EU-EaP Co-patenting Analysis Report

Project	STI International Cooperation Network for Eastern Partnership Countries – PLUS
Project Acronym	EaP PLUS
Project Number	692471
Deliverable Number:	D3.1
Submission Date	27.07.2018
Responsible author(s):	Stefan PHILIPP (ZSI), Karina SHAHBAZJAN (NASU)

In this study, the technological capability and the existing cooperation patterns between EaP and EU countries are analysed. The data base is comprised by patent applications filed under the Patent Cooperation Treaty and via national routs during the timeframe 2007-2016. The methodology builds on descriptive statistics and tools from Social Network Analysis. The empiric part of the report starts with a brief overview of the patenting activities in EU and EaP countries, the dynamics and technological patterns before finally describing the observed cooperation in technology development.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 692471.

Document Control Sheet

Work package Number	WP3
Work package Title	Enhancing EU-EaP research and innovation partnership
Task Number	T3.1
Task Title	Co-patenting analysis focusing on international patents
Deliverable Number	D3.1
Deliverable Title	EU-EaP Co-patenting Analysis Report
File Name	EaP_patent_report_final_draft2.docx
Number of pages	33
Dissemination level	Public
Main author	Stefan PHILIPP (ZSI)
Contributors	Karina SHAHBAZJAN (NASU)
Quality Assurance (if applicable)	Review by Piotr SWIATEK, PTJ/FZJ

Versioning and Contribution History

Version	Date	Author/Editor	Contributors	Description/Comments
_v01	27.04.2018	Stefan PHILIPP	Karina SHAHBAZJAN	Final draft
_final	27.07.2018	Stefan PHILIPP	Karina SHAHBAZJAN, Piotr SWIATEK	Finalisation after external review

Contents

List of figures

List of tables

Executive Summary

The study discusses the patenting activities of the EU28 and the EaP countries, using national and PCT patent applications recorded in the database of the European Patent Office (PATSTAT, spring 2017 version) in the timeframe of 2007-2016.

In general, the patenting activity in the EaP countries is much lower than in the EU. However, the difference is lower when normalised by GDP. The numbers for EaP based applicants are a little lower than those for inventors, which hints to a negative balance for foreign ownerships. The partnership countries are diverse among themselves. The overall outputs of the Ukraine are on the same level as many EU countries, however since 2010 this trend has been quickly decreasing. Nevertheless, the vast majority of EaP applications are developed by Ukraine-based inventors. Moldova has an above EaP average activity for national applications, but all other countries are far below the number observed in the EU-context. The trend in the EaP countries is negative for national applications, mainly but not exclusively due to the Ukrainian influence, but positive for PCT applications which indicate that the international perspective for intellectual property rights is gaining importance in these countries.

The most important technology fields and sections for EaP countries are often different for national and PCT applications. However, the most important technology sections in the EaP countries are chemistry and mechanical engineering. While most applications from Armenian inventors are for food chemistry technologies, most applications from Azerbaijan are related to civil engineering and medical technologies. Belarusian inventors file most applications in civil engineering, optics and measurement technologies. Inventors based in Georgia develop technologies for food chemistry, engines, pumps and turbines. Moldovan inventors most often are involved in technology development in the fields of medical technology and special machines. The applications of Ukraine based inventors are attributed to measurement, materials and metallurgy and other special machines for national and computer technology, engines, pumps and turbines in the case of PCT applications.

The cooperation in technology development between EaP and EU countries, as measured by joint patent applications, is rather low. The most important EU cooperation partners for the EaP countries are Germany, France and the United Kingdom. Besides the links to the top-performing countries, there are significant links to Poland and Romania. However, the cooperation network between the EaP and EU countries mainly includes Ukraine, Belarus and as for national applications to some extent Moldova. The network for PCT applications is very sparse with a few jointly developed applications between the Ukraine and Austria, Germany and the United Kingdom.

The technological capability of the EaP countries is much lower than the one of most EU countries. While this is only true partially for the Ukraine, the trend in this country is negative, which might be explained by the ongoing political problems the country is facing. However, the results presented in this report and summarised above, give traces of specialisation patterns and existing knowledge links, which could serve as foundation for future developments. Support for R&I activities should be focused on these areas of specialisation.

1. Introduction

The Eastern Partnership Initiative, founded in 2009, is comprised by Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine and unites states with diverse ambitions and numerous challenges. While some states seek sectoral and economic cooperation with the European Union, others, on the other hand consider the partnership as an opportunity for developing political and economic ties with the European Union, which would eventually lead to membership prospects. This report is analysing the technological capability and existing cooperation between the member states of the European Union (EU28) and the countries of the Eastern Partnership (EaP) by applying patents as an indicator for inventive and often research-intensive activity. Thereby, this report is mostly a "bibliometric" study and while it certainly can help to understand the technological output and activities of different countries, such a complex phenomenon like innovation, cannot be fully explained by exploiting such a single indicator.

Patents are a protective right for a technological solution that is granted by a government in exchange for the publication of the said solutions. Therefore, patents are considered a valuable indicator for technological capability that however, has some drawbacks. Most importantly, a patent per se does not represent any economic value, only its use in a successfully marketed product, service or process creates value but many patents are never used. However, the aim of this report is not to assess the economic impact of research and development in the EaP countries but to describe the capability in technology development and the cooperation patterns in this knowledge production between the EU28 and the EaP countries. Therefore, this report focuses on patent applications rather than granted patents because the application as such already indicates inventive activities.

Usually, international comparisons of the technological capability of countries are conducted on the basis of patent applications filed under the Patent Cooperation Treaty (PCT). This internationally standardised procedure safeguards the comparability of the data, which is not given for patent applications filed under national laws as these processes vary significantly. Therefore, this study has initially been designed to cover only PCT applications and only when the first results showed that the overall numbers of PCT applications are too low to answer the core questions of this study, the authors decided to include these applications as well. As the comparability of the data is at least questionable, the methodology of analysis has been adapted to a more descriptive approach, mainly covering the overall patenting activity and the networks of international co-inventions.

With these data sources and their restrictions in mind, the study discusses the patenting activities of the EU28 and the EaP countries, using national and PCT patent applications recorded in the database of the European Patent Office (PATSTAT, spring 2017 version) in the timeframe of 2007-2016. Patents are only published after the examination procedure, this results in a publication lag limiting the possible coverage of the most recent years. In fact, there is a drop in applications for 2016 observable which is most likely due to this lag.

The following report is structured as follows. The second chapter is discussing the methodology of the report, which includes the research questions and description of the database available including its restriction, and the methodology deployed to analyse the data. The chapter also discusses patents as an indicator for technology development and their strengths and drawbacks. The third chapter contains the empiric results. It starts with a brief overview of the legal frameworks for filing patent applications in the EaP countries, before giving a descriptive overview of the patenting activities of EaP and EU based inventors and applicants, the development of the patenting activity in the ten

years covered in this study as well as an overview of technological patterns observed. The fourth section of this chapter discusses the joint technology development of inventors within the EaP countries and in cooperation with colleagues from EU countries. The final section of the empiric chapter contains results of patenting activity in the six EaP countries with a finer technological granularity and the co-inventions with EU based collaborators. Finally, the results are summarised and briefly discussed in the fourth chapter.

2. Research question and methodology

This introductory chapter presents the research questions, discusses the data basis and applied methodology including its limitations. In the first subchapter, we specify our research questions and provide a short overview of our data. In the second part of this chapter, we discuss the value of patent applications as indicators for innovative activity and lay out the methodology we used.

2.1 Research questions

With this report we give an overview of the collaborative patterns in technology development between countries of the Eastern Partnership (EaP) and the member states of the European Union as measured by patenting activities. Patent applications and patents have long been used as indicators of innovation output (cf. Griliches 1990; Nagaoka et al. 2010). Conscious of the potentially misleading notion of innovation output, patent applications and patents are the most important 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 in the EaP countries.

- What is the dynamics of patenting activity in the EaP countries for different technology fields?
- What are the characteristics of EU-EaP cooperation in patenting activities?

We aim to answer these questions on the basis of patent applications filed under the Patent Cooperation treaty (PCT) as well as on the basis of national applications. We focus on patent applications and do not limit our analysis on granted patents as we are interested in knowledge production and international cooperation. The time frame of the analysis is defined as patent applications filed during the period of 2007-2016. This is necessary because information on patent applications is only published (18 months for PCT) after filing and examination which causes a delay in the period a study like this can cover. Besides descriptive statistics, a Social Network Analysis (SNA) is deployed to analyse the international cooperation of patenting activities. SNA for inventor networks will be based on degree and eigenvector centrality on country level.

2.2 Data basis and methodology

The following analysis builds on national and PCT patent data received from European Patent Office's (EPO) PATSTAT database (version April 2017). PCT applications are generally better for international comparison than national applications as the procedures are standardised. The OECD Patent Statistics Manual[1] actually advises against comparing national level patent applications as scope and filing processes can differ substantially around the globe (affecting the numbers of application

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

output). However, the first test showed that the numbers of PCT patent applications are low for many EaP countries and thus national applications were included as well. When interpreting the results one must keep in mind that the national applications are not standardised and that various factors, which do not necessarily reflect on the technological capability of a country, influence the outputs and these are not easily comparable.

The core of our analyses is the set of patent applications, which was developed by inventors either based in the EU or EaP countries and that was filed in the period from 2007 to 2016. While only patent applications are analysed, regardless if these applications have ever been granted, we use the term "patent" for reasons of readability. 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. The methodological approach for the following analysis is the fractional-count method (Dernis and Guellec 2001).

Patent applications as an indicator

The Swiss Federal Institute of Intellectual Property (2014) 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 (2013) 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 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[2].

From an innovation analyst’s perspective, literature has long discussed the value of patents in order to assess innovation performance (e.g. Griliches 1990, 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 and 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).

[2] 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.

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. the 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. Additionally, a granted patent only represents an economic value if it is exploited. Studies using survey methodology to get information on the usage and commercialisation of a limited set of patents estimate that around 40% of patents reach the market launch stage (Webster and Jensen 2011) or that around 65% of inventions involving academics are commercially used (Meyer 2006)[3]. 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). 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.

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.

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 (co-inventions), there are patents that are owned by two different legal entities (co-applications) or patents where the applicant is from a different country than one or several of the inventors (foreign ownership). This report is based on the collaborative generation of knowledge on level of the inventors and therefore co-inventions are deployed to measure international cooperation. Co-inventions are defined as:

> **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 cooperative research among several firms or institutions (collaboration between inventors belonging to different universities or public research organisations). In that sense, co-invention indicators also reflect international flows of knowledge.

In order to make the international comparison of patent output possible, the patent classification system developed by the Fraunhofer ISI, the Observatoire des Sciences et des Technologies and the French Patent Office (INPI) is used (Schmoch, 2008). This patent classification system is based on the codes of the International Patent Classification (IPC). It is comprised of 5 technology sections (electrical engineering, instruments, chemistry, mechanical engineering and other fields) that are broken down in 35 smaller technology fields.

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

With the aim of providing a classification system as consistent and systematic as possible, the classification used exclusively the codes of the International Patent Classification and covered all inherent technology fields in a balanced way by using an appropriate level of differentiation to avoid too large, too small and overlapping technology fields. Due to these characteristics, the patent classification system is well-suited to serve as a basis for the analysis of country structures and international comparisons, notably for the determination of specialisation profiles. Equipped with these conceptual clarifications, we can now continue with the methodological approach of the analysis.

Table 1: Technological classification of patents by technology sections and technology fields

No.	Name of Section	Name of Field
1	Electrical engineering	Electrical machinery, apparatus, energy
2		Audio-visual technology
3		Telecommunications
4		Digital communication
5		Basic communication processes
6		Computer technology
7		IT methods for management
8		Semiconductors
9	Instruments	Optics
10		Measurement
11		Analysis of biological materials
12		Control
13		Medical technology
14	Chemistry	Organic fine chemistry
15		Biotechnology
16		Pharmaceuticals
17		Macromolecular chemistry, polymers
18		Food chemistry
19		Basic materials chemistry
20		Materials, metallurgy
21		Surface technology, coating
22		Micro-structural and nano-technology
23		Chemical engineering
24		Environmental technology
25	Mechanical engineering	Handling
26		Machine tools
27		Engines, pumps, turbines
28		Textile and paper machines
29		Other special machines
30		Thermal processes and apparatus
31		Mechanical elements
32		Transport
33	Other fields	Furniture, games
34		Other consumer goods
35		Civil engineering

Schmoch, 2008

Methodology and indicators

The aim of this study is to analyse the cooperation in research and technology development between researchers and institutions in Europe and the EaP countries, with a special focus on the international collaboration in knowledge production. The data basis for this endeavour is the output of PCT and national patent applications on country level between 2007 and 2016. In this analysis, we distinguish between the inventor and the applicant level. The geo-location of the patent applications is based on the home address of the inventor, normally close to the location of invention, and the address of the filing entity, which in most cases is the institution owning the patent (unless ownership was transferred at a later stage). These two locations do not necessarily have to be in the same country. For example, the patent could be filed using the headquarters address while the actual research has been carried out at a different branch.

While the study mostly builds on descriptive statistics, the joint patenting activity between EaP and EU based inventors constitutes a network that is described deploying techniques from social network analysis.

Social Network analysis

Social Network Analysis (SNA) is a set of methods and techniques for investigating social structures through the use of network and graph theories. From the view of SNA, the social environment can be expressed as patterns in relationships among different units. It characterises network structures in terms of nodes and edges that connect them (Wasserman and Faust, 1994). In recent years, SNA has been exploited to analyse the structure and dynamics of R&D networks (cf. Scherngell, 2006, Heller-Schuh et al. 2011). In this context, the relationship between innovating entities in form of individuals, organisations, regions or countries is scrutinised, based on project, publication or patenting data.

These networks most often are described using graph-theoretic or sociometric notions. Within graph theory, networks consist of actors (nodes) and their relationships (edges). In this analysis, we define inventors as actors represented by nodes which stand in a relationship and are connected with each other through an edge if they jointly developed a patent. As we aggregate data on country level, each unit may be connected by a multitude of links. To capture the cooperation intensity, these links will be weighted by the number of patent applications between two entities. Therefore, our graph *G* consists of a set of nodes *N*, a set of edges *L* and a set of weights *W* and it can be described as (Wasserman and Faust, 1994; Brandes and Erlebach, 2005; Carrington et al., 2005):

$$\mathcal{G} = \{\mathcal{N}, \mathcal{L}, \mathcal{W}\} \quad (2)$$

whereby

$$\mathcal{N} = \{n_1, n_2, ..., n_G\}, \ \mathcal{L} = \{l_1, l_2, ..., l_L\} \text{ and } \mathcal{W} = \{w_1, w_2, ..., w_L\}$$

and n_g with g=1,…, G describes elements of the set of nodes N, l_L with l=1,…, L are elements of the set of edges and w_L with l=1,…, L are the weights which are attributed to the set of edges. An edge l between two nodes u and v is defined as:

$$l_q = (n_u n_v) \text{ for } q=1,..., L \text{ and } u, v = 1,..., G. \quad (3)$$

Additionally, networks can also be described by a sociomatrix or adjacency matrix $X=(x_{uv})$. This notion is especially useful for defining measures like centrality, which will constitute the core of this analysis. In a sociomatrix the elements x_{uv} represent the intensity of interaction between the two elements n_u and n_v. The aim of the study is to identify the most important actors and links within the co-invention network. The relevance of the actors will be calculated by measures describing their position within the network. These measures are based on the number of edges (degree) each node has. In SNA these measures are summarised under the terms centrality (Wasserman and Faust, 1994; Brandes and Erlebach, 2005).

The simplest definition of actor centrality is that central actors must be most active in the sense that they have the most ties to other actors in the network. An actor with a high centrality level, as measured by degree centrality, is "where the action is" in a network. Thus, this measure focuses on the most visible actors in the network. The degree of a node n_u is defined by the number of its edges. In weighted networks, like ours, the number of edges is multiplied with its weights. The degree centrality $C'_D(n_u)$ can be calculated by standardising the degree by dividing the number of nodes within the network (Wasserman and Faust, 1994):

$$C'_D(n_u) = \frac{\sum_{\substack{v=1 \\ u \neq v}}^{G} x_{uv}}{G-1} \qquad (4)$$

A second centrality measure we use is the eigenvector centrality developed by Bonacich (1987). The basic thought behind this measure is, that the centrality of every single actor is depending on the centrality of actors it is connected with. Thus, the importance of nodes increases if they are neighbouring other important nodes or connected to a multitude of other actors. In a graph the eigenvector centrality $C_E(n_u)$ of a node n_u is defined as (Faust, 1997):

$$C_E(n_u) = \frac{1}{\lambda} \sum_{v=1}^{G} x_{uv}\, c_v \qquad (5)$$

where λ is the largest eigenvalue of the GxG-adjacency matrix X. This definition implies feedback effects. In order to create unambiguousness, the eigenvector centrality is defined as eigenvector for the largest eigenvalue λ.

The introduced centrality measures will be applied in the empirical analysis to determine the centrality of EU and EaP countries in a network of co-inventions. Thus, the innovative capability of these countries will be assessed not only using descriptive statistics but also from the point of network theory.

3. Outputs and cooperation between EU and EaP countries

The following chapter contains the results of the empirical analysis based on the data and methodology presented above. However, the first section contains a short discussion of the legal framework and systematic conditions for patenting in the EaP countries, in order to provide a context of the numbers observed. After this brief overview of legal aspects, a descriptive analysis of the general country results, dynamics and technological characteristics follows. With this understanding of the overall situation and the differences between the single countries, the co-inventions between them are illustrated by looking at the social networks between inventors. The final section of this chapter is analysing the patenting activity of the EaP countries with a finer technological granularity.

3.1 Industrial Property protection in EaP countries

After 1991 all states of the former USSR had to adopt their own legislative norms, in order to safeguard the protection of intellectual property for legal entities and individuals, and therefore established various state bodies, ensuring such protection. However, the transition phase has been characterised by various problems: the need to ensure the validity of the USSR protection documents and convert them into national documents, the need to file individual applications in each country, the lack of qualified experts, and the absence of patent funds in a number of former USSR countries.

In 1993, the heads of the governments of the nine states, participating in the Commonwealth of Independent States (CIS) - Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Ukraine and Uzbekistan signed an agreement on measures to protect industrial property and establish the Interstate Council for the Protection of Industrial Property[4]. The following year Azerbaijan joined the Agreement. The Interstate Council coordinated activities to create a cross-national system for the protection of inventions, industrial designs, trademarks and service marks, as well as the development of national legislations for legal protection of industrial property. Additionally to these cross-national initiatives, bilateral agreements have been reached among CIS countries. The main objectives of such agreements are:

- To simplify the procedure for obtaining protection documents for industrial property objects,
- To recognize USSR security documents for industrial property objects,
- To protect the rights of their owners and authors,
- To enable the conversion of Soviet copyright certificates and
- USSR certificates for industrial designs in national patents and
- Mutual exchange of patent documentation.

The ten CIS countries adopted the Eurasian Patent Convention, which was developed by the Interstate Council with the participation of the WIPO and the European Patent Office, in 1994. The Convention's aim was to create a single patent space on the territory of the CIS, leading to the creation of legal framework for the integration of national economies into a common alliance and the active support for cooperation with the most developed countries. The EaP countries are also all members of international agreements on the use and protection of intellectual property: the Paris

[4] EaP countries that are member states in the CIS are: Armenia, Azerbaijan, Belarus, Moldova. Georgia exited CIS in 2009 and Ukraine has started process to exit in 2014.

Convention for the Protection of Industrial Property, the World (Geneva) Copyright Convention, and the Berne Convention for the Protection of Literary and Artistic Works, as well as in the WIPO Treaties, TRIPS and several others.

This common history and joint development explains the similarity in approaches of the EaP countries' legislation regarding the regulation of industrial property issues, including patenting. The ambition for further association or even integration into the European economic framework, as expressed by the signing Association Agreements, would require another step of legal unification of the IPR framework conditions in the EaP countries. The main challenges would arise in the protection of rights to industrial designs, the protection of geographical names, trademarks. In the regard of patenting inventions, legal amendment's would be required in specifics regulations e.g. in biotechnology. However, the patenting procedures (including national procedures of patenting abroad) would not be affected by the Association Agreement.

3.2 Descriptive analysis of the patenting activities

The following section describes the patenting activity of the EU member state and the Eastern partnership countries as measured by national and PCT patent applications. First, the general counts for inventors and applications are presented before trends and technological aspects of this patenting activity are described for inventor level.

Total patenting activity by inventors

At large, the EaP countries show much lower levels of patent activity than the countries of the European Union. While inventors living in EaP countries accounted for 19.000 national applications in total, their colleagues in the EU28 developed 1.9 million applications during the same timeframe. The biggest share (77%) of the EaP applications has been developed by Ukraine based inventors (see Table 2). The Ukrainian output in national applications is on a similar level as one of the smaller or moderately innovating EU countries like Ireland. In the European Union the patent output is mainly developed by three major players - Germany, France and the United Kingdom. The total output for national patents of EaP inventors is less than the Polish (34.000) and around half of what Belgium based inventors applied for in these ten years. These trends are even more pronounced for applications filed under the PCT procedure. The total PCT output of the EaP countries is less than the Czech one (2.000), which itself is only moderate when compared to the inner-EU one. Also for PCT applications, the output of the EaP countries is mainly due to the Ukrainian activity (1.280) with a share of 76% of all PCT applications are developed in the there.

When not looking at the total numbers but at the normalised results, the picture is a little more differentiated. While the normalisation by population does not change the overall picture significantly, the consideration of the GDP gives some insights. The normalisation by populations shows that the output in the EaP countries is only around 7% of the EU28 average for national applications and 2,5% for PCT applications. However, this ratio is higher for Ukraine and Moldova for national patents. In Armenia (21 national applications), Azerbaijan (6), Belarus (33) and Georgia (36), the output per million inhabitants is much lower than the EU28 average. When normalising the output per GDP (in billion dollars, year 2016) the output in the EaP countries is 78% of the EU28 average for national applications whereby the activity of Ukrainian and Moldavian inventors is even

higher than that average. The gap between the EU28 and EaP countries is much more pronounced for PCT applications even when normalised by GDP. The EaP average is around a quarter of the EU28 and only Ukrainian inventors reach half of that average. However, the normalised PCT patenting activity for Ukraine (13,7 applications per billion $ GDP) is at the same level as Spain (13,1) or Ireland (12,3) while Moldova (5,6) and Georgia (5,5) are in the range of Greece (5,2) or Poland (5,8).

Table 2: Overview of normalized national and PCT patents on inventor level

Country	National patent applications	PCT patent applications	National app. per mil. Inhabitants	PCT app. per mil. Inhabitants	National app. per billion $ GDP	PCT app. per billion $ GDP
Austria	52.022,54	13.016,81	5.979,28	1.496,10	134,57	33,67
Belgium	38.377,37	11.596,24	3.392,89	1.025,21	82,26	24,85
Bulgaria	1.593,01	386,15	222,68	53,98	30,41	7,37
Cyprus	347,56	95,12	409,70	112,13	17,54	4,80
Czech Republic	11.797,70	1.996,96	1.117,86	189,22	60,40	10,22
Germany	820.679,21	170.477,78	9.986,89	2.074,55	235,88	49,00
Denmark	33.837,66	11.424,03	5.928,89	2.001,67	110,32	37,24
Estonia	1.205,54	346,91	916,10	263,62	51,67	14,87
Spain	49.093,02	16.094,33	1.057,13	346,56	39,83	13,06
Finland	47.641,12	14.470,10	8.682,06	2.637,01	199,67	60,65
France	306.759,03	70.100,70	4.596,99	1.050,51	124,37	28,42
United Kingdom	217.656,51	57.506,52	3.328,97	879,54	82,78	21,87
Greece	5.549,19	1.011,90	514,59	93,84	28,51	5,20
Croatia	1.961,73	442,61	468,12	105,62	38,67	8,72
Hungary	8.466,44	2.245,71	861,24	228,44	68,07	18,06
Ireland	13.567,88	3.740,89	2.870,73	791,51	44,57	12,29
Italy	96.297,75	30.973,86	1.587,35	510,57	52,03	16,74
Lithuania	1.186,69	262,23	410,83	90,78	27,75	6,13
Luxembourg	2.299,91	530,79	3.991,17	921,11	38,35	8,85
Latvia	1.841,70	232,30	935,37	117,98	66,51	8,39
Malta	222,09	67,82	493,09	150,56	20,18	6,16
Netherlands	87.700,75	30.276,39	5.165,21	1.783,15	112,79	38,94
Poland	34.297,58	2.736,81	903,35	72,08	73,08	5,83
Portugal	4.569,49	1.342,41	441,87	129,81	22,33	6,56
Romania	8.576,46	522,26	434,02	26,43	45,72	2,78
Sweden	68.582,29	27.900,03	6.961,95	2.832,20	134,21	54,60
Slovenia	4.862,80	1.220,82	2.355,79	591,43	108,72	27,30
Slovakia	2.473,78	450,52	455,89	83,03	27,63	5,03
Armenia	221,50	78,44	73,87	26,16	20,97	7,42
Azerbaijan	231,01	41,00	23,80	4,22	6,15	1,09
Belarus	1.569,83	161,70	165,27	17,02	33,13	3,41
Georgia	520,42	78,87	139,88	21,20	36,32	5,50
Moldova	2.121,72	37,64	597,15	10,59	313,26	5,56
Ukraine	14.737,30	1.280,28	346,02	30,06	158,02	13,73
EU28	1.923.466,82	471.469,03	3.769,45	923,95	116,95	28,67
EaP	19.180,27	1.677,93	266,15	23,28	91,39	7,99

Source: GDP 2016, IMF online; Population 2016, Eurostat online

Total patenting activity by applicants

While the description above illustrates the activities of inventors living in the EU28 and EaP countries, the following section deals with the applicant level. In contrast to inventors, who are always natural persons, applicants are the entity who owned the patent applications at the time of filing. The applicants can be natural or legal persons and often it is a combination of both e.g. the inventors and the company they work for. The legal ownership status are often complex and are not part of

PATSTAT database. Therefore, the following analysis builds on the assumption that every applicant owns the same share of the joint application and the total numbers on inventor and applicant level are similar. The difference, however, might hint if a country is importing knowledge developed abroad or the other way round. Table 3, displaying the results on applicant level, illustrates this situation for the EU28 and EaP countries. The overall numbers for national applications are similar as on the inventor level, with 1.9 million national applications from applicants in the EU28 and a little more than 17.300 from applicants in EaP countries. The total output of PCT applications for EU28 applicants is 466.000 while EaP applicants account for a little less than 1.500 applications. This number indicates an outflow of knowledge for the EaP countries in both patent classes while the EU28 are experiencing an inflow of national applications and only a small negative balance in PCT applications. The observable flow trends indicate that Moldova is the only EaP country with a positive knowledge flow balance. All other countries tend to face an outflow of knowledge in both national and PCT patents. These negative balances are the highest in Georgia and Armenia.

Table 3: Overview of normalized national and PCT patents on applicant level

Country	National patent applications	PCT patent applications	National per mil. Inhabitants	PCT per mil. Inhabitants	National per billion $ GDP	PCT per billion $ GDP
Austria	51.384,61	12.136,58	5.905,96	1.394,93	132,92	31,39
Belgium	37.117,27	10.762,49	3.281,49	951,50	79,56	23,07
Bulgaria	1.340,95	351,80	187,45	49,18	25,60	6,71
Cyprus	1.515,56	267,65	1.786,54	315,51	76,50	13,51
Czech Republic	9.766,70	1.716,73	925,42	162,66	50,00	8,79
Germany	828.909,42	168.168,29	10.087,04	2.046,45	238,24	48,33
Denmark	35.059,72	11.603,50	6.143,01	2.033,11	114,30	37,83
Estonia	1.046,97	326,45	795,61	248,07	44,87	13,99
Spain	48.935,48	15.089,05	1.053,73	324,91	39,70	12,24
Finland	53.841,82	15.847,47	9.812,06	2.888,02	225,66	66,42
France	320.400,55	70.237,17	4.801,41	1.052,55	129,90	28,48
United Kingdom	181.526,19	52.525,78	2.776,37	803,36	69,04	19,98
Greece	4.930,77	885,60	457,24	82,12	25,33	4,55
Croatia	1.727,51	393,38	412,23	93,87	34,05	7,75
Hungary	6.370,47	1.740,55	648,03	177,06	51,22	13,99
Ireland	17.762,85	3.839,66	3.758,31	812,40	58,35	12,61
Italy	84.233,94	28.388,17	1.388,50	467,95	45,51	15,34
Lithuania	1.092,58	258,31	378,24	89,43	25,55	6,04
Luxembourg	10.552,61	1.966,22	18.312,59	3.412,10	175,94	32,78
Latvia	1.832,33	225,30	930,61	114,42	66,18	8,14
Malta	1.251,58	304,49	2.778,74	676,03	113,75	27,67
Netherlands	114.038,59	33.702,01	6.716,40	1.984,91	146,66	43,34
Poland	32.363,20	2.393,30	852,40	63,04	68,96	5,10
Portugal	4.240,95	1.270,01	410,10	122,81	20,72	6,21
Romania	7.197,13	338,71	364,22	17,14	38,37	1,81
Sweden	89.052,11	30.686,67	9.039,89	3.115,08	174,27	60,05
Slovenia	4.434,27	1.094,74	2.148,19	530,35	99,14	24,48
Slovakia	1.965,69	396,57	362,26	73,08	21,96	4,43
Armenia	93,06	60,89	31,04	20,31	8,81	5,76
Azerbaijan	153,88	39,29	15,86	4,05	4,10	1,05
Belarus	1.200,09	128,09	126,35	13,49	25,32	2,70
Georgia	107,20	63,85	28,81	17,16	7,48	4,46
Moldova	2.155,00	36,70	606,52	10,33	318,17	5,42
Ukraine	13.605,11	1.138,82	319,44	26,74	145,88	12,21
EU28	1.953.891,83	466.916,64	3.829,08	915,03	118,80	28,39
EaP	17.314,34	1.467,63	240,25	20,36	82,50	6,99

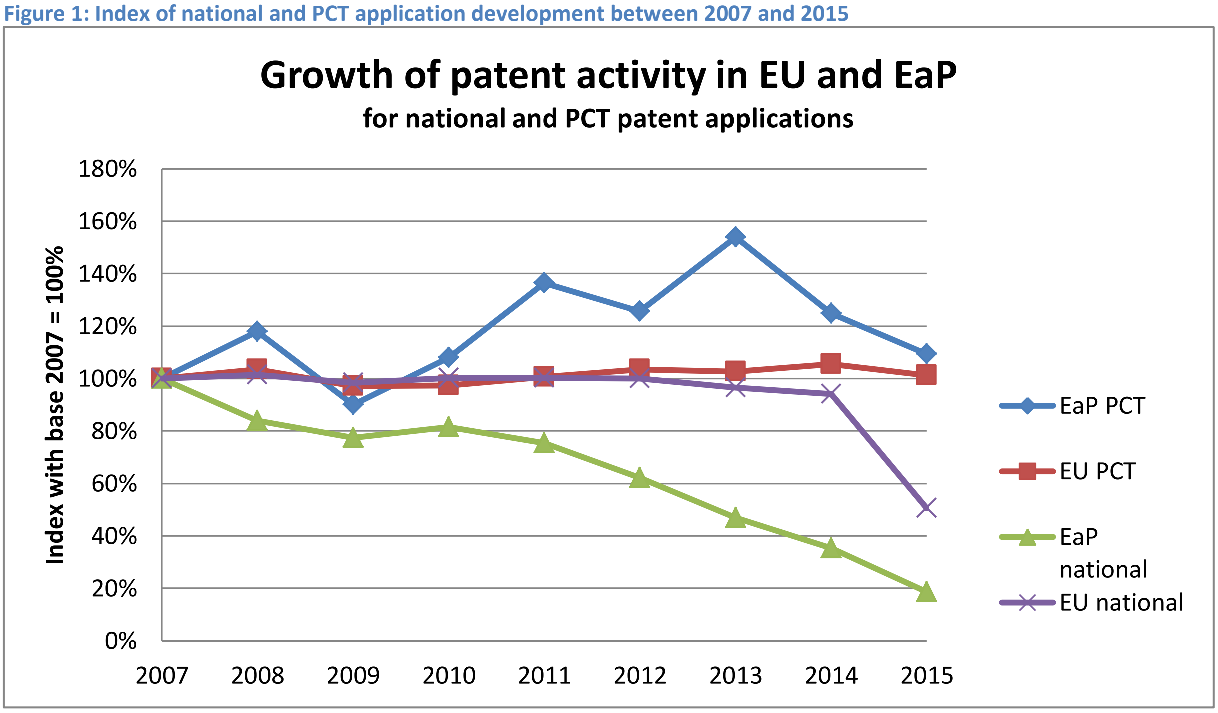
Source: GDP 2016, IMF online; Population 2016, Eurostat online

The effects of normalisation are the same as for the inventor level, where the effects of displaying the patenting activity by population are negligible while normalisation by GDP is helpful for understanding the overall situation. Applicants from the EaP countries file only 6% of the EU28 average per capita for national applications and only 2% of the PCT applications. Again, the levels are higher in the Ukraine and Moldova but they are still far below the EU28 average. The average for national patents normalised by the GDP indicates that the activity of Ukrainian and especially Moldovan applicants is above the EU28 average. Anyhow, the results for the PCT applications are below in the EU28 average in both countries and in Moldova even below the EaP average.

Development of the patenting activities over time

The study considers patent applications that were filed between 2007 and 2016. However, as patent applications have a time gap between filing and publication, and there is a sharp drop of published applications observable for 2016 and after, this year is not included in the following subsection. Figure 1 displays the index of development for national and PCT patent applications in the EU28 and the EaP counties, whereby the years 2007 serves as a baseline value.

Figure 1: Index of national and PCT application development between 2007 and 2015



While the development of number of applications over the described timeframe is rather stable for the EU28 countries, the trend in the EaP countries is varying. For the EU28 the index value for PCT applications is between 97% and 105% of the baseline 2007 and the number of national applications is stable around the baseline value until a drop in the year 2014. This drop is most likely the result of the discussed publication gap. The situation in the EaP countries shows a steady decline in the number of national applications while the share of PCT applications is growing. The decreasing trend is too stable to suspect that the year 2007 has been extraordinary productive and therefore skewing the picture. In contrast, the output of PCT applications increased up to plus 50% in the year 2013. An increase of the number of PCT applications is observable in Armenia, Belarus and the Ukraine. Whereby, most applications are developed by Ukrainian based inventors and therefore the overall trend is carried by this country. In a similar way, the decrease in national applications is mirroring the

Ukrainian development. However, the number national applications is decreasing in all EaP countries with the exceptions of Armenia and Azerbaijan. In these two countries a doubling from a low baseline can be observed.

Patenting activities by technology sections

The technological profiles and specialisations will be analysed deploying the technology field approach (see section 2.2) on the inventor level. A general overview of technology sectors of national and PCT patent applications will be provided on the basis of the five technology sections while the technology fields will be discussed for the EaP countries in section 3.4. However, differences between the technological focus for EU28 and EaP countries can already be observed at the level of the technology sections.

Table 4: National patent applications by technology sections, 2007-2016

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
Austria	11.973,07	7.120,71	10.326,82	16.676,51	5.925,43
Belgium	7.655,80	4.141,69	15.799,22	7.964,10	2.816,56
Bulgaria	570,52	190,54	316,77	343,95	171,23
Cyprus	102,79	40,48	105,31	57,03	41,95
Czech Republic	2.465,42	1.720,42	3.068,76	3.495,60	1.047,51
Germany	166.617,28	116.280,59	166.776,70	309.236,93	61.767,70
Denmark	6.357,26	5.026,63	10.729,54	8.674,80	3.049,43
Estonia	411,39	192,40	323,56	183,21	94,97
Spain	8.626,24	5.980,75	14.753,05	13.808,50	5.924,49
Finland	19.699,92	4.843,32	8.275,23	11.383,40	3.439,25
France	73.021,58	39.952,27	74.804,17	93.281,56	25.699,45
United Kingdom	60.678,63	34.926,72	50.014,78	45.755,95	26.280,43
Greece	1.160,71	564,29	1.491,87	1.502,29	830,04
Croatia	340,53	223,94	445,34	574,41	377,52
Hungary	2.086,88	932,61	2.682,95	1.980,57	783,42
Ireland	5.007,31	2.915,38	2.351,50	2.109,07	1.184,62
Italy	15.528,74	10.946,71	23.252,52	33.142,09	13.427,69
Lithuania	152,45	236,29	419,83	262,93	115,20
Luxembourg	316,08	214,92	690,86	924,69	153,36
Latvia	235,80	254,11	805,52	392,06	154,22
Malta	62,83	24,83	43,41	43,22	47,80
Netherlands	23.254,52	17.074,60	22.414,83	17.487,76	7.469,05
Poland	4.812,09	4.549,65	11.352,00	9.288,18	4.295,66
Portugal	762,70	655,76	1.494,96	1.012,69	643,38
Romania	1.860,20	1.537,91	2.178,19	2.321,59	678,57
Sweden	26.381,41	9.404,62	12.854,25	15.384,76	4.557,25
Slovenia	774,25	594,87	1.254,87	1.135,09	1.103,72
Slovakia	506,99	231,44	590,91	887,93	256,51
Armenia	70,53	17,32	95,05	21,98	16,63
Azerbaijan	23,99	38,25	92,64	33,72	42,40
Belarus	210,10	326,25	391,05	431,07	211,35
Georgia	56,39	43,68	183,89	189,95	46,50
Moldova	191,10	438,77	881,00	501,58	109,27
Ukraine	1.981,77	2.586,05	4.979,96	4.163,44	1.026,08
EU28	441.423,38	270.778,44	439.617,72	599.310,87	172.336,41
EaP	2.533,87	3.450,32	6.623,59	5.341,75	1.452,23

While in the EU28 mechanical engineering, with a share of 31% of all national application falling under this section, is the most important technology section, the EaP countries show the highest output in the chemistry section (34%). Besides mechanical engineering, electrical engineering and chemistry, with 23% each, are the sections with the highest activity for EU28 countries. The inventions from EaP countries are allocated in the chemistry section, the mechanical engineering (28%) and instruments section (18%).

Table 5: PCT patent applications by technology sections, 2007-2016

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
Austria	2.887,47	1.706,15	2.831,21	4.053,92	1.538,07
Belgium	2.175,25	1.452,53	4.681,20	2.414,88	872,38
Bulgaria	102,38	38,26	68,99	121,16	55,36
Cyprus	18,84	15,13	30,27	16,31	14,56
Czech Republic	317,40	268,33	663,81	568,43	178,98
Germany	35.723,56	25.484,10	40.997,05	57.465,88	10.807,20
Denmark	1.942,82	2.014,99	3.658,16	2.823,42	984,64
Estonia	119,72	61,48	99,92	48,58	17,22
Spain	2.652,99	2.328,32	5.045,63	4.049,27	2.018,13
Finland	6.965,08	1.450,99	2.454,42	2.888,72	710,89
France	16.261,21	10.077,00	19.432,83	19.706,63	4.623,03
United Kingdom	14.455,97	10.739,55	14.948,59	11.080,02	6.282,39
Greece	191,73	128,65	312,89	265,87	112,76
Croatia	72,55	48,70	151,76	101,35	68,25
Hungary	707,20	272,37	641,50	463,08	161,57
Ireland	1.189,92	997,25	729,63	546,04	278,05
Italy	4.177,78	4.111,15	7.513,40	10.532,74	4.638,80
Lithuania	44,39	50,68	78,98	54,68	33,50
Luxembourg	96,73	58,03	130,57	200,45	45,02
Latvia	33,48	27,24	109,68	43,38	18,52
Malta	18,39	5,68	15,52	21,98	6,25
Netherlands	8.014,67	6.937,76	7.960,72	5.223,53	2.139,71
Poland	561,96	329,77	894,81	652,75	297,52
Portugal	215,22	222,70	461,90	276,00	166,60
Romania	210,48	65,76	68,65	137,21	40,16
Sweden	11.573,68	3.756,37	4.193,95	6.568,17	1.807,87
Slovenia	174,04	138,24	421,56	247,33	239,66
Slovakia	106,27	44,87	96,86	156,18	46,35
Armenia	15,33	6,96	26,14	22,02	8,00
Azerbaijan	9,67	5,83	8,57	11,75	5,18
Belarus	25,01	30,72	33,43	57,95	14,58
Georgia	14,63	16,98	25,35	13,24	8,68
Moldova	2,74	8,53	9,10	13,00	4,27
Ukraine	341,63	169,09	300,19	329,16	140,21
EU28	111.011,17	72.832,02	118.694,46	130.727,97	38.203,41
EaP	409,00	238,12	402,78	447,12	180,91

Again, the overall trend is mainly mirroring the Ukrainian domination, as three quarters of EaP national applications are developed there. Looking at the results of the individual countries, the picture is more differentiated. In Armenia (43%), Azerbaijan (40%) and Moldova (42%) the share of application falling under the chemistry section is higher than the regional average, while inventors from Georgia (37%) and Belarus (27%) are specialised in mechanical engineering. Armenia (32%) is the only EaP country with a significant share of applications in the electrical engineering section for national patent applications. Azerbaijan (18%) and Belarus (13%) have high shares in the other fields.

When discussing the technological profile of the EaP countries for PCT patent applications, it needs to be stressed that the overall numbers are so low that the results are only of little informative value. The exception is again Ukraine, whose inventors are developing most of the EaP countries' PCT applications. However, exceptional results are the shares of Belarus (36%) of Moldova (35%) in mechanical engineering, the concentration of Armenian (33%) and Georgian (32%) inventions in the chemistry section, the shares of instruments in Moldova (23%) and Georgia (22%) as well as the share of Azerbaijan (24%) in electrical engineering.

3.3 Co-inventions and networks

With this overview of the overall situation in production of technology in the EU28 and EaP countries in mind, we now turn towards collaboration in patenting activities. This subsection will be based on a subset of the data presented above, whereby a co-invention is defined as a patent application with at least more than one inventor (see section 2.2) and therefore single inventor applications are filtered out. First, we will give a general overview of the collaborative patenting efforts before we will analyse the co-invention networks between the EaP and EU28 countries.

The EaP countries follow the international trend and show a high share of collaborative inventions that are filed as patents. From the 19.000 EaP national patent applications around 17.000 – or 90% – have been developed by at least two inventors. This share is more or less the same for all EaP countries with the exception of Azerbaijan, which has a very low activity in general and only a little more than 50% of the national applications are developed in a collaborative process. In contrast, not only the total numbers but also the shares of co-inventions are much lower for PCT patents developed by inventors from the EaP countries. The overall PCT co-invention share is 55% and only Armenia (42%) and Azerbaijan (67%) deviate from this regional average, however the overall numbers are particularly low in these two countries.

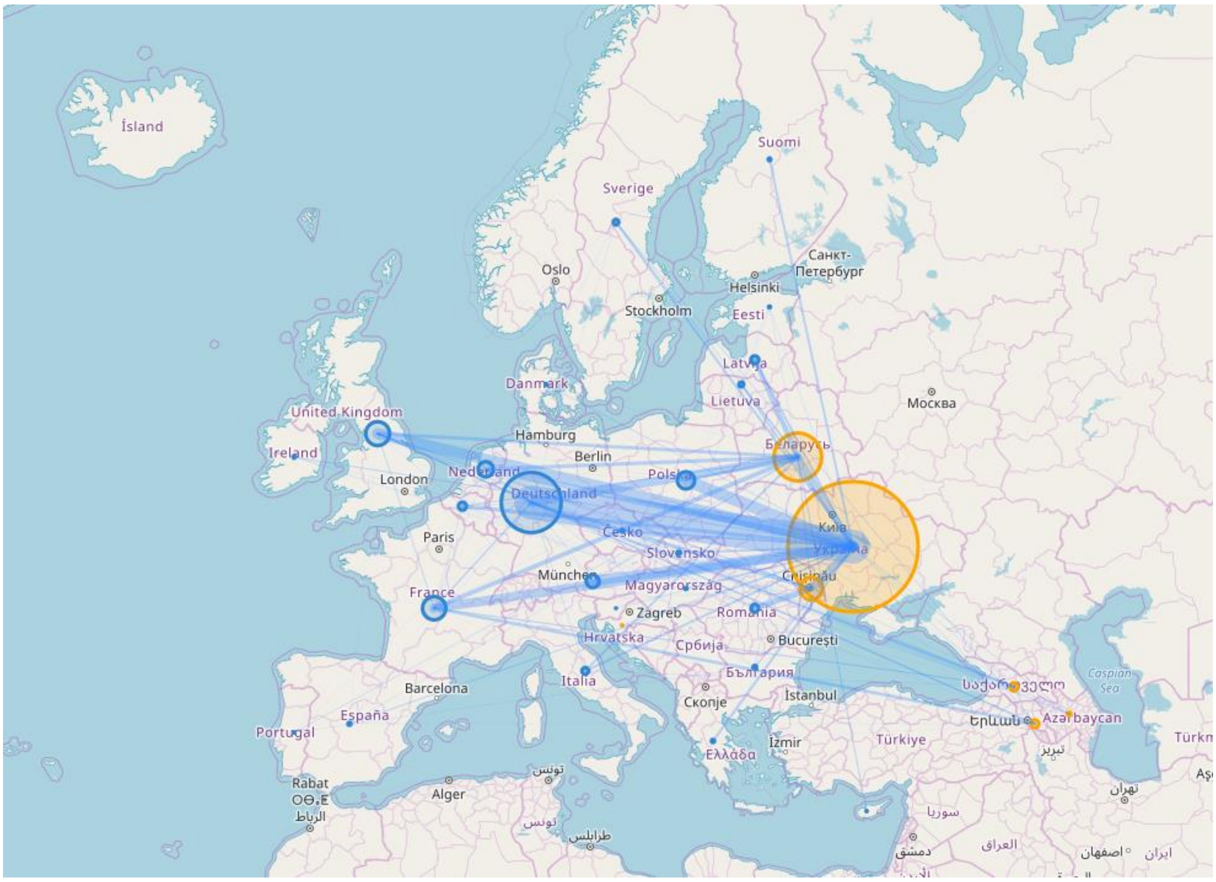
Table 6: Co-inventions of EaP based inventors for national and PCT applications, 2007-2016

Country	All national co-inventions	All national co-inventions with inventors from EU and EaP	All PCT co-inventions	All PCT co-inventions with inventors from EU and EaP
Armenia	113,17	21,22	33,36	5,29
Azerbaijan	211,45	7,70	27,67	0,56
Belarus	1.425,70	130,36	92,41	13,89
Georgia	452,73	26,31	40,34	6,02
Moldova	1.844,47	104,46	21,58	3,65
Ukraine	13.062,06	406,89	700,58	53,29
EaP	17.109,57	696,93	915,94	82,81
EU28	-	818,79	-	106,78

The co-inventions between EaP and EU28 based inventors are a subset of the total co-inventions in turn. Around 1.500 national patent co-inventions developed by EaP and EU28 inventors are registered in the database, whereby 800 are allocated to EU28 inventors and 700 to EaP based ones. The most intense cooperation with the EU28 is observable between Ukrainian based inventors, these links account for more than half of the cases. Especially, co-inventions between EU28 based inventors and inventors from Armenia, Azerbaijan and Georgia are rare. The cooperation patterns in PCT patenting applications are even sparser as the overall output of PCT patents in the EaP countries is low. A total of 190 collaborative PCT patent applications between EU28 and the EaP countries are

recorded. From these, 107 are attributed to EU based inventors while 83 have been development by inventors based in EaP countries. Again, with around two thirds, the majority of EaP applications is attributed to Ukrainian inventors (53). Belarus is the only other EaP country that has a double-digit number of co-inventions with EU countries.

Figure 2: International co-invention network for national patent applications

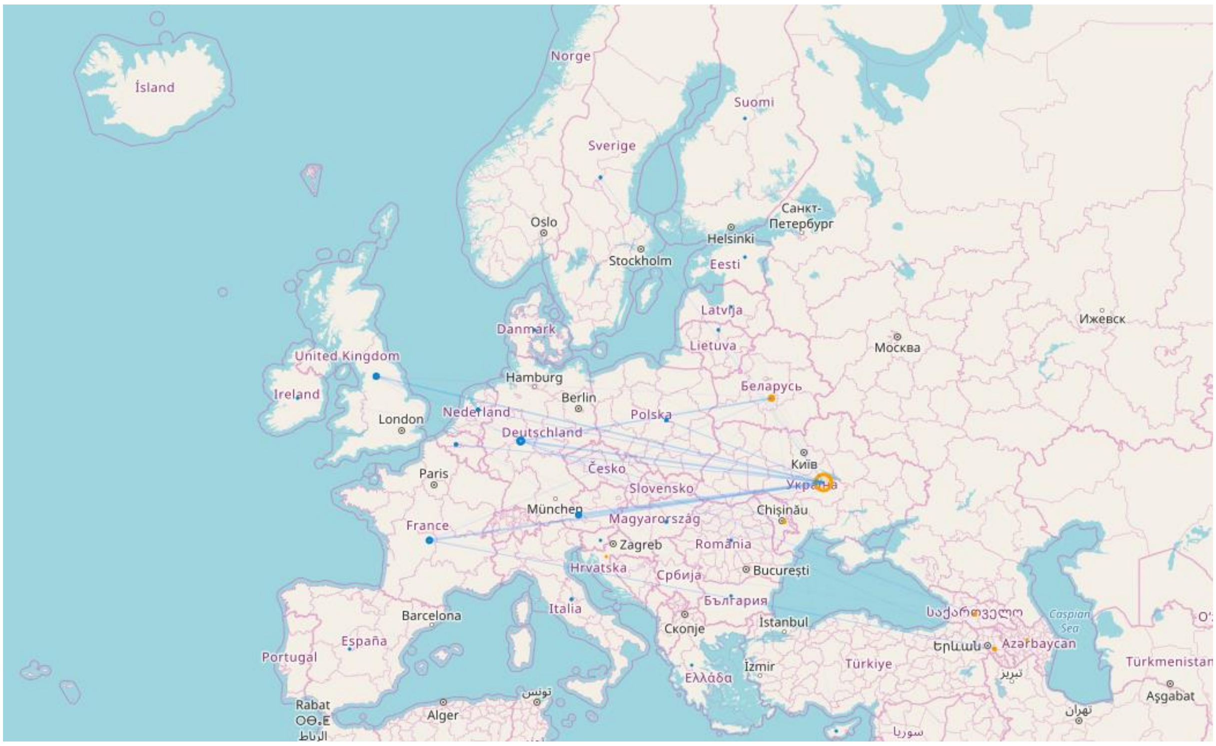


At a more detailed level, highest interaction rates for national patent applications are observable between EaP countries, mostly the Ukraine, and the biggest EU countries. In absolute numbers the following collaboration patterns are apparent: 256 national applications attributed to German inventors have been developed in cooperation with EaP colleagues, 100 in cooperation with French inventors and 77 with partners in the United Kingdom. Taking the general technological capacity of the EU28 countries into account, the high cooperation intensity between EaP colleagues and Poland (70) and Romania (47) stands out. This cooperation is mainly present in the Ukraine-Poland and Moldova-Romania ties. The cooperation between Armenia, Azerbaijan and Georgia with the EU28 is very low in the development of joint-patent applications. The cooperation within the EaP region itself is important for the ties Ukraine-Belarus and Ukraine-Moldova.

The overall number of PCT applications and PCT-co-inventions are much lower and therefore the graph in figure 3 shows less density and the links between countries are less intense. The total shares of PCT co-inventions distributed to inventors in EU28 and EaP countries in the ten years covered do not exceed 190 applications. The most common ties are again between the Ukraine and EU28 countries, whereby the ties Ukraine-Austria, Ukraine-Germany and Ukraine-United Kingdom are most relevant. Additionally, the link between Belarus and Germany is above average. However, none

of those ties exceeded the average of one joint patent application per year. The cooperation within the EaP region is hardly measurable in joint PCT patent activities.

Figure 3: International co-invention network for PCT patent applications



While the overall pattern in co-inventions between EU28 and EaP countries has been described above based on descriptive statistics and the network visualisations, the following insights are based on network measures. For both networks the normalised degree and eigenvector centralities can be found in table 7. While the degree centrality is based on the absolute numbers of connections a country has, the eigenvector centrality is taking the importance of the connected countries into account and therefore reflects if a country is connected with the important ones in the network (see chapter 2.2). The maximum value of the normalised degree centrality in a network would be 1 in a situation where one node has links to all other nodes.

In both networks the most central actor is the Ukraine, which is not surprising as only patents from EaP inventors with EU28 co-inventors have been selected and the Ukraine has the highest activity of the EaP countries. In the national patent network Belarus has a very central role as well with a normalised degree centrality of 0,81. However, as the EaP countries do not constitute a subcomponent with a higher density within the network, the networks other central actors are the frequent cooperation partners of the EaP countries in the EU. As visible in figure 2 and described above, the most central actors form the EU28 are Germany (0,94), United Kingdom (0,68), France (0,55). The centralities of the Netherland (0,55) and Georgia (0,55) and Poland (0,52) are considerable too. The eigenvector centrality does not provide any additional insights – the most central actors are Ukraine and Belarus from the EaP countries and Germany, United Kingdom and France in the EU, which is again a result of the selection of this specific set of patent applications. The PCT network is sparser with a smaller number of connections. The highest degree centralities are observable for Ukraine (0,82), Germany and the United Kingdom (0,54), followed by Belarus (0,46)

and France (0,36). This network does not show significant differences for the eigenvector centrality either.

Table 7: Co-invention network centralities for national and PCT patent applications, 2007-2016

Country	Eigenvector, national network	Degree, national network	Eigenvector, PCT network	Degree, PCT network
Austria	0,15	0,32	0,11	0,11
Belgium	0,20	0,45	0,20	0,25
Bulgaria	0,11	0,26	0,09	0,07
Cyprus	0,02	0,03	0,03	0,04
Czech Republic	0,12	0,26	-	-
Germany	0,32	0,94	0,33	0,54
Denmark	0,13	0,26	0,20	0,21
Estonia	0,14	0,32	0,20	0,21
Spain	0,15	0,32	0,13	0,18
Finland	0,10	0,23	0,17	0,18
France	0,23	0,55	0,25	0,36
United Kingdom	0,27	0,68	0,35	0,54
Greece	0,09	0,19	0,02	0,04
Croatia	0,06	0,10	0,05	0,04
Hungary	0,13	0,26	0,05	0,04
Ireland	0,16	0,32	0,07	0,07
Italy	0,19	0,42	0,13	0,14
Lithuania	0,16	0,35	0,08	0,07
Luxembourg	-	-	-	-
Latvia	0,12	0,26	0,14	0,14
Malta	-	-	-	-
Netherlands	0,23	0,55	0,19	0,21
Poland	0,21	0,52	0,15	0,14
Portugal	0,09	0,19	-	-
Romania	0,11	0,23	0,06	0,07
Sweden	0,17	0,39	0,14	0,14
Slovenia	0,02	0,03	0,05	0,04
Slovakia	0,10	0,23	-	-
Armenia	0,16	0,39	0,12	0,18
Azerbaijan	0,15	0,29	0,08	0,07
Belarus	0,29	0,81	0,30	0,46
Georgia	0,22	0,55	0,22	0,29
Moldova	0,20	0,48	0,20	0,29
Ukraine	0,32	0,97	0,43	0,82

3.4 Overview of country profiles

In the previous subsections the total output of EaP countries and their collaboration with the EU28 countries has been described. It has become apparent that the technological output measured in patent applications in some EaP countries is rather low. Nevertheless, the following section contains country profiles discussing the patenting activity of these countries with a higher technological granularity. These profiles will contain the number of national and PCT patents per technology field, the share of these fields, as a proxy for specialisation, and the growth observed within the patenting activity in the single fields.

Armenia

Armenia is one of the EaP countries with the lowest patenting activity. In total around 220 national and 80 PCT patent applications are recorded for the period 2007 to 2016. That corresponds to

around 70 national and 26 PCT patent applications per million inhabitants. Technology-wise the following patterns are observable: most national patent applications from Armenian inventors are filed in “food chemistry” (46) and “computer technology” (36). In the technology fields “civil engineering”, “biotechnology” and “electrical machinery, apparatus, energy” double-digit number of national applications are observable. For PCT applications the fields “food chemistry” (12), “electrical machinery, apparatus, energy” (8) and “machine tools” (7) are most prevalent while there are hardly filings under “computer technology”, one of the most important fields for national applications.

Table 8: Overview of the Armenian patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	10,25	8,41	2,46	1,50	4,60%	10,70%
Audio-visual technology	8,04	0,5	0,25		3,60%	0,60%
Telecommunications	0,5	-	0,25		0,20%	0,00%
Digital communication	4,01	1,5	0,83		1,80%	1,90%
Basic communication processes	2,06	-	0,58		0,90%	0,00%
Computer technology	35,83	2,07	3,68	0,33	16,20%	2,60%
IT methods for management	0,7	1,2			0,30%	1,50%
Semiconductors	9,15	1,65	0,47	0,22	4,10%	2,10%
Optics	2,68	2,61	1,38	1,02	1,20%	3,30%
Measurement	3,35	3,25	0,06		1,50%	4,10%
Analysis of biological materials	0,71	-			0,30%	0,00%
Control	5,77	0,5	0,44		2,60%	0,60%
Medical technology	4,81	0,6	0,98		2,20%	0,80%
Organic fine chemistry	8,92	2,73	1,45	0,35	4,00%	3,50%
Biotechnology	10,58	2,71	0,92	0,08	4,80%	3,50%
Pharmaceuticals	8	2,54	1,00	0,08	3,60%	3,20%
Macromolecular chemistry, polymers	1,77	0,75	1,07		0,80%	1,00%
Food chemistry	46,47	12,42	2,66	0,92	21,00%	15,80%
Basic materials chemistry	2,87	1,5	0,13		1,30%	1,90%
Materials, metallurgy	5,43	2	0,22		2,50%	2,50%
Surface technology, coating	4,57	0,5	1,67	0,50	2,10%	0,60%
Micro-structural and nano-technology	0,81	-	0,09		0,40%	0,00%
Chemical engineering	4,24	0,83	0,31		1,90%	1,10%
Environmental technology	1,39	0,17			0,60%	0,20%
Handling	7,33	3,5			3,30%	4,50%
Machine tools	2,08	6,5			0,90%	8,30%
Engines, pumps, turbines	4,9	5,33			2,20%	6,80%
Textile and paper machines	-	-			0,00%	0,00%
Other special machines	6,02	2,71	0,30	0,13	2,70%	3,50%
Thermal processes and apparatus	0,92	2,93			0,40%	3,70%
Mechanical elements	0,72	-			0,30%	0,00%
Transport	-	1,05			0,00%	1,30%
Furniture, games	3,67	1,5			1,70%	1,90%
Other consumer goods	0,88	1,17	0,04	0,17	0,40%	1,50%
Civil engineering	12,08	5,33			5,50%	6,80%

The cooperation between Armenian and EU28 based inventors is low and there is no technological pattern observable. However, most national co-inventions that are attributed to Armenian inventors are in “computer technology” (3,6), “electrical machinery, apparatus, energy” (2,5) as well as in “food chemistry” (2,7). Jointly developed PCT applications are in the same technologies classes.

Due to the overall low patenting activity the growth rates in single technologies are without informative value. When aggregated, the national patenting activity of Armenian inventors increased from 2007 to 2013 and decreased slightly after that, which could be due to the reporting gap. The PCT patenting activity seems to be rather stable with peaks in the years 2011-2012.

Azerbaijan

Between 2007 and 2016 inventors from Azerbaijan accounted for the development of 230 national and 41 PCT patent applications which corresponds to 24 national and 4 PCT patent applications per million inhabitants. This makes Azerbaijan the country with lowest technological capability in the EaP. Most national patent applications developed there are protecting “civil engineering” (41) technology, “medical technology” (26) or technologies from the “macromolecular chemistry, polymers” (21) field. The picture for PCT applications differs as most applications fall to the field of “engines, pumps, turbines” (7), “civil engineering” (5) or “measurement” (4).

Table 9: Overview of the Azerbaijani patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	4,07	3,17	0,50		1,80%	7,70%
Audio-visual technology	0,72	-	0,39		0,30%	0,00%
Telecommunications	2,03	0,33	0,20		0,90%	0,80%
Digital communication	3,83	-			1,70%	0,00%
Basic communication processes	0,5	-			0,20%	0,00%
Computer technology	3,83	1,25	0,25		1,70%	3,00%
IT methods for management	4,17	1,75			1,80%	4,30%
Semiconductors	4,83	3,17	0,40		2,10%	7,70%
Optics	1	-			0,40%	0,00%
Measurement	6,29	4,00	0,10		2,70%	9,80%
Analysis of biological materials	1,25	-			0,50%	0,00%
Control	4,03	0,33			1,70%	0,80%
Medical technology	25,69	1,50	2,01	0,33	11,10%	3,70%
Organic fine chemistry	10,79	1,22	0,60		4,70%	3,00%
Biotechnology	3,72	-			1,60%	0,00%
Pharmaceuticals	15,95	1,00	1,17		6,90%	2,40%
Macromolecular chemistry, polymers	21,33	0,44	0,19		9,20%	1,10%
Food chemistry	5,74	2,00			2,50%	4,90%
Basic materials chemistry	16,7	0,54	0,08		7,20%	1,30%
Materials, metallurgy	4,56	0,79	0,50		2,00%	1,90%
Surface technology, coating	1,5	-			0,60%	0,00%
Micro-structural and nano-technology	0,92	-			0,40%	0,00%
Chemical engineering	7,87	1,83	0,42	0,11	3,40%	4,50%
Environmental technology	3,57	0,75			1,50%	1,80%
Handling	2,08	-			0,90%	0,00%
Machine tools	0,5	-			0,20%	0,00%
Engines, pumps, turbines	11	7,33			4,80%	17,90%
Textile and paper machines	-	-			0,00%	0,00%
Other special machines	8,63	0,58			3,70%	1,40%
Thermal processes and apparatus	0,88	-	0,19		0,40%	0,00%
Mechanical elements	7,25	1,00			3,10%	2,40%
Transport	3,38	2,83	0,08		1,50%	6,90%
Furniture, games	1	0,25			0,40%	0,60%
Other consumer goods	0,14	-			0,10%	0,00%
Civil engineering	41,26	4,93	0,61	0,11	17,90%	12,00%

The co-invention activity between Azerbaijani and EU28 based inventors is very low as well. While there is less than one PCT application that is attributed to Azerbaijan, there are a little less than 8 national applications. The technology fields “medical technology” “pharmaceuticals” are the only ones with more than one jointly developed application.

The development over time suggests a slight increase in national patenting activity between 2007 and 2014. The drop observable after that, again, might be due to a lag in publication. The output of PCT applications is low and no trend is visible. Even though the overall numbers are really low, the national patenting activity in the fields “macromolecular chemistry, polymers” and “civil engineering” is increasing.

Belarus

In contrast to the two Caucasian countries discussed above, Belarus shows moderate patenting activities on both the national application and the PCT level.

Table 10: Overview of the Belarusian patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	59,5	6,03	8,89	1,18	3,80%	3,70%
Audio-visual technology	19,76	1,14	5,40		1,30%	0,70%
Telecommunications	18,33	1,73	0,97	0,13	1,20%	1,10%
Digital communication	16,76	4,94	1,67		1,10%	3,10%
Basic communication processes	17,75	1,33	0,25		1,10%	0,80%
Computer technology	45,07	7,95	7,08	0,33	2,90%	4,90%
IT methods for management	9,53	0,78	1,69	0,40	0,60%	0,50%
Semiconductors	23,4	1,13	7,13	0,13	1,50%	0,70%
Optics	98,5	1,87	11,17	0,92	6,30%	1,20%
Measurement	97,45	6,46	6,02	1,23	6,20%	4,00%
Analysis of biological materials	22,05	1,62	2,14	0,45	1,40%	1,00%
Control	22,75	5,38	0,98	0,13	1,40%	3,30%
Medical technology	85,5	15,4	6,29	0,50	5,40%	9,50%
Organic fine chemistry	15,37	1,56	1,41	0,20	1,00%	1,00%
Biotechnology	14,88	0,16	1,80	0,13	0,90%	0,10%
Pharmaceuticals	57,82	4,77	6,20	0,83	3,70%	2,90%
Macromolecular chemistry, polymers	21,65	2,32	5,52	1,35	1,40%	1,40%
Food chemistry	27,57	0,44	1,85	0,44	1,80%	0,30%
Basic materials chemistry	57,45	3,32	6,99	1,31	3,70%	2,10%
Materials, metallurgy	79,16	10,56	7,71	1,32	5,00%	6,50%
Surface technology, coating	37,62	1,68	4,63	0,08	2,40%	1,00%
Micro-structural and nano-technology	13,66	1,36	0,33	0,33	0,90%	0,80%
Chemical engineering	50,69	5,65	4,73	0,33	3,20%	3,50%
Environmental technology	15,18	1,63	1,24	0,75	1,00%	1,00%
Handling	61,03	15,93	1,50		3,90%	9,90%
Machine tools	45,77	3,33	3,93		2,90%	2,10%
Engines, pumps, turbines	51,24	14,67	9,31	0,50	3,30%	9,10%
Textile and paper machines	13,34	0,51		0,06	0,80%	0,30%
Other special machines	93,66	5,2	4,20		6,00%	3,20%
Thermal processes and apparatus	21,35	0,5	1,08	0,50	1,40%	0,30%
Mechanical elements	66,9	8,3	3,11	0,06	4,30%	5,10%
Transport	77,79	9,51	1,44	0,22	5,00%	5,90%
Furniture, games	27,72	3,67	2,50		1,80%	2,30%
Other consumer goods	12,17	3,9	0,58		0,80%	2,40%
Civil engineering	171,47	7,02	0,60	0,08	10,90%	4,30%

In the ten years covered, inventors from Belarus accounted for nearly 1.600 national and more than 160 PCT applications. Normalised by population, this means that per one million inhabitants on average of 165 national and 17 PCT applications are filed. Thereby, most of the national applications protect “civil engineering” (171) technology, are for “optics” (99), “measurement” (97) or “other special machines” (94). The technology fields where most PCT applications are filed are “handling” (16), “engines, pumps, turbines” (15), “materials, metallurgy” (11) and “transport” (10).

Not only is the overall patenting activity higher in Belarus, also the co-invention activity with EU28 based inventors is higher than for the countries discussed above. This is apparent as around 8% of all national and PCT patent applications from Belarusian inventors are co-developed by European colleagues. In total numbers, the collaboration between EU28 and Belarus based inventors resulted in 130 national and 14 PCT patent applications that are attributed to Belarusian inventors. Most national co-inventions are filed in “optics” (11), “engines, pumps, turbines” (9) and in “electrical machinery, apparatus, energy” (9). The PCT patent applications are spread over the technology fields with no obvious concentration. The fields with the highest numbers are “macromolecular chemistry, polymers”, “materials, metallurgy” and “basic materials chemistry “ with around 1,3 applications.

While the output of PCT patent applications in Belarus is rather stable, the trend for national patent applications is decreasing. If the observed timeframe of ten years, is divided into two five-year periods (2007-2011: 1.094 applications, 2012-2016: 475 applications), the output shrank by more than 50% between these two periods.

Georgia

Georgia is the Caucasian EaP country with the highest technological capability covered in this study. In the ten years between 2007 and 2016 Georgian inventors developed 520 national 80 PCT applications. Normalised by the population of this country this relates to 140 national and 21 PCT applications per million inhabitants. The technology fields with the highest number of national applications are “food chemistry” (55), “engines, pumps, turbines” (52) and “other special machines” (50). Most PCT applications are filed in the technology fields “medical technology” (10), “pharmaceuticals” (8).

The cooperation between Georgian and EU28 inventors is limited. From the total national application output attributed to Georgian inventors, 26 were developed in cooperation with EU based inventors and only 6 PCT applications were based on collaborative developments. Most national co-inventions fall into the technology fields “civil engineering” (2,7), “measurement” (2,6) and “tele-communications” (2,4). The joint PCT applications are distributed over the technology fields with no technology field having more than one patent application.

The number of application in the ten years covered in this study is decreasing for both national and PCT patent applications. For patents filed under the PCT the trend has been stable between 2007 and 2013 with around 10 applications per year, in the following three years the average has been 4 applications per year. The development of the number of national patent applications is even more negative. The output of national patent applications attributed to Georgian inventors shrank by nearly two thirds in the two five year comparison (2007-2011 and 2012-2016).

Table 11: Overview of the Belarusian patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	16,56	3,45	0,75	0,11	3,20%	4,40%
Audio-visual technology	1,37	1,83	0,20		0,30%	2,30%
Telecommunications	5,13	1,48	2,37	0,48	1,00%	1,90%
Digital communication	5,04	1,33	1,00		1,00%	1,70%
Basic communication processes	5,31	1			1,00%	1,30%
Computer technology	11,18	4,5	0,57		2,10%	5,70%
IT methods for management	1,46	-	0,50		0,30%	0,00%
Semiconductors	10,35	1,03	0,55	0,33	2,00%	1,30%
Optics	5,98	2,83	0,11		1,10%	3,60%
Measurement	16,52	2	2,59		3,20%	2,50%
Analysis of biological materials	2,88	0,83	0,88	0,83	0,60%	1,10%
Control	1,38	0,83			0,30%	1,10%
Medical technology	16,92	10,48	1,00	0,20	3,30%	13,30%
Organic fine chemistry	1,68	0,05	0,72	0,05	0,30%	0,10%
Biotechnology	3,25	1,33	0,80	0,17	0,60%	1,70%
Pharmaceuticals	40,8	8,13	2,22	0,87	7,80%	10,30%
Macromolecular chemistry, polymers	4,78	2,08	0,68	0,26	0,90%	2,60%
Food chemistry	54,71	2,01	0,13		10,50%	2,50%
Basic materials chemistry	11	1,62	1,59	0,29	2,10%	2,10%
Materials, metallurgy	30,02	4,06	2,13	0,96	5,80%	5,10%
Surface technology, coating	8,06	2,05	0,13	0,05	1,50%	2,60%
Micro-structural and nano-technology	0,21	-			0,00%	0,00%
Chemical engineering	20,96	2,11	0,82		4,00%	2,70%
Environmental technology	8,42	1,92	0,50	0,50	1,60%	2,40%
Handling	15,58	2,21		0,17	3,00%	2,80%
Machine tools	11,68	0,17	0,44		2,20%	0,20%
Engines, pumps, turbines	51,74	3,96	0,50	0,13	9,90%	5,00%
Textile and paper machines	3,33	0,33	0,33		0,60%	0,40%
Other special machines	49,65	4,89	0,29	0,02	9,50%	6,20%
Thermal processes and apparatus	6,1	0,85	0,60	0,15	1,20%	1,10%
Mechanical elements	27,33	-	0,50		5,30%	0,00%
Transport	24,54	0,83	0,50	0,17	4,70%	1,10%
Furniture, games	2,5	1,5			0,50%	1,90%
Other consumer goods	5,24	2,92	0,24		1,00%	3,70%
Civil engineering	38,76	4,26	2,67	0,30	7,40%	5,40%

Moldova

Moldovan inventors are attributed with the development of more than 2.100 national and 37 PCT patent applications. These numbers represent the highest disparity of patent types in favour of national applications in the EaP countries. This output normalised by population, relates to nearly 600 national and 11 PCT applications per one million inhabitants. The most important technology fields for national applications are “medical technology” (285), “other special machines” (181), “food chemistry” (159), “pharmaceuticals” (157) as well as “engines, pumps, turbines” (120). The PCT applications are most often filed under “civil engineering” (2,9) and transport (2,8).

The cooperation with colleagues from the EU28 resulted in filing 104 national and 3,7 PCT applications which are attributed to the Moldovan inventors. The national patent applications are

filed in the fields “materials, metallurgy” (12), “pharmaceuticals” (10) and “organic fine chemistry” (9). The few shares of PCT patents are distributed over a few technology fields without any patterns.

The development of PCT applications is rather stable on a very low level. In contrast the development of national applications is decreasing. When looking at the two five-year periods, the output during 2012-2016 is nearly 40% under the level of 2007-2011. This trend also can be seen the technology fields with a high output.

Table 12: Overview of the Moldovan patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	67,18	-	1,20	0,40	3,20%	0,00%
Audio-visual technology	14,19	0,6	0,98	0,10	0,70%	1,60%
Telecommunications	18,98	1	0,17		0,90%	2,70%
Digital communication	5,8	-	0,05		0,30%	0,00%
Basic communication processes	11,86	-	0,36		0,60%	0,00%
Computer technology	34,43	1,14	3,28	0,25	1,60%	3,00%
IT methods for management	5,54	-			0,30%	0,00%
Semiconductors	33,12	-	2,34		1,60%	0,00%
Optics	15,64	-	0,85		0,70%	0,00%
Measurement	98,43	1,43	2,88	0,10	4,60%	3,80%
Analysis of biological materials	17,36	-	1,75		0,80%	0,00%
Control	22,61	3	0,47		1,10%	8,00%
Medical technology	284,73	4,1	4,48	0,10	13,40%	10,90%
Organic fine chemistry	89,67	0,35	8,91	0,25	4,20%	0,90%
Biotechnology	87,32	0,22	4,61		4,10%	0,60%
Pharmaceuticals	157,89	1,17	9,75		7,40%	3,10%
Macromolecular chemistry, polymers	8,06	-	0,61		0,40%	0,00%
Food chemistry	159,34	1	2,73		7,50%	2,70%
Basic materials chemistry	76,12	1,96	4,93	0,33	3,60%	5,20%
Materials, metallurgy	63,77	1,67	12,19	0,67	3,00%	4,40%
Surface technology, coating	67,27	0,2	1,55		3,20%	0,50%
Micro-structural and nano-technology	13,67	-	0,75		0,60%	0,00%
Chemical engineering	90,3	1,03	5,16	0,67	4,30%	2,70%
Environmental technology	67,59	1,5	3,84	0,25	3,20%	4,00%
Handling	18,52	0,4			0,90%	1,10%
Machine tools	64,13	0,57	2,82		3,00%	1,50%
Engines, pumps, turbines	120,37	5	7,12		5,70%	13,30%
Textile and paper machines	8,28	-	0,81		0,40%	0,00%
Other special machines	181,41	1,7	4,39		8,60%	4,50%
Thermal processes and apparatus	48,52	1,5	4,50		2,30%	4,00%
Mechanical elements	36,18	1	0,80		1,70%	2,70%
Transport	24,17	2,83	5,82	0,33	1,10%	7,50%
Furniture, games	14,77	1,1	2,21	0,10	0,70%	2,90%
Other consumer goods	20,52	0,3	1,95	0,10	1,00%	0,80%
Civil engineering	73,97	2,87	0,19		3,50%	7,60%

Ukraine

The Ukraine is the EaP country with the highest patenting activity and its output is in the range of moderately innovating EU countries. In total more than 13.000 national and 1.140 PCT patent applications are attributed to Ukrainian inventors. These numbers, normalised by population, translate to an activity of 319 national and 27 PCT applications per one million inhabitants. From

these inventions, 407 national and 53 PCT applications have been developed in cooperation with EU based colleagues. In contrast to other EaP countries, not only the total numbers are higher, but also the distribution among the 35 technology classes is more consistent. The technology classes with the highest amount of national patent applications are “measurement” (1.230), “materials, metallurgy” (1.175) and “other special machines” (1.058). Most PCT application are filed in the technology classes “computer technology” (114), “engines, pumps, turbines” (92), “civil engineering” (77) and “electrical machinery, apparatus, energy” (72).

Table 13: Overview of the Ukrainian patenting activity, 2007-2016

Name of Field	Sum of national patents	Sum of PCT patents	Sum of national co-inventions with EU	Sum of PCT co-inventions with EU	Share in technology field (national)	Share in technology field (PCT)
Electrical machinery, apparatus, energy	743,84	71,98	15,49	2,35	5,00%	5,60%
Audio-visual technology	129,57	40,95	13,32	0,98	0,90%	3,20%
Telecommunications	157,67	21,27	2,59	0,40	1,10%	1,70%
Digital communication	141,96	51,93	13,94	4,70	1,00%	4,10%
Basic communication processes	122,53	4	3,08		0,80%	0,30%
Computer technology	506,22	113,98	29,38	5,98	3,40%	8,90%
IT methods for management	42,38	29,22	4,08	2,06	0,30%	2,30%
Semiconductors	137,6	8,3	13,02	1,38	0,90%	0,60%
Optics	114,62	21,96	17,77	1,79	0,80%	1,70%
Measurement	1.229,91	54,72	21,15	4,92	8,30%	4,30%
Analysis of biological materials	160,35	5,02	6,37	0,84	1,10%	0,40%
Control	222,3	20,69	3,73	0,34	1,50%	1,60%
Medical technology	858,87	66,71	16,51	1,67	5,80%	5,20%
Organic fine chemistry	330,76	18,86	49,08	3,32	2,20%	1,50%
Biotechnology	213,6	22,8	8,63	1,36	1,40%	1,80%
Pharmaceuticals	678,45	58,97	12,64	2,63	4,60%	4,60%
Macromolecular chemistry, polymers	126,55	4,15	5,87	1,24	0,90%	0,30%
Food chemistry	454,39	13,28	2,39	0,03	3,10%	1,00%
Basic materials chemistry	496,96	57,61	20,39	2,57	3,40%	4,50%
Materials, metallurgy	1.174,77	33,08	32,56	3,52	8,00%	2,60%
Surface technology, coating	301,91	15,02	8,51	1,60	2,00%	1,20%
Micro-structural and nano-technology	25,84	2,79	1,14		0,20%	0,20%
Chemical engineering	713,7	51,83	13,38	1,03	4,80%	4,00%
Environmental technology	463,04	21,8	7,88	1,13	3,10%	1,70%
Handling	258,93	30,4	1,72		1,80%	2,40%
Machine tools	623,44	19,09	8,49	0,32	4,20%	1,50%
Engines, pumps, turbines	686,43	92,24	12,70	0,83	4,70%	7,20%
Textile and paper machines	81,44	8,1	1,00	1,10	0,60%	0,60%
Other special machines	1.057,83	46,3	27,38	1,66	7,20%	3,60%
Thermal processes and apparatus	450,86	30,2	9,79	1,09	3,10%	2,40%
Mechanical elements	427,46	34,41	3,82	0,08	2,90%	2,70%
Transport	577,05	68,42	8,02	1,11	3,90%	5,30%
Furniture, games	116,74	28,05	2,14	0,17	0,80%	2,20%
Other consumer goods	151,81	34,62	2,93		1,00%	2,70%
Civil engineering	757,52	77,54	6,00	1,11	5,10%	6,10%

The share of co-inventions that were developed in collaboration with European colleagues is lower in Ukraine than in many other EaP countries, however in total numbers this cooperation pattern is the strongest between EU28 and EaP countries. The most national joint applications were filed in “organic fine chemistry” (49), “materials, metallurgy” (32), “computer technology” (29) and “other

special machines" (27). The most of joint PCT applications were developed in the fields "computer technology" (6), "measurement" (5) and "digital communication" (5).

The development over the observed timeframe reveals an uneven trend for national and PCT applications. While the number of PCT applications was increasing by more than 9% between the two five-year periods (2007-2011, 2012-2016) (even though the numbers for 2016 are way below the annual average because of the publication lag), the number of national applications dropped by two thirds between these two periods. During 2007 and 2011 Ukrainian based inventors developed close to 11.000 applications while during 2012-2016 the number declined to 3.800 applications.

4. Summary of main findings

This report is based on a bibliometric analysis of the patenting activity in and between the countries of the European Union and the Eastern Partnership. The aim is to describe the technological capability of the covered countries and the cooperation between the EU28 and countries of the EaP. The analyses are based on national and PCT patent applications filed between the years 2007 to 2016. The methodological building stones are mainly descriptive statistics and tools of social network analyses. The potential and restrictions of such an approach are discussed in the methodology chapter. In this section the main findings are presented and discussed.

While international comparisons are normally conducted on the basis of PCT patent application, this was not possible in the case of the EaP countries as the overall numbers are too low. Therefore, national applications are used to extract information about the state of technology production in EaP countries and their cooperation with the EU. The international comparability is not given for these patent applications, however, the common background and shared history of the EaP countries is also noticeable in the countries' legal patenting framework. Thus, the preconditions for patenting activities are similar.

In general, the patenting activity in the EaP countries is much lower than in the EU. The number of applications attributed to EaP inventors per one million inhabitants, is 266 for national applications and 23 for PCT applications – in contrast the numbers for the EU28 are 3.770 national and 923 PCT applications per one million inhabitants. However, the difference is lower when normalised by GDP. The numbers for EaP based applicants are a little lower than those for inventors, which hints to a negative balance for foreign ownerships. The partnership countries are diverse among themselves. The overall outputs of the Ukraine are on the same level as many EU countries, however since 2010 this trend has been quickly decreasing since 2010. Nevertheless, the vast majority of EaP applications are developed by Ukraine-based inventors. Moldova has an above EaP average activity for national applications, but all other countries are far below the number observed in the EU-context. The trend in the EaP countries is negative for national applications, mainly but not exclusively due to the Ukrainian trend, but positive for PCT applications which indicate that the international perspective for intellectual property rights is gaining importance in these countries. The question, why the drop of national applications is that severe, cannot be answered by a bibliometric approach and calls for a qualitative analysis of the presented results.

Technology-wise, it is interesting that the most important technology fields and sections for EaP countries are often different for national and PCT applications. However, the most important technology sections in the EaP countries are chemistry and mechanical engineering. The results on

country level are to some extent more concentrated or show varying specialisation patterns. While most applications from Armenian inventors are for food chemistry technologies, most applications from Azerbaijan are related to civil engineering and medical technologies. Belarusian inventors file most applications in civil engineering, optics and measurement technologies. Inventors based in Georgia develop technologies for food chemistry, engines, pumps and turbines. Moldovan inventors most often are involved in technology development in the fields of medical technology and special machines. The applications of Ukraine based inventors are attributed to measurement, materials and metallurgy and other special machines for national and computer technology, engines, pumps and turbines in the case of PCT applications.

The cooperation in technology development between EaP and EU countries, as measured by joint patent applications, is rather low. The total amount of joint applications that are attributed to either EaP or EU based inventors is around 1.500 national and 190 PCT applications. Whereby, more than half is attributed to EU based inventors and the majority of the EaP share is developed by Ukrainian inventors. The most important EU cooperation partners for the EaP countries are Germany, France and the United Kingdom. Besides the links to the top-performing countries, there are significant links to Poland and Romania. However, the cooperation network between the EaP and EU countries mainly includes Ukraine, Belarus and as for national applications to some extent Moldova. The network for PCT applications is very sparse with a few jointly developed applications between the Ukraine and Austria, Germany and the United Kingdom.

In general, the technological capability of the EaP countries is much lower than the one of most EU countries. While this is only true partially for the Ukraine, the trend in this country is negative, which might be explained by the ongoing political problems the country is facing. However, the results presented in this report and summarised above, give traces of specialisation patterns and existing knowledge links, which could serve as foundation for future developments. However, these general results are only meant to feed a further discussion with stakeholders and support a qualitative analysis. Essential for the strengthening of the technology production system and subsequently the future economic development of the EaP will be to address fields with a competitive advantage or the chance to gain one. Support for R&I activities should be focused on these areas of specialisation. Establishing links with strategically relevant stakeholders and regions with high technological capability can support these processes.

5. Bibliography

Archibugi, D. and Pianta, M. (1996): Measuring Technological Change through patents and innovation surveys, in: *Technovation*, 16(9), 451-468.

Bonacich, P. (1987): Power and centrality: A family of measures. American Journal of Sociology 92(5), 1170-1182

Brandes, U. and Erlebach, T. (2005): *Network Analysis - Methodological Foandations*. Berlin, Heidelberg and New York, Springer

Carrington, P.J., Scott, J. and Wasserman, S. (2005): *Models and methods in social network analysis.* New York, Cambridge University Press

Dernis, H. and Guellec, D. (2001): Using patent counts for cross-country comparisons of technology output, OECD, Paris. Online available at: http://www.oecd.org/sti/inno/21682515.pdf

Faust, K. (1997): Centrality in affiliation networks. *Social Networks 19*(2), 157-191

Giuri, P. et al. (2007): Inventors and invention processes in Europe: Results from the PatVal-EU survey, in: *Research Policy*, 36, 1107-1127.

Griliches, Z. (1990): Patent Statistics as Economic Indicators: A Survey, in: *Journal of Economic Literature*, 28, 1661-1707.

Heller-Schuh, B., Barber, M., Henriques, L., Paier, M., Pontikakis, D., Scherngell, T., Veltri, G.A. and Weber, M. (2011): Analysis of networks in European framework programmes (1984-2006). Luxembourg

Meyer, M. (2006): Academic Inventiveness and Entrepreneurship: On the Importance of Start-Up Companies in Commercializing Academic Patents, in: *Journal of Technology Transfer*, 31, 501-510.

Nagaoka, S., Motohashi, K. and Goto, A. (2010): Patent statistics as an innovation indicator, in: Hall, Bronwyn / Rosenberg, Nathan (eds.): *Handbook of the Economics of Innovation*, Volume 2, 1083-1127.

OECD (2013): OECD Science, Technology and Industry Scoreboard 2013, Paris: OECD, Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2013/technological-advantage_sti_scoreboard-2013-55-en

Pakes, A. and Griliches, Z. (1984): Patents and R&D at the Firm Level: A First Look, in: Griliches, Zvi (ed.): R&D, Patents, and Productivity, Chicago: University of Chicago Press, 55-72.

Scherer, F. M. and Harhoff, D. (2000): Technology policy for a world of skew-distributed incomes, in: *Research Policy*, 29, 559-566.

Scherngell, T. (2006): *Interregionale Wissensspillovers in der europäischen High-Tech Industrie. Eine empirische Analyse.* Wiesbaden, DUV

Schmoch, U.(2008): Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Organisation, Geneva: WIPO, online at: http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf.

Swiss Federal Institute of Intellectual Property (2014): Patents, online at: https://www.ige.ch/en/ip4all/patents/patents.html?type=kxftokfxvjku, last accessed: 22 April 2015

Wasserman, S. and Faust, K. (1994): *Social Network Analysis: Methods and Applications*. Cambridge, Cambridge University Press

Webster, E. and Jensen, P. H. (2011): Do Patents Matter for Commercialization?, in*: Journal of Law and Economics*, 54(2), 431-4