BLACK SEA HORIZON

Bi-regional STI Dialogue

BSH Policy brief #2

"Policy brief on thematic patterns of cross-border S&T cooperation based on co-publication and co-patent analysis"

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LIST OF ABBREVIATIONS

AC – Associated Countries
BSH – Black Sea Horizon
EC – European Commission
EU – European Union
FP – Framework Programme
STI – Science, Technology and Innovation

Executive Summary

This **policy brief** summarises the most important outcomes derived from the co-publication and co-patent analysis in the BSH project. It aims at providing the base for the identification of thematic strengths of the non-EU Black Sea countries and collaboration patterns with the EU/AC and it should therewith support evidence based policy making.

E.g. We have seen that the strongest co-publication partner countries of BSCs-based researchers are Germany, France, UK and partly Turkey (for Azerbaijan), Romania (for Moldova), Poland (for Moldova and Ukraine) and Italy (for Armenia and Turkey). The numbers of co-invented patent applications involving BSCs-based inventors is limited, which allows a comparison only for the few countries with the highest output. For them, co-inventors from EU are most frequently based in Germany, France, UK, the Netherlands, Italy and Finland (for Russia).

Detailed information about the results is provided in two background papers attached to this policy brief: Background Paper #2 – Part One: “Thematic patterns of cross-border S&T cooperation based on co-publication analysis” and Background Paper #2 – Part Two: ““Thematic patterns of cross-border S&T cooperation based on co-patent analysis”.

The first part of the study **(Background Paper #2 – Part One)** scrutinises the co-publications of Black Sea (BS) countries for the years of 2003-2013. The actual analysis of the publication data was carried out along several dimensions: overall co-publication output numbers per country to provide an overview, the internationalisation of publications, main scientific research fields, and finally some highlights regarding scientific impact.

The target group of this study involves all interested relevant stakeholders in the field of international STI cooperation from the EU and the non-EU BS countries.

The second part of the study **(Background Paper #2 – Part Two)** addresses the question of a general characterisation of patent output in Black Sea countries. It focuses on thematic, but also geographic patterns of specialisation, particularly in view of cooperation with the European Union.

Patent applications and patents have long been used as indicators of innovation output (cf. Griliches 1998; Nagaoka et al 2010). Conscious of the potentially misleading notion of innovation output, we consider patent applications and patents a viable and available indication of inventive activity and novel codified knowledge. Whether or not the inventive activity triggers innovations with actual economic or social impact is something that cannot be answered by patent statistics (there again surveys would be needed). With this limitation in mind, we make use of patent applications as an indicator of inventive activity. The results of the analyses of patent output can help to inform policy dialogue on bi-regional research and innovation cooperation.

The results as such, however, need to be contextualised and discussed with experts knowledgeable about the innovation systems of the Black Sea countries. Our aim is to provide discussion input and point to some peculiar characteristics. The interpretation of these characteristics needs a more qualitative setting.

1. Introduction

Target groups of the policy brief are the policy-makers in the region, EC representatives, and researchers in the field of international STI cooperation.

The policy brief gives an overview of the most important results; for more details on the co-publication and co-patent analysis see Background Paper #2 – Part One: “Thematic patterns of cross-border S&T cooperation based on co-publication analysis” and Background Paper #2 – Part Two: ““Thematic patterns of cross-border S&T cooperation based on co-patent analysis”. All three documents are part of the Deliverable D1.2 – “Thematic patterns of cross-border S&T cooperation based on co-publication and co-patent analysis”.

The policy brief is structured as follows: it begins with an introduction of the data and methods used. This is followed by giving information on the size and development of BSC knowledge outputs (publications and patent applications), the strongest knowledge production links between Black Sea and EU countries, and the areas of

strength in collaborative knowledge production based on the co-publication and co-patent analysis. In the last chapter the results are compared.

The policy brief has been prepared within the H2020 EU project BLACK SEA HORIZON (BSH), which started in February 2015 for a duration of 3 years.

2. Publication output

2.1. Methodology

This report uses the term BSCs (Black Sea Countries) when referring to the non EU-countries Armenia, Azerbaijan, Georgia, Moldova, Russia, Turkey and Ukraine. This definition takes also into consideration the Eastern Partnership countries Armenia, Azerbaijan and Moldova that are not directly riparian Black Sea countries, but can be considered as part of the wider BS-region and that are represented with partners in the BSH project.

The analysis of Black Sea co-publication output in the years 2003 to 2013 is based on the two best known and most comprehensive multidisciplinary academic citation databases:

- Elsevier's Scopus
- Thomson Reuter's Web of Science (short: WoS; at present containing the following databases: Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index)

For this study, we retrieved all publications from both databases that featured a BSC affiliation (any of the countries). This comprehensive coverage allows us to draw conclusions on the differences between general output and international co-publication output. The exceptions are Russia and Turkey, in whose case the sheer number of publications would have by far exhausted the resources available for this study; consequently, only Russia's and Turkey's co-publications with EU/ACs countries are covered in this report. In order to get a comparative overview of the

total publication output we used data from Scimago, which is based on data from Scopus.

The study does not make any discrimination regrading document types, meaning that scientific articles are taken into account the same way as conference proceedings, academic letters, and other document types that were tracked by both data sources. For more information regarding the methodology, please refer to the BSH Background Paper #2 “Thematic patterns of cross-border S&T cooperation based on co-publication analysis”.

2.2. Size and development of Black Sea region knowledge outputs

The Black Sea region is a diverse geographical area, where Turkey, Russia and Ukraine are bigger countries, whereas Armenia, Azerbaijan, Georgia and Moldova are smaller countries. In terms of the performance of national research and innovation systems, these countries are quite diverse as well. This difference, resulting from more or less spending on RTDI system affects also the publication output of the research institutions.

Figure 1 shows the distribution of publications over time from 1994 – 2014. For this overview, we retrieved data also from Scimago, a public website offering aggregate Scopus data, to allow a comparison of the total publication outputs including Turkey and Russia.

Turkey shows an extraordinary increase in publications between 1996 and 2013. Also Russia’s publications show a strong growth of publication output, however starting from a higher level than Turkey. The publication output of Ukraine has only slightly increased.

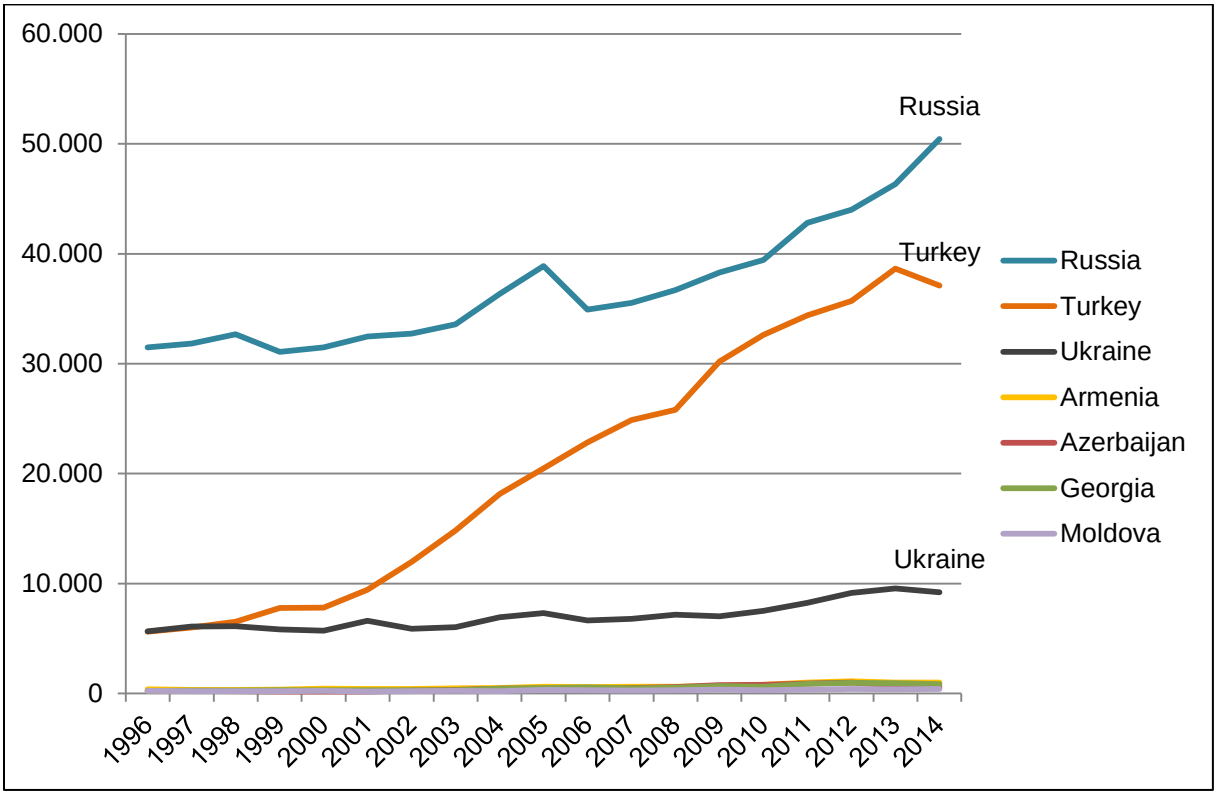

FIGURE 1: DISTRIBUTION OF PUBLICATIONS FROM 1996 - 2014; (SOURCE: SCIMAGO)

2.3. Strongest knowledge production links between BSCs and EU countries

For BS countries the most important co-publication partner within the EU/AC is Germany; the only exception is Azerbaijan where Germany holds the second position and Turkey is the most important co-publication partner. When looking at the other positions (third, fourth etc. co-publication partner), the picture is rather diverse. Table 1 below shows the top 10 co-publication countries for the BS countries.

Armenia		**Azerbaijan**		**Georgia**		**Moldova**	
Germany	1,716	Turkey	1,321	Germany	1,288	Germany	489
France	1,507	Germany	483	Italy	985	Romania	292
Italy	1,444	United Kingdom	430	United Kingdom	944	Poland	245
United Kingdom	1,292	France	371	France	863	France	234
Poland	1,090	Italy	361	Spain	828	Spain	212
Switzerland	1,043	Switzerland	334	Switzerland	821	Italy	202
Czech Republic	888	Portugal	329	Poland	798	Ukraine	168
Spain	859	Poland	328	Turkey	714	Belgium	98
Greece	827	Spain	325	Austria	706	United Kingdom	95

Serbia	729	Netherlands	314	Greece	694	Switzerland	94

Russia		**Turkey**		**Ukraine**	
Germany	37,659	Germany	8,033	Germany	6,956
France	20,609	United Kingdom	7,298	Poland	5,416
United Kingdom	16,004	Italy	5,296	France	3,837
Italy	13,311	France	4,816	United Kingdom	3,231
Poland	8,699	Spain	3,368	Italy	2,401
Spain	8,473	Netherlands	3,268	Spain	1,961
Switzerland	8,075	Switzerland	2,621	Switzerland	1,340
Ukraine	7,311	Greece	2,351	Czech Republic	1,221
Netherlands	7,280	Belgium	2,124	Austria	1,178
Sweden	6,925	Austria	2,040	Sweden	1,156

TABLE 1: DEVELOPMENT OF CO-PUBLICATIONS WITH 10 MOST IMPORTANT PARTNERS IN EU/AC 2003 – 2013 (SOURCE: WOS+SCOPUS)

2.4. Areas of strength in collaborative knowledge production

A comparison[1] of the shares of scientific field distribution in total and in co-publications with EU/AC shows the prominent position of Physics & Astronomy. The field makes up between 30 and 70% of co-publications and co-publications with the EU/AC countries. Especially in Armenia, Azerbaijan and Georgia, the role of Physics & Astronomy in their co-publications with EU/AC is even more pronounced than in their co-publications in general. The only other field that is more prominent in a BS country's co-publications with the EU/AC (compared to its overall co-publications) is chemistry in the case of Moldova.

	Armenia			**Azberbaijan**			**Georgia**		
Science Metrix fields	total co-publications (share in %)	co-publications with EU/AC (share in %)	Differences in shares between co-publications and co-publications with EU/AC	total co-publications (share in %)	co-publications with EU/AC (share in %)	Differences in shares between co-publications and co-publications with EU/AC	total co-publications (share in %)	co-publications with EU/AC (share in %)	Differences in shares between co-publications and co-publications with EU/AC
Agriculture, Fisheries & Forestry	0.84	0.29	0.55	1.67	2.06	-0.39	1.30	0.85	0.45
Biology	2.05	1.47	0.58	3.41	3.36	0.05	3.23	2.67	0.55
Biomedical Research	3.40	3.04	0.37	2.27	2.60	-0.33	5.15	4.12	1.03

[1] As for Russia and Turkey the total publication output is not available in our data set, this comparison is limited to Armenia, Azerbaijan, Georgia, Moldova and Ukraine.

Built Environment & Design	0.13	0.00	0.13	0.18	0.11	0.07	0.14	0.11	0.03
Chemistry	4.90	3.55	1.36	**11.19**	7.48	3.70	5.95	4.60	1.35
Clinical Medicine	7.22	6.17	1.06	6.78	6.94	-0.16	**10**.81	7.72	3.09
Communication & Textual Studies	0.07	0.03	0.03	0.14	0.11	0.03	0.12	0.07	0.04
Earth & Environmental Sciences	2.08	1.63	0.45	2.84	4.66	-1.82	3.49	3.04	0.44
Economics & Business	0.46	0.35	0.11	3.23	2.71	0.52	1.45	0.82	0.63
Enabling & Strategic Technologies	6.16	3.87	2.30	9.34	6.07	3.27	3.91	2.90	1.02
Engineering	2.21	1.31	0.90	8.70	5.21	3.49	3.87	3.04	0.82
General Arts, Humanities & Social Sciences	0.13	0.03	0.10	0.14	0.11	0.03	0.02	0.00	0.02
General Science & Technology	1.35	1.12	0.23	1.24	0.76	0.48	1.54	1.56	-0.02
Historical Studies	0.93	0.70	0.22	0.32	0.76	-0.44	1.80	2.26	-0.46
Information & Communication Technologies	1.99	1.63	0.36	3.27	1.95	1.31	2.96	2.52	0.44
Mathematics & Statistics	2.43	1.95	0.48	8.17	3.69	4.48	8.23	8.46	-0.23
Philosophy & Theology	0.04	0.00	0.04	0.04	0.00	0.04	0.14	0.07	0.07
Physics & Astronomy	**61.70**	**71.81**	-10.12	**35.51**	**49.13**	-13.62	**40.93**	**52.15**	-11.22
Psychology & Cognitive Sciences	0.15	0.16	-0.01	0.11	0.22	-0.11	1.26	1.26	-0.01
Public Health & Health Services	1.04	0.32	0.72	0.39	0.43	-0.04	2.02	1.04	0.98
Social Sciences	0.71	0.58	0.13	1.07	1.63	-0.56	1.61	0.71	0.91
Visual & Performing Arts	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.07

Chemistry is also one of the few areas making up more than 10% of the thematic portfolio in the publication output in Azerbaijan, Moldova and Ukraine. Enabling & Strategic Technologies are of importance in the co-publication output (both generally and with the EU/AC) of Moldova and Ukraine. Clinical medicine is relative output strength in Georgia.

	Moldova			Ukraine		
Science Metrix fields	total co-publications share in %	co-publications with EU/AC share in %	Differences in shares between co-publications and co-publications with EU/AC	total co-publications share in %	co-publications with EU/AC share in %	Differences in shares between co-publications and co-publications with EU/AC
Agriculture, Fisheries & Forestry	0.87	0.78	0.08	0.80	0.86	-0.06
Biology	2.15	2.29	-0.15	2.35	2.34	0.01
Biomedical Research	1.86	1.29	0.57	4.32	4.11	0.20
Built Environment & Design	0.08	0.11	-0.03	0.07	0.06	0.01
Chemistry	**26.31**	**28.58**	-2.27	**10.66**	**10.36**	0.29
Clinical Medicine	6.73	6.71	0.02	5.66	5.64	0.02
Communication & Textual Studies	0.04	0.06	-0.01	0.02	0.02	0.00
Earth & Environmental Sciences	0.99	0.84	0.15	3.32	2.83	0.49
Economics & Business	0.41	0.56	-0.15	0.45	0.47	-0.02
Enabling & Strategic Technologies	**12.52**	**10.35**	2.17	**12.82**	**12.05**	0.76
Engineering	4.17	3.64	0.54	6.21	5.25	0.95
General Arts, Humanities & Social Sciences	0.04	0.06	-0.01	0.02	0.00	0.01
General Science & Technology	0.62	0.73	-0.11	0.70	0.72	-0.03
Historical Studies	0.78	0.89	-0.11	0.74	0.90	-0.15
Information & Communication Technologies	4.01	4.08	-0.08	3.61	3.05	0.56
Mathematics & Statistics	3.55	3.13	0.42	5.64	6.35	-0.71
Philosophy & Theology	0.04	0.06	-0.01	0.04	0.04	0.00
Physics & Astronomy	**33.09**	**34.34**	-1.25	**41.66**	**44.17**	-2.51
Psychology & Cognitive Sciences	0.17	0.11	0.05	0.17	0.13	0.04
Public Health & Health Services	0.91	0.78	0.13	0.39	0.33	0.06
Social Sciences	0.62	0.62	0.00	0.37	0.32	0.04
Visual & Performing Arts	0.04	0.00	0.04	0.01	0.00	0.00

TABLE 2: DIFFERENCES IN SCIENTIFIC FIELD DISTRIBUTION IN TOTAL PUBLICATIONS AND CO-PUBLICATIONS WITH EU/AC; PERCENTAGES ARE BASED ON THE TOTAL CO-PUBLICATION OUTPUT (100%) AND THE CO-PUBLICATION OUTPUT WITH THE EU/AC (100%)

3. Patent output

3.1. Methodology

The present analysis of patent application output in the Black Sea region builds on data from the European Patent Office's (EPO) PATSTAT database. PATSTAT is, globally, the most comprehensive database of patent applications. The April 2014 and November 2015 versions of the database have been used for the purposes of this paper. Unless otherwise stated, we report on the patent application output between 2003 and 2013.

In our analysis, we focus on patent applications, not only granted patents. Whether or not a patent application is actually granted depends on a number of factors, some of which have to do with the application's contents and others with the applicant strategies. For our purposes, a patent application is a sufficient indication of novel, codified, potentially innovation-related knowledge that the applicants consider relevant enough to disclose.

We consider both national patent applications (so called 'A' patents) and patent applications filed according to the procedures established by the Patent Cooperation Treaty (PCT; so-called 'W' patent applications). Whereas national applications are useful as an indication of inventive activity (we focus on so called first filings only), PCT applications make country-data more comparable. In order to assess international cooperation patterns, we analyse both co-inventions and foreign ownership patterns. Please refer to the background reports for detailed descriptions of these different kinds of patent applications and more information on patents as indicators of inventive activity.

3.2. Size and development of BSCs patent application outputs

According to the 80m patent applications covered in the PATSTAT database, from 2003 to 2013, Black Sea country-based inventors were involved in 2.7% of global patent application output in terms of national patents and in 0.9% of global PCT application output.

Russia (i.e. inventors based in Russia) has by far the largest output in terms of patent applications. The number of over 228,000 national applications indicates that Russia-based inventors are involved in over 80% of all national patent applications with BSCs based inventors. Russia's PCT output 2003-2013 includes approximately 9,600 applications. This is about 60% of the regional PCT output, but only 4% compared to Russia's national application output. This difference results from the fact that the PCT application procedure is relatively more important in other BSCs. Turkey-based inventors, for instance, are involved in approx. 3,700 PCT applications, which is about 40% of its national application output (8,800 applications). In some smaller countries like Armenia, Azerbaijan or Georgia, the PCT procedures are also

relatively more important, indicating that the knowledge produced in the region is deemed potentially relevant for a global market (otherwise applicants would not go for the more expensive PCT procedure). The question to what extent public policies and support is behind increased PCT patenting would have to be pursued separately.

Country	A all	A co-inv	Co-inv share	W all	W co-inv	Co-inv share	W/A share
Armenia (AM)	142	102	71,8%	96	35	36.5%	67,6%
Azerbaijan (AZ)	243	138	56,8%	68	11	16.2%	28,0%
Georgia (GE)	732	105	14,3%	121	56	46.3%	16,5%
Moldova (MD)	3,044	488	16,0%	64	29	45.3%	2,1%
Russia (RU)	228,682	7,564	3,3%	9,609	2,268	23.6%	4,2%
Turkey (TR)	8,791	495	5,6%	3,772	335	8.9%	42,9%
Ukraine (UA)	27,593	2,197	8,0%	1,391	521	37.5%	5,0%
Total[2]	**276,858**	**10,159**	3,7%	**15,849**	**3,416**	**21.6%**	5,7%

TABLE 3: PATENT OUTPUT AND INTERNATIONAL CO-INVENTIONS

Apart from the country outputs, table 3 also shows the degree of internationalization of the BSCs patent application outputs. Similar to the case of international co-publications, international co-inventions are more frequent in the case of smaller countries. However, especially when it comes to PCT applications, some larger countries also have substantial internationalization rates in their patent output: for instance Russia or Ukraine. Only Azerbaijan and Turkey have low internationalization shares in their PCT output.

3.3. Strongest co-invention production links between BSCs and EU countries

The strongest co-invention links between the BSCs and the EU countries little surprisingly involve the largest countries: Germany-Russia (502 national co-inventions, 313 PCT) is followed by France-Russia (103/94) and UK-Russia (88/125).

A few links within the BSCs are stronger than those towards the outside. This is especially the case for Russia-Ukraine (1,083/185), Moldova-Russia (117/<20), Azerbaijan-Russia (102/<20) and Moldova-Ukraine (85/<20) co-inventions. Other

[2] All Black Sea applications with address information for at least one inventor

strong links with EU countries include Germany-Turkey (84/68), Germany-Ukraine (50/30), or Germany-Moldova (39/<20).

Building on our data, two observations can be made in addition: the share of co-inventions with EU countries as part of the BSCs overall output is limited. However, especially in the case of the PCT applications, the EU is the second most important partner region are the most important partner countries (the EU as a whole is second only to the US).

3.4. Areas of strength in co-inventions

On average, throughout the strongest Black Sea co-invention links, *chemistry* is the technology sector with the highest number of patent application output ('A' first fillings). Applications indexed in this sector dominate the portfolio of Finland-Russia (77.3% of applications!), Germany-Russia, Italy-Russia and Moldova-Romania co-inventions. They make up over 45% of the output there. This is consistent with the finding that Russian national patent application output in general is comparatively strong in the chemistry sector. The chemistry sector is even more dominant in Turkey's patent application output. This is not represented, however, in its strongest co-invention links.

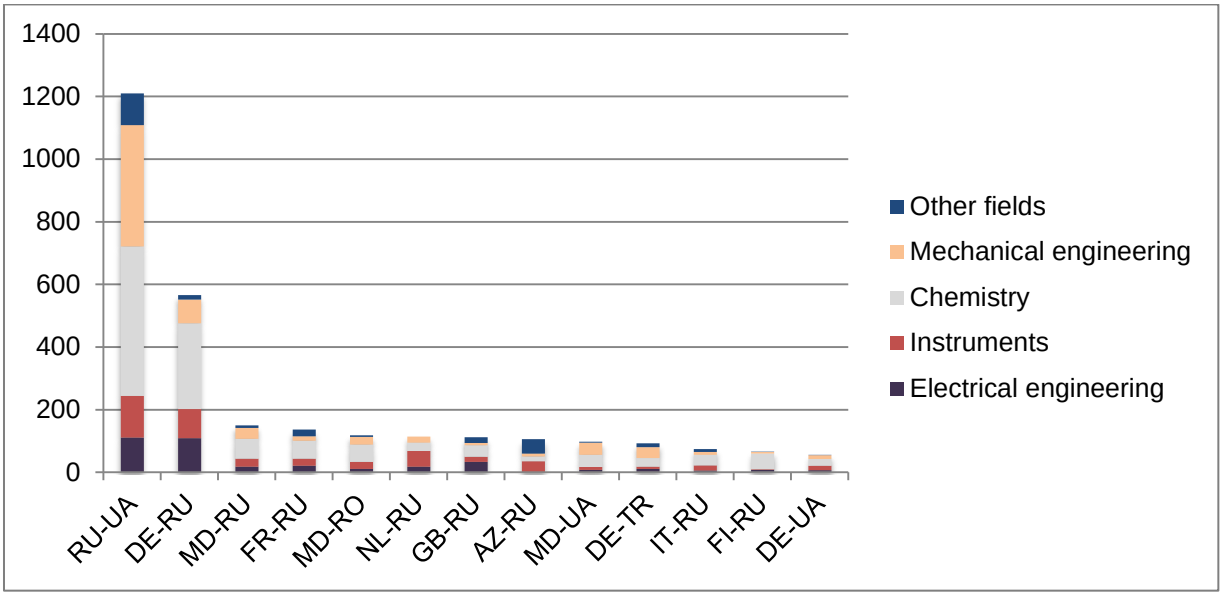

FIGURE 2: THEMATIC SECTORS IN MAJOR BLACK SEA AND BLACK SEA-EU CO-INVENTION LINKS - NATIONAL APPLICATIONS, ABSOLUTE

The sector of *electrical engineering* is strong in UK-Russia (and Turkey-US) co-inventions (>40%). The sector of *instruments* plays a major role in the co-invention links between the Netherlands and Russia (>40%; especially optical and medical technology), Azerbaijan and Russia (33%; medical technology) as well as between Germany and Ukraine (27%). Azerbaijan and Russia form also the co-invention link with the strongest focus on the '*other*' category. A look at the more detailed level of technology fields reveals that this concerns the field of civil engineering. Finally, *mechanical engineering* is the technology sector with the highest application output in Germany-Turkey and Moldova-Ukraine co-invention links.

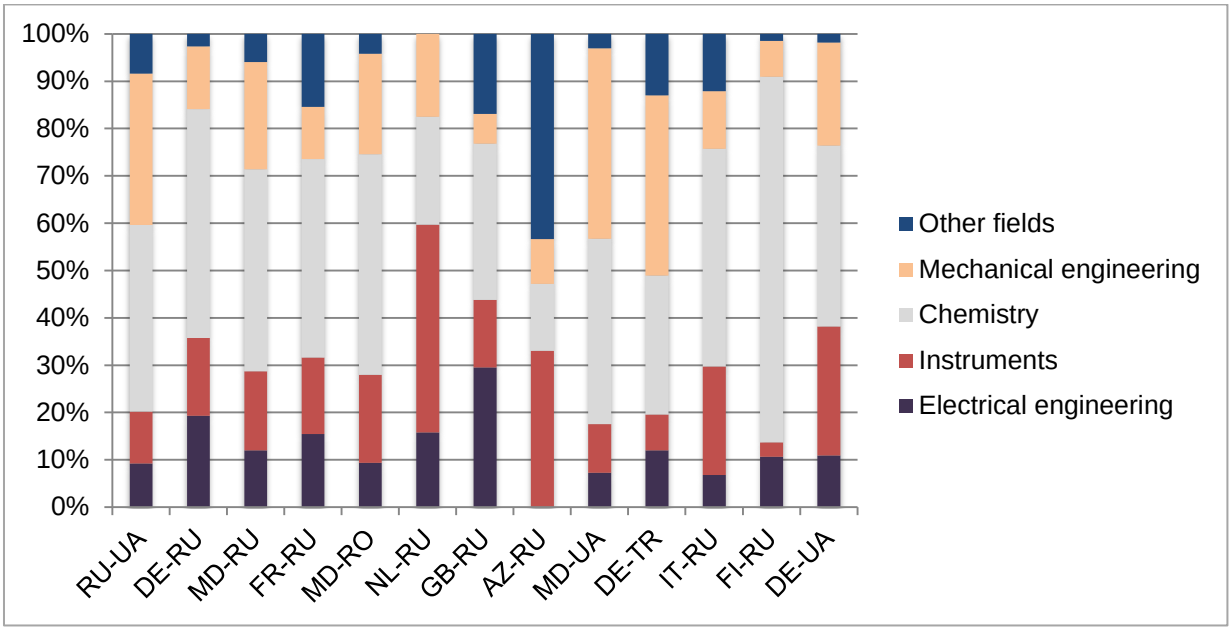

FIGURE 3: THEMATIC SECTORS IN MAJOR BSC AND BLACK SEA-EU CO-INVENTION LINKS - NATIONAL APPLICATIONS, RELATIVE

The patent analyses performed within the Black Sea Horizon project can contribute to answering a series of other questions of potential interest for policy makers and interested experts. For instance, the analysis of knowledge flows (by scrutinizing foreign ownership of patent applications) can contribute further to the understanding of patent-oriented collaborative knowledge production and utilization. Moreover, we also look at the filing activity at the patent offices in the region and at domestic versus foreign filing.

4. Comparison

Comparing results of publication and patent analyses is challenging as both types of research output are only loosely related. Both are valid indicators of activities potentially contributing to innovation. However, many areas of scientific research are producing publications, but no patents. Conversely, many areas where patents are important do not typically publish scientific papers (e.g. in construction, buildings, machinery). With these limitations in mind, we propose a comparison along two lines: knowledge production linkages (in co-publications and co-inventions) and thematic specialisations.

We have seen that the strongest co-publication partner countries of BSCs-based researchers are Germany, France, UK and partly Turkey (for Azerbaijan), Romania (for Moldova), Poland (for Moldova and Ukraine) and Italy (for Armenia and Turkey). The numbers of co-invented patent applications involving BSCs-based inventors is limited, which allows a comparison only for the few countries with the highest output. For them, co-inventors from EU are most frequently based in Germany, France, UK, the Netherlands, Italy and Finland (for Russia). The strong patent-related links between Romania and Moldova are also visible in publication output. The links between Moldova and Ukraine are more pronounced in patent applications than in publications. Conversely, the relevance of Poland as a co-publication partner for Moldova and Ukraine is not visible in co-inventions. On the limited space available in this policy brief, we cannot go beyond these general trends involving the countries with the largest amount of research investments and outputs.

Regarding the thematic specialisations, the technology sector and field classification introduced above is not entirely comparable to the classification of scientific journals. Chemistry and engineering related fields are the ones where a comparison is possible.

In publication output, Moldova has a clear specialisation in the field of chemistry (over 20% of its output). This focus is also visible in Moldova's patent application output (40% of national patent applications are in chemistry). According to scientific publications, Ukraine is relatively specialised in engineering (around 10% of publication output; 3-8% for the other countries). This focus is only partly reflected in its patent application output: nationally filed output is somewhat concentrated around mechanical engineering and instruments. In PCT filed applications, the field of electrical engineering is more prominent in Ukraine than in other countries in the region. In both PCT and nationally filed patent application output, Russia shows a specialisation on chemistry, which is somewhat reflected in its publication output (10% of overall output). Georgia's strong specialisation on chemistry and mechanical engineering in terms of patent applications is not visible in its publication output. The reason for this can either be that Georgia's public research in these areas is not related to the more industrially oriented chemistry sector (which might be dominated by foreign companies) or that, by contrast, academic players also focus on patent

output and less on publications. Further qualitative analyses would be required in order to clarify this.

These country-level findings show well that both publication and patent analyses can feed into, but never replace qualitative discussions on innovation system performance.

5. Conclusions

Our analysis of publications and patent applications sheds light on the knowledge production relationships among the BSCs and between the BSCs and the EU Member States. It also helps to clarify thematic strengths in publication and patent application output, both in general and with regard to the strongest links. We refrain from a further aggregation of results presented above as this could not be justified properly.

The results of the analyses of publication and patent output and collaboration patterns can help to inform policy dialogue on bi-regional research and innovation cooperation. The results as such, however, need to be contextualised and discussed with experts knowledgeable about the innovation systems of the Black Sea countries. Our aim is to provide discussion input and point to some peculiar characteristics. The interpretation of these characteristics needs a more qualitative setting.

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