured as the innovation process at four levels:

- Inputs (investment in research and innovation, human resoures);
- Activities (cooperation, mobility);
- Outputs (publications, citations and patents);
- Short-term and long-term effects (more innovation, higher productivity, export).

The main goal is to compare the current state of the knowledge society in the region with the state in 2010 in individual innovation steps.

For more than 10 years, the European Commission has been publishing a comprehensive assessment of countries' innovation performance. It is a composite indicator consisting of 27 different indicators. Based on the resulting score, the countries are then categorized into four categories – innovation leaders, strong innovators, mild innovators and weak innovators. Of the countries that are part of the Danube region, most are among the moderate innovators, Germany and Austria are part of the strong innovators group, and Bulgaria, Romania and Ukraine are the weak innovators (Figure 1). Moldova, Montenegro and Bosnia and Herzegovina are not part of the evaluation, but we expect them to fall significantly behind the Ukraine. We will be able to track such a division of countries in virtually every comparison of research and innovation performance.

Graph 1 European Innovation Scoreboard



Data: Innovation Union Scoreboard 2019

Note: Year 2010 added form previous Scoreboards

3.1.Inputs

3.1.1. Investments to research and innovation

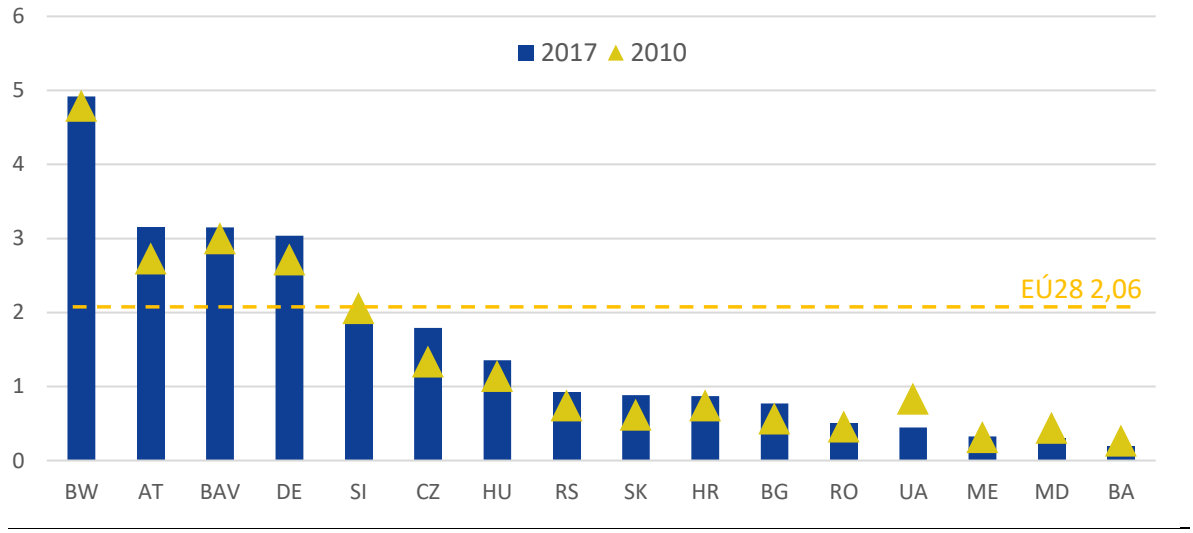
The main objective of this section is to describe trends in investments in research and innovation in the region and to possibly compare them to the EU average and other countries.

In 12 out of the 16 countries surveyed, **R&D expenditures in relation to GDP** increased over the analysed period, mostly in the Czech Republic (0.45% of GDP), Austria (0.43% of GDP) and Germany (0.32% of GDP). On the other hand, the largest decreases were recorded in Ukraine (0.38% of GDP) and Slovenia (0.2% of GDP). Interestingly, non-EU countries, in particular, are stagnating in R&D investment. The only exception is Serbia, which grew by 0.18% of GDP, investing more than four EU Member States.

The most successful countries are the EU-15, or their regions, to be precise. The highest investments were recorded in Baden-Württemberg (4.92%), Austria (3.16%), Bavaria (3.15%) and Germany (3.04%). At the same time, these are the only countries that exceed the EU average (2.06%) as well as the targets of the Europe 2020 Strategy (3%). Of the new member states, Slovenia is in the best position, ahead of Czech Republic and Hungary.

The comparison above shows that EU membership has a positive impact on R&D investment. In particular, the new member states have the opportunity to benefit from this fact. This has been particularly evident until 2015, when the investments of new member states were highest. These countries had the opportunity to draw from EU Structural Funds for research and innovation. After this period, there was a decline in virtually each of these countries, mainly due to the loss of these resources.

Graph 2 Gross domestic R&D expediture (% GDP) - GERD



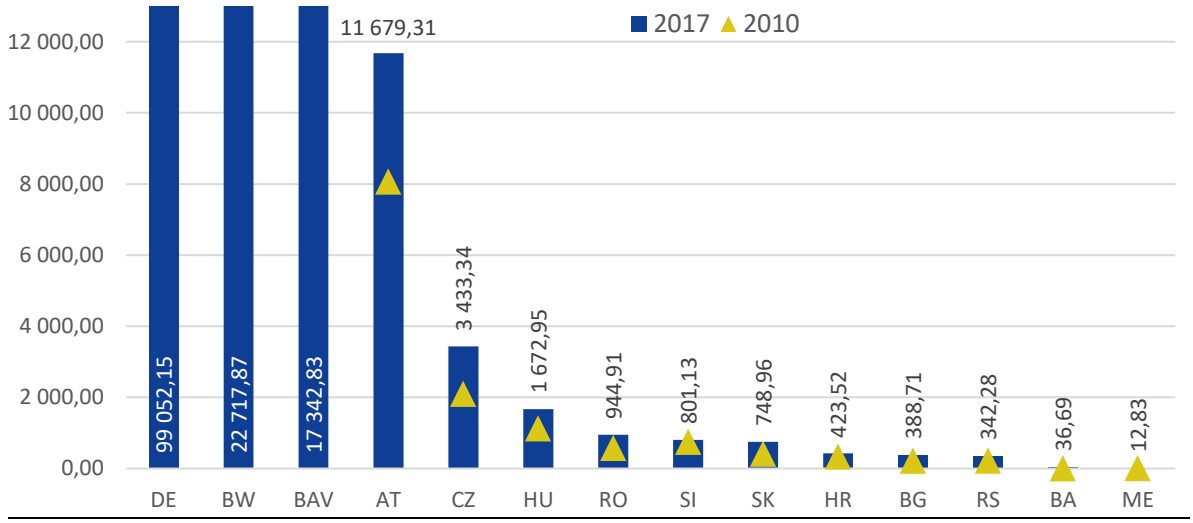
Data: Eurostat [rd_e_gerdtot],[rd_e_gerdreg]; UNESCO

Note: Bosnia and Herzegovina 2012; Montenegro 2011,2016; Baden- Württemberg (2011 a 2015).

The enormous difference between countries proves the distinction between the country that invests most in R&D (Germany) and least (Montenegro) – which is more than 7 720-fold difference. **Overall investment** is again dominated by Germany, Baden-Württemberg, Bavaria and Austria. They are

followed by the Czech Republic, Hungary and Romania. Countries outside the EU ranked last. The positive aspect is that in absolute terms investment rates have increased in all countries.

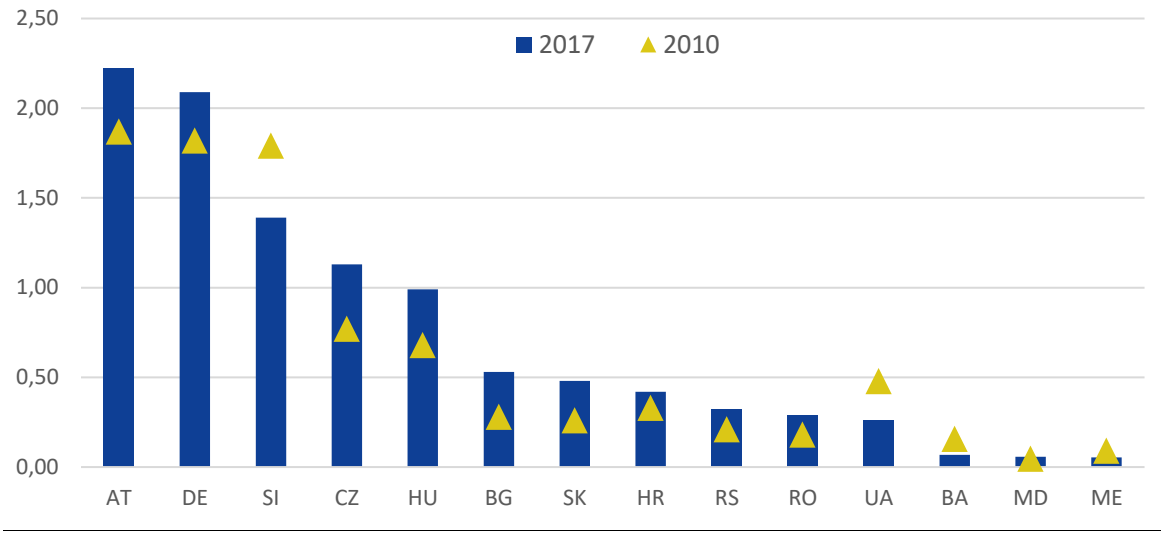
Graph 3 Gross domestic R&D expenditure in absolute terms 20 (million EUR) – GERD



Data: Eurostat [rd_e_gerdtot]
Note: Bosnia and Herzegovina 2014; Montenegro 2011, 2016; Baden- Württemberg and Bavaria 2012, 2016. Missing data for Moldova and Ukraine.

In 10 out of 14 surveyed countries **private investment in research and innovation** relative to GDP increased over the period under review. The highest increase was visible in Czech Republic (0.36% GDP), Austria (0.35%) and Hungary (0.31%). In contrast, the largest decrease was recorded in Slovenia (0.4%) and Ukraine (0.22%). Bosnia and Herzegovina, Moldova, and Montenegro remained at similar figures as in 2010. This comparison shows again that the oldest member states (Austria and Germany) have the highest investment, both exceeding the Strategy Europe 2020 which states that 2/3 of all R&D investment is funded by private sources. This is followed by the second group of countries (Slovenia, Czech Republic, and Hungary) in which investment is above or just below 1% of GDP. Into the third group belong five countries, including Slovakia, ranging from 0.26 to 0.53%. The last group includes Bosnia and Herzegovina, Moldova and Montenegro, where private investment is below 0.1% of GDP.

Graph 4 R&D expenditure in the business sector



Data: Innovation Union Scoreboard 2019;

Note: Missing data for Baden- Württemberg and Bavaria.

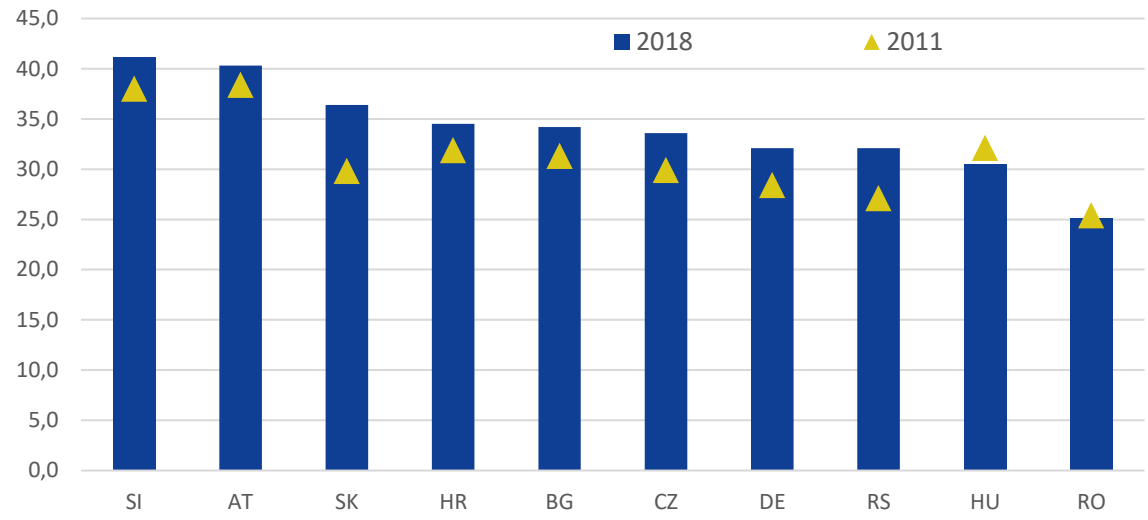
3.1.2. Human resources

The European economy is increasingly oriented towards knowledge and services with high added value. Therefore, investment in skills and scientific education is important for future development and competitiveness vis-à-vis other world regions. Qualified human capital for research and innovation is key to meeting the needs of the knowledge economy. In the EU, we can see the growing need for educated human capital, with 14% of all jobs expected to be automated in the near future and a further 32% will undergo substantial changes. [1] Therefore, there is increasing pressure to provide better education that will produce resources for research and innovation.

One of the objectives of the Strategy Europe 2020 is that at least 40% of the population year should have **completed higher education**. Among the countries under review, Slovenia and Austria met this target. There are less than 30% of university graduates in Romania. In Romania and Hungary, this share has even decreased since 2011. In other countries, we can observe the number growing (mostly in Slovakia and Serbia).

[1] OECD, Putting faces to the jobs at risk of automation. Policy brief on the future of work. March 2018

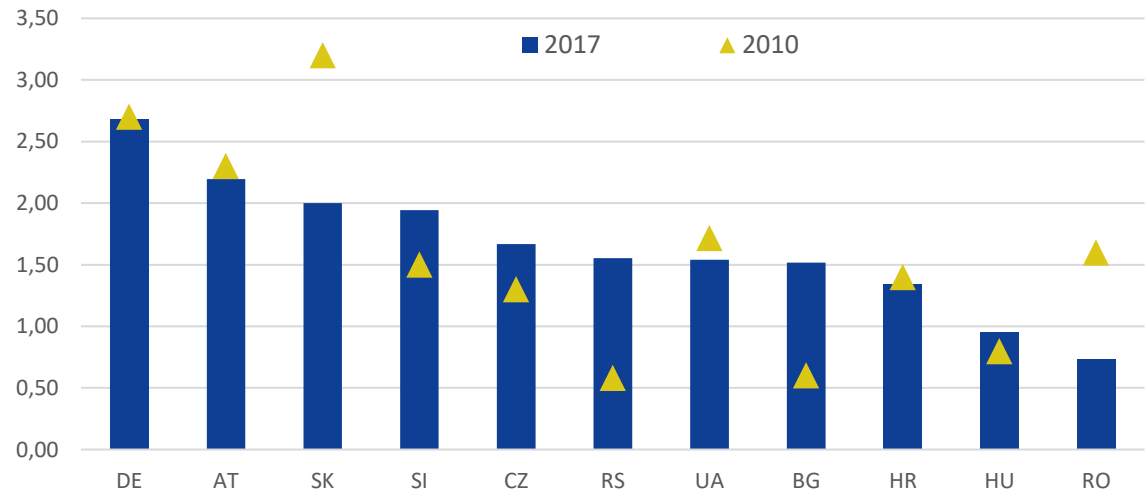
Graph 5 Population aged 25-34 with tertiary education



Data: Innovation Union Scoreboard 2019
Note: Missing data for Bosnia and Herzegovina, Montenegro, Baden- Württemberg, Bavaria, Moldova and Ukraine.

Well-prepared and well-educated people are the basic prerequisite for the implementation of cutting-edge research and innovation. One of the basic prerequisites for a successful scientific career is the **completion of doctoral studies**. In this comparison, out of eleven countries there has been a decrease in the proportion of graduates in six of them and an increase in five of them. In Germany, Austria and Croatia, this decrease was minimal (less than 0.1%). The highest increase was in Slovakia (1.2%) and Romania (0.87%). By contrast, Serbia (0.97%) and Bulgaria (0.92%) recorded the highest growth.

Graph 6 New doctorate graduates per 1000 population aged 25-34

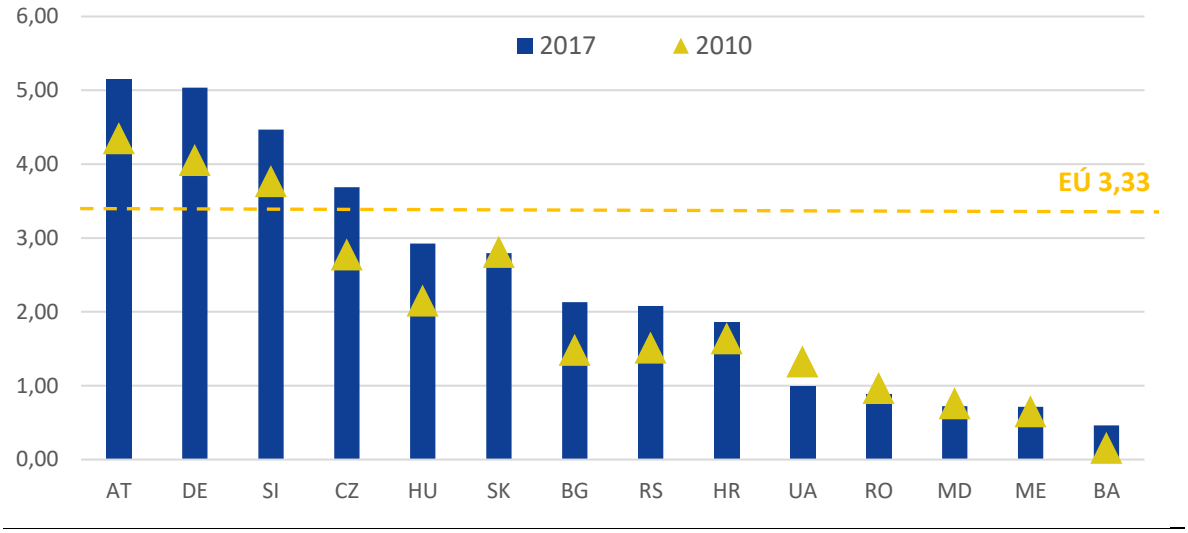


Data: Innovation Union Scoreboard 2019
Note: Missing Data for Baden- Württemberg, Bavaria, Montenegro, Bosnia and Herzegovina, Moldova

The number of doctoral graduates, as well as investment in research and innovation, has a positive impact on the number of researchers in a given country. There are 3.33 researchers per thousand inhabitants in the EU on average. Among the countries of the Danube Strategy, Austria, Germany,

Slovenia and Czech Republic are above average. The lowest number of researchers is in Moldova, Montenegro and Bosnia and Herzegovina. Almost all countries recorded an increase in the number of researchers, only in Slovakia, Romania and Moldova there was a slight decrease. There was a visible decline in Ukraine (0.34).

Graph 7 Number of researchers in R&D (per 1000 population) - FTE



Data: OECD, Dataset: Science, technology and innovation
Note: Missing data for Baden- Württemberg, Bavaria

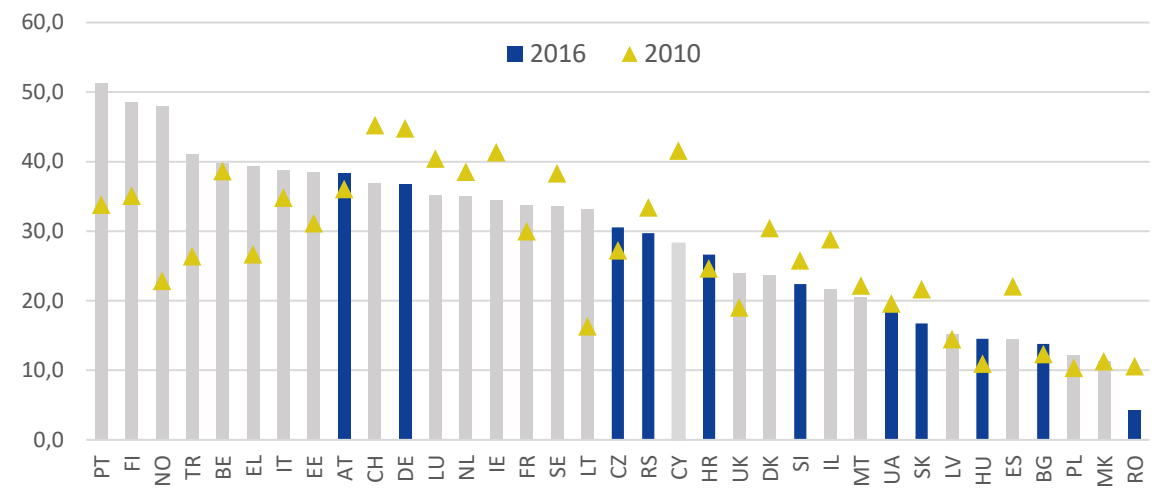
3.2. Activities

When it comes to activities, the analysis focuses on two main areas – the ability to innovate and cooperation between academic institutions and industry, and participation and cooperation in the Horizon 2020 Framework Program for Research and Innovation.

3.2.1. Cooperation on knowledge and innovation

This comparison monitors the extent to which SMEs can present the products or processes they have developed within their own business. Austria is the country where the largest share of SMEs in the Danube region is **innovating internally** (38.3%), followed by Germany and Czech Republic. The lowest share of such companies is in Romania, Bulgaria and Hungary. In five countries where data is available, this share increased between 2010 and 2016, while in other six it decreased.

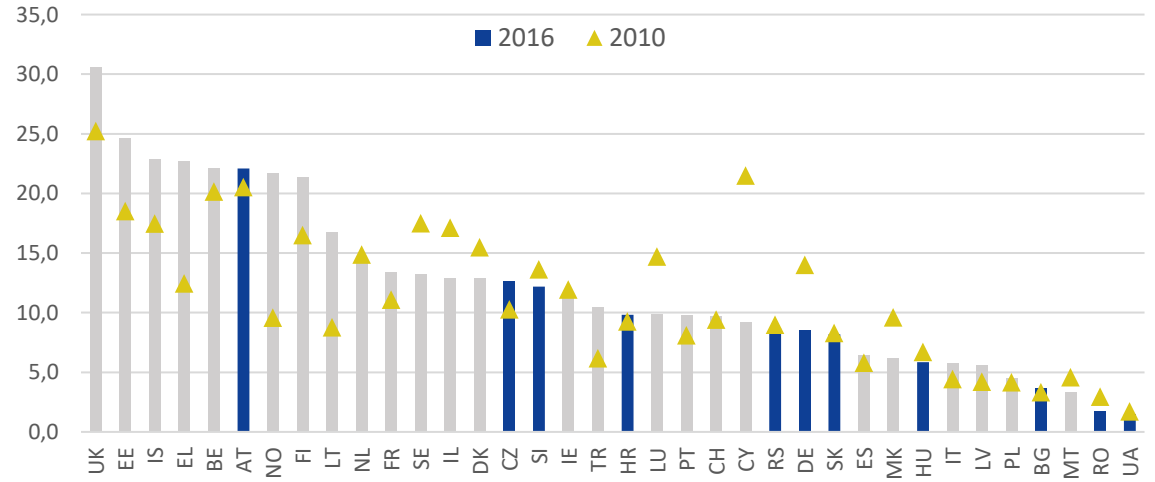
Graph 8 SMEs innovating in-house (% SMEs)



Data: Innovation Union Scoreboard 2019

Austria also has the highest share of SMEs (22.1%) **working with other SMEs**. Austria is followed by Czech Republic (12.6%) and Slovenia (12.2%). In contrast, virtually no cooperation is declared by companies in Ukraine, Romania and Bulgaria. There is an interesting situation in Germany where at least some cooperation reported only 8.5% of companies. In five countries, the number of such firms increased, in five countries it fell and in Romania it remained the same.

Graph 9 Innovative SMEs collaborating with others

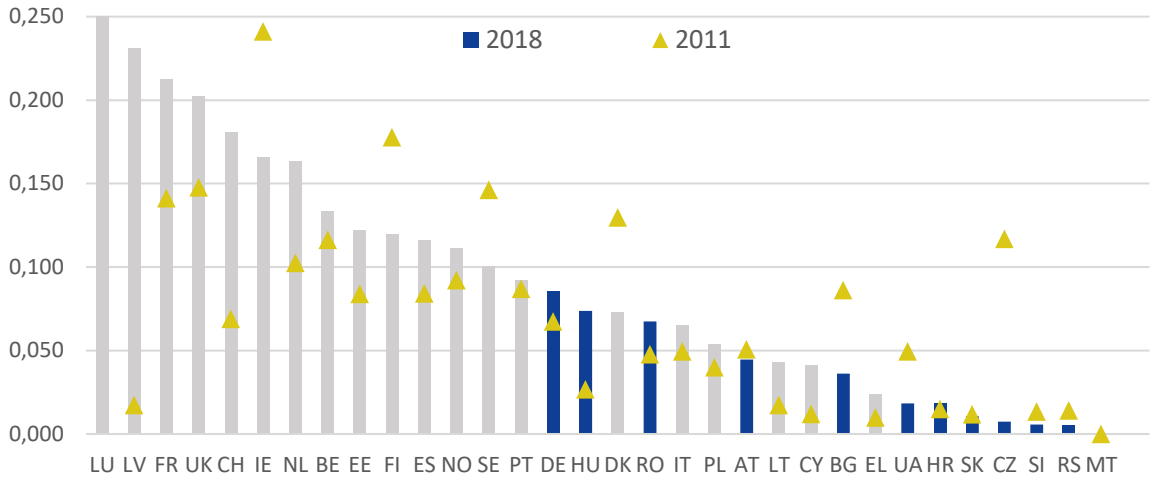


Data: Innovation Union Scoreboard 2019

Access to risk capital is one of the basic preconditions for the growth and development of new start-ups, especially those based on research and innovation results. Overall, the EU lags far behind the USA in its approach to venture capital. In 2016, US venture capital funds amounted to 38 billion €, while in the EU it was only € 6 billion €. From a European perspective, all the states in the Danube region are in the lower half in terms of access to venture capital. The best position has Germany with 0.0686% of

GDP, Hungary (0.074%) and Romania (0.067%). On the other hand, companies in Serbia, Slovenia and the Czech Republic have the worst access to venture capital. In five countries, access to risk capital was increased between 2011 and 2018, while in six countries it decreased. The largest decline is seen in the Czech Republic (from 0.117% to 0.007%).

Graph 10 Venture capital expenditures



Data: Innovation Union Scoreboard 2019

3.2.2. Participation in Horizon 2020

Horizon 2020 is the largest EU program for research and innovation. Between 2014 and 2020, 77 € billion was allocated within calls under the three pillars. Participation in Horizon 2020 projects is considered a prestigious matter, as the primary criterion for evaluation is the excellence of projects and research teams. Horizon 2020 can thus be considered as a way of assessing the quality of the research and innovation ecosystem in each country.

According to terms of participation in Horizon 2020, the countries of Danube region can be divided into three groups:

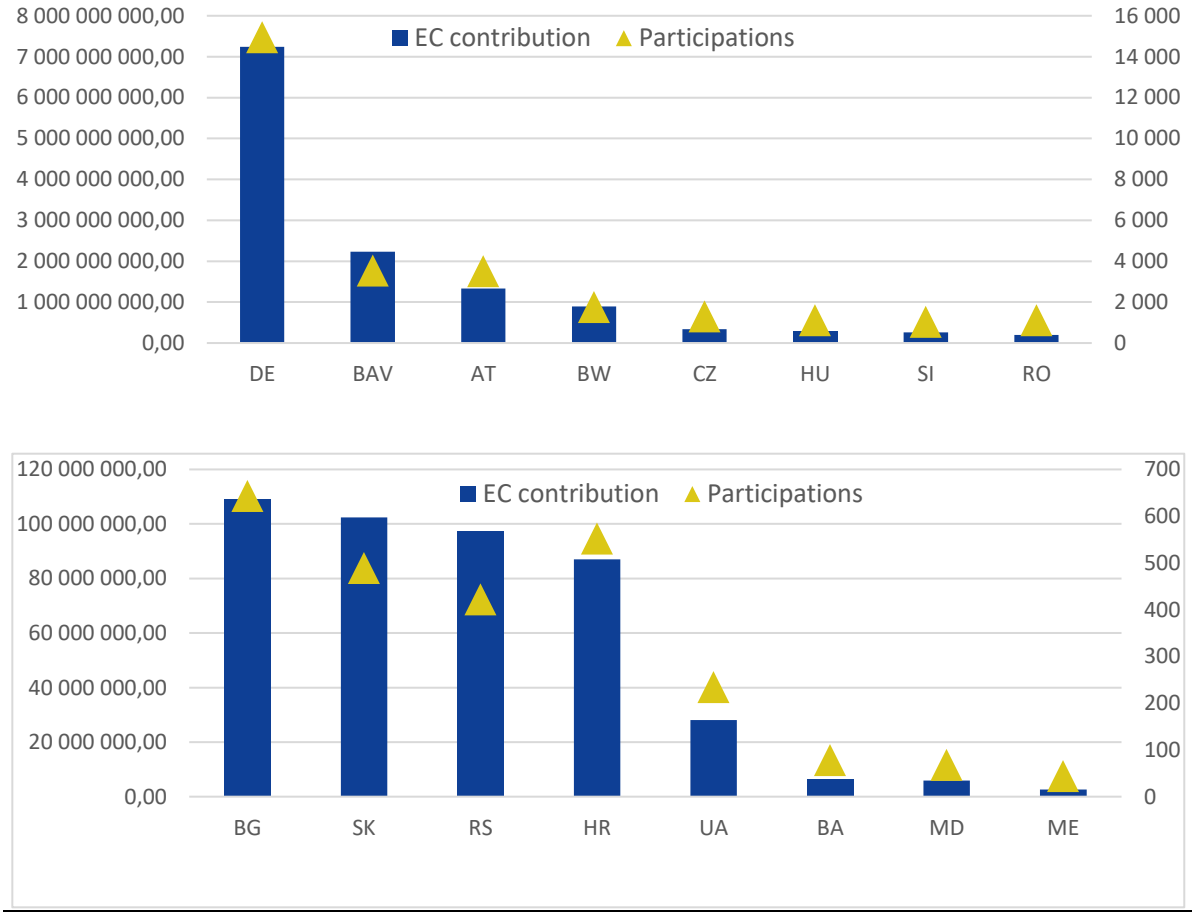
- Member states of the EU (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia, Slovenia);
- Associated acceding countries (Bosnia and Herzegovina, Montenegro, Serbia);
- Associated countries (Moldova, Ukraine).

In theory, all the above-mentioned countries have the same rights and opportunities to participate in the calls within Horizon 2020.

Germany dominates in terms of overall participation in the program with 14 949 participations in the projects for more than 7,23 billion €. Bavaria and Austria follow. 8 countries and regions exceeded the level of 1 000 participations. By contrast, Montenegro, Moldova and Bosnia and Herzegovina have the lowest participation rates in terms of both the number of participants and the amount of the contribution received from the European Commission. From the above-mentioned comparison it is clear that the EU member states have disproportionately better starting position which allows them

higher participation of their researchers and innovators. From the non-member states, only Serbia reaches the EU lower level.

Graph 11 EC contribution and participation in Horizon 2020

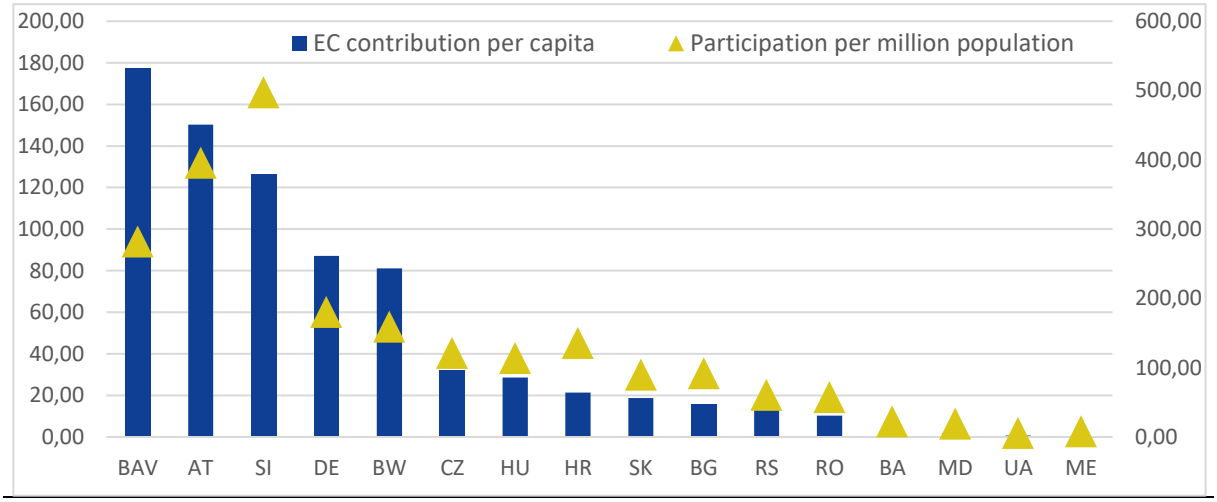


Data: E-corda (15/10/2019)

The comparison of absolute figures does not consider several factors such as the size of the country, population and the size and development of research and innovation ecosystem. Therefore, it is a quantitative comparison. In terms of qualitative comparison, we will compare participation in Horizon 2020 with the population and afterwards with the number of researchers.

Bavaria is the country with the highest EU contribution (177,17€) per capita, followed by Austria (150,26€) and Slovenia (126,17€). On the contrary, the lowest contribution gained Montenegro (0,48€), Ukraine (0,67€) and Moldova (1,66€). In terms of participation per million inhabitants, Slovenia (497,38) has the best position followed by Austria (395,77) and Bavaria (281,8). The lowest number of projects has Ukraine (5,55), Montenegro (8,07) and Moldova (19,17).

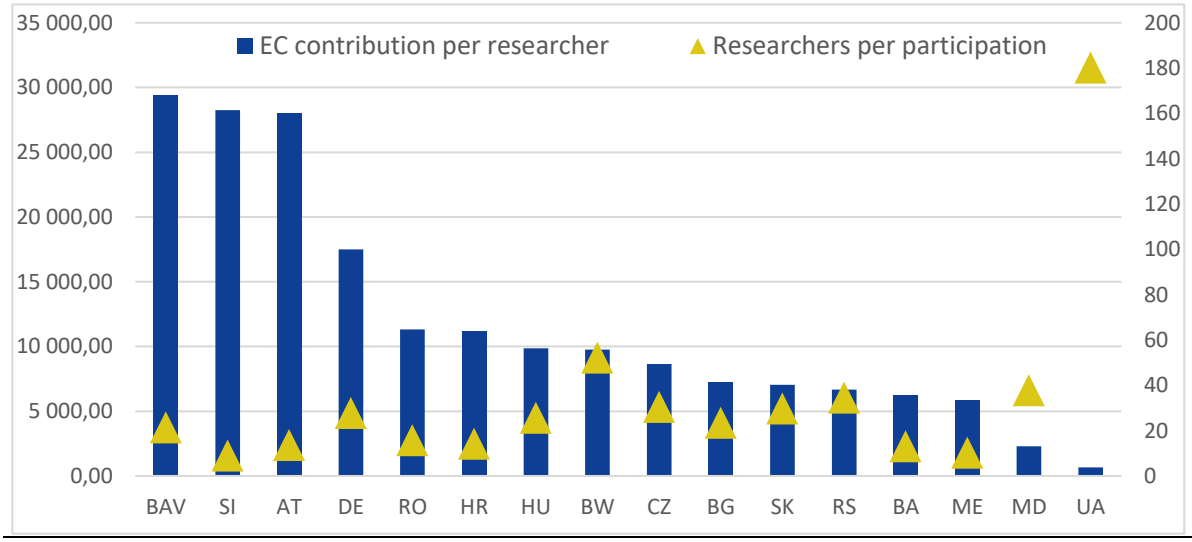
Graph 12 EC contribution and participation in Horizon 2020 per capita



Data: E-corda (15/10/2019); Eurostat

A similar pattern can be identified when we look EC contribution per one researcher. Again, the highest amount of financial assistance has been acquired by Bavaria (29,403€) followed by Slovenia (28,252€) and Austria (28,013€). There is a bigger gap after these 3 countries. On the other side of the scale is Ukraine with 666€ per researcher, mostly because of high number of Ukrainian researches participating in the project. Similarly to other statistics, the non-EU countries end up at the bottom of the overall ranking. Looking at the number of researchers per one participation one can conclude that Slovenia is the most successful country (8.98) followed by Monte Negro (10.2) and Bosnia and Herzegovina (13.05). Relatively small amount of researchers from these two countries is a contributing factor (449 researchers from Monte Negro and 1,018 from Bosnia and Herzegovina).

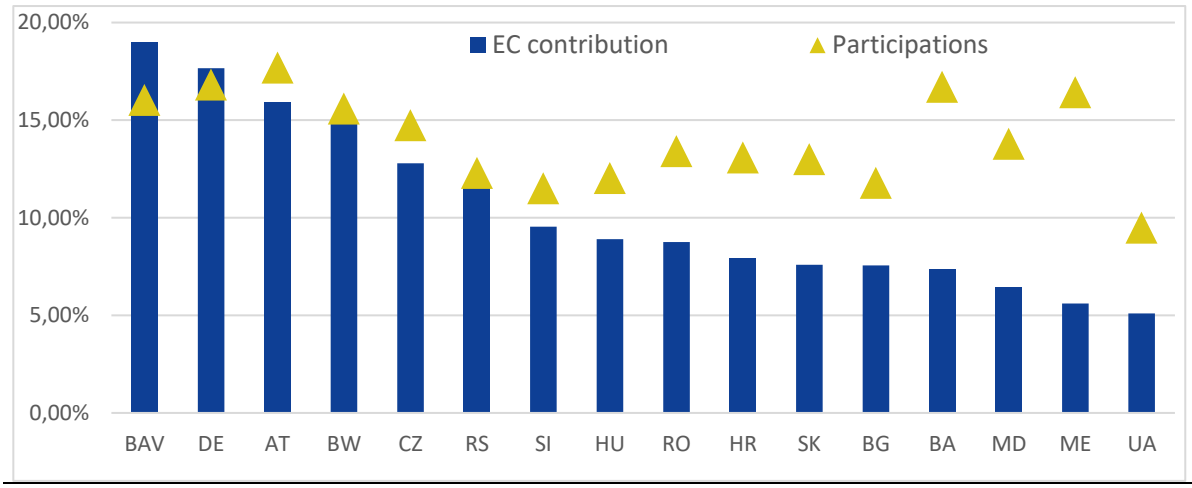
Graph 13 EC contribution and participation in Horizon 2020 per researcher (FTE)



Data: E-corda (15/10/2019)

Being successful in getting the Horizon 2020 projects is one of the biggest challenges. When compared to 7th framework programme the number successfully acquired projects has dropped below 14%. This number illustrates both the ability to get projects as well as the ability to join a research cluster. The numbers suggest that when it comes to EC contribution Bavarian researchers are the most successful ones (18.97%), followed by researchers from Germany (17.65%) and Austria (15.92%). On the other side of the ranking there are researchers from Ukraine (5.11%), Montenegro (5.6%) and Moldova (6.42%). If we look at projects acquired, it is Austria that takes the lead with 17.69%, closely followed by Germany (16.82%) and, surprisingly, Bosnia and Herzegovina (16.7%) and Montenegro (16.43%). We could conclude that playing a minor role in bigger research clusters (lower budget demands) brings success for both Bosnia and Herzegovina and Montenegro.

Graph 14 Success rate in Horizon 2020



Dáta: E-corda (15/10/2019)

The table below contains on overview of cooperation between the countries of Danube region. Obviously, Germany is the number one partner for majority of the countries. There is a low degree of cooperation between associated countries which is understandable because countries with more intensive research have higher chances to succeed.

Table 1 Cooperation between countries in the Danube region

	AT	DE	BG	CZ	HR	HU	RO	SI	SK	ME	RS	BA	MD	UA
AT	2620	9492	318	1024	361	668	616	670	424	12	199	32	24	100
DE	9492	20781	1002	3059	878	2325	1821	1724	961	32	591	87	53	385
BG	318	1002	718	208	173	233	314	224	114	23	117	21	23	61
CZ	1024	3059	208	512	189	379	337	300	321	10	100	14	18	129
HR	361	878	173	189	375	198	224	241	112	24	117	37	21	63
HU	668	2325	233	379	198	465	357	314	165	16	122	17	26	105
RO	616	1821	314	337	224	357	853	319	158	27	109	23	45	126
SI	670	1724	224	300	241	314	319	545	155	23	133	28	15	68
SK	424	961	114	321	112	165	158	155	218	8	47	10	14	45
ME	12	32	23	10	24	16	27	23	8	24	37	11	12	5
RS	199	591	117	100	117	122	109	133	47	37	238	29	14	27
BA	32	87	21	14	37	17	23	28	10	11	29	75	5	4
MD	24	53	23	18	21	26	45	15	14	12	14	5	18	25
UA	100	385	61	129	63	105	126	68	45	5	27	4	25	150

Data: E-corda (15/10/2019)

The Horizon 2020 regulation supports mobility of research personnel. In case of participation in projects that belong to scope of Marie Sklodowska-Curie activities each researcher has an opportunity to spend part of his career working in foreign research institutions or to return back to his home country when foreign assignment is over. The table shows that researchers from Germany, Austria and Bavaria are the most active in these mobility programs. On the other hand the number of MSCA participants is lowest in Montenegro, Moldova and Bosnia and Herzegovina. The mobility program is very popular in Ukraine (30% of all Horizon 2020 participations). In Germany the mobility program represents 18% of all participations.

Since its beginning in 2007 the ERC is a synonym of excellent research. Within research community, an ERC grant is considered as a prestigious recognition. Recently it has been used to measure research quality on country level, institutional level as well as on individual level. Traditionally the EU countries with most ERC grants include Great Britain, followed by Germany with 1,049 participations and a contribution of the EC exceeding 1.5 billion €. Within Danube region it is Bavaria with 372 and Austria with 182 participations. It is worth to mention that Bavaria and Baden-Wurttemberg combined were able to get almost 50% of all German ERC contributions. The rest of the countries in the region are quite behind – Hungary with 39 participations and Czech Republic with 32. There are four associated countries with no ERC project – Ukraine, Bosnia and Herzegovina, Moldova and Montenegro.

Table 2 Participation in MSCA

Country	Participations	EC contribution
DE	2805	595 382 237,52
AT	563	127 311 877,38
BAV	539	147 384 055,03
BW	305	84 207 533,32
CZ	169	34 174 704,34
HU	141	18 430 929,27
RO	118	12 966 501,14
SI	108	18 046 304,39
BG	89	7 406 019,90
RS	78	7 757 593,09
UA	70	9 237 458,92
SK	62	10 216 014,24
HR	57	7 768 394,45
BA	15	978 306,80
MD	10	1 243 600,00
ME	4	117 085,00

Table 3 Participation in ERC

Country	Participation	EC contribution
DE	1049	1 543 395 713,90
BAV	372	570 990 825,34
AT	182	261 037 851,87
BW	144	198 662 331,53
HU	39	58 579 435,91
CZ	32	46 352 189,83
SI	11	11 828 059,00
RO	7	6 312 550,00
RS	4	3 185 485,00
HR	4	2 727 355,50
SK	3	562 499,93
BG	2	207 412,50
UA	0	0,00
BA	0	0,00
ME	0	0,00
MD	0	0,00

Data: E-corda (15/10/2019)

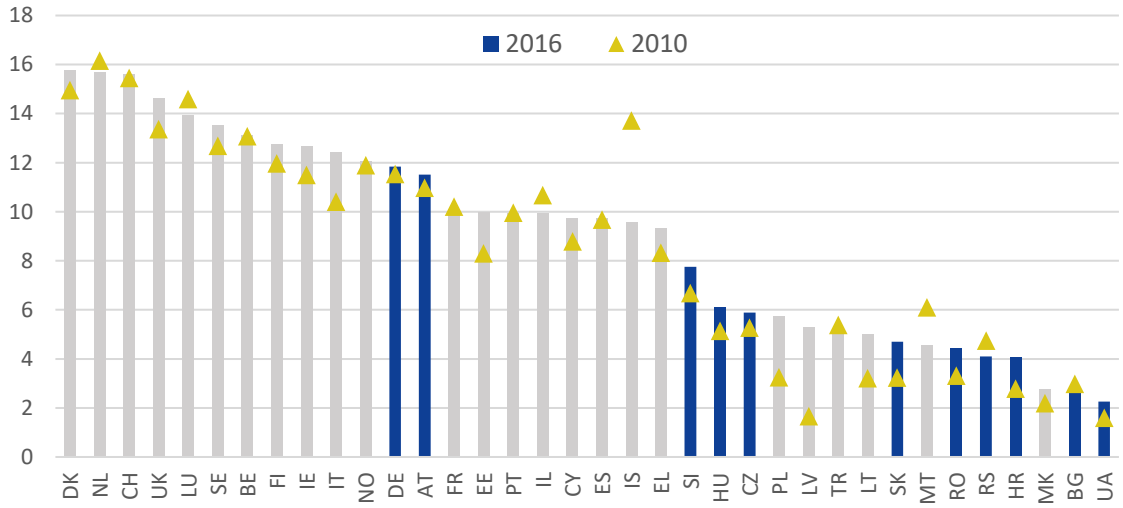
3.3. Outputs

Scientific work outputs are an important indicator in evaluating the effectiveness of research and innovation ecosystems in translating investment in knowledge activities into tangible and intangible values that expedite the realisation of higher added-value activities. It is the excellent outputs, whether publications or patents, that are important for innovations as well as for new knowledge that can be applied in the economy and society.

3.3.1. Publications

The publication of scientific results is a fundamental method of disseminating the work of researchers and innovators. Within Europe, considerable differences pertain between the publication performances of individual countries. This can be demonstrated by comparing the share of publications which rank among the **10% most cited** world-wide. Within the EU countries, researchers from the Nordic countries, Benelux and the UK are the highest ranked. Of the Danube region countries, Germany (11.83%) and Austria (11.51%) are the most successful. The other Danube region countries are ranked only in the lower half of the list of the countries studied. Ukraine (2.25%) and Bulgaria (2.68%) occupy the last two positions. On the other hand, however, all the countries in the Danube region countries (except for Bulgaria) improved their position in comparison with 2010.

Graph 15 Scientific publications among the top 10% most cited publications worldwide



Data: Innovation Union Scoreboard 2019

Table 4 Number of publications per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
BW	2 438,99	2 494,60	2 546,03	2 601,64	2 701,07	2 738,53	2 906,18	2 907,17	2 818,82	**24 153,02**
AT	2 209,79	2 282,48	2 363,87	2 468,85	2 667,86	2 754,56	2 968,02	2 971,86	2 880,76	**23 568,04**
SI	2 189,91	2 407,12	2 447,49	2 535,91	2 561,38	2 641,15	2 737,75	2 684,41	2 648,36	**22 853,49**
BAV	2 076,52	2 126,19	2 178,48	2 253,26	2 393,52	2 441,44	2 614,05	2 589,26	2 549,76	**21 222,49**
CZ	1 602,38	1 610,55	1 678,15	1 768,77	2 056,66	2 237,41	2 239,38	2 205,11	2 001,73	**17 400,14**
DE	1 718,66	1 758,93	1 799,58	1 854,35	1 935,43	1 979,98	2 071,87	2 071,57	1 989,53	**17 179,90**
HR	1 179,27	1 273,48	1 253,36	1 236,68	1 313,22	1 320,82	1 386,82	1 495,98	1 430,73	**11 890,35**
SK	921,58	881,58	1 017,90	1 074,96	1 351,82	1 383,75	1 486,31	1 387,97	1 178,62	**10 684,50**
HU	861,07	877,85	939,04	989,49	1 079,53	1 066,54	1 086,80	1 111,87	1 100,92	**9 113,09**
RS	809,19	866,49	1 109,31	1 030,48	1 035,07	1 064,08	1 072,41	1 072,84	1 010,80	**9 070,67**
RO	716,95	699,99	732,62	815,24	858,23	931,16	864,87	848,07	765,35	**7 232,47**
BG	480,57	463,43	492,57	497,57	517,28	506,28	583,71	636,00	587,57	**4 764,97**
BA	212,70	223,27	208,42	192,15	204,42	252,39	257,53	319,48	293,21	**2 163,57**
UA	144,26	156,60	159,04	162,17	175,22	166,42	181,13	195,57	177,73	**1 518,13**
MD	98,38	110,22	113,04	118,11	125,44	122,90	151,09	135,02	140,10	**1 114,29**
ME	36,88	40,55	45,87	55,78	55,78	71,37	77,06	80,73	70,82	**534,82**

Data: InCites, Web of Science Core Collection (30. 8. 2019)

Austria (6,939) and Slovenia (5,672) rank highest in the **number of publications per million inhabitants** which originated from collaboration with any other Danube region country. By contrast, Montenegro (236), Ukraine (240) and Moldova (252) have the lowest number of such publications. A positive trend can be observed in that the number of collaborative publications in the Danube region countries is increasing. Compared with 2010, this shows a 1.76-fold increase. The highest increase in collaborative publications was reported by Moldova (2.43), Serbia (2.27) and Romania (1.99). The lowest increases were recorded for Bulgaria and Germany (Table 5). A significant increase can also be seen when comparing the number of publications over a five-year period (Table 6).

Table 5 Number of scientific publications in cooperation with countries in the Danube region per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	2010-2018
AT	582,36	614,42	669,84	704,05	790,85	811,74	902,72	926,76	936,81	**6 939,56**	1,61
SI	435,87	482,48	547,36	579,55	619,92	717,96	727,09	751,59	810,70	**5 672,52**	1,86
CZ	230,05	241,98	274,09	290,99	349,02	381,98	401,60	433,06	454,28	**3 057,05**	1,97
SK	232,64	240,72	262,92	266,77	327,86	344,19	385,47	386,39	380,70	**2 827,67**	1,64
HR	209,75	231,09	276,73	267,40	311,07	340,02	364,31	407,48	403,31	**2 811,16**	1,92
HU	173,95	193,29	214,58	220,10	252,54	257,76	284,98	294,49	303,19	**2 194,88**	1,74
BW	178,35	194,95	212,28	217,90	228,88	238,86	263,53	269,06	282,04	**2 085,83**	1,58
BAV	159,34	164,18	185,88	192,24	223,15	231,49	252,87	251,12	260,26	**1 920,53**	1,63
RS	114,45	141,30	183,81	180,22	189,98	213,25	229,19	245,13	260,06	**1 757,38**	2,27
DE	102,39	107,57	115,91	120,39	132,10	137,55	149,97	153,30	152,87	**1 172,04**	1,49
BG	97,43	99,43	114,86	113,29	116,00	113,57	142,57	153,43	141,43	**1 091,99**	1,45
BA	74,80	82,23	78,23	76,80	89,65	112,77	116,49	144,47	147,89	**923,33**	1,98
RO	50,87	58,60	72,26	82,00	88,86	92,11	97,72	100,35	101,43	**744,21**	1,99
MD	20,30	29,03	30,73	31,57	44,54	47,64	48,77	50,18	49,33	**352,08**	2,43
UA	20,02	22,54	23,39	25,88	28,04	27,00	30,20	31,72	31,65	**240,43**	1,58
ME	17,98	19,81	20,00	23,30	22,93	29,36	33,76	35,41	34,13	**236,68**	1,90

Data: InCites, Web of Science Core Collection (30. 8. 2019)

Table 6 Number of scientific publications in cooperation with countries in the Danube region (five years periods)

	2010-2014	2011-2015	2012-2016	2013-2017	2014-2018
DE	48 015	50 934	54 454	57 558	60 254
AT	29 779	31 811	34 365	36 641	38 703
CZ	14 762	16 380	18 080	19 773	21 512
HU	10 305	11 124	12 020	12 801	13 613
SK	7 254	7 862	8 651	9 324	9 945
RO	6 841	7 641	8 400	8 945	9 322
RS	5 639	6 327	6 939	7 366	7 922
SI	5 546	6 133	6 642	7 067	7 548
HR	5 283	5 814	6 357	6 890	7 444
UA	5 053	5 347	5 670	6 021	6 264
BG	3 787	3 900	4 202	4 472	4 669
BA	1 407	1 540	1 660	1 892	2 141
MD	554	651	721	790	853
ME	567	629	705	789	848

Data: InCites, Web of Science Core Collection (30. 8. 2019)

Table 7 provides an overview of the number of publications resulting from collaborations between the Danube region countries from 2010 to 2018. The largest number of such publications was produced in Austria and Germany (50,741), followed by Germany and the Czech Republic (18,509). The lowest production of such publications is observed in the non-EU member Danube region countries, e.g.

Montenegro and Moldova have only 16. Moldova and Bosnia and Herzegovina have only 21 such publications. This implies that researchers naturally publish more with partners from innovative countries (Germany and Austria). A certain role can also be ascribed to some historical background. For example, Slovak researchers have 9,019 publications produced in collaboration with their Czech peers, while this number declines close to half (5,010 publications) for collaborations with German researchers. Slovakia and Montenegro are the only countries in the Danube region that did not produce the highest number of joint publications with Germany, as pertains for the other Danube region countries. As already mentioned, Slovakia's major publishing partner is the Czech Republic and that of Montenegro is Serbia.

Table 7 Number of publications among countries in the Danube region (2010 – 2018)

	AT	BA	BG	HR	CZ	DE	HU	MD	ME	RO	RS	SK	SI	UA	BAV	BW
AT	0	236	1 980	2 669	6 637	50 741	5 751	76	91	3 200	2 936	3 095	3 249	1 842	15 149	13 334
BA	236	0	109	1 182	183	427	122	21	149	170	1 579	79	486	74	88	65
BG	1 980	109	0	1 415	2 159	4 851	1 933	49	86	1 567	1 796	836	704	1 315	1 032	1 827
HR	2 746	1 182	1 415	0	2 400	5 284	2 174	45	256	1 262	2 572	791	2 574	1 329	1 336	2 036
CZ	7 358	183	2 159	2 400	0	18 509	4 668	72	84	2 792	2 713	9 019	2 587	2 365	5 218	6 073
DE	50 741	427	4 851	5 284	18 509	0	13 348	580	142	8 721	5 162	5 010	5 206	6 988	-	-
HU	5 751	122	1 933	2 174	4 668	13 348	0	68	38	3 968	2 745	2 476	1 949	1 722	3 438	4 322
MD	76	21	49	45	72	580	68	0	16	534	47	37	27	145	163	87
ME	91	149	86	256	84	142	38	16	0	120	861	68	163	44	65	62
RO	3 200	170	1 567	1 262	2 792	8 721	3 968	534	128	0	2 064	1 900	1 726	1 381	2 476	3 163
RS	2 936	1 579	1 796	2 572	2 713	5 162	2 745	47	790	2 064	0	1 564	2 501	1 208	1 565	2 339
SK	3 095	79	836	791	9 019	5 010	2 476	37	58	1 900	1 564	0	1 514	1 184	1 684	1 996
SI	3 249	486	704	2 574	2 587	5 206	1 949	27	161	1 726	2 501	1 514	0	420	1 947	2 005
UA	1 842	74	1 315	1 329	2 365	6 988	1 722	145	52	1 381	1 208	1 184	420	0	983	2 524
BAV	15 149	88	1 032	1 336	5 218	-	3 438	163	65	2 476	1 565	1 684	1 947	983	0	-
BW	13 334	65	1 827	2 036	6 073	-	4 322	87	62	3 163	2 339	1 996	2 005	2 524	-	0

Data: InCites, Web of Science Core Collection (30. 8. 2019)

3.3.2. Citations

Citations to published papers act as a basic measure indicating the impact a paper has on the scientific community. Put simply, the more frequently a publication is cited, the greater its impact on a particular field of research. In the Danube region, over the period under study, the highest number of citations per million inhabitants was achieved in Baden-Württemberg, followed by Bavaria and Austria. By contrast, Montenegro, Moldova and Ukraine accrued the lowest number of citations (Table 8).

Table 8 Number of citations per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
BW	63 688,02	58 836,17	58 975,23	53 524,39	46 871,46	39 453,35	30 292,04	18 872,90	8 362,01	**378 875,57**
BAV	53 711,44	49 072,21	47 283,68	44 041,03	38 047,33	32 108,78	26 382,41	16 192,11	7 003,04	**313 842,02**
AT	50 370,40	48 073,69	46 665,82	42 424,83	37 994,42	32 171,04	26 204,75	16 582,77	7 585,70	**308 073,41**
SI	33 120,16	33 596,87	38 712,91	32 252,75	29 229,07	25 613,82	22 553,62	12 703,11	6 438,54	**234 220,83**
DE	38 024,19	35 834,56	34 063,07	31 025,26	27 080,00	22 848,61	17 356,02	11 157,16	4 775,98	**222 164,85**
CZ	21 858,06	20 326,77	21 486,79	20 244,79	18 437,06	16 145,09	13 073,86	8 734,06	3 912,94	**144 219,42**
HR	16 730,84	15 849,63	16 406,76	13 503,36	12 300,04	11 046,93	7 957,81	5 967,26	2 677,46	**102 440,09**
HU	14 674,16	14 285,84	15 667,84	13 002,58	12 074,59	10 395,63	9 062,34	6 396,35	2 603,36	**98 162,69**
SK	10 260,68	9 132,69	11 143,54	9 123,15	8 717,68	8 892,34	7 679,41	4 615,42	1 717,67	**71 282,57**
RS	8 067,48	8 719,42	11 459,03	9 259,36	9 436,13	8 514,36	6 517,02	4 333,86	1 791,27	**68 097,94**
BG	5 805,97	5 751,68	6 509,39	5 057,69	5 413,97	4 911,97	3 537,98	2 452,70	1 309,56	**40 750,92**
RO	4 582,19	4 797,58	5 531,95	5 328,82	5 421,50	4 349,01	3 804,62	2 492,98	1 097,38	**37 406,03**
BA	1 390,70	1 146,88	1 003,55	1 171,72	1 228,25	1 154,30	1 662,50	1 146,31	287,79	**10 192,00**
UA	1 203,99	1 576,27	1 505,96	1 274,68	1 304,79	1 200,88	876,45	621,61	241,43	**9 806,06**
MD	1 219,16	836,35	873,28	828,18	1 056,79	778,00	788,15	672,86	153,35	**7 206,12**
ME	359,79	565,46	354,28	266,95	359,79	259,61	205,49	256,13	73,94	**2 701,44**

Data: InCites, Web of Science Core Collection (30. 8. 2019)

If attention is paid only to the number of citations to publications between individual countries of the Danube region, Austria, Slovenia and Baden-Württemberg rank best and Montenegro, Moldova and Ukraine show the lowest number of citations (Table 9).

Table 9 Number of citations with countries in the Danube region per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
AT	21 704,13	20 657,03	21 952,58	19 260,23	17 357,48	15 280,56	13 262,67	8 266,15	4 012,74	**141 753,57**
SI	12 117,79	12 184,58	18 069,04	13 527,75	12 612,28	12 638,71	11 725,17	6 929,19	3 863,70	**103 668,21**
BW	7 954,33	7 443,42	9 883,05	7 391,53	7 465,83	6 898,58	6 257,77	3 624,83	1 839,08	**58 758,42**
CZ	8 322,97	6 816,28	8 527,11	7 973,48	7 052,62	6 527,73	5 598,51	3 734,62	1 847,26	**56 400,59**
HR	8 347,39	6 759,90	9 451,59	7 269,19	6 688,26	6 197,61	4 475,44	3 724,75	1 476,36	**54 390,49**
BAV	8 220,42	6 087,16	7 901,20	6 630,81	6 728,00	5 709,60	5 540,10	2 920,16	1 485,99	**51 223,43**
HU	5 820,26	6 212,27	7 983,01	5 916,75	5 854,85	5 119,44	5 197,00	3 898,59	1 477,27	**47 479,44**
SK	5 854,41	4 505,52	6 529,59	4 864,39	4 885,31	5 468,94	5 266,38	3 037,56	1 091,48	**41 503,58**
RS	2 548,48	3 253,84	5 853,30	3 845,19	4 522,41	4 668,17	3 696,13	2 669,10	1 006,50	**32 063,12**
BG	2 982,84	3 115,27	4 286,26	3 009,70	3 450,12	3 434,12	2 369,27	1 593,28	950,99	**25 191,86**
DE	3 620,69	3 457,63	3 566,57	3 203,02	3 078,97	2 597,87	2 320,16	1 505,78	664,10	**24 014,80**
RO	1 305,40	1 416,37	2 374,02	2 017,87	2 509,89	1 664,39	1 671,71	1 061,20	409,50	**14 430,36**
BA	874,51	636,96	529,04	716,62	892,78	745,17	1 305,05	865,66	212,42	**6 778,20**
UA	417,19	804,35	804,19	612,43	595,68	663,39	476,59	334,35	121,91	**4 830,10**
MD	287,81	367,30	394,64	338,83	638,19	468,21	487,66	526,00	96,40	**3 605,03**
ME	257,23	424,55	172,10	157,79	170,45	157,42	139,99	192,83	41,10	**1 713,45**

Data: InCites, Web of Science Core Collection (30. 8. 2019)

Just as with publications, a positive trend in citations can be observed; in all the countries examined; the number of citations in the citation window 2014 – 2018 increased over the period of 2010 – 2014 (Table 10). On average, this growth is over 50% for the whole Danube region. The second positive outcome is that the greatest increase was achieved by the Danube region non-EU countries: in Moldova by 2.9 times and in Bosnia and Herzegovina by 2.8 times. On the other hand, the lowest increases of just 1.3 to 1.4 were achieved by Croatia, Austria, Montenegro and Germany.

Table 10 Numer of citation with countries in the Danube region (five years period)

	2010-2014	2011-2015	2012-2016	2013-2017	2014-2018
DE	452 643	492 944	550 333	587 728	649 026
AT	281 025	307 097	343 307	360 349	394 468
CZ	134 866	149 658	176 495	187 366	203 009
HU	103 294	119 679	138 289	140 000	161 590
RO	61 964	79 367	99 310	102 571	111 807
RS	47 116	60 880	77 040	76 522	89 842
SK	51 434	55 580	67 383	70 300	83 041
HR	53 634	57 576	67 373	66 126	71 249
SI	46 812	55 869	67 266	67 422	76 056
UA	47 218	59 350	65 195	66 173	72 885
BG	42 806	48 655	57 879	57 676	65 072
BA	3 687	3 731	5 017	7 393	10 469
MD	2 112	2 813	3 561	4 607	6 163
ME	1 972	2 082	1 769	2 103	2 787

Data: InCites, Web of Science Core Collection (30. 8. 2019)

Table 11 gives an overview of the number of citations to publications produced between the individual Danube region countries. As with publications, the highest number of such citations was accrued by Austria and Germany followed by the Czech Republic and Germany. The majority of the Danube region countries have the highest number of citations to publications produced in collaboration with Germany; Bosnia and Herzegovina and Montenegro in collaboration with Serbia.

Table 11 Number of citations among countries in the Danube region (2010 – 2018)

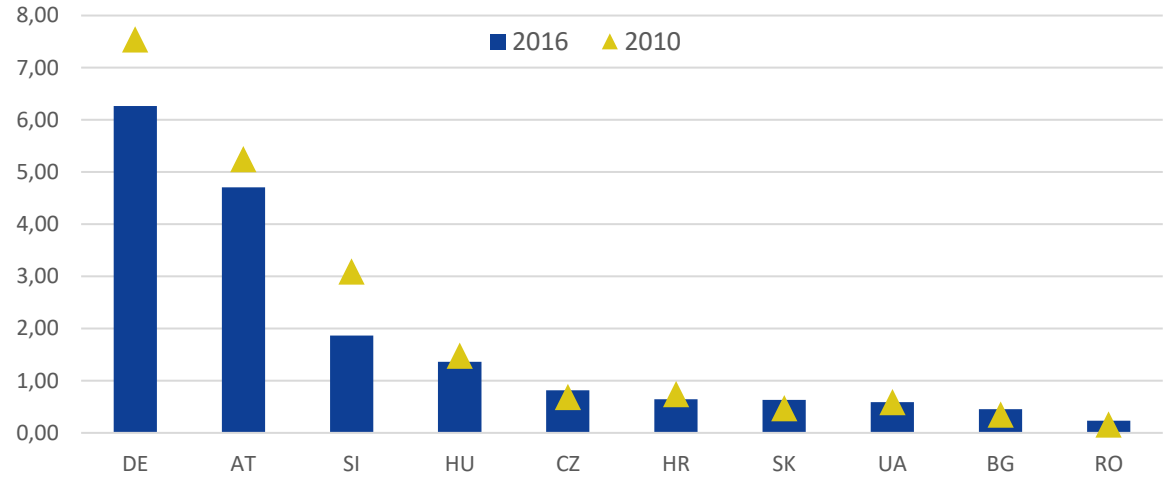
	AT	BA	BG	HR	CZ	DE	HU	MD	ME	RO	RS	SK
AT	0	5 222	72 447	83 295	197 114	1 033 590	158 941	978	2 508	100 884	113 199	85 900
BA	5 222	0	2 861	9 472	5 226	7 845	3 719	758	1 290	3 910	8 641	3 668
BG	72 447	2 861	0	52 570	65 890	134 363	62 267	782	2 507	43 096	62 342	22 832
HR	86 005	9 985	52 570	0	80 912	158 728	72 695	1 243	1 937	42 110	66 396	27 243
CZ	197 835	5 226	65 890	80 957	0	424 634	150 077	1 245	2 757	94 615	103 941	120 241
DE	1 033 590	7 845	134 363	155 238	424 634	0	333 996	7 835	4 564	199 624	156 524	123 380
HU	158 941	3 719	62 267	73 155	150 077	333 996	0	1 318	2 391	99 077	99 322	72 910
MD	978	758	782	1 211	1 245	7 835	1 318	0	704	3 358	1 104	808
ME	2 508	1 290	2 507	2 051	2 757	4 564	2 391	704	0	2 924	5 021	2 356
RO	100 884	3 910	43 096	42 310	94 615	199 624	99 077	3 358	2 924	0	76 377	73 598
RS	113 199	8 641	62 342	65 640	103 941	156 524	99 322	1 104	5 021	76 377	0	65 842
SK	85 900	3 668	22 832	25 917	120 241	123 380	72 910	808	2 356	73 598	65 842	0
SI	85 955	5 753	13 329	31 456	72 590	128 711	64 803	785	1 499	52 913	56 292	49 919
UA	72 732	2 478	54 741	57 855	74 077	159 838	69 453	1 096	2 269	55 675	63 332	34 619
BAV	319 858	2 451	47 445	48 990	153 752	0	115 021	2 576	3 638	78 618	65 093	60 786
BW	311 325	1 688	89 141	86 749	187 363	0	153 544	2 307	3 733	113 136	111 856	82 223

Data: InCites, Web of Science Core Collection (30. 8. 2019)

3.3.3. Patents

Patents express the ability of companies and research institutions to develop new products and services that enhance their competitiveness. Hence, patents serve as a proxy to measure the innovative capabilities of countries, companies and institutions. Figure 16 provides an overview of the number of **PCT applications** filed **at the European Patent Office** (EPO Graph 16). For a better comparison, this number is converted per billion GDP of individual countries. The graph only includes the EU countries and Serbia. The highest number of such patent applications were filed by Germany (6.27) and Austria (4.71) followed by the remaining Danube region countries with a great gap in between. The lowest numbers, below one patent application, were filed by Romania (0.23) and Bulgaria (0.46). In the four countries under review, the number of applications decreased on comparison with 2010.

Graph 16 PCT patent applications per billion GDP (in PPS)



Data: Innovation Union Scoreboard 2019
Note: Missing Data for Baden- Württemberg and Bavaria, Montenegro, Serbia, Moldova and Bosnia and Herzegovina.

Similarly, if the **number of EPO applications** is expressed **per million inhabitants**, the highest numbers were recorded for Germany (322.02) and for Austria (258.73). The other Danube region countries follow with a significant difference; Slovenia (47.58) and the Czech Republic (22.72). Moldova ranks last with no patent application filed in the past three years.

Table 12 EPO patent application per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018
DE	**329,18**	315,61	328,23	319,32	308,76	298,81	300,32	307,63	**322,02**
AT	**196,87**	195,74	211,54	224,97	221,70	224,52	228,47	249,36	**258,73**
SI	**62,95**	61,99	51,90	64,88	60,07	56,71	54,30	47,09	**47,58**
CZ	**15,68**	15,21	13,15	14,18	15,68	20,00	17,75	19,34	**22,72**
HU	**10,95**	9,82	10,74	10,54	11,67	9,93	10,95	9,72	**12,28**
SK	**4,59**	7,89	6,42	5,32	4,77	8,62	8,07	7,52	**9,17**
BG	**1,57**	2,29	1,71	3,29	4,57	4,71	2,57	4,57	**4,57**
HR	**4,17**	4,42	4,66	2,45	2,94	2,21	3,93	2,45	**3,43**
RO	**0,72**	1,08	1,80	1,70	1,44	1,55	1,60	2,68	**2,42**
RS	**1,15**	0,86	0,72	1,58	1,58	0,57	0,14	1,44	**1,29**
UA	**0,26**	0,26	0,28	0,59	0,33	0,45	0,24	0,00	**0,57**
ME	**0,00**	0,00	0,18	0,18	0,00	0,00	0,18	0,18	**0,37**
BA	**0,57**	0,00	0,86	0,29	0,00	0,00	0,29	0,00	**0,29**
MD	**0,56**	0,00	0,28	0,56	0,56	0,28	0,00	0,00	**0,00**

Data: EPO

The same situation is repeated in the **number of patents granted per million inhabitants**. Germany (250.59) heads the list followed by Austria (186.82) and Slovenia (36.52). In the last three years no patent was granted to patent applications originating from Bosnia and Herzegovina.

Table 13 EPO patents per million population

	2010	2011	2012	2013	2014	2015	2016	2017	2018
DE	**151,17**	163,55	160,38	161,71	157,63	170,01	225,59	226,61	**250,59**
AT	**75,74**	83,19	89,85	94,48	100,58	117,40	154,65	165,37	**186,82**
SI	**15,86**	20,18	18,26	24,99	24,51	31,24	38,44	44,21	**36,52**
CZ	**4,23**	5,26	5,26	6,29	6,20	6,95	8,92	11,55	**11,83**
HU	**5,93**	4,71	3,89	5,12	4,20	3,89	6,34	6,04	**6,75**
SK	**2,20**	0,55	2,39	0,92	2,02	2,02	2,75	3,30	**5,14**
BG	**0,43**	1,14	0,71	0,71	1,00	1,00	1,57	3,14	**2,57**
HR	**2,45**	1,23	2,70	1,72	1,72	1,47	1,23	1,47	**1,47**
RS	**0,29**	0,57	0,29	0,43	0,29	0,00	0,14	0,14	**1,29**
RO	**0,15**	0,10	0,15	0,10	0,21	0,46	0,98	0,67	**0,46**
MD	**0,00**	0,00	0,28	0,28	0,28	0,00	0,00	0,00	**0,28**
UA	**0,26**	0,00	0,07	0,12	0,12	0,05	0,19	0,09	**0,26**
BA	**0,29**	0,29	0,29	0,29	0,00	0,29	0,00	0,00	**0,00**
ME	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

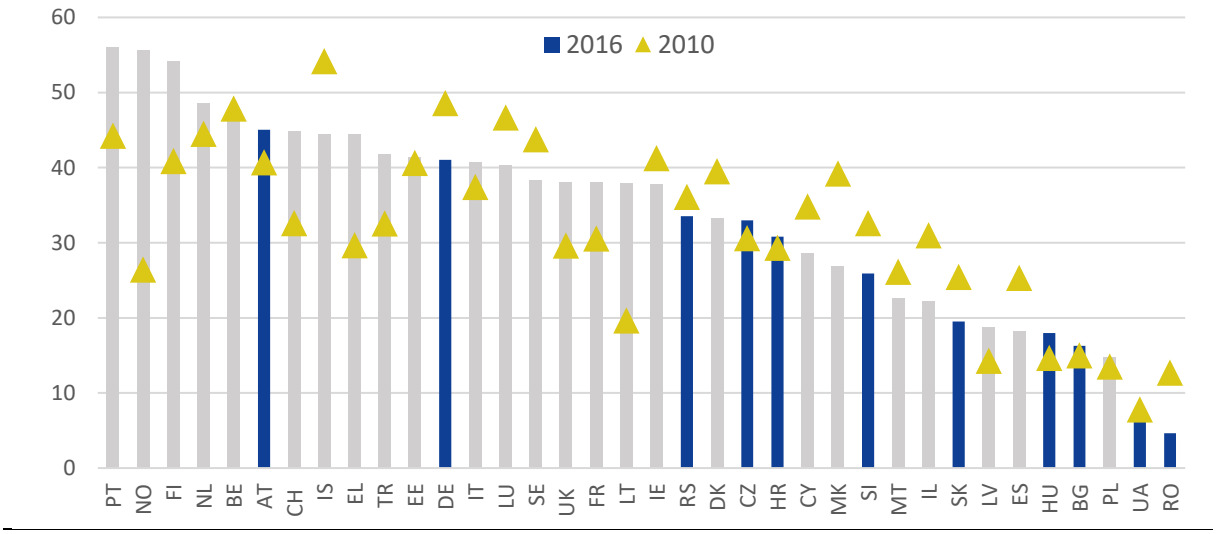
Data: EPO

3.3.4. Innovations

In addition to publications and patents, innovation itself is one of the principal outputs of the research and innovation process. This analysis focuses on comparing SMEs that have adopted at least one

product or process innovation, either in a business or in the market. In the Danube region, such companies predominate in Austria (45%) and Germany (41%). The lowest coverage of such companies is in Romania (4.63%) and Ukraine (7.4%). Five countries saw an increase in innovative SMEs, while six saw a decrease,

Graph 17 SMEs introducing product or process innovations (percentage of SMEs)

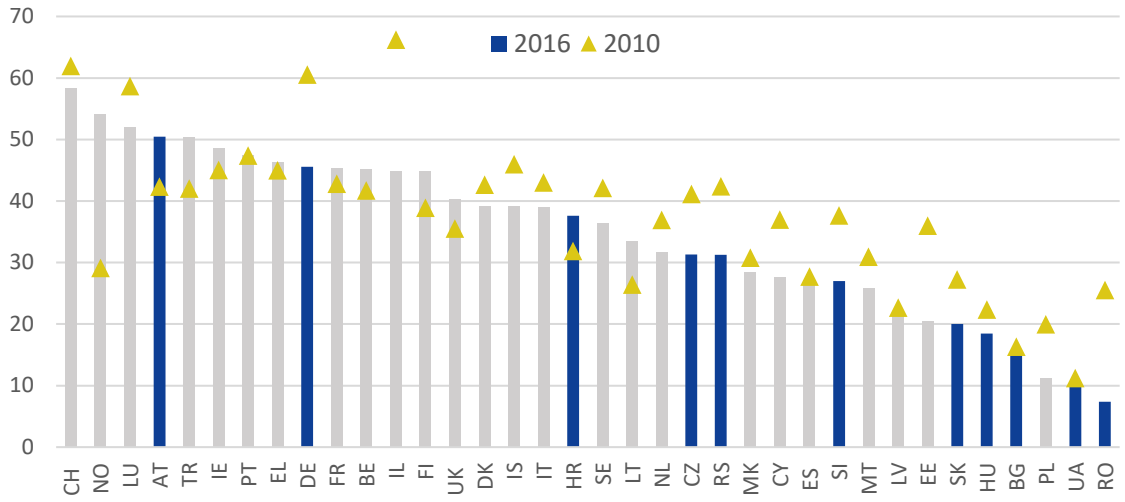


Data: Innovation Union Scoreboard 2019

The following comparison shows those SMEs that introduced either **organisational or marketing innovation** during the reference year. Organisational innovation is defined as a new organisational method in the business practices of a company (including knowledge management), workplace organisation or external relations that a company has not previously used. A new marketing concept or strategy is termed a marketing innovation.

Once again, Austria is the most successful in this comparison, with 50% of SMEs reporting such innovations in 2016 and followed by Germany with 45% of such SMEs. At the other end of the scale are Romania with 7% and Ukraine with 10%. Compared with 2010, only two countries reported an increase in the percentage of innovative enterprises; all the other countries exhibit a decrease, sometimes a significant one.

Graph 18 SMEs introducing marketing or organisational innovations (percentage of SMEs)



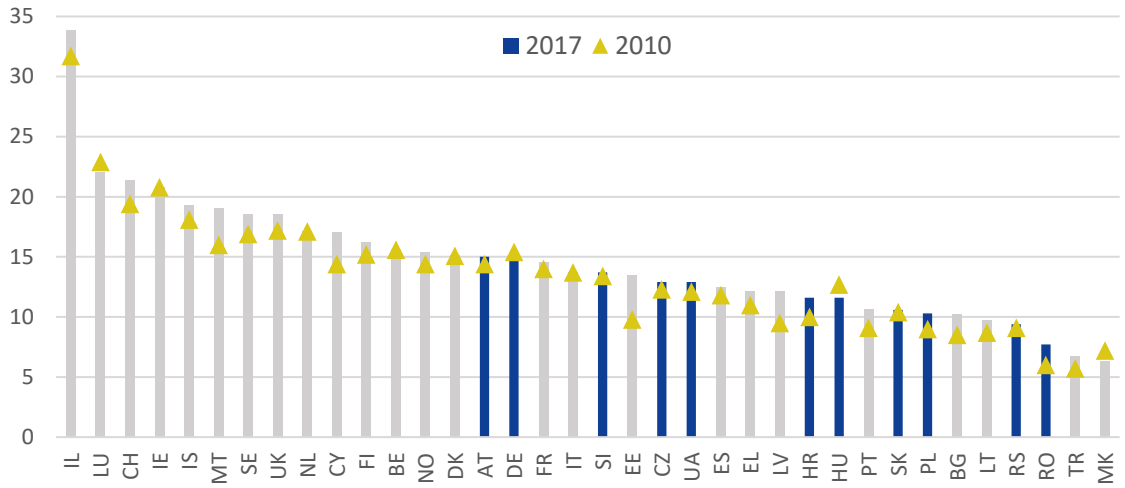
Data: Innovation Union Scoreboard 2019

3.4. Short-term and long-term effects (more innovation, higher productivity, exports)

The short-term and long-term effects of research and innovation are compared on the basis of employment in innovative companies, and innovative activities, sales of innovations and their export.

Knowledge-intensive activities are defined as those services that are provided direct to customers (e.g. telecommunications) and which, at the same time, provide inputs for innovative activities of other companies in all sectors of the economy. In this comparison, the Danube region countries trail behind the other EU Member States. In the Danube region, Austria (15%) and Germany (14.8%) have the highest employment rates. On the other hand, employment rates were among the lowest in Romania (7.7%) and Serbia (9.4%). Only in nine of the countries under review can an increase be demonstrated in the share of employment in knowledge-intensive activities.

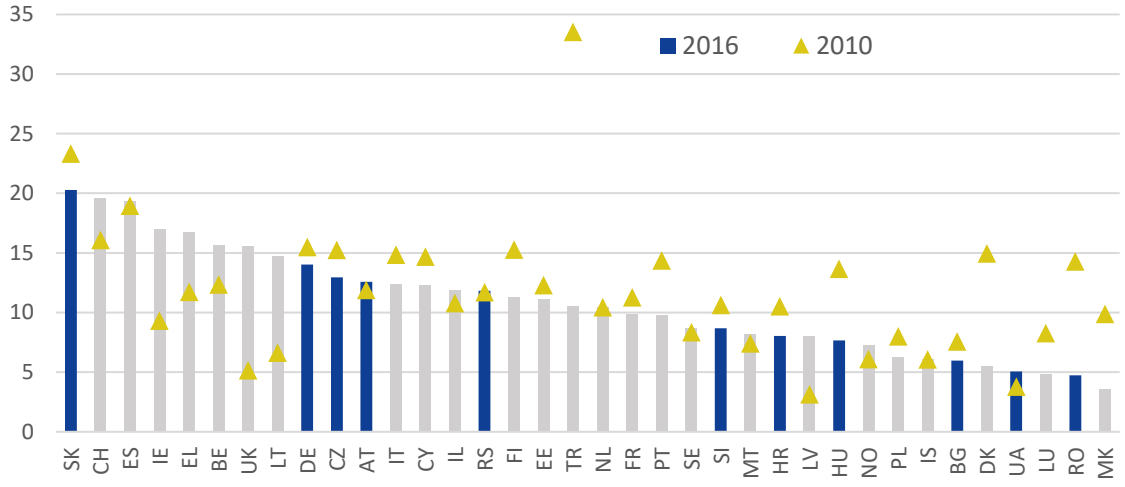
Graph 19 Employment in knowledge-intensive activities (percentage of total employment)



Data: Innovation Union Scoreboard 2019

In this evaluation, the **turnover of new or substantially improved products**, new both to the company and to the market, is measured. The evaluation measures the turnover of new or significantly improved products and includes both products which are only new to the firm and products which are also new to the market. In this comparison, Slovakia is the most successful country, not only within the Danube region, but across the EU. Sales of such innovations make up 20% of the turnover of Slovak companies. Slovakia is followed by Germany (14%) and the Czech Republic (13%). By contrast, sales of new innovations in Romania account for 4.8% and in Ukraine 5.% which are the lowest turnover shares. Compared with 2010, in only eight countries of the Danube region did the share of such sales decrease.

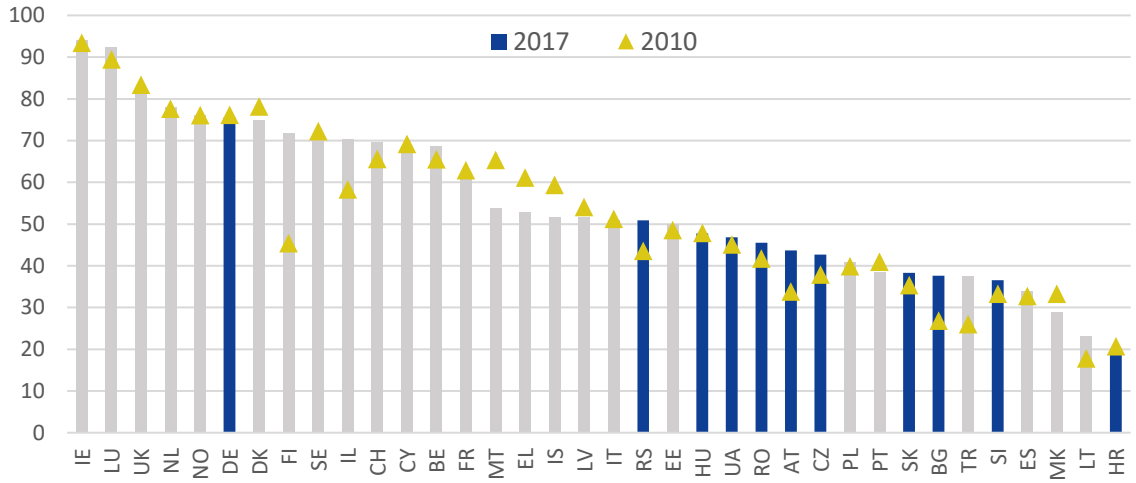
Graph 20 Sales of new-to-market and new-to-firm innovations as percentage of turnover



Data: Innovation Union Scoreboard 2019

Another comparison measures the **competitiveness of the knowledge-based service sector**. Measures to enhance competitiveness and innovation strategies can complement each other to facilitate growth in employment, export and turnover. This comparison reflects the ability of the innovation-based economy to export high-value-added services while being part of a knowledge-intensive global process. Within the EU, Ireland dominates this sector. In the Danube region it is Germany (75%), followed by Serbia with a relatively large gap (51%), and then by the other countries. The low export figures were recorded in Croatia (19%) and Slovenia (36%).

Graph 21 Knowledge-intensive services exports as percentage of total services exports



Data: Innovation Union Scoreboard 2019

4. Meeting the 2016 objectives

Priority Area 7 of the Danube Strategy – Knowledge Society (Research, Education and ICT) is coordinated jointly by Slovakia and Serbia. In 2016, with the aim of better monitoring, the Steering Committee revised its objectives. The following five objectives are defined in this analysis:

1. Increase the efficiency of funding research and innovations by setting up a coordinating funding network to initiate at least two activities per year (e.g. joint calls; proposals for joint strategic project applications (within a multilateral framework)).
2. Increase by 20% the number of EPO and PCT patent applications filed in the Danube region by 2020.
3. Enhance regional research and educational collaboration with a view to achieving 20% of academic mobility by 2020.
4. Increase the annual share of joint publications by 15% by 2020.
5. Develop RIS3 in each country (and its regions) by 2020.

4.1. Effectiveness of investment in research and innovation

Three calls were announced under the Interreg Danube Transnational Programme. The first in September 2015, the second in May 2017 and the third in January 2019. The second round of the third call was concluded in November 2019.

Seventeen projects in the Innovation and Social Responsibility priority were supported in the first call. Eights projects were supported in the second call. The third is currently being evaluated, with 17 projects which have advanced to the second round of the evaluation.

Within the framework of the EUREKA programme, three dedicated calls were launched for the Danube Region. The first call was launched in March 2015. It was a joint initiative of Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Montenegro, Romania, Serbia and Slovakia. The second call was open to institutions from Austria, Croatia, the Czech Republic, Germany, Hungary and Romania. Projects could be submitted up to March 2017. The third call with a deadline in March 2018 was a joint activity of Austria, Croatia, the Czech Republic, Hungary and Romania.

4.2. Increase the number of patents

The second objective of PA7 is to achieve a 20% increase in the number of EPO and PCT patent applications filed by the Danube region countries by 2020. With th**e number of EPO patent applications filed** increased by only 0.33%, this objective **has not been met** and it is unlikely this target will be achieved. This indicator does not appear to be optimally adjusted since, in order to meet the goal, the number of patent applications would have to increase by 4,435. The number of such patent applications, excluding Germany, attained 2,932. Germany is the key factor in meeting this objective. From a long-term perspective, it does not appear feasible that such a rapid increase might occur over just two years. This largely results from the differences in size of the countries and their research and innovation environs. In the Danube region countries, excluding Austria, the number of patent applications is counted in units or tens.

Table 14 EPO patent applications and growth (2010 – 2018)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth
AT	1 744	1 734	1 874	1 993	1 964	1 989	2 024	2 209	2 292	**31,42%**
BA	2	0	3	1	0	0	1	0	1	**-50,00%**
BG	11	16	12	23	32	33	18	32	32	**190,91%**
CZ	167	162	140	151	167	213	189	206	242	**44,91%**
DE	27 328	26 202	27 249	26 510	25 633	24 807	24 932	25 539	26 734	**-2,17%**
HR	17	18	19	10	12	9	16	10	14	**-17,65%**
HU	107	96	105	103	114	97	107	95	120	**12,15%**
MD	2	0	1	2	2	1	0	0	0	**-100,00%**
ME	0	0	1	1	0	0	1	1	2	**200,00%**
RO	14	21	35	33	28	30	31	52	47	**235,71%**
RS	8	6	5	11	11	4	1	10	9	**12,50%**
SI	131	129	108	135	125	118	113	98	99	**-24,43%**
SK	25	43	35	29	26	47	44	41	50	**100,00%**
UA	11	11	12	25	14	19	10	0	24	**118,18%**
Total	**29 567**	**28 438**	**29 599**	**29 027**	**28 128**	**27 367**	**27 487**	**28 293**	**29 666**	**0,33%**

Data: EPO

With PCT patent applications, the situation is similar. A decrease of -1.23% in comparison with 2010 is observed, even with an increase of 11.3% recorded in Germany. Only four of all the Danube region countries filed more than 100 applications over the whole period. Hence, meeting the target of 15% by 2020 appears highly improbable.

Table 15 PCT patent applications and growth (2010 – 2018)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	Growth
AT	426	162	503	477	413	462	471	524	403	3 841	**-5,40%**
BA	0	0	0	0	0	0	0	0	0	0	**0,00%**
BG	1	2	0	1	2	0	2	2	1	11	**0,00%**
HR	14	10	12	9	14	4	5	5	2	75	**-85,71%**
CZ	137	148	163	197	189	191	199	145	125	1 494	**-8,76%**
DE	905	690	936	1 041	852	922	1 175	1 046	1 007	8 574	**11,27%**
HU	11	5	5	7	31	10	0	6	0	75	**-100,00%**
MD	0	0	11	20	62	59	64	34	20	0	**2000,00%**
ME	0	0	0	0	0	0	0	0	0	0	**0,00%**
RO	14	15	8	18	17	6	6	0	0	84	**300,00%**
RS	16	17	17	22	12	29	15	18	20	166	**400,00%**
SK	27	49	28	32	48	19	19	24	28	274	**3,70%**
SI	76	80	67	87	88	37	29	0	0	464	**0,00%**
UA	1	1	1	3	2	2	2	4	2	18	**100,00%**
Total	1 628	1 179	1 751	1 914	1 730	1 741	1 987	1 808	1 608	15 346	**-1,23%**

Data: WIPO; Patent offices

In addition, it is difficult to monitor this indicator, since it deals only with patent applications; and Moldova, for instance, is not an EPO member. Hence, the number of patents granted is also compared.

The disadvantage of this criterion is that the number of patents granted could also include those patents for which the applications could have been filed several years prior to the patent being granted. In this comparison, the increase between 2010 and 2018 was 70%.

Table 16 Number of EPO patents

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Growth
AT	671	737	796	837	891	1 040	1 370	1 465	1 655	146,65%
BA	1	1	1	1	0	1	0	0	0	-100,00%
BG	3	8	5	5	7	7	11	22	18	500,00%
CZ	45	56	56	67	66	74	95	123	126	180,00%
DE	12 550	13 578	13 315	13 425	13 086	14 114	18 728	18 813	20 804	65,77%
HR	10	5	11	7	7	6	5	6	6	-40,00%
HU	58	46	38	50	41	38	62	59	66	13,79%
MD	0	0	1	1	1	0	0	0	1	100,00%
ME	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RO	3	2	3	2	4	9	19	13	9	200,00%
RS	2	4	2	3	2	0	1	1	9	350,00%
SI	33	42	38	52	51	65	80	92	76	130,30%
SK	12	3	13	5	11	11	15	18	28	133,33%
UA	11	0	3	5	5	2	8	4	11	0,00%
Total	13 399	14 482	14 282	14 460	14 172	15 367	20 394	20 616	22 809	70,23%

Data: EPO

4.3. Increase academic mobility

In assessing mobility, focus was directed towards joint projects within the framework of Marie Skłodowska-Curie activities which entailed the **mobility of researchers** and in which at least two Danube region countries collaborated. A total of 414 such projects were identified, with 1,878 participations. The most active was Germany, which collaborated in at least one project with each of the Danube region country. Then Austria, Bulgaria and Romania follow, each cooperating with 12 countries. Montenegro has the lowest number of collaborations (9) while participating in only one project. Bulgaria and Romania, the Danube region member countries which are located in the middle of the region, collaborate with almost every country.

Table 17 Common MSCA mobility projects

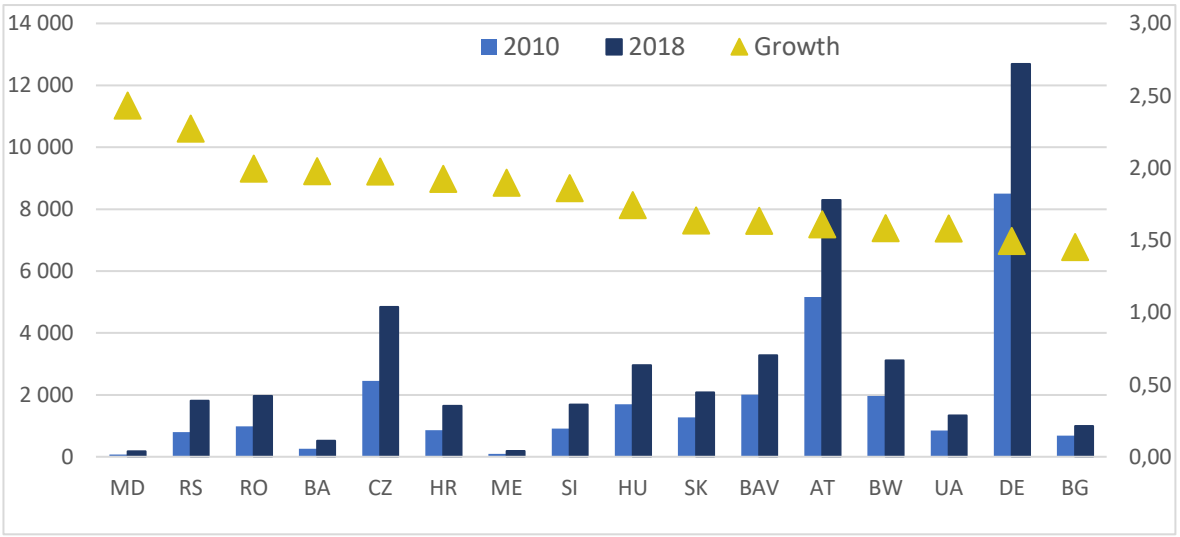
	AT	BA	BG	CZ	DE	HR	HU	MD	ME	RO	RS	SI	SK	UA	Total
AT	363	0	4	45	575	9	34	1	1	18	3	30	15	6	**1 104**
BA	0	7	1	0	11	2	0	0	0	0	2	3	0	0	**26**
BG	5	1	30	3	41	6	1	1	0	5	5	3	2	1	**104**
CZ	59	0	2	122	204	1	22	0	0	9	4	6	12	7	**448**
DE	332	5	19	95	984	23	74	4	1	46	16	48	25	34	**1 706**
HR	11	2	6	1	38	28	4	0	0	3	3	6	3	0	**105**
HU	43	0	1	16	165	3	98	2	0	7	3	6	3	3	**350**
MD	1	0	1	0	4	0	1	7	0	3	0	0	1	7	**25**
ME	3	0	0	0	1	0	0	0	1	2	0	2	0	0	**9**
RO	25	0	6	9	54	4	11	2	1	65	1	7	3	9	**197**
RS	3	2	4	4	23	4	5	0	0	1	26	0	2	1	**75**
SI	39	1	1	6	81	3	5	0	1	7	0	59	2	1	**206**
SK	20	0	2	12	50	3	3	2	0	4	2	1	46	5	**150**
UA	5	0	1	9	55	0	2	5	0	11	1	1	4	42	**136**
Total	**909**	**18**	**78**	**322**	**2 286**	**86**	**260**	**24**	**5**	**181**	**66**	**172**	**118**	**116**	

Data: E-corda (15/10/2019)

4.4. Increase in number of joint publications

The fourth PA7objective was to achieve a 15% increase in the number of joint publications of the Danube region countries by 2020. **This target was met as early as 2018** when, on average, the number of joint publications increased by 62%. The increase was most prominent in Moldova, Serbia and Romania, and least prominent in Bulgaria and Germany. However, it exceeded 15% in all the individual Danube region countries. A positive observation is that this increase was significantly higher than the overall increase in the number of publications for individual countries, which reached 18.8%. Hence, it may be concluded that the production of joint publications between the Danube region countries has intensified.

Graph 22 Number of publication and growth by country with other countries in the Danube region



Data: InCites, Web of Science Core Collection (30. 8. 2019)

An increase of almost 32% is clear if the number of publications is also compared in each country over a five-year period. With an increase of almost 54%, Moldova ranks best. The lowest increase, of 23%, was noted in Bulgaria.

Table 18 Number of publication and growth by country with other countries in the Danube region (five years period)

	2010-2014	2011-2015	2012-2016	2013-2017	2014-2018	Growth
AT	29 779	31 811	34 365	36 641	38 703	**129,97%**
BA	1 407	1 540	1 660	1 892	2 141	**152,17%**
BG	3 787	3 900	4 202	4 472	4 669	**123,29%**
HR	5 283	5 814	6 357	6 890	7 444	**140,90%**
CZ	14 762	16 380	18 080	19 773	21 512	**145,73%**
DE	48 015	50 934	54 454	57 558	60 254	**125,49%**
HU	10 305	11 124	12 020	12 801	13 613	**132,10%**
MD	554	651	721	790	853	**153,97%**
ME	567	629	705	789	848	**149,56%**
RO	6 841	7 641	8 400	8 945	9 322	**136,27%**
RS	5 639	6 327	6 939	7 366	7 922	**140,49%**
SK	7 254	7 862	8 651	9 324	9 945	**137,10%**
SI	5 546	6 133	6 642	7 067	7 548	**136,10%**
UA	5 053	5 347	5 670	6 021	6 264	**123,97%**
Total	**144 792**	**156 093**	**168 866**	**180 329**	**191 038**	**131,94%**

Data: InCites, Web of Science Core Collection (30. 8. 2019)

4.5. RIS3 in each country

The fourth objective is for each country and region within the Danube Strategy to develop Strategies for Smart Specialisation (RIS3) by 2020. The evaluation is based on the Smart Specialisation Platform operated by the Joint Research Centre of the European Commission. All the Danube Region countries developed and approved the RIS3 strategies or other strategic documents for research and innovation. In some countries, the national RIS3 strategy applies to all the regions (e.g. Slovakia). For more information, see the table below. This goal can be achieved on an ongoing basis. However, it is important to observe that every country has RIS3 prepared and approved for the 2021 – 2027 programming period.

Table 19 RIS in the Danube region countries and regions

AT	CZ	HU	RO
Lower Austria	Karlovy Vary Region	South Great Plain	Centre
Upper Austria	Moravian Silesian Region	South Transdanubia	North-East
Salzburg	Olomouc Region	North Great Plain	North-West
Styria	Prague	North Hungary	South-Muntenia
Vienna	South Bohemian Region	Central Transdanubia	South-East
BA	South Moravian Region	Central Hungary	South-West Oltenia
BG	Centra Bohemian Region	West Transdanubia	West
Ruse Pprovince	Zlín Region	MD	SK
Sofia City	DE	ME	Bratislava
HR	Baden-Württemberg	RS	SI
	Bavaria	Vojvodina	UA

Source: https://s3platform.jrc.ec.europa.eu/s3-platform-registered-regions

5. Evaluation of current best practice and SWOT analysis of PA7

In terms of research and innovation performance, the Danube Region can be broadly divided into four groups:

1. Germany and Austria;
2. Slovenia, the Czech Republic and Hungary;
3. Slovakia, Croatia, Serbia, Bulgaria and Romania;
4. Ukraine, Montenegro, Bosnia and Herzegovina, and Moldova.

This grouping results from a comparison of the overall EU Innovation Index as well as the other indicators used in this study.

In addition, some past relations exist that can partly affect, whether positively or negatively, collaboration between countries. These are, for example, Slovakia and the Czech Republic and also the countries of the former Yugoslavia. For example, Slovak researchers in the region most often publish with Czech peers and researchers from Montenegro with their peers from Serbia. In the case of all the other countries, co-authorships with researchers from Germany are most frequent. On the other hand, Serbia has no joint MSCA mobility project with Slovenia.

The region as a whole is most heterogeneous, in terms of the size of the countries, the number of inhabitants and the countries' innovative performance. This is one of the obstacles to its overall development.

In terms of inputs, Austria and Germany devote the highest level of funding in research and innovation in relation to their GDP, being the only countries in the region which exceed the targets of the Europe 2020 Strategy, i.e. the expenditure in these areas exceeds 3% of GDP. These are followed by the second group of countries (Slovenia, the Czech Republic and Hungary), whose expenditure is between 1 and 2% of GDP. In the third group, the funding is in the range of from 0.5 to 1% of GDP and that of the last group is below 0.5% of GDP. Large differences are also observed in the private sector's funding of research and innovation.

In terms of human resources, the share of the population with higher education in the 24-34 age group exceeds 40% in Slovenia and Austria; in Slovakia this figure is more than 35% and less than 30% in Romania. Germany, Austria and Slovakia attain the highest share of doctoral graduates per thousand inhabitants (more than 2%). Austria, Germany, Slovenia and the Czech Republic are also the only countries in the region where the number of full-time equivalent (FTE) researchers per thousand inhabitants surpasses the EU average of 3.33.

While, in research and innovation activities, Austria and Germany have the highest percentage of SMEs which innovate internally, in Romania this share is negligible. In Austria, more than 20% of the innovative SMEs collaborate with other SMEs; in the Czech Republic and Slovenia this figure is only just over 10%. Germany, Hungary and Romania are best placed to access venture capital. The least favourable conditions in this respect obtain in Serbia and Slovakia.

In terms of participation in Horizon 2020, both per capita and per researcher, Austria, Slovenia and Germany, respectively the German regions of Bavaria and Baden-Württemberg, rank best while a very low participation rate is especially characteristic of the non-EU countries. This is also reflected in success in applying for both projects and EC funding. The non-EU countries' negligible participation in Horizon 2020 projects also results in their low collaboration in joint projects. In particular, mutual

collaboration for these countries is very poor. They participate much more frequently in projects with Germany and Austria; this is natural as the success rate increases with collaboration with more research-intensive countries. The fact that the best quality research within the region is largely conducted in Germany and Austria is also supported by a comparison of ERC projects obtained by researchers from these countries, but also mobility within MSCA.

The best outputs are achieved by researchers from Germany and Austria, who, across the region, have the greatest share of publications among the 10% most cited papers. Baden-Württemberg, Austria and Slovenia have the highest number of publications per million inhabitants. By contrast, this figure is up to 45 times lower in Montenegro, the country in the region with the lowest publication output per million inhabitants. However, the number of joint publications in the region exhibits an increasing trend. Compared with 2010, this is a 1.76-fold increase. The highest increase in co-authored publications was reported by Moldova (2.43), Serbia (2.27) and Romania (1.99). Germany and Austria, and Germany and the Czech Republic had the highest number of joint publications in the region; Montenegro and Moldova are at the opposite end of the scale.

The situation is similar with publications. The highest number of publications per million inhabitants in the region was achieved in Baden-Württemberg, Bavaria, Austria and Slovenia, the lowest in Montenegro. In the number of citations between only countries in the Danube region, the most influential are publications mainly from Austria and Slovenia. As with publications, a positive trend in citations can be observed, as the number of citations in the citation window 2014 – 2018 increased in all the countries in comparison with the 2010 – 2014 period. On average, this increase is more than 50% for the whole region. A second positive aspect is that the highest increase was observed in the non-EU countries.

Germany and Austria have the highest number of PCT patent applications per billion of GDP. This is also the case with the number of EPO applications per million inhabitants, with a significant disproportion between Germany and Austria and the other Danube region countries. This applies also to the number of patents granted.

In innovations realised, Austria and Germany have the highest share (more than 40%) of SMEs that introduced product or process innovations in 2016. The same applies to marketing and organisational innovations.

Employment in knowledge-intensive activities is highest in Austria and Germany (more than 15%) and lowest in Romania and Serbia. Sales of innovations both to the market and to companies are greatest in Slovakia. Knowledge-intensive services exports are highest in Germany, exceeding 70% of total services exports.

Table 20 SWOT analysis

STRENGTHS	WEAKNESSES
• National smart specialisation strategies to support research and innovation (RIS3) adopted • Strong position of Germany and Austria in the European Research Area	• The region is notably disparate • Innovation performance varies widely between countries in the region • Low levels of investment in research and innovation in up to 9 countries in the region • Low private sector investment in research and innovation in most countries • Low patent activity in all countries, except for Germany and Austria • Low levels of collaboration in Horizon 2020 • Low number of researchers in most countries • Inadequate research infrastructure in non-EU Member States
OPPORTUNITIES	**THREATS**
• Increasing number of joint publications • Increasing citations to joint publications • Increasing share of population with higher education • Increasing investment in research and innovation in most countries in the region	• Insufficient support for research and innovation activities at political level • Increasing disparities in the quality of research and innovation between countries in the region • Non-EU countries in the Danube region trailing further behind

6. Recommendations for improving the current situation in the Danube Region

Based on the analysis presented, we recommend that the following suggestions and recommendations should be taken into account:

1. Projects supported within the Danube Region should aim at developing cooperation, which in turn would also support participation in other schemes and programs, in particular Horizon 2020 and Horizon Europe, but also in COST, Eureka and Erasmus +. It is important to establish synergies between the calls at European, regional and national levels.
2. Projects should also aim at improving the mobility of researchers within the region, including encouraging and motivating joint projects through Marie Skłodowska-Curie actions. Brain circulation must be an important factor, not the brain drain.
3. Short-term internships for researchers, innovators and project managers could also be supported within the region to disseminate best practice.
4. Projects supported by the region should also aim at bringing together academia and the private sector, in particular SMEs. There should also be increased cooperation between SMEs across the region. Cooperation should be encouraged in knowledge-intensive sectors.
5. It is crucial for the Danube countries to engage in the upcoming European Partnerships and thus to gain a strategic position in Horizon Europe. It is important to plan the entry into these partnerships efficiently and strategically and to ensure financial coverage of the obligations related to the entry of individual entities into the partnerships.
6. The under-funding of science and research, which is present in a large part of the region, needs to be addressed primarily at national level. These missing funds cannot be substituted from other (international) sources. The government of each country must prioritize support for science and research, as this is the way to become a knowledge-intensive country. National stakeholders of the Danube Strategy should strongly enforce the requirement to spend on R&D at least the EU average of 2.06% of GDP.
7. It is important to encourage companies to be innovative and to invest in research and innovation. Only in this way can the competitiveness of the Danube Region be increased by reflecting the requirements of the world market and by the industry offering services and products based on knowledge and innovation.
8. Initiatives need to be taken to promote innovation by businesses. Whether it is product, process or organizational innovation, it must be systematically promoted at both national and transnational level.
9. Several countries in the region are heavily dependent on the automotive industry. Therefore, it is important to implement adaptation processes in education so that people in training can be prepared to better reflect on future trends in automation in industry.
10. All the Danube Region countries have RIS3 strategies in place. However, it is important to monitor how these strategies are implemented in practice through action plans. Evaluation of the fulfillment of RIS3 strategies should be monitored on a regular basis. It is also necessary to proceed with the development of RIS3 for the next period well in advance and to pay due attention to this preparatory process. Foreign experts should also be involved in the preparatory teams for the transfer of experience and good practice. RIS3 is a key document that determines the direction for national funding of science, research, innovation, as well as funding from the structural funds.