BLACK SEA HORIZON

Bi-regional STI Dialogue

BSH Background Paper #2 – Part Two

"Thematic patterns of cross-border S&T cooperation based on co-patent Analysis (PATSTAT)"

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Abstract	The present study (as part of the D.1.2) 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.

BLACK SEA HORIZON POLICY BRIEFS	The BSH Policy Briefs and related Background Papers are available for download from the Black Sea Horizon Website: https://blacksea-horizon.eu/policy-dialogue/briefs **Policy Brief #1:** "Obstacles, drivers and opportunities to enhance EU-Black Sea STI cooperation" – **BSH Policy Paper #1** (D1.1) "Obstacles, drivers and opportunities to enhance EU-Black Sea STI cooperation – **BSH Background Paper #1**" (D1.1) **Policy Brief #2:** "Thematic patterns of cross-border S&T cooperation based on co-publication and co-patent analysis" – **BSH Policy Paper #2** (D1.2) "Thematic patterns of cross-border S&T cooperation based on co-publication analysis" – **BSH Background Paper Part One"** (D1.2) "Thematic patterns of cross-border S&T cooperation based on co-patent analysis" – **BSH Background Paper Part Two"** (D1.2) For further information please visit https://blacksea-horizon.eu/ or contact office@blacksea-horizon.eu.

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LIST OF ABBREVIATIONS

BSH – Black Sea Horizon

EU – European Union

EPO – European Patent Office

OECD – Organization for Economic Co-operation and Development

PCT – Patent Cooperation Treaty

USPTO – United States Patent and Trademark Office

WIPO – World Intellectual Property Organization

IPC –

CPC –

‘A’ – National (applications)

‘W’ – International (applications)

EXECUTIVE SUMMARY

The present study 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. With this limitation in mind, we make use of patent applications as an indicator of inventive activity.

We consider the following results noteworthy:

- While Russian-based inventors are involved in over 80% of all national patent applications in the Black Sea countries, they are in only 61% of PCT applications.
- Almost a fourth of PCT applications in the region involve Turkey-based inventors (but only 3% of national applications), indicating the country's role in patenting activities targeting a global market.
- Moldova has the lowest PCT output in the region, suggesting the conclusion that the patenting activities involving Moldova-based inventors target national and regional markets (e.g. Russia where much of national applications with Moldova inventors are filed).
- Romania, Georgia and Moldova are the countries with the most internationalised PCT output. While Turkey's PCT output is significant (both in absolute numbers, where it is higher than Ukraine's output, as well as in relation to nationally filed output with Turkey-based inventors), the share of international co-inventions in its PCT output is low.
- In most Black Sea countries, the share in global patent output is between a tenth and a third of the share in global publication output. This means that these BSC's play a stronger role in global academic knowledge production than in patenting. By contrast, for Russia and Moldova, the share in global

patent output (national applications, first filings) is higher than their share in global publication output.

- Bulgaria's national application output is focused on electrical engineering. It's the only country in the region with this pronounced focus. Georgia's output is focused on chemistry and mechanical engineering. The other fields have fairly low shares in national output. Moldova's output is strongest in the field of chemistry. Romania has a balanced output profile close to the regional averages. Russia's output is heavily focused on chemistry. Mechanical engineering is also strong. Turkey's output is particularly strong in mechanical engineering. Ukraine has the largest regional share (next to Azerbaijan) in the instruments area. Chemistry is also important in its output portfolio.
- Bulgaria's PCT output is focused on electrical engineering and mechanical engineering. Romania's focus in electrical engineering is not reflected in PCT output. The 'others' sector (containing fields like furniture, games, consumer goods and civil engineering) is of relevance, by contrast. Russia's PCT output reveals a specialisation on electrical engineering related fields that is not visible in national application output. Turkey's PCT output is less focused on mechanical engineering. Chemistry features stronger in PCT output compared to national output. In the case of Ukraine, PCT output shows a stronger concentration on electrical engineering and less focus on instruments.
- In the case of Turkey, Ukraine, Moldova and Romania, over 90% of national patent applications indexed in PATSTAT (and two thirds of PCT applications) involved domestic applicants. Among the smaller countries (patent application output wise), Azerbaijan has a fairly high share of domestic ownership, especially in PCT patents. Moldova has a significantly higher share of domestic ownership in its national patents than Bulgaria, but less than Bulgaria in PCT patents. Romania has one of the lowest shares of domestic ownership in PCT patents in the entire Black Sea region.
- Korean applicants are most active in filing Black Sea invented or co-invented patent applications. Apart from this case, the US are the most important foreign owner of Black Sea (co-)invented patent applications. US applicants hold significant numbers of patent applications involving Russia, Romania or Turkey-based inventors. However, in the case of Bulgaria, Romania and

Turkey, German ownership is more frequent than US ownership, making the EU as a whole by far the most important foreign owner of first filed national applications with Black Sea inventors from these countries. Other EU countries also play a major role as foreign owners of Black Sea invented applications, especially the Netherlands, Great Britain and France.

- Within the Black Sea region, Russia is the largest owner of applications involving non-Russian Black Sea inventors (mostly from Ukraine, but also from Azerbaijan). The Ukraine (holding applications with Russian inventors) and Moldova (holding applications with Romanian or Russian inventors) are other important foreign owners within the Black Sea region.
- In terms of co-inventions, the US are the most important non-Black Sea partner country for most BSCs. In the case of Bulgaria, Germany is the most important co-invention partner country. In the case of Moldova and Azerbaijan, Russia is the most important partner country. As regards networks with Europe in general, Germany, Great Britain and France are the strongest partners, as one would expect. At the same time, however, the Netherlands (especially with Russia and Romania) and Ireland (strong links with Romania) are also heavily involved.
- The location of the first filing office can indicate the target market the IP owner has in mind for the exploitation of the codified knowledge. Bulgaria-Germany, Romania-Ireland, Netherlands-Russia and UK-Russia co-inventions are most frequently first filed in the US, whereas Romania-Germany co-inventions are typically first filed in Germany. Most of Moldova-Russia and Moldova-Romania co-inventions are filed in Moldova first, while practically all of the Ukraine-Russia co-inventions are first filed in Russia. Asian patent offices play a limited role for Black Sea co-invented patent applications (first filings).
- 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 section dominate the portfolio of Finland-Russia (77.3% of applications!), Japan-Russia, 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 strong link between Ireland and Romania practically exclusively concerns the field of *electrical engineering* (almost 95% of co-inventions between these countries) and, more concretely, computer and audio-visual technologies. The field is also dominant in Romania-US and Bulgaria-Germany co-inventions (more than 65% of the co-invention output in each of the two links) and strong in Turkey-US and Bulgaria-US co-inventions (>40%)..
- The sector of *instruments* plays a major role in the co-invention links between the Netherlands and Russia (>40%) as well as between Azerbaijan and Russia (33%; medical technology).
- Azerbaijan and Russia is 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-Romania, Germany-Turkey and Moldova-Ukraine co-invention links.

Further analyses and particularly qualitative discussions with knowledgeable stakeholders is an important step in interpreting and making use of these results.

1. Methodology

The following chapters illustrate the Black Sea countries' scientific and technological activities using data on patent applications that are either filed at Black Sea patent authorities, are developed in cooperation with at least one Black Sea-based inventor or owned by at least one Black Sea-based entity. Our analysis builds on patent data received from European Patent Office's (EPO) PATSTAT database (version April 2014) as well as some complimentary queries in the PATSTAT Online database (version November 2015). The core of the analyses is the set of Black Sea-related patent applications filed in the period from 2003 to 2013. Patent applications filed before that period may be used for illustrating the dynamics of the region's patent application activity.

We deliberately use the term ‘patent applications’ instead of simply 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 (a patent application might be found non-patentable), others with applicant strategies. Sometimes applicants only want to publish their invention in the form of a patent application in order to prevent others from protecting the same knowledge[1]. 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.

Our core interest in this study lies in characterising not only patent application output as such, but also patterns of international cooperation in patent application output. During the last decades, an increase in the level of cooperation among researchers from different countries is observable, reflecting the greater openness and internationalisation of S&T activities. This information is found in patent documents, which list inventors from different countries. Patent applications with multiple inventors from different countries (or applications that are filed under more than one technology class) can either be attributed to each country (or class) as a whole or as a fraction, based on the total number of regional and technological entities. Such patents can either be partly attributed to each country mentioned (fractional counts) or fully attributed to each country (whole counts). The methodological approach for the following analysis is the whole-count method (OECD 2009).

Different patent types exist that vary in procedure, costs, scope and subject of protection (e.g. registered design). The following analysis is based on two different types of patent applications. National (type ‘A’) patent applications are filed in a national or regional patent office and seek protection in a single market[2]. The patent office performs “searching and examining” the application in order to learn whether or not a patent may be granted, i.e. whether the invention is directed to patentable subject matter, is novel, inventive (“non-obvious to persons skilled in the art”) and

[1] Once a specific piece of knowledge is published as a patent application (or any other forms that can be found by patent examiners), it counts as prior art for subsequent applications. As patents are not granted for already published knowledge, the patent application alone prevents subsequent applicants from securing a patent for the same piece of knowledge. For the initial applicant, this might be enough motivation for the application. A granted patent is not needed in this case. It is only needed if the applicant intends to sell or license the invention.

[2] Applications to the European Patent Office (according to the European Patent Convention) are included in the ‚A’ kind applications as European patent applications translate into a series of national patents in the EU Member States.

capable of industrial application. Independent of the outcome of this examination, the application is typically published around 18 months after the filing. After a positive so-called search report, which confirms to the applicant that the invention can be patented, the applicant decides whether or not to obtain a granted patent – and whether or not to pay the necessary fees.

As patents are territorial rights, the nature of national patent applications is that they have to be filed in each national office separately. Therefore, a set of national patent applications can refer to the same inventions. Concretely, after (or in parallel to) filing a national application for an invention (e.g. in the home or target market), subsequent national applications for the same invention can be filed at other offices. These are called secondary filings (compared to first filings) and, together with the first filing, constitute patent families. If a patent is filed in parallel at several national offices, their relation is not apparent. However, what happens more frequently is that applicants make use of a cost-saving procedure established with the Paris Convention for the Protection of Industrial Property, which all Black Sea countries have signed. According to the Paris Convention, applicants in all of the 176 signatory states can first file a national application at their home office at a certain date, called the priority or first filing date. They then have a period of up to 12 months to file subsequent applications at other offices. For each of these subsequent filings, the same priority date applies. This means that the effective protection in case of an eventually granted patent starts with this priority date. For the sake of our study, it is interesting to distinguish the priority filings from subsequent filings as the former indicate the moment and place where the new knowledge was first disclosed. They are the first available indication for codified knowledge coming out of inventive activity. Unless otherwise stated, we therefore exclusively focus on first filings when analysing national patent applications.

Different from national ‘A’ patent applications, international ‘W’ patent applications are filed according to a procedure established under the International Patent Cooperation treaty (PCT). A PCT patent[3] can be filed in an IP office in one of the PCT signatory states, at a regional office (like the European Patent Organisation EPO) or directly at the World Intellectual Property Organisation (WIPO). After the

[3] For details on the PCT patent application process, see: http://www.wipo.int/pct/en/appguide/

filing, it enters a so-called international phase followed by national phases in those countries (their IP offices, to be precise) the applicant selected for protection. In the end, the PCT application translates into a set of national patents (which are secondary filings to the first filed PCT applications). The advantage the PCT process offers is that it is cheaper than filing a series of national applications. The PCT application process is also easier and usually faster.

Applicants initially filing their invention in one or several national offices can still decide to apply for PCT protection later. In this case, the PCT application is actually a secondary filing to the national application. Inventions are frequently filed as national 'A' patents first. One reason for this can be that applicants seek an initial limited protection in their home or target market and decide later (when they can better assess the economic potential of the invention) whether or not to go for global protection. The application is then often filed under the PCT to increase the geographical coverage of the protection (OECD 2009). In the case of 'W' patent applications, the focus on first filings does not apply. 'W' applications can be secondary filings to national application first filings. In this case we also include these applications in the analysis. This is justified by the fact that we are interested in the moment and place where global protection for a certain invention is considered. We therefore analyse PCT applications regardless of whether they are first filings or secondary filings to earlier 'A' applications.

In our analysis, both 'A' and 'W' patent applications are considered in answering the research questions. 'W' applications are generally better comparable as the procedures are standardised. The OECD Patent Statistics Manual[4] actually advises against comparing 'A' level patent applications as scope and filing processes can differ substantially around the globe (affecting the numbers of application output). Nevertheless, we operate under the hypothesis that Black Sea IP systems are comparable to each other, ensuring a certain level of comparability within the region. We therefore analyse not only 'W', but also national 'A' patent applications. Other protectable characteristics like registered designs or utility models are not part of the study.

[4] http://www.oecd.org/sti/inno/oecdpatentstatisticsmanual.htm

The coverage of both 'A' and 'W' patent applications is a particular advantage of PATSTAT as a data source[5]. As EPO's Worldwide Patent Statistical Database, PATSTAT encompasses over 80m records from around 90 patent authorities. Over 60m are national 'A' applications, around 3m 'W' applications (others include: utility models, translations, etc). While the coverage is not global, PATSTAT has the best possible approximate and aims to be globally comprehensive (unlike USPTO for instance). It covers all major patent authorities worldwide. Whereas the WIPO or OECD databases provide useful aggregates, PATSTAT offers interfaces for analyses at the level of individual patent applications. At this and other levels, there are also limitations in data quality: First, individual patent application records can have incorrect or missing information. One of the most frequent errors is the different spelling of applicant names. However, following EPO's collaboration with OECD and KU Leuven, PATSTAT now provides harmonised standard names.

A second data quality issue is the time lag. Most patent offices publish patent applications after a maximum of 18 months upon filing. This means that the newest applications that can technically appear in the 2014 version of PATSTAT have been filed at the beginning of 2013. Some authorities take longer than that in publishing applications. In addition, EPO retrieves patent data from national authorities. These authorities' reporting speed varies greatly. This means that it takes between two and four years until most national records to appear in the PATSTAT database. So while PATSTAT has the advantage of allowing for global comparisons of patent application output, data for recent years (in our case 2012 and 2013) is incomplete and cannot be interpreted. The situation is better for 'W'/PCT applications where EPO does not rely on national authorities' reporting, but on WIPO registers. Regardless of the time lag issue, PATSTAT is still the best possible source available for our purposes.

Regardless also of the type of patent application we are looking at, there are two other specificities of patent application data, which also makes it different from other scientometric data (e.g. data on journal publications): First, there are two types of actors involved in producing knowledge codified as patent applications: one or several inventors and one or several applicants. While the inventors are the individuals that developed the piece of knowledge, the applicants (often companies)

[5] As indicated above, we build on the April 2014 release of the database and punctually retrieve requests from PATSTAT Online Beta (November 2015).

are the ones who register and therefore own it. The knowledge is registered at a specific patent authority, which is the second specificity in patent application data. Particularly when discussing where a certain patent application was created, it is important to always keep in mind what level one is referring to: the level of the inventors of the knowledge, the owners of the knowledge or the place where the knowledge was first registered (filed for patent protection).

In the following chapters, we structure the presentation of our results along these three dimensions: First, patent applications are scrutinised on the level of the (national) patent authorities. Second, the patent activity of inventors based in Black Sea countries is analysed, followed by an analysis at the thematic level. We complement this general picture with specific analyses of international cooperation patterns, both concerning foreign ownership as well as co-inventions. Results are integrated into the respective chapters depending on the level they address (inventors, applicants). However, before turning to the data, we will address the question of patent applications as indicators in more detail.

1.1. Patents as indicators

The Swiss Federal Institute of Intellectual Property[6] defines patents as "titles conferring the right to an invention granted by intellectual property authorities. Legally, an invention is something that solves a technical problem with technology". The OECD's[7] definition focuses less on the technology dimension and more on the aspects of publication and transfer of rights: "A patent is a right granted by a government to an inventor in exchange for the publication of the invention; it entitles the inventor to prevent any third party from using the invention in any way, for an agreed period".

Patents are protected and published results of inventive activities that contain codified knowledge on novel technological solutions.

[6] https://www.ige.ch/en/patents/patents.html
[7] https://stats.oecd.org/glossary/detail.asp?ID=2023

Patents can thus be seen as an outcome of inventive and often research-intensive activity that is used most often by firms in order to protect and codify new knowledge. At the same time, patents are public and the knowledge they contain can thus be used to inspire further inventive activity[8].

From an innovation analyst's perspective, literature has long discussed the value of patents in order to assess innovation performance (e.g. Griliches 1998, Nagaoka et al. 2010). As the direct outcome of inventive processes aiming at commercial impact, patents seem to be an appropriate indicator to capture technological change, particularly the latter's competitive dimension (cf. Archibugi/Pianta 1996, 452). As filing patents is a costly process, it can be expected that applications are filed "for those inventions which, on average, are expected to provide benefits that outweigh these costs" (ibid., 453).

A number of drawbacks of patents as innovation indicators are also apparent, though: not all inventions are technically patentable (software in most cases), neither are all technically patentable inventions patented. This depends on the sectors as well as on the specific technologies. Firms might opt to avoid the time and resource-consuming patenting process for strategic reasons. Their propensity to patent innovation varies. Furthermore, decisions on who features as inventor and as applicant (i.e. owner of the intellectual property) or where a patent is filed first are strategically taken, which analysts need to keep in mind when drawing conclusions. Pavitt (1988) also points to differences among countries in economic costs and benefits of patents, the rigor of exam, the subject matter coverage, etc.

Keeping these caveats in mind, patent applications and patents can be used as an indication for inventive activity (at a sector and country-wise varying level) and, relatedly, of innovations with potential economic or social impact. What actually happens to and with patent applications or granted patents is however difficult to estimate. The patent offices do not track information on actual use and commercialisation of patents, neither on mergers and company (and, thus, patent portfolio) acquisitions. Studies using survey methodology to get information on the usage and commercialisation of a limited set of patents estimate that around 40% of

[8] Whether or not the knowledge codified in patents is enough to follow up on the research that they embody, or whether significant tacit knowledge would be needed to do so, is a separate question that we will not discuss here.

patents reach the market launch stage (Webster/Jensen 2011) or that around 65% of inventions involving academics are commercially used (Meyer 2006)[9]. In the early 2000s, the European PatVal-EU 1 Survey questioned the inventors of 9,017 patents granted by the European Patent Office (EPO) between 1993 and 1997 and found, among other observations, that around 36% of the patents are not used in any economic activities (Giuri et al. 2007). About half of these are so called 'blocking patents' that are neither internally used nor licensed, but block competitors. The other half are 'sleeping patents' with no use, not even in blocking competition. Another finding of the PatVal-EU 1 Survey is that large companies have higher shares of unused patents than SMEs (around 40% blocking and sleeping patents vs. around 20% in SMEs). Public research institutions and universities were found to also have around 40% of their patents unused. In a second wave of the PatVal-EU Survey, carried out from 2009 to 2011 for over 20,000 patents granted by the EPO between 2003 and 2005, this share was higher: 43% unused patents, and over 50% unused patents in public research institutions and large companies (Gambardella et al. 2012).

Among the patents that are commercially used there exists a significant difference in their economic impact as Pakes and Griliches (1984) or Scherer and Harhoff (2000) have already pointed out. A very small number of patents is responsible for the largest part of the economic value in a firm's or a country's patent portfolio.

Patents are outputs of inventive processes with expected benefits. The patent application or granted patent itself offers no indication of economic value. Only a share of the patents granted generates economic returns, only a few of them most of the returns.

With these limitations in mind, patents can be an informative and relevant indication of inventive as well as research and development activity and a proxy pointing to economic and intellectual potential for innovation. This also and especially applies to collaboration in applied research, technology development and inventive activity. Studies show that the level of collaboration in technology and inventive activities has

[9] mostly if they are produced already in collaboration with industry; of the purely academic inventions, only between 10 and 40% are commercially utilised

not reached the level of co-authorship in scientific research (Meyer/Bhattacharya 2004). The share of patents with a single inventor is significantly higher than in the case of academic publications and the relevance of small collaborations with two to three inventors is also higher than co-authorship networks of similar size (ibid., 449f). The reason for this is partly that co-inventions are still more of an intra-mural phenomenon involving small groups of inventors from one firm or research group only. Other reasons include strategic decisions and hierarchical considerations in assigning or not assigning patent "authorship". Different from publications, patents are legal documents. This also affects what kind of collaboration co-patents reflect, namely more formalised partnerships (compared to co-publications).

Studies (Bergek/Bruzelius 2010) have also shown that the majority of internationally co-invented patents are not the result of R&D collaboration in a narrow sense (as collaborative research between independent entities). In most cases, the collaboration takes place between subsidiaries of a firm or within the same firm rather than between completely independent firms. R&D advice, support in patent writing or other industrial services can also lead to the indication of a co-invention. If we take co-inventions as a proxy for research collaboration, what we get is an indication of invention-oriented collaboration in the broadest sense: between or within entities located in different countries, as a result of a variety of invention and research related activities. For our purposes in this aggregate analysis, this limitation is acceptable as we are interested in identifying and assessing innovation-related network linkages in the Black Sea region regardless of their intra- or inter-institutional nature. At this aggregate-level, international technological and invention-oriented collaboration results in knowledge flows between countries, in innovation networks and in externalities to other countries (De Prato/Nepelski's 2014).

Co-invented patent applications are an indication of collaborative invention-oriented activities (including, but by no means limited to collaborative research) carried out within a firm, between its subsidiaries or involving independent entities.

Generally speaking, the share of patents that are collaboratively produced and actually filed with more than one inventor is increasing. More importantly for us, the

share of patents with inventors from at least two countries is still marginal, but increasing. Using the global patent application data of the European Patent Office's PATSTAT, De Prato and Nepelski (2014) calculated a share of internationally co-invented patents of 0,8% (6.229 out of 777.551) in 2007 compared to 0,18% in 1990 and 0,59% in 2000. The related growth rate in co-inventions is nearly ten times higher than the growth of patent applications. The global network of technological collaborations also grew to include a higher number of countries. It also became more integrated and denser (i.e. there are more patent co-invention links between a higher number of countries).

Another study using USPTO data (Guan/Chen 2012) reports a similarly strong growth in granted co-inventions at a higher base level: 1,23% international co-inventions in the period 1981-1985 compared to 2,41% for 1991-1995 and 4,5% for 2001-2005. The shares are similar to what Guellec and van Pottelsberghe de la Potterie (2001) found for patents filed at the European Patent Organisation: They report a share of international co-inventions of over 4% already in 1995. Interestingly, the PatVal-EU 1 Survey (Giuri et al. 2007) found that 15% of the surveyed 9.000 granted patents involved a co-inventor from outside the applicants firm (this is according to what respondents indicate, not according to patent data analysis). The share is slightly lower for firms as they tend to internalise the invention process.

The co-patenting share is not comparable with the share of co-authorship in academic articles, but it is growing.

The discussion on the reasons and exact mechanisms of this increasing techno-globalisation are ongoing. The literature points to an increasing number of countries participating in the global technological advances (Guan/Chen 2012), an increased capacity to codify and share knowledge across distances, enabling collaboration (Moreschalchi et al. 2015), increased mobility of scientists and engineers (Guellec/van Pottelsberghe de la Potterie 2001), the exploitation, decentralisation and related internationalisation of firms' R&D (Picci/Savorelli 2012; Penner-Hahn/Shaver 2005), etc. It should be taken into account that by far the largest part of patenting activity is firm-based, most of it in large corporations (Meyer/Bhattacharya 2004, 448), and that the dominance of firm patent holders especially applies to

international co-patents (Picci 2010)[10]. As also indicated above, not only do multinationals and other firms own the largest part of internationally invented patents, but international co-inventions are in fact produced/invented within the same multinational firm or among its subsidiaries (Bergek/Bruzelius 2010). Nevertheless, co-patents are an indication of knowledge exchange and collaborative inventive activity between the countries involved. We can trace this activity at an aggregate level at some level of detail. Separating firm-based "intra-mural" and extra-mural international co-inventions from each other is not possible at a national-level aggregate scale due to the fact that inventor names cannot be traced to their potential (and changing) company affiliations (this could only be done for small samples allowing for inventor and firm surveys).

Recalling that most patenting activity is firm-based, there is, indeed, some indication in patent data, which can give us additional meta-level insights into transnational activities of firms: Apart from patent applications with inventors from two or more countries, there are patents where the applicant is from a different country than one or several of the inventors. This indicates knowledge flow out of the country of the inventor(s) and into the country of the applicant, i.e. towards the owner of the intellectual property (IP). Guellec and van Pottelsberghe de la Potterie (2001) showed that the share of this kind of foreign ownership of patents is more frequent than co-inventions (12% already in 1995). We can thus distinguish two major forms of international collaborative patenting activity:

- **Co-inventions**: Co-inventions represent the international collaboration in the inventive process. International collaboration by researchers can take place either within a multinational corporation (with research facilities in several countries) or through co-operative research among several firms or institutions (collaboration between inventors belonging to different universities or public

[10] This links to discussions of the reasons of companies to decentralise and internationalise their R&D. The research on this indicates that firms might follow a strategy of exploiting home-based R&D, leveraging existing expertise abroad, or on augmenting the home-base, i.e. on seeking knowledge available only abroad (cf. Penner-Hahn/Shaver 2005; Kuemmerle 1997; Song et al. 2011). Niosi (1999) identified three purposes multinationals might pursue with locating research facilities abroad: adapting products to local markets; monitoring new technology developments occurring in foreign countries; and developing special technology using the partner country's comparative advantages. Yet another line of research (Patel 1995) points to the simple fact that after mergers and acquisitions, the buying company ends up with R&D facilities abroad. Besides these motives of knowledge and technology transfer, actual collaborative knowledge generation and innovation-oriented inventive activity is also observed (Archibugi/Iammarino 1999).

research organisations). In that sense, co-invention indicators also reflect international flows of knowledge.

- **Foreign ownership**: Cross-border ownership of patent applications and patents reflects international flows of knowledge from the inventor country to the applicant countries and international flows of funds for research (multinational companies). In most cases, patents with inventors from abroad correspond to inventions made at the research laboratories of multinational companies and applied for at company headquarters (although in some cases national subsidiaries also may own or co-own the patents). Hence, this indicator expresses the extent to which foreign firms control domestic inventions.

Co-ownership (or co-application) would be a third kind of collaborative patenting: the presence of applicants from different countries in the same patent application. This also occurs, but it is considered a separate topic and is of limited interest to us here. There is literature discussing patterns of and reasons for patent co-applications (e.g. Hagedoorn 2003). It points to strong sectoral differences in co-applications that seem to be rooted in some sectors providing more legal security for firms to engage in co-applications as a kind of ex ante sharing of intellectual property.

We distinguish two relevant kinds of collaborative patent applications (co-patents): Co-inventions, indicating networks engaging in collaborative invention-oriented activities, and foreign owned applications where the inventors and applicants are from different countries, indicating knowledge flow networks.

Equipped with these conceptual clarifications, we can now approach the data and results of our patent application analyses. In the various sections, each addressing specific parts of our research questions, the practical use of these key concepts will become clear.

2. Results and discussion

2.1. Patent applications to Black Sea patent authorities registered in PATSTAT

TABLE 1: PATENT APPLICATIONS TO BLACK SEA PATENT AUTHORITIES REGISTERED IN PATSTAT

Country	counts all	A	U	W/PCT	2009	2010	2011	2012	2013
Armenia (AM)	231	127	5	73	9	10	17	14	5
Azerbaijan (AZ)	180	93	3	67	16	6	17	7	0
Bulgaria (BG)	54693	43620	2316	470	260	307	341	236	78
Georgia (GE)	5042	3853	1028	81	233	149	71	19	2
Moldova (MD)	5784	5400	223	43	280	269	207	196	54
Romania (RO)	71386	69726	128	401	650	1126	1166	553	126
Russia (RU)	692851	539240	136508	11387	48836	51265	40677	31596	7764
[Soviet Un (SU)]	1371975	1349829	177	1992	-	-	-	-	-
Turkey (TR)	66718	27843	23181	1904	4186	4481	4558	2988	199
Ukraine (UA)	52570	25036	25859	1071	304	401	393	230	38

Findings:

- Little surprisingly, the authorities receiving the largest number of applications (first filings!) are: Russia, Romania, Turkey, Bulgaria and Ukraine.
- In terms of international PCT patent applications, the differences between Russia and the other countries are more pronounced.
- While it is the second most important patenting authority in the region (in terms of patent applications in general), Romania is not an important office for first filings of PCT patents (although it is a member of the Patent Cooperation Treaty since 1979 (Turkey only since 1996 and Ukraine since 1991).
- In Armenia and Azerbaijan, countries with very few first filings, PCT filings are almost as frequent as national applications.
- As it is unlikely that patent output has decreased in the last few years, we see slightly varying and considerable time lags in the reporting of patent applications. In the case of Russia, for instance, it seems to take around 4 years for all applications to be indexed in PATSTAT, for Bulgaria, Romania,

Turkey and most others three (for Georgia and Moldova apparently more than four).

- Utility models play an important role in the IP output registered in local patent offices, particularly in Turkey, Georgia and Ukraine.

2.2. Patent applications with inventors from the Black Sea region

TABLE 2: PATENT APPLICATIONS WITH INVENTORS FROM THE BLACK SEA REGION

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%
Bulgaria (BG)	2,105	360	17,1%	400	120	30.0%	19,0%
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%
Romania (RO)	7,519	711	9,5%	550	263	47.8%	7,3%
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[11]	**276,858**	**10,159**	3,7%	**15,849**	**3,416**	**21.6%**	5,7%

*particularly interesting findings are highlighted in grey

Findings

- Little surprisingly, Russia (i.e. inventors based in Russia) has by far the largest output in terms of patent applications. The number of over 228,000 applications indicates that Russia-based inventors are involved in over 80% of all patent applications with Black Sea based inventors. Ukraine, Turkey and Romania could be considered a second group of somewhat similar output (of 7,500-27,000 applications). Moldova and Bulgaria still have significant patent application output (around 2-3,000 patent applications with inventors from these countries between 2003 and 2013). Patent application output with inventors from Armenia, Azerbaijan and Georgia is small (at around 200 applications).

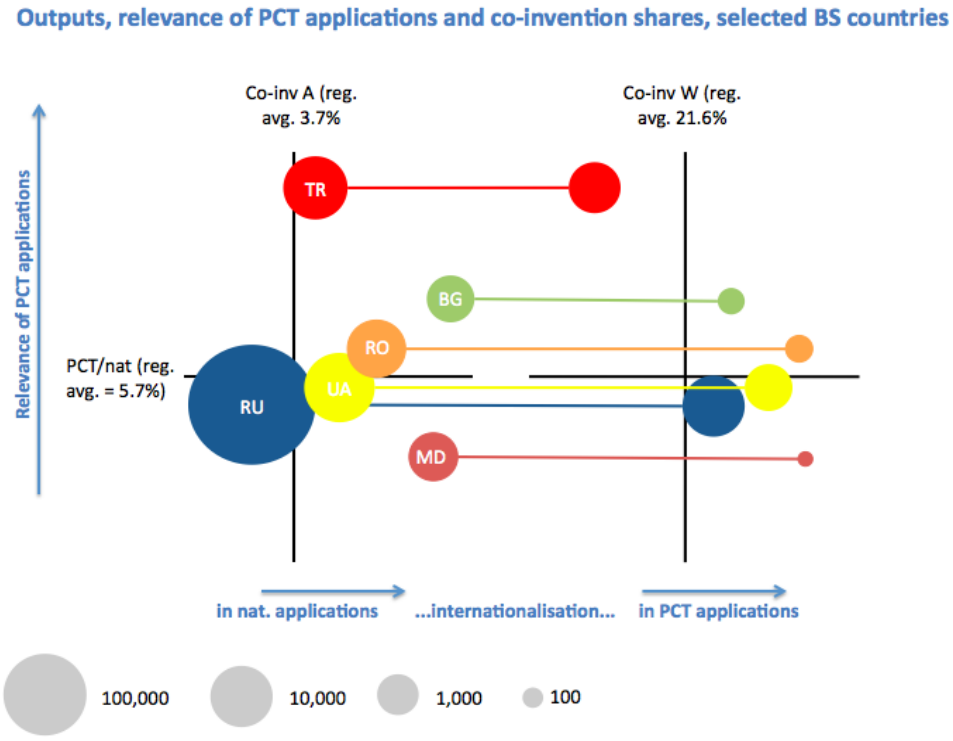
[11] All Black Sea applications with address information for at least one inventor

- In the PCT patents ('W'), the differences are less significant. There are "only" three times as many applications with Russia-based inventors than there are with Turkey-based inventors (compared to a factor of 15 in national applications). In other words: While Russian-based inventors are involved in over 80% of all national patent applications in the Black Sea countries, they are in only 61% of PCT applications. Accordingly, Russia's share of W applications to A applications is among the lowest (4.2%). At 2.1, 5.0% and 7.3% respectively, it is also low in Moldova, Ukraine and Romania.
- Turkey's share in BSC PCT applications, by contrast, is higher than its share in nationally filed BSC output (which is comparable to the output in Romania and Ukraine) might suggest: Almost a fourth of PCT applications in the region involve Turkey-based inventors (but only 3% of national applications). Over a third of patent applications with Turkey-based inventors are international PCT applications. These numbers are only higher for Armenia, a small country with a supposedly higher systemic relevance of international linkages (also somewhat visible in the case of Azerbaijan).
- The other extreme is Moldova: While its national patent application output is comparable to Bulgaria's, its PCT output is not. It is in fact the lowest PCT output in the Black Sea region. Only 2.1% of its application output are PCT applications. Moldova is bound to the Patent Cooperation Treaty since 1991 (Turkey only since 1996), so the reasons for this low level of PCT applications in Moldova must be sought elsewhere.
- As expected, in most cases, the 'internationalisation' of the patent applications (measured through the share of international co-inventions in overall application output) is higher for countries with smaller output. In the case of national applications, it is highest in Armenia, the country with the smallest overall output. The situation is different in the case of PCT applications: Romania, Georgia and Moldova are the countries with the most internationalised PCT output.
- Considering the size of the overall output, internationalisation is fairly low in Azerbaijan's PCT applications and in Georgia's national applications.
- Among the countries with larger output, internationalisation is particularly high in Romanian, Russian and Ukrainian PCT output. Almost half of the PCT

applications involving Romania-based inventors are international co-inventions.

- While Turkey's PCT output is significant (both in absolute numbers, where it is higher than Ukraine's output, as well as in relation to nationally filed output with Turkey-based inventors), the share of international co-inventions in its PCT output is low.
- The share of internationalisation in application output of Bulgaria-based inventors is relatively high in nationally filed applications, less so in PCT applications.
- NB: For around a third of the patent applications covered in the 2003-2013 period in PATSTAT, no address data on inventors is available. As to the 63% where address data is available, a certain number (impossible to estimate on the basis of the PATSTAT data) has partially missing address information. Thus, the data presented here is not a complete picture, but the best possible picture of geographical indications of inventive activity.

FIGURE 1: OUTPUTS, RELEVANCE OF PCT PUBLICATIONS AND CO-INVENTIONS SHARES, SELECTED BY BS COUNTRIES



We have now compared the Black Sea countries' patent application output in general as well as in terms of its internationalisation shares. The geographic patterns of co-inventions (country-country links) will be discussed below. Before we turn to a thematic analysis of patent application output in the Black Sea region, it might be interesting to not only compare the output between the Black Sea countries, but as part of the world average. Building on additional bibliometric data, we can compare the Black Sea countries' share in worldwide patent application output with their share in worldwide publication output.

TABLE 3: BLACK SEA COUNTRIES SHARE IN PATENT APPLICATION OUTPUT WITH THEIR SHARE IN WORLDWIDE PUBLICATION OUTPUT

Country	A with Black Sea inv	Share of global	W with Black Sea inv	Share of global	Share in global publication output[12]
Armenia (AM)	142	0,00%	96	0,01%	0,03%
Azerbaijan (AZ)	243	0,00%	68	0,00%	0,03%
Bulgaria (BG)	2,105	0,02%	400	0,02%	0,16%
Georgia (GE)	732	0,01%	121	0,01%	0,03%
Moldova (MD)	3,044	0,03%	64	0,00%	0,02%
Romania (RO)	7,519	0,07%	550	0,03%	0,36%
Russia (RU)	228,682	2,23%	9,609	0,56%	2,01%
Turkey (TR)	8,791	0,09%	3,772	0,22%	1,12%
Ukraine (UA)	27,593	0,27%	1,391	0,08%	0,38%
Total[13]	**276,858**	**2,70%**	**15,849**	**0.92%**	**NA**

This comparison with global patent output shows that the Black Sea region's share is smaller in PCT applications. While this applies to most individual countries in the region as well, it is different in the case of Turkey: Its share in global PCT applications is higher than its share in global national level applications.

Comparing patent and publication output, several interesting features appear: In most Black Sea countries, the share in global patent output is between a tenth and a third of the share in global publication output. For Russia and Moldova, the share in global patent output (national applications, first filings) is actually higher than their

[12] Totals as reported by scimagojr.com on the basis of Scopus data; period: 1996-2014
[13] All Black Sea applications with address information for at least one inventor

share in global publication output. Differences between the two shares are particularly noteworthy in Turkey (involved in over 1% of global publication output, but only 0.09% of patent application output (0,22% of PCT output)), Romania (0.36% vs 0.07%) and Bulgaria (0.16% vs 0.02%).

NB: The global output in national ('A') patent applications (first filings) in the 2003-2013 period is roughly 10,2m applications (registered in PATSTAT, version autumn 2015). 1,722,498 are 'W' or PCT applications (base for 'share of global' column in 'W' applications).

2.3. Applications with inventors from the Black Sea region per topic

In order to give an overview of differences and similarities in Black Sea countries' thematic strengths in terms of patent application output, the following table shows for each country the number of patent applications ('A' and 'W' respectively) per CPC-1 area[14] as well as its share in a country's output. Top three topic areas per country are highlighted in grey to facilitate comparison.

TABLE 4: A' APPLICATIONS (IPC SECTIONS; CPC SECTIONS NOT COMPLETE)

inventor country	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Row total**	**Total** (as above)
AM	21	13	20	0	9	7	33	30	133	142
AZ	77	13	39	0	52	17	8	8	214	243
BG	310	346	282	11	118	274	581	324	2,246	2,105
GE	245	119	90	4	42	138	51	50	739	732
MD	1,196	564	892	5	96	348	384	260	3,745	3,044
RO	1,377	1,240	1,235	106	381	979	1,411	874	7,603	7,519
RU	65,333	33,993	37,344	1,357	14,454	23,366	30,222	16,033	222,102	228,682
TR	2,159	1,892	638	401	675	1,480	1,050	819	9,114	8,791
UA	4402	3187	3204	126	1052	2225	2385	1265	17846	27,593
AM	15,8%	9,8%	15,0%	0,0%	6,8%	5,3%	24,8%	22,6%	NB1: Applications	

[14] A = Human necessities; B = performing operations, transporting; C = chemistry, metallurgy; D = textiles, paper; E = fixed constructions; F = mechanical engineering, lighting, heating, weapons, blasting; G = physics; H = electricity; Y = general tagging of new technological developments and cross-over technologies

AZ	36,0%	6,1%	18,2%	0,0%	24,3%	7,9%	3,7%	3,7%	are sometimes not assigned any IPC section. Sometimes, they are assigned to several IPC esctions. This explains the variance between total and row total.
BG	13,8%	15,4%	12,6%	0,5%	5,3%	12,2%	25,9%	14,4%	
GE	33,2%	16,1%	12,2%	0,5%	5,7%	18,7%	6,9%	6,8%	
MD	31,9%	15,1%	23,8%	0,1%	2,6%	9,3%	10,3%	6,9%	
RO	18,1%	16,3%	16,2%	1,4%	5,0%	12,9%	18,6%	11,5%	
RU	29,4%	15,3%	16,8%	0,6%	6,5%	10,5%	13,6%	7,2%	
TR	23,7%	20,8%	7,0%	4,4%	7,4%	16,2%	11,5%	9,0%	
UA	24,7%	17,9%	18,0%	0,7%	5,9%	12,5%	13,4%	7,1%	

TABLE 5: W APPLICATIONS W' APPLICATIONS (CPC SECTIONS)

inventor country	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Y**	**Row total**	**Total** (as above)
AM	11	11	8	0	3	10	9	8	4	64	96
AZ	7	7	5	0	5	19	11	8	6	68	68
BG	45	58	31	7	18	49	43	34	25	310	400
GE	24	9	11	0	5	10	8	4	2	73	121
MD	8	7	8	0	2	10	10	2	3	50	64
RO	46	28	28	0	23	52	28	17	26	248	550
RU	1,643	1,449	1,302	37	502	1,168	1,584	1,027	432	9,144	9,609
TR	642	298	113	62	121	259	154	116	75	1,840	3,772
UA	191	190	168	3	71	173	174	169	77	1,216	1,391
AM	17,2%	17,2%	12,5%	0,0%	4,7%	15,6%	14,1%	12,5%	6,3%		
AZ	10,3%	10,3%	7,4%	0,0%	7,4%	27,9%	16,2%	11,8%	8,8%		
BG	14,5%	18,7%	10,0%	2,3%	5,8%	15,8%	13,9%	11,0%	8,1%		
GE	32,9%	12,3%	15,1%	0,0%	6,8%	13,7%	11,0%	5,5%	2,7%		
MD	16,0%	14,0%	16,0%	0,0%	4,0%	20,0%	20,0%	4,0%	6,0%		
RO	18,5%	11,3%	11,3%	0,0%	9,3%	21,0%	11,3%	6,9%	10,5%		
RU	18,0%	15,8%	14,2%	0,4%	5,5%	12,8%	17,3%	11,2%	4,7%		
TR	34,9%	16,2%	6,1%	3,4%	6,6%	14,1%	8,4%	6,3%	4,1%		
UA	15,7%	15,6%	13,8%	0,2%	5,8%	14,2%	14,3%	13,9%	6,3%		

NB: sum per row is not 1 as applications can be assigned to more than 1 CPC class

In the case of Armenia, Azerbaijan and, as far as international PCT applications ('W') are concerned, also Georgia and Moldova, the number of patent applications per CPC section are too low to draw any meaningful conclusions from the data. If anything, one can conclude that Azerbaijan has a stronger focus on 'human necessities' in national patents than in international ones.

In national patent applications, the 'human necessities' category is the one with the quantitatively strongest output in all Black Sea countries except Bulgaria and Romania. It is particularly relevant in the case of Russia, Moldova and Georgia. Bulgaria, by contrast, shows a focus on physics that is unique in the context of Black Sea countries with sizeable patent application output. Only Romania has a comparable specialisation on this topic.

Apart from 'human necessities': Much of Moldova's national output is in chemistry/metallurgy. Georgia's output is strong in mechanical engineering, as is Turkey's. Turkey and Ukraine show a relative strength in the 'performing operations and transport' category. Textiles and paper play a marginal role in terms of output, which is only exceeding 100 applications (2003-2013) in the case of Turkey-based inventors. In Russia, Ukraine, Georgia and Moldova, the chemistry and metallurgy section 'C' is relatively more important in the national patent application portfolio. For Bulgaria, Georgia and Turkey, the 'mechanical engineering, lighting, heating, weapons, blasting' section is relevant nationally in terms of 'A' applications (first filings) 2003-2013.

Differences in thematic strengths between 'A' and 'W'/PCT patent applications:

- Georgia and Moldova have significant national application output, but little PCT applications.
- Physics play a much larger role in Russia's PCT output than in its national patent output. The same goes for Moldova and Ukraine (where electricity is also a field with more prominence in PCT patents)
- Mechanical engineering patent applications ('F') play a larger role in PCT output in most countries. The only exception is Turkey whose mechanical engineering output is a more relevant part in its national application portfolio compared to its PCT patent application output.

- Turkey shows a clear thematic focus on 'human necessities' when it comes to PCT patents. Over a third of its approximately 2,000 indexed PCT applications fall under this section.
- The 'Y' section, reserved in the CPC classification for new technological developments and cross-sectoral technologies, features relatively prominent in the case of Romania's PCT application output. Over 10% of its PCT applications 2003-2013 fall under this section.

The quite generic IPC and CPC classes are of limited use for the thematic analysis of a country's patent output. For this reason and to allow for better comparability with the bibliometric analysis of publication output, we include data on the patent applications with inventors from Black Sea countries by technological field (Schmoch 2008). More precisely, we first give an overview for each country for five large technological sectors. We then provide results based on an analysis of technological specialisation by 35 technology fields. We start with the results for nationally filed patent applications and then look at specialisation patterns in international PCT patents in comparison to that.

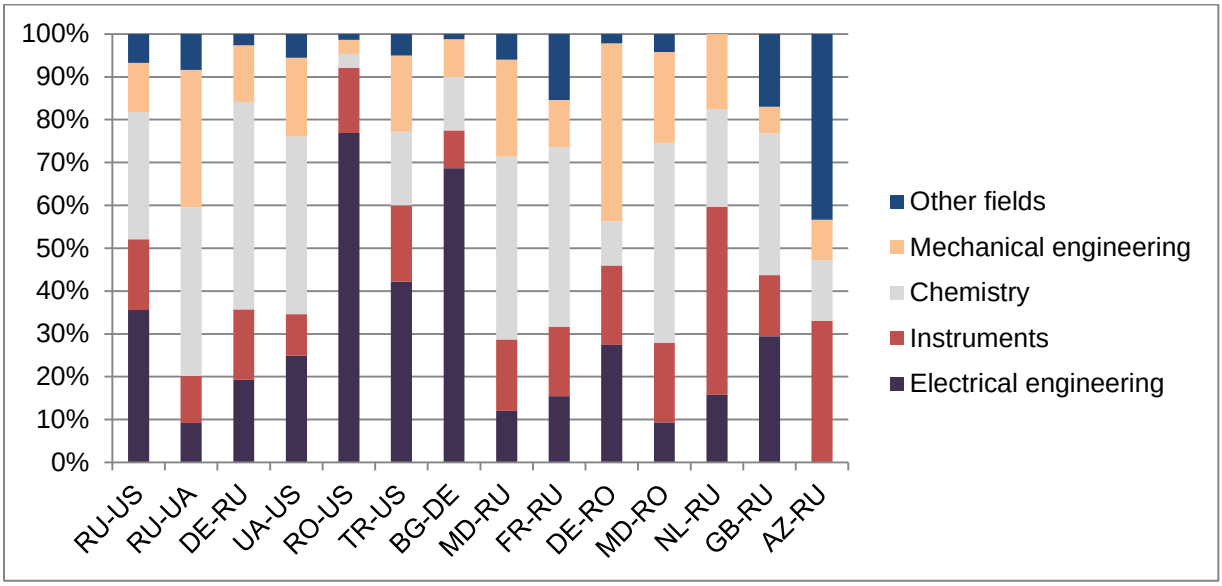
TABLE 6: A APPLICATIONS (TECHNOLOGICAL SECTOR)

Country / Sector	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Row total
AM	48	15	41	14	12	130
AZ	10	58	53	26	55	202
BG	670	285	477	537	200	2169
GE	51	63	279	267	56	716
MD	335	741	1410	855	176	3517
RO	1234	1325	2144	2048	619	7370
RU	19050	42234	81069	51642	20411	214406
TR	3	2	8	2		15
UA	1295	948	1803	3102	1815	8963
AM	36,9%	11,5%	31,5%	10,8%	9,2%	100%
AZ	5,0%	28,7%	26,2%	12,9%	27,2%	100%
BG	30,9%	13,1%	22,0%	24,8%	9,2%	100%
GE	7,1%	8,8%	39,0%	37,3%	7,8%	100%
MD	9,5%	21,1%	40,1%	24,3%	5,0%	100%

RO	16,7%	18,0%	29,1%	27,8%	8,4%	100%
RU	8,9%	19,7%	37,8%	24,1%	9,5%	100%
TR	14,4%	10,6%	20,1%	34,6%	20,2%	100%
UA	9,2%	21,3%	32,7%	29,1%	7,7%	100%

*Noteworthy results in the portfolio shares are highlighted in grey

FIGURE 2: A APPLICATIONS (TECHNOLOGICAL SECTOR)



In terms of nationally filed output, the following specialisation patterns can be observed:

- Bulgaria's output is focused on electrical engineering. It's the only country in the region with this pronounced focus.
- Georgia's output is focused on chemistry and mechanical engineering. The other fields have fairly low shares in national output.
- Moldova's output is strongest in the field of chemistry.
- Romania has a balanced output profile close to the regional averages. Slight specialisation on electrical engineering, mechanical engineering and chemistry can be observed.
- Russia's output is heavily focused on chemistry. Mechanical engineering is also strong.
- Turkey's output is particularly strong in mechanical engineering.
- Ukraine has the largest regional share (next to Azerbaijan) in the instruments area. Chemistry is also important in its output portfolio.

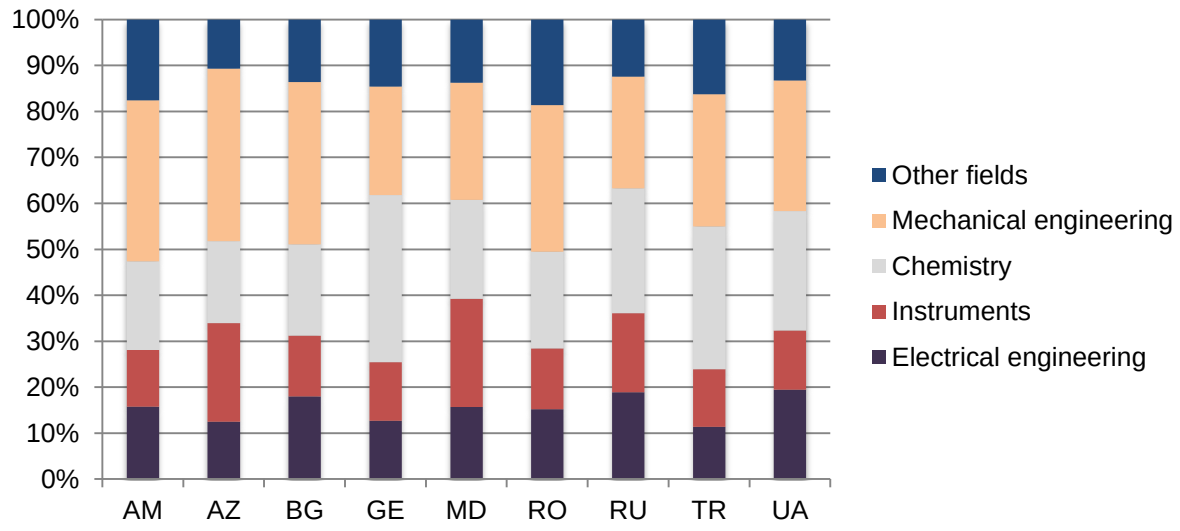
- Armenia and Azerbeijan also show quite pronounced specialisation patterns (electrical engineering and chemistry in the case of Armenia; instruments, chemistry and other fields in the case of Azerbaijan). However, the number of cases is too low to draw reliable conclusions from it.

TABLE 7: W APPLICATIONS (TECHNOLOGICAL SECTORS)

Country / Sector	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Row total
AM	9	7	11	20	10	57
AZ	7	12	10	21	6	56
BG	49	36	54	96	37	272
GE	7	7	20	13	8	55
MD	8	12	11	13	7	51
RO	31	27	43	65	38	204
RU	1,588	1,443	2,278	2,044	1,040	8393
TR	195	215	534	493	279	1716
UA	219	145	292	320	149	1125
AM	15,8%	12,3%	19,3%	35,1%	17,5%	100%
AZ	12,5%	21,4%	17,9%	37,5%	10,7%	100%
BG	18,0%	13,2%	19,9%	35,3%	13,6%	100%
GE	12,7%	12,7%	36,4%	23,6%	14,5%	100%
MD	15,7%	23,5%	21,6%	25,5%	13,7%	100%
RO	15,2%	13,2%	21,1%	31,9%	18,6%	100%
RU	18,9%	17,2%	27,1%	24,4%	12,4%	100%
TR	11,4%	12,5%	31,1%	28,7%	16,3%	100%
UA	19,5%	12,9%	26,0%	28,4%	13,2%	100%

*The top three shares per field are highlighted; specialisation patterns that are not visible in national patents are highlighted in green, specialisations that are visible in national patent application output, but not in PCT patents are highlighted in red.

FIGURE 3: W APPLICATIONS (TECHNOLOGICAL SECTORS)



Comparing the PCT and the national 'A' level specialisation patterns reveals a few interesting differences

- Bulgaria's output is again focused on electrical engineering and mechanical engineering. However, the focus is on the latter in PCT output (and was on the former in national output). This can indicate a number of things, most notably a stronger inclusion of the mechanical engineering-related inventive activity in global innovation chains, either through Bulgarian companies or international players based in Bulgaria.
- In the regional comparison, Romania's focus in electrical engineering is not reflected in PCT output. The 'others' field is of relevance, by contrast.
- Russia's PCT output reveals a specialisation on electrical engineering related fields that is not visible in national application output.
- Turkey's PCT output is less focused on mechanical engineering. Chemistry features stronger in PCT output compared to national output.
- In the case of Ukraine, PCT output shows a stronger concentration on electrical engineering and less focus on instruments.
- In addition to Armenia and Azerbaijan, Georgia's and Moldova's PCT output is too small to draw conclusions from it.

3. Specialization analysis

National-level patent applications ('A')

If we continue the analysis of the technological specialisation of the patent application output, the following conclusions can be drawn for the Black Sea countries[15]:

- **Armenia's** specialisation on the area of chemistry is due to a number of pharmaceutical as well as basic materials and food chemistry patents with Armenia-based inventors. Apart from this, the number of civil engineering, electrical machinery and medical technology patent applications is relatively high. It is important to note, however, that the base set of around 140 categorised patent applications is too low to draw meaningful conclusions.
- For the case of **Azerbaijan**, at the sector-level analysis, relative strengths in the 'instruments' and 'other' fields are apparent. The strength in the instruments field is clearly related to medical technology (>20% of total A patent application output). Another 20% of the classified patent applications (50) are in the civil engineering field. No other country in the region has such a pronounced specialisation in these two fields. Again, the number of cases is low (235).
- At the broad level of technological sectors, **Bulgaria** showed a regional specialisation in electrical as well as mechanical engineering. At the more detailed level, the technology field with the most substantial output is computer technology (355 'A' applications). Other areas of strength are: electrical machinery (153), measurement (141), engines/pumps/turbines (138), other special machines (120) and civil engineering (118). These results are also more reliable and relevant than in the case of the former two countries for the

[15] What we did here is to calculate the share of 35 technology fields in the patent application output of each of the nine countries. We then highlight those technology fields that have a particularly high relevance in each country's respective output. This does not mean that the country has the highest absolute number of patent applications in this field! It just indicates relative specialisation. An example: If all but one countries have 10% of their patent applications in technology field x, and the one country has 20% of its output in this field, this country is relatively specialised on field x. Especially in a region with such a high diversity in output (compare the application numbers of Russia and Armenia, for instance), such a relative analysis makes sense.

simple fact that the base set of applications with Bulgaria-based inventors is much larger.

- In patent applications with **Georgia**-based inventors, the sectoral analysis has shown strengths in mechanical engineering and chemistry. At the more detailed level, particularly strong technology fields are: food chemistry (83 applications), pharmaceuticals (78) other special machines (75) and engines/pumps/turbines (66).
- Showcasing once more the diversity in terms of the Black Sea countries' patent application output, we have analysed over 4,000 classified 'A' patent applications with inventors based in **Moldova**. Sector-level analysis has shown a strong specialisation in chemistry and a secondary specialisation in instruments. In chemistry, the strongest technology field specialisations are: food chemistry (323 applications) and pharmaceuticals (311). In the instruments sector, the specialisation is related to the high output of medical technology patent applications (460, or over 10% of Moldova's applications).
- **Romania's** application portfolio is the most evenly spread at the level of technology sectors. The data show a slight specialisation in electrical engineering, particularly in electrical machinery/apparatus/energy (559 applications, almost 7% of Romania's output) and computer technology (351). A strong field-level specialisation exists in the field of measurement (682 applications amounting to over 8% of Romania's application output) and engines/pumps/turbines (501). Electrical machinery is a field that occupies a more central role in Romania's output than in any other Black Sea country (6.8% of its output).
- In absolute numbers, **Russia's** patent application output 2003-2013 is the strongest in the region, regardless of the technological sector. There is, however, a relative specialisation in chemistry, especially in these fields: food chemistry (28,095 applications) and materials and metallurgy (14,868). Apart from chemistry, Russia's inventive output is specialised in the area of measurement (15,847) and civil engineering (14,445). Another technology field where Russia is relatively specialised is the analysis of biological materials (only 4,631 applications, but 2% of its entire portfolio; in most other countries this is close to or below 1%).

- At the sector level, **Turkey** shows a clear specialisation on mechanical engineering, electrical engineering and other fields. In mechanical engineering, this is reflected especially in the following fields: transport (617 applications, over 6% of its output), other special machines (501), thermal processes (435) and handling (352 applications, almost 4% of its output). In the other fields category, Turkey shows a particularly strong specialisation on 'other consumer goods' (632 applications or 6.5% of its output, four times the share of other countries) and furniture/games (584 applications or 6% of its output, three times the share or more compared to other countries).
- **Ukraine's** specialisation pattern is similar to the ones of Romania or Russia and, thus, to the regional average. Chemistry is the field with the highest output, followed by mechanical engineering. There is a slight specialisation, however, in the area of instruments. At the level of technology fields, relative specialisation is strong in: medical technology (1,871, almost 10% of its output), measurement (1,260 applications or almost 7% of its output), and in other sectors in: materials/metallurgy (1,499 applications), machine tools (867 and with almost 5% a higher share than in any other Black Sea country) and other special machines (1305).

International PCT ('W') patent applications

Comparing 'A' to 'W' patents, we can observe the following: While specialisation patterns are similar to those of national level applications, in some cases they are not:

- Armenia shows a specialisation in mechanical engineering that was not visible in nationally filed application output. However, due to the low numbers of cases, no conclusions can be drawn from this. The same goes for Azerbaijan, Georgia and Moldova, all with very small numbers of classified PCT applications.
- In PCT application output with **Romania**-based inventors, the specialisation on electrical engineering is less pronounced whereas a clear specialisation on other fields becomes visible. The more detail field-level shows that this mostly concerns the field of civil engineering. Whereas 5% of all nationally filed

applications with Romania-based inventors were in this field, its share is 10% among Romanian inventors' PCT applications. It should be noted, however, that this amounts to only 24 applications. As shown above, Romania's PCT output is relatively low compared to its production of nationally filed patents (the share of PCT patents to nationally filed patents is 7%, comparable to Moldova, Russia and Ukraine and much lower than in the case of Turkey).

- **Turkey's** specialisation pattern is also slightly different in its PCT output: While the specialisation on consumer goods and furniture/games is confirmed, the focus in other sectors is less on mechanical engineering and more on chemistry. At the more detailed level of fields, Turkey's PCT output is highly specialised in pharmaceuticals. The 342 PCT applications with Turkey-based inventors filed in the category of pharmaceuticals amount to over 18% of Turkey's PCT output (the share was slightly over 4% in its national output (392 applications)). The output is also remarkable in absolute numbers: Russian-based inventors have been involved in 646 PCT patent applications in the field of pharmaceuticals (9,913 nationally filed ones). In all other fields Russia's output is four to ten times of Turkey's. Two conclusions are possible here: Turkey-based inventors are heavily involved in pharmaceutical inventions. These inventions are to large extents filed internationally.
- In PCT applications with **Russian**-based inventors, the specialisation on chemistry is still visible. It shifts slightly from food chemistry and metallurgy to organic fine chemistry and pharma. The electrical engineering sector gains in relevance. Russia is relatively more specialised in the following fields: computer technology, digital communication and telecommunications.
- The situation in the **Ukraine** is similar with electrical engineering fields like audio-visual technology, digital communication and computer technology being relatively more important in its portfolio.

3.1. Patent applications with applicants/owners from the Black Sea region vs foreign ownership

Foreign ownership of patent applications can be seen as an indicator of knowledge flows (see, for instance: Guellec and van Pottelsberghe de la Potterie 2001). It indicates the amount of knowledge entirely or partly created in one country (i.e. with at least one inventor of a specific application based in the country), which is at least partly owned by actors in another country. This outflow of knowledge can be interpreted positively (as an indicator of the attractiveness and market relevance of a country's stock of knowledge) as well as negatively (as knowledge flowing out of a country's innovation system, put to use elsewhere).

While we are not able to bring this discussion to an end, we can provide indication of knowledge flows in the Black Sea region.

As a first step, we will have a look at the share of purely domestically owned patent applications in 2004-2013 (inventor(s) and applicant(s) from the same (Black Sea) country).

TABLE 8: SHARE OF PURELY DOMESTICALLY OWNED PATENT APPLICATIONS IN 2004-2013

Patent authority	A all	Domestic ownership	Share	W all	Domestic ownership	Share
Armenia (AM)	142	61	43,0%	96	44	45,8%
Azerbaijan (AZ)	243	105	43,2%	68	54	79,4%
Bulgaria (BG)	2,105	1,842	87,5%	400	240	60,0%
Georgia (GE)	732	33	4,5%	121	42	34,7%
Moldova (MD)	3,044	2,926	96,1%	64	30	46,9%
Romania (RO)	7,519	6,908	91,9%	550	192	34,9%
Russia (RU)	228,682	190,863	83,5%	9,609	6,281	65,4%
Turkey (TR)	8,791	8,377	95,3%	3,772	3,315	87,9%
Ukraine (UA)	27,593	25,658	93,0%	1,391	738	53,1%
All	**276,858**	**236,343**	**85.4%**	**15,849**	**10,936**	**69.0%**

In table 8 on domestic ownership shares, we see that in the case of Turkey, Ukraine, Moldova and Romania, over 90% of national patent applications indexed in PATSTAT (and two thirds of PCT applications) involved domestic applicants. This is little surprising given the size of the innovation community. The numbers for Russia are a bit lower, which might be an issue of data quality. Many applications seem to

have no applicant assigned, thus decreasing the share. The low share of domestic ownership in the case of Georgia might also be a result of data quality issues. If we only extract those first filed ‚A' applications that have any applicant assigned, we get only 76 applications with Georgian applicants, resulting in a more realistic domestic ownership share of over 50%. This is still low.

The general trend that domestic ownership decreases with the size of the country is little surprising. More interesting are the variations within countries of similar size. For instance, among the smallest countries (patent application output wise), Azerbaijan has a fairly high share of domestic ownership, especially in PCT patents. Moldova has a significantly higher share of domestic ownership in its national patents than Bulgaria, but less than Bulgaria in PCT patents. While Romania, Turkey and Ukraine show very similar patterns of domestic ownership in national patents, Romania has a significantly lower share of domestic ownership in its (few) PCT patents. In fact, it has one of the lowest shares of domestic ownership in PCT patents in the entire Black Sea region. It would be an interesting qualitative follow-up question who the foreign (co-)owners[16] of Romanian PCT patents are. We can answer this question when analysing foreign ownership patterns in national and PCT patents.

Before doing so, however, we would like to raise another related question of interest here, namely: Are the exclusively domestically owned patent applications in the above table mostly filed in the national patent authority, or do other authorities (and, thus, markets) play a major role here?

[16] I use the formulation (co-)owner or (co-)ownership here and subsequently to indicate the fact that the patent applications referred to could also involve other inventors from other countries

TABLE 9: DOMESTICALLY OWNED PATENT APPLICATIONS VS. OTHER PATENTING AUTHORITIES

Patent authority	**A - domestic ownership**	**Most important patenting authorities** (top 4 or threshold: 10)			
Armenia (AM)	61	US: 29	RU: 26		
Azerbaijan (AZ)	105	EA[17]: 59	RU: 22	US: 15	
Bulgaria (BG)	1,842	BG 1,490	US: 310	EP: 14	
Georgia (GE)	33	US: 13	GE: 12		
Moldova (MD)	2,926	MD: 2,866	RU: 41		
Romania (RO)	6,908	RO: 6,590	US: 239	EP: 37	MD: 11
Russia (RU)	190,863	RU: 188,334	US: 1,154	EA: 835	UA: 202
Turkey (TR)	8,377	TR: 7,796	EP: 282	US: 210	DE: 50
Ukraine (UA)	25,658	UA: 24,096	RU: 1,289	US: 160	PL: 26
Patent authority	**W - domestic ownership**				
Armenia (AM)	44	AM: 40			
Azerbaijan (AZ)	54	AZ: 50			
Bulgaria (BG)	240	BG: 228	IB: 10		
Georgia (GE)	42	GE: 40			
Moldova (MD)	30	MD: 28			
Romania (RO)	192	RO: 164	IB: 17		
Russia (RU)	6,281	RU: 6,054	IB: 162	EA: 60	
Turkey (TR)	3,315	TR: 1,521	EP: 1,065	IB: 721	
Ukraine (UA)	738	UA: 691	IB: 35		

In most cases, domestically owned applications are filed nationally in more than 90% of the cases. Exceptions are Turkey and Ukraine. In the former case, in national applications and particularly in PCT applications, a significant share of applications (first filings) goes directly to EPO. In the case of Ukraine, the Russian IP office plays a major role. In PCT applications, the WIPO ("IB") itself also acts as a relevant application authority. The Eurasian Patent Office plays relevance for the filings of Azerbaijan-based and owned inventions.

We have had a close look at the share of domestically invented and owned patent application output. We can thus now turn to the question of foreign ownership patterns. From which countries are the applicants (= IP owners) involved in those patent applications that are not exclusively owned domestically?

[17] Eurasian Patent Organisation

TABLE 10: FOREIGN OWNERSHIP LINKS, FIRST FILINGS 'A' (THRESHOLD IN 'A' APP: 40)

inv_cty	app_cty	A app (threshold 50)	First filed in (threshold 30)		W/PCT
RU	KR	1,879	KR: 1,586	RU: 290	44
UA	RU	550	RU: 529		40
RU	US	477	US: 378	RU: 59	558
RU	DE	272	DE: 182	EP: 44	151
BG	DE	181	US: 137	DE: 32	15
RU	NL	162	RU: 116		174
RO	DE	132	DE: 86	EP: 38	26
RU	UA	127	RU: 69	UA: 54	39
UA	KR	127	KR: 127		9
RU	CY	121	RU: 73	US: 38	53
RO	US	108	US: 80		82
TR	DE	106	DE: 71		85
RU	VG	99	RU: 45	US: 43	3
TR	US	82	US: 66		57
AZ	RU	78	RU: 78		1
UA	US	78	US: 66		86
RO	MD	75	MD: 74		1
TR	KR	72	KR: 72		2
RU	GB	68			263
RU	CH	67			92
RU	MD	56	MD: 55		2
UA	PL	46	PL: 44		3
RU	FR	44			204
RU	SG	42	US: 37		7
UA	DE	41			10

*Foreign ownership patterns involving EU countries are marked in blue; foreign ownership within the Black Sea region is marked in red

Interestingly, the US is not the most important foreign owner of patent applications invented or co-invented in the Black Sea region when it comes to first filings. Instead, Korean applicants are most active in filing Black Sea invented or co-invented patent applications.

Apart from this case, the US are by far the most important foreign owner of Black Sea (co-)invented patent applications. US applicants hold significant numbers of patent applications involving Russia, Romania or Turkey-based inventors. However, in the

case of Bulgaria, Romania and Turkey, German ownership is more frequent than US ownership, making the EU as a whole by far the most important foreign owner of first filed national applications with Black Sea inventors from these countries.

Other EU countries also play a major role as foreign owners of Black Sea invented applications, especially the Netherlands, Great Britain and France. Interestingly, applicants based in Cyprus hold a significant amount of applications involving Russian inventors. This has to do with companies' strategies regarding the location of their headquarters and related transfer pricing (affiliates paying license fees to headquarters located in tax havens). The same company strategies also become apparent in the significant amount of national-level applications involving Russian inventors that are owned by applicants based on the Virgin Islands (99!).

Within the Black Sea region, Russia is the largest owner of applications involving non-Russian Black Sea inventors (mostly from Ukraine, but also from Azerbaijan). The Ukraine (holding applications with Russian inventors) and Moldova (holding applications with Romanian or Russian inventors) are other important foreign owners within the Black Sea region.

Comparing national ('A') and international ('W') applications, we see that GB, France, Netherlands, Germany and Switzerland-based owners of Russian co-invented patents frequently make use of the PCT procedure. The same goes for US owners of Russian, Romanian, Turkey or Ukraine co-invented applications. No other third country owners have comparable shares of PCT/national patent applications.

Regarding the question of the filing offices receiving foreign owned Black Sea (co-) invented applications, the South Korean, Russian, US and German offices play the most important role. Interestingly, the Taiwanese office, which features prominently when considering all 'A' fillings, is not relevant when looking at first filings only. In the case of Bulgaria, the USPTO receives most of the foreign owned applications with Germany-based applicants. In Ukraine co-invented applications owned by Russia-based actors, the Russian office is the most important one.

3.2. Co-inventions

Different from foreign ownership patterns, which can be seen as an indicator for knowledge flows, co-inventions are an indicator for collaborative inventive activity.

TABLE 11: CO-INVENTIONS WITHIN THE REGION

inv_cty_1	inv_cty_2	A app	W/PCT
RU	UA	1,038	185
MD	RU	117	8
AZ	RU	102	1
MD	RO	91	2
MD	UA	85	3
GE	RU	34	4
AM	RU	32	7
BG	RU	22	2
RU	TR	8	0
RO	RU	8	5

Additional data show that most co-inventions between Russia and Ukraine are filed in Russia. Most co-inventions between Moldova and Russia as well as Moldova and Romania are filed in Moldova. Other application authorities play a role only in Russia-Ukraine co-inventions (64 of these are first filed in Korea, 22 at the Eurasian Patent Organisation).

TABLE 12: CO-INVENTIONS – COMPARISON WITH OTHER REGIONS (THRESHOLD 40)

inv_cty_1	inv_cty_2	A app	A First filed in (threshold 30)			W/PCT (t. 20)
RU	UA	1083	RU: 919	UA: 97		185
RU	US	1046	US: 734	RU: 237	KR: 42	893
DE	RU	502	RU: 234	DE: 163	US: 43	313
RO	US	200	US: 180			111
UA	US	178	US: 122			183
TR	US	154	US: 141			163
BG	DE	152	US: 105			34
MD	RU	117	MD: 71	RU: 40		
DE	RO	113	DE: 72			52
FR	RU	103	RU: 41			94
AZ	RU	102	RU: 101			
MD	RO	91	MD: 81			
IE	RO	91	US: 88			41
GB	RU	88	US: 40			125
MD	UA	85	RU: 38	MD: 34		
FI	RU	84	RU: 41	FI: 35		50
DE	TR	84	DE: 62			68
JP	RU	82	RU: 42	KR: 33		55
NL	RU	82	US: 41			84
BG	US	56	US: 48			30
IT	RU	55	RU: 33			85
DE	UA	50				30
LV	RU	46	RU: 34			
CN	RU	46				41
IN	RU	40				
DE	MD	39				
ES	RU	38				
LT	RU	36				
FR	RO	35				29
GE	RU	34				
AT	RU	32				23
AM	RU	32				

*Foreign ownership links within the Black Sea region are marked in red, links with the EU in blue

The US are not surprisingly the most important non-Black Sea partners for many Black Sea countries. In the case of Bulgaria, Germany is the most important co-

invention partner country. In the case of Moldova and Azerbaijan, Russia is the most important partner country.

Interestingly, other Asian countries like Japan, China or India do not feature prominently in first filed national applications involving Black Sea inventors. A comparison of national with PCT patents reveals that some of the co-invention links, especially within Black Sea countries and between emerging economies (e.g. between Russia and India) are limited to nationally filed patents.

At the level of the patent authorities where Black Sea co-inventions are filed, another interesting finding is the varying role of USPTO as the first filing office: Practically all of the Romania-Ireland co-inventions are first filed in the US. How this relates to the applicants/IP owners of the Romania-Ireland co-inventions remains to be clarified. Bulgaria-Germany, Netherlands-Russia and UK-Russia co-inventions are also most frequently first filed in the US (a finding that confirms what has been said above for Bulgaria-Germany foreign ownership), whereas Romania-Germany co-inventions are typically first filed in Germany. Equally interesting is the fact that most of Moldova-Russia and Moldova-Romania co-inventions are filed in Moldova first, while practically all of the Ukraine-Russia co-inventions are first filed in Russia. Asian patent offices play a limited role for Black Sea co-invented patent applications (first filings).

The location of the first filing office can indicate the target market the IP owner has in mind for the exploitation of the codified knowledge. This is especially the case for national patent applications. The location of first filing can also be related to the location of the IP owner, particularly if the IP owner intends to exploit the patent application in the home market. International PCT applications are also usually first filed (sometimes have to be first filed) at the applicant’s home office (as protection can be extended from there). Finally, especially in countries with a weak IP regime (long filing processes, etc), the first filing can also be carried out

Apart from the two-country links analysed above, it remains an open question what other inventor countries these co-inventions involve. In further rounds of analysis, it might be interesting to analyse whether the co-inventions are actually driven by, for instance, inventors from China and Turkey or whether they are part of larger groups. Likewise, it would be interesting to see what share of co-inventions with European countries comes out of multi-country inventive activity.

As regards networks with Europe, Germany, Great Britain and France are the strongest partners, as one would expect. At the same time, however, the Netherlands (especially with Russia and Romania) and Ireland (strong links with Romania) are also heavily involved. Ireland is Romania's second strongest co-invention partner countries in the EU, second only to Germany. Germany's co-inventions links are stronger with Turkey than with Romania. In the case of France and the Netherlands, Romania is the more important partner of the two.

The situation in PCT patents is similar. However, the links between Russia and Italy, Russia and Finland, as well as Russia and Austria appear more prominently in PCT output.

3.3. Thematic strengths/topics in co-inventions

The thematic analysis of the co-inventions discussed above can give useful results only for those country-country links, which are beyond a certain threshold. Analyses for Azerbaijan and Armenia are difficult. We find that their only major co-invention link of Armenia-based inventors is with US co-inventors in the physics section. In the case of Azerbaijan, links with Russia are strong in the 'human necessities' section.

Here are the major results for those country-country links that were beyond a threshold of 100 indexed 'A' applications (2003-2013) for all technology sectors. The table shows the details.

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 section dominate the portfolio of Finland-Russia (77.3% of applications!), Japan-Russia, 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 strong link between Ireland and Romania practically exclusively concerns the field of *electrical engineering* (almost 95% of co-inventions between these countries) and, more concretely, computer and audio-visual technologies. The field is also dominant in Romania-US and Bulgaria-Germany co-inventions (more than 65% of

the co-invention output in each of the two links) and strong in Turkey-US and Bulgaria-US co-inventions (>40%)..

The sector of *instruments* plays a major role in the co-invention links between the Netherlands and Russia (>40%) as well as between Azerbaijan and Russia (33%; medical technology).

Azerbaijan and Russia is 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.

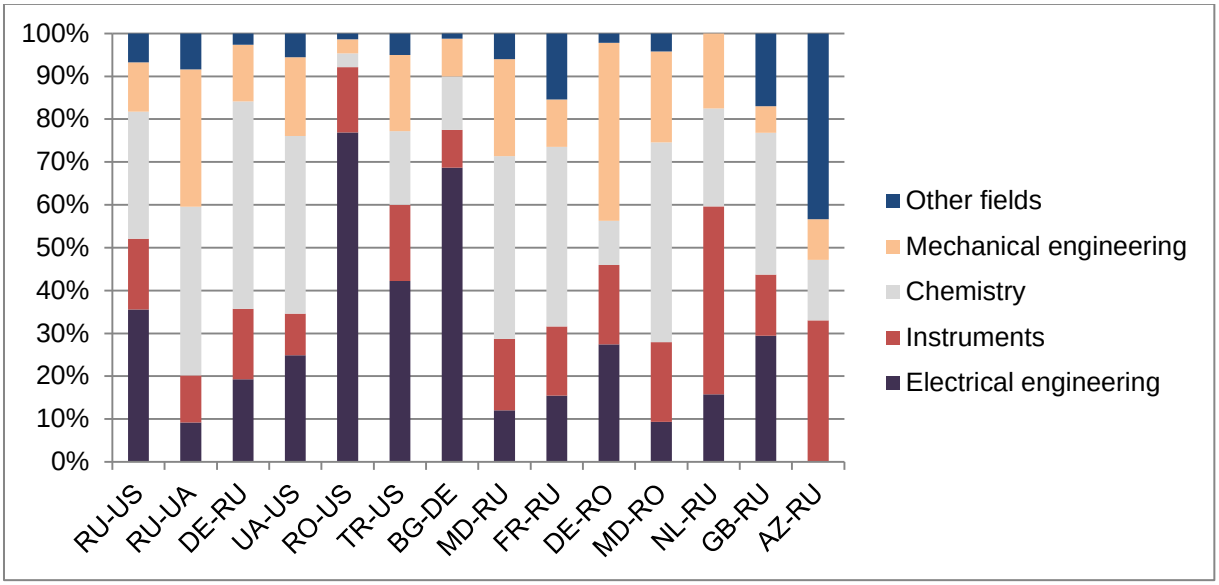
Finally, mechanical engineering is the technology sector with the highest application output in Germany-Romania, Germany-Turkey and Moldova-Ukraine co-invention links.

TABLE 13: CO-INVENTIONS: A APPLICATIONS PER TECHNOLOGY SECTOR

inv_cty_1	inv_cty_2	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
RU	US	436	203	364	141	83
RU	UA	111	133	477	387	102
DE	RU	109	93	274	75	15
UA	US	54	21	90	40	12
RO	US	166	33	7	7	3
TR	US	76	32	31	32	9
BG	DE	116	15	21	15	2
MD	RU	18	25	64	34	9
FR	RU	21	22	57	15	21
DE	RO	37	25	14	56	3
MD	RO	11	22	55	25	5
NL	RU	18	50	26	20	
GB	RU	33	16	37	7	19
AZ	RU		35	15	10	46
MD	UA	7	10	38	39	3
IE	RO	89	4	1		
JP	RU	19	9	57	5	3
DE	TR	11	7	27	35	12
IT	RU	5	17	34	9	9
FI	RU	7	2	51	5	1
BG	US	29	7	11	9	8
DE	UA	6	15	21	12	1
CN	RU	14	4	22	7	3

The distribution of the technology sectors in country-country co-invention links beyond a threshold of 100 applications are also shown in the following chart:

FIGURE 4: DISTRIBUTION OF THE TECHNOLOGY SECTORS IN COUNTRY-COUNTRY CO-INVENTIONS



In the case of international PCT patents, the number of cases is even lower. A few highlights from the findings:

- Similar to Black Sea national patent application output, most country's PCT co-invention links with Russia are strongest in chemistry sector.
- Only in China-Russia and Netherlands-Russia co-invention links, the strongest sector is instruments with a strong field-level focus on telecommunications (for the case of China), optics and medical technology (for the case of the Netherlands).
- Ireland-Romania links are almost exclusively focused on electrical engineering. As in the case of national applications, this concerns computer and audio-visual technology. Romania-US and Ukraine-US co-invention links are also strongest in electrical engineering with a focus on computer technology.

The thematic analysis of co-inventions according to technological fields would be a possible extension of the present study.

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