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Embeddedness levels in Central and East European countries as revealed by patent-related indicators

Annamária Inzelt*

IKU Innovation Research Centre at Financial Research PLC, Felhévízi út 24, Budapest 1023, Hungary

Central and East European countries (CEECs) still show many features of the Soviet era. Consequently, the region seems, in several ways, to have been shaped by a single universal phase of transformation. This explains, at least in part, the relatively weak patenting activities and innovation performance of these countries. This paper deals with quantitative information originating from a newly created databank and investigates CEECs, employing various patent indicators in a Triple Helix context.

New member states of the European Union (EU) from CEECs accounted for less than 1% of European patents between 1990 and 2006. This figure does not improve if patent applications are normalised according to population, and the number of patents registered in the region has evolved very little over the years. Analysing the relationships among old and new member states of the EU and their regions in terms of citations shows the pattern of intellectual linkages within Europe quite clearly. Even if CEECs feature relatively rarely in cited European publications, there are still 43 CEE affiliations recorded among the top 500 in Europe (ranked by performance). Intellectual linkages are still weak (both within the CEE area and among old and new EU member states and their regions), and the citation pattern clearly shows the importance of externally derived knowledge for CEE countries. Self-citation highlights the weakness of scientific impulses from the immediate environment to patenting activity. A very low level of self-citation may be indicative not only of low capabilities in terms of knowledge production, but also of a basic weakness in knowledge dissemination and absorption. In this respect, CEE universities have not yet shown themselves to be strong regional innovation organisers.

Introduction

Public research institutions, such as universities and public laboratories, have made enormous efforts to protect and exploit their output, whilst governments have recognised the international structures of intellectual property protection as essential elements of economic competitiveness, and as necessary conditions for access to the global economic system (Cameron, 1999). In parallel with this trend, the related phenomenon is collaboration, which takes many forms and may involve work carried out among independent organisations, where participants may collaborate at regional, national or international levels.

*Email: inzelt.annamaria@penzugykutato.hu

The Triple Helix (TH) model of university–industry–government (introduced by Etzkowitz and Leydesdorff in 1995) provides a good frame for policy-making in the age of the knowledge-based economy. The TH concept sees universities as a catalyst of knowledge-driven economic development in a region. Etzkowitz (2008) emphasises that the availability of a critical mass of research in a local area is a necessary condition for science-based regional economic development. Any actors within the TH model can become regional innovation organisers and a university may take the lead if the industrial base or local government is relatively weak, which is the situation in many Central and East European countries (CEECs). Collaboration among helices affects both producing and exploiting research and development (R&D) activity, a phenomenon which has attracted the attention of policy-makers, the managers of intellectual assets and the research community. Policies in many countries aim to stimulate the exploitation of the output of public research institutions and their cooperation in the knowledge triangle at different levels. Beyond this, several national governments and the Lisbon Agenda of the European Union (EU) encourage university–industry–government collaboration for regional renewal, a process that includes cross-border regions.

The TH model is the conceptual framework behind a new line of indicator development. In fact the literature on TH indicators has grown steadily since the early 2000s, and Meyer (2012) gives an overview of rich and diverse work on TH indicator development. Chung and Park (2014) follow various studies by Leydesdorff and his collaborators, and a special edition of *Scientometrics* (Leydesdorff *et al.*, 2014) adds another dimension, based on newly available major data (webometrics, scientometrics, informetrics). The analysis in this paper is based on traditional indicators, such as patents and citation indices, using them in a TH context (OECD, 2009). These indicators are relevant to investigating TH-type developments and activities associated with universities (Meyer *et al.*, 2003; Persson, 2006; Leydesdorff *et al.*, 2014). The majority of European universities generate patentable research and development output, though their role in invention depends on patent ownership regulations. They also differ in their capabilities to manage intellectual property. New EU member states (the former planned economies) share some specific features from their inheritance of planned economic life and in their stage of transformation. These specificities are mirrored in patent metrics and citation indices.

A unique, recently-developed database[1] has allowed us to investigate two hypotheses: (1) that the technology output of CEECs makes only a limited contribution to CEE development and the advancement of the EU; and (2) that the transition of CEECs and their EU membership has had a positive effect on their embeddedness in the world. The paper goes on to provide information on specificities of new member states in order to establish the context for their technical performance, their practice-oriented research output and their international collaboration patterns. Even though the transition process of these economies began over 20 years ago, traces of the Soviet model are still visible.

The paper then offers some empirical findings employing patent-metrics, based on the new databank created as an element of multi-purpose patent statistics for monitoring and evaluating the progress and performance of the European Research Area (ERA). The analysis focuses on the CEEC-10 (the Central and East European transition economies which have joined the EU since 2004 – also known as new member states).[2] These internationally comparable patent indicators allow us to investigate the geographical structure of university inventions in CEECs and the globalisation of universities' R&D activities. This section also analyses university references found in patent documents, broken down by geographic origin and focusing on CEECs. First it analyses the patent performance of CEE sub-regions, and then investigates the embeddedness of CEE sub-regions in European technology knowledge production. This new data set allows us to explore innovation in CEECs and knowledge exchange among regions. The conclusions section discusses possible reasons for the low performance levels measured in CEECs, and then suggests how CEECs might tackle the challenges and limitations they face.

Relics left in new member states from the Soviet era and the single universal phase of transformation

New member states have several special problems which must be taken into account when analysing their patent indicators. The predecessors of today's CEECs created new technology in a different functional combination from the market economies (Hanson and Pavitt, 1987; Inzelt, 1999; Radosevic, 1999; Dyker, 2004; Meske, 2004). In a bipolar world regime, these economies were isolated from the Western world. Key actors in the TH model were far away from each other in the strict Soviet model, or at arm's length in the reformed socialist economies. The transition economies have abandoned the system of central planning and, over the last 20 years, have introduced many structural reforms (including new intellectual property regimes) and reconfigured their national innovation systems. On both the legal and organisational levels, countries are restructuring their R&D systems, so facilitating the diffusion of knowledge and their valorisation capabilities (see Ranga and Etzkowitz, 2010).

In the period immediately prior to joining the EU, the transition economies made tremendous efforts to modernise their systems (including HE and intellectual property rights) and to adapt themselves to European practice. In the context of university patent/technical innovation performance, four elements of social heritage seriously affected by the transition must be discussed: (1) the role of universities in the Science and Technology (S&T) system, (2) the discipline structure, (3) intellectual property issues, and (4) other factors. This transformation has coincided with the 'fundamental change at organisational and institutional level within and between university, industry, and government [which] constitutes a new innovation environment, based on science, technology and a culture of entrepreneurial initiative' in market economies, a phenomenon which Etzkowitz (2011, p.76) termed 'endless transition'.

The role of universities in the S&T system

Under the original Soviet model, the S&T system was divided into three main sections: institutes of higher education (HE), academies of science, and other public institutes such as institutes of branch ministries. In a few countries there were a few in-house R&D departments of enterprise (Hanson and Pavitt, 1987; Inzelt, 1995, 1999; Organisation for Economic Co-operation and Development [OECD], 1997; Radosevic, 1999). HE institutes were responsible mainly for teaching and played a limited role in research. Unlike their counterparts in Western Europe (and their pre-communist role in CEE), universities did not play an important role in the basic sciences. The institutes of academies of science played leading roles in basic research and doctoral education, and so basic research and doctoral training were performed separately from universities in these countries (Inzelt, 1999).[3] Applied research and experimental development was the task of branch ministry institutes and design bureaux. The research mission and the third mission of universities were very weak, insofar as they were present at all.

The transition period has brought tremendous changes to the role of universities in research and doctoral training in that they have regained their right to undertake basic research and doctoral education (strengthened by the Bologna process). The HE system and HE institutes have adjusted themselves to the post-Humboldt model. New laws on HE have (re)regulated the invention rights of universities (public research organisations), while technology transfer organisations have also been established. Parallel with the redeployment of the science system and the reform of the HE system, the management of universities' intellectual assets has also changed. Apart from the inexperienced intellectual property rights (IPR) management of universities, underfunded HE institutions can barely afford to cover the costs involved in patenting, and those of maintaining patents already in force.

Discipline structure and re-evaluation of performance

The value of CEE science was re-evaluated by transformation, and a slow adjustment to new challenges is clear. Reverse engineering and imitation capabilities are important for innovative performance, but these capabilities (as well as scientific novelties and inventions) were devaluated by the disappearance of the bipolar world system and by the introduction of the new patent regime. Another important common feature of CEECs is their discipline structure, which also has an impact on the frequency of inventions and patents. The CEECs were strong in basic science, mainly in the traditional hard sciences, such as physics, chemistry and related areas, where they had technological advantages. They were weak in the applied sciences and they are still weak in emerging disciplines, such as biotechnology and artificial intelligence (Dyker, 2004). Disciplinary comparative advantage is still heavily concentrated in physics, mathematics and chemistry, where patent and publication density is lower than in the emerging fields. This disciplinary structure has had a long-lasting effect on the volume and structure of patent applications.

Intellectual property issues

The effect of intellectual property protection varies from one country to another, depending on the level of technological development, degree of orientation towards foreign markets, legal system and law enforcement practice. Before the transition period, the former socialist countries had a different intellectual property regime from that of the market economies, even though their pre-sovietised patent system followed Austrian or German patent legislation. Soviet-type IPR legislation started in 1917–1918 and, adjusting to the changing economic and social system, changed several times before the end of World War II (WWII). The most important feature of this legal transformation was that exclusive rights in patenting were emasculated and the state prohibited the personal manufacture of inventions, except at the artisan level. Patents could no longer be a licence for private enterprise. A planning office or ministry would decide which state-owned firm was to exploit the patent. Even though the planned economies used the same IPR terminology as the market economies, the meaning differed.

In the transition economies investigated in this paper, two statutes of the Soviet Union (dating from 1942 and 1959) are interesting as these were the models for transforming their own patent system. In 1942, Soviet legislation introduced a new concept in inventors' rights, the author's certificate. The inventor could apply for either a patent or an author's certificate. The right to exploit belonged to the state, but the inventor had the right to remuneration (calculated on the basis of savings to industry). Remuneration was much more advantageous in the case of the author's certificate than for the patent. Rejected applications for an author's certificate had no charge levied, but filing and issuance fees were charged on patent applications. There were three protectable items: (1) inventions, (2) technical improvements and (3) rationalisation processes. Technical improvements and rationalisation were protected only by the certificate.[4]

These laws repeated the legal recognition of 'technical improvements' (first introduced in 1931), so creating a legal environment in which reverse engineering could also result in an author's certificate. The statute of 1959, Discoveries, Inventions and Rationalization Proposals, enacted by the Council of Ministers of the USSR, specified the inventors' rights for remuneration and exploitation abroad. Where the invention was pursuant to normal employment duties or its effectuation was state supported, the patent device was precluded. However, the inventor might receive the appropriate royalty payments in addition to his regular wage. This law declared that patents may be utilised outside the national borders only with government consent, which (as might be expected) is rather difficult to obtain.

After WWII, all the Baltic States had to follow the Soviet system since they became republics of the Soviet Union.[5] As part of the Soviet Union, these republics not only followed the Soviet legal system in respect of IPRs, but also had no kind of patent office, as the patent organisation existed only at the Union level. The above law was valid in all Soviet Baltic Republics until their independence in 1991. At the beginning of independence and transition, they could restore their industrial property protection system, set up patent offices and patent courts, develop the patent attorney profession, and restore their membership in the Paris Convention. In the course of EU membership, they joined the European Patent Convention, a process taking some two years before they could apply for a patent.

Formally independent states of the Soviet bloc (Council for Mutual Economic Aid [CMEA] members) ran their own patent offices and had their own legal systems.[6] Before WWII, most had followed a very similar IPR system to the Austrian for decades. The penetration of Soviet-type IPR regulation went on parallel to building the command economies, but the year of introduction and the depth of transformation of the patent system differed by country. For example, Hungary was the second country (after Yugoslavia) to follow the Soviet IPR legislation model, introducing the certificate of authorship in 1948. In this system, patents were placed in the hands of the state and were no longer exclusive rights. An alternative form of protection existed. However, at the same time, the patent law of 1895 remained in force. Certificates of authorship were abolished in 1957 – after the uprising. Some other elements of Soviet patent legislation remained valid until the end of the socialist system, but they were significantly decreased in 1969, at the beginning of Hungarian economic reform. During the socialist period, the full protection of the patent existed only in Yugoslavia, and Hungary eliminated alternative protection. However, they could not follow the modernisation of the Austro-German patent model until the end of the socialist era. In the early stage of transition, the new

Hungarian patent law came into force in 1996 and allowed applications to the European Patent Convention.

Another historical example is Czechoslovakia, which adopted the Soviet law model much more slowly than other satellite countries. The old Austrian-type patent law was slightly modified in the 1950s and significantly changed in 1957, when it granted the invention to the state. Only in 1972 did an Act introduce the so-called author's certificate to complete the move away from the old system of IPRs. Until the end of the socialist system in 1990, the country followed the Soviet model, with the patent and its alternative, the author's certificate, co-existing. Since then, both the successor countries to Czechoslovakia have gradually harmonised their patent systems with that of the EU.

Since the beginning of the transition period, the IPR system has been modernised in every country, and most CEECs have signed the World Trade Organisation (WTO) Trade Related Intellectual Property Rights (TRIPs) agreement. The US most favoured nation clause was also linked to the modernisation of the IPR system (in pharmaceutical industry-related IPRs). For CEE countries, joining the EU allowed application to the European Patent Office (EPO). All of these changes made it easier for foreign companies to collaborate with the region. By the first decade of the new millennium, these countries had up-to-date legislative and administrative structures, as well as functioning laws for the protection of intellectual property. However, the history of patent legislation shows that there are differences in intellectual property culture, codified and tacit knowledge in the institutional system, and also knowledge-producing organisations and inventors. There is insufficient professional skill to handle industrial property matters, patenting and licensing at universities. Several decades of a distorted patenting system have made some countries almost newcomers to the new international community of intellectual property.

Other transition-related factors

Other transition-related factors deeply affected knowledge production, dissemination and patenting activities. The opening up of the closed economies led to a remarkable inflow of foreign direct investment (FDI). FDI was an important factor in the redeployment and restructuring of business organisations, and played an influential role in stimulating innovativeness (Dyker, 1999; Inzelt, 2010). Foreign actors played an important role in disseminating and employing new knowledge products. Few of them invested in R&D in CEECs, although CEE R&D-based innovation and patenting frequently occurred in other countries (closer to corporate headquarters).

Another important factor which affected R&D capabilities was the emerging pattern of mobility (Inzelt, 2008). New job opportunities for researchers in the domestic labour market resulted in an outflow from S&T to other highly skilled jobs. At the same time, international mobility increased the outflow and inflow of R&D personnel. The direction of the flow was westward and the outflow was usually much higher than the inflow. Both the pattern of international mobility and the character of domestic mobility have resulted in shrinking or stagnating intellectual capacities – and these may, in turn, lead to decreasing intellectual products.

Changes in FDI and in international mobility have resulted in a significant increase in international collaboration. Building collaborative capabilities was influenced by the degree to which economies were open or closed to S&T cooperation. Even in more open economies, which participated in socialist economic reforms, organisations which invented were not well prepared to manage their intellectual assets in an open world because of defective regulation and lack of expertise. CEECs are moving away from their old, not very innovative model. The arm's length character of the CEE TH model is changing (Ranga and Etzkowitz, 2010). However, as innovation indicators clearly show, they have yet to find an effective innovative model. Innovative performance remains low because their innovative actors do little to stimulate R&D. As Glänzel and Schlemmer (2007, p.274) note, 'the time lapse between the decisions made by national policy and measurable output indicators might be measured in decades. Nonetheless, European integration, international collaboration and the coordination of European S&T activities certainly stimulate and catalyse this process'.

Empirical findings

This section puts CEECs in the broader European patent performance context, and gives a short overview of the ranking position of CEECs in the ERA. It goes on to investigate CEECs' collaboration and knowledge diffusion capabilities through various patent indicators, focusing on the relationship between applicants and inventions. Assuming that universities can be regional organisers in CEECs, the paper presents the differences in regional performances and their impact on linking universities to other regions.[7]

CEECs in the EU context

The EU-27 countries with the highest ranking are: (1) Germany, (2) France, (3) Great Britain, (4) the Netherlands and (5) Italy.[8] Together, they account for almost 84% of the total number of patents (by applicant address and by inventor address).[9] At the same time, CEECs account for between 0.5 and 0.7% of European patents (by assignees and by inventor) between 1990 and 2006. The position of CEECs does not improve if patent applications are normalised by population. The number of patents registered in the region has grown little over the years. The overall correlations between counts based on inventors and on applicants for the EU-27 and for all regions are very high (sub-region correlation is 0.955). However, the differences in absolute value are illuminating (Table 1). When counting shifts from applicant-based to inventor-based, the number of applicant addresses is above that of inventor addresses in the EU-17 countries (as well as in the EU-27 countries), the opposite of the CEEC-10 average.

Table 1 also illustrates that the number of patent applications based on inventor address exceeds the number of patent applications based on applicant address in each CEEC. Among the reasons for this deviation from the general, the headquarters phenomenon is prominent. The other side of the coin is that, because of the location of the headquarters of multinational corporations (MNCs) in nine countries from the EU-17 (Cyprus, Germany, Finland, France, Ireland, Luxembourg, Malta, the Netherlands and Sweden), the number of patents is higher by applicant address than by inventor address. The inventor/applicant relationship is the opposite in CEECs, where very few headquarters are located. In each of these countries, the inventor per applicant index is above 1.

In this index, individual countries differ only in terms of magnitude. The inventor to applicant indicator is lowest in Slovenia, where FDI penetration is lower than in other countries in the region, although it is higher than in the EU member states,

Table 1. Comparison of patents by inventor and applicant addresses, 1990–2006.

	Number of patents		Difference in absolute value	Comparison
	by inventors (1)	by applicants (2)		(1)/(2)
EU 27	646,569	663,056	16,487	0.98
EU 17	642,025	659,826	17,801	0.97
CEECs	4544	3230	−1314	1.41
Hungary	1453	1011	−342	1.44
Czech Rep.	894	662	−232	1.35
Poland	767	562	−205	1.36
Slovenia	645	521	−124	1.24
Slovakia	256	134	−122	1.91
Bulgaria	181	126	−55	1.44
Romania	133	97	−36	1.37
Latvia	88	41	−47	2.15
Estonia	87	50	−37	1.74
Lithuania	40	26	−14	1.54

EU: European Union; CEECs: Central and East European Countries. Source: Author's compilation from background tables of the project.

which are important MNC countries. The Czech Republic, Poland, Romania, Bulgaria and Hungary are around the CEE average (1.4), while the indicator is quite high in the former Soviet republics (Lithuania, Estonia, Latvia) and Slovakia. This difference may relate not only to the headquarters phenomenon, but also to the historical differences in the patenting system between satellite countries and Soviet member states.

European sub-regions

As we move from country to European sub-region, further regional differences appear; these are strongly influenced by such factors as the size of the region and the country in which the region is located. Among CEECs, differences in economic and technological development are more important factors in grouping countries than size. Normalised patent indicators (the number of patents per head of population) help us to recognise some differences. Poland, large by CEE standards, is second by number of applications, but only seventh (out of 10) in terms of patent intensity. Tiny Estonia shows the opposite characteristics. Patent intensity is highest in the most advanced small country, Slovenia, followed by medium-sized countries, such as Hungary and the Czech Republic. Intensity is lowest in Romania (large-medium), Lithuania (small) and Bulgaria (medium).

One of the important factors explaining this is the absolute and relative size of invention-related human resources measured by R&D personnel. The Pearson correlation between number of patents and number of R&D personnel is 0.88 between patent intensity (patent/R&D personnel) and proportion of R&D personnel to employees. These correlations express very strong linkages between the availability of relevant human resources and technology output. This correlation highlights the fact that the pool of researchers is not very high in CEECs, which is a factor limiting inventive capacity.

Table 2. Breakdown by inventors of Central and East European regions by patent application levels, 1990–2006.

Patent applications	**HU**	**SI**	**CZ**	**PL**	**SK**	**BG**	**RO**	**EE**	**LV**	**LT**	**∑**
> 500	**1**	1									2
200–499			**1**	**1**							2
100–199	2		3		**1**	**1**					7
50–99	4		3	6	1		**1**	1	1		17
25–49			1	2	2					1	6
10–24				4		4	3				11
< 10				3		1	4				8

HU: Hungary; SI: Slovenia; CZ: Czech Republic; PL: Poland; SK: Slovakia; BG: Bulgaria; RO: Romania; EE: Estonia; LV: Latvia; LT: Lithuania. Source: Background table to Ranga, Inzelt *et al.*, 2009.

At the regional level, there are big differences between European sub-regions (Ranga, Looy *et al.*, 2009). The minimum patent performance of a region as measured by applicant and inventor addresses is 1, while the maxima are 70,031 (based on applicant address) and 41,253 (based on inventor address). The reason for the difference between applicant and inventor data is that not only do MNCs tend to centralise the application process, so do large national companies. Inventive activities are much more regionally dispersed. The headquarters phenomenon is clearly visible not only internationally but also nationally, and sub-regions are affected more strongly than countries.

Of the 265 EU regions, the top-ranking 25 – by number of patents – account for 66% of the total based on applicant addresses, and 57% based on inventor addresses. No CEE region is among them. The most active patenting CEE NUTS2 region (Central Hungary) achieved 2.4% by inventor and 1.0% by applicant compared with the EU region that patented most between 1990 and 2006.[10] Countries may be located in different clusters, depending on their regional performance. A lower level of patent activity is visible in each CEEC and in most south European countries (Greece, Portugal and Spain; Ranga, Looy *et al.*, 2009).

The size classifications of patent applications relevant to CEECs are used in Table 2 to show the level of regional patent performance in each country. The number of patent applications is under 1000 in every CEE region. In fact, there are only two regions above 500, followed by two others between 200 and 500, and 25 have fewer than 50 patents. Among the last, eight regions produced fewer than 10 patents between 1990 and 2006. Patent intensity can, to some degree, counter the size differences between countries and regions. The rank of patenting intensity (described as the number of applications per million inhabitants) by region does not coincide with the rank by patent numbers, as some smaller regions move ahead. In most cases, the top patenting regions are those which lead the intensity ranking, but several changes can be seen. For example, the rank of Poland among the EU-27 is 14 by number of patent applications and 24 by patent intensity. Estonia is ranked 24 by number and 20 by intensity.

Citation linkages: CEECs collaborating and embedding

Research has become a co-operative endeavour, often involving a large number of institutions (within the sector and between sectors), such as government research stations, universities, corporate in-house R&D laboratories and international partners.

There are several approaches to assessing national, regional, sub-regional and international partnerships and their level of embeddedness. This paper employs various citation indices (citing, cited and citing/cited pairs) to observe the performances and linkages of CEE regions, the roles of their universities and public research institutes, and their links. Citations are references to prior art in patent documents, and may be made by the examiner or by the applicant/inventor (Meyer, 2000). These actors compile a list of references which are believed to be relevant prior art and which may have contributed to defining the scope of the claims of the application. References can be made to other patents, technical journals, textbooks, handbooks and other sources. There is great analytical potential in comparing the source items of both sides – the citing and cited sides – of the citation link. Persson (2006), for instance, has used citation links relating to the publication of papers. A similar approach may be employed to analyse patent citation (citing/cited) linkages.[11]

Citation linkages

Analysing citation relationships highlights the intellectual linkages among countries, sub-regions and organisations. It also offers a picture of the diffusion of knowledge and the knowledge-producing/dissemination capabilities of organisations. In the databank employed in this paper, the citing patents' data are EPO patents applications made since 1990, published before the end of 2007, and having at least one applicant from the EU-27. The cited patents can be from any patent office from any year. The cited non-patent references have a stricter constraint on the priority year of the citing patent, which is between 1996 and 2005. Each patent is duplicated for every applicant, inventor and applicant/affiliation of the university references.

Technology outputs and technology-related outputs of universities can be measured as their patent production (as applicant and/or inventor). The cited patent databank focuses on university-related patents as well as university publications cited in patents. There are 15,433 unique EPO patents having university references, and 171 have no named inventor. There are 20,714 unique EPO patents and university references, which are, therefore, included in this databank. The indicators on citing, cited and citing/cited pairs were developed from applicant and inventor addresses, located by country and by sub-region. Quite naturally, the most citing countries are also the most active patenting countries. It is not surprising that the CEECs' position in citing/cited activities in publications is very similar to their patent performance. Among the EU-27, the citing and cited country position of these countries is very low. As Table 3 clearly shows, CEECs as citing countries represent 0.9% of the EU-27 by inventor, and 0.4% by applicant.

Table 3. Total numbers of counted publications as citing/cited countries, 1996–2005.

	Citing countries		Cited countries	
Countries	**By applicants**	**By inventors**	**By applicants**	**By inventors**
EU-27	12147	11923	3724	3951
EU-17	12094	11815	3614	3840
CEECs	53	108	110	111

EU: European Union; CEECs: Central and East European Countries. Source: Author's compilation from background table of Ranga, Inzelt *et al.*, 2009.

From the perspective of the citing country, the publication count is slightly higher by applicant than by inventor for the EU-17 (2%), while CEECs show the opposite tendency. When counted by inventor, the number of patent publications is twice that by applicant, a trend which is consistent across the CEE as citing countries. From the perspective of the cited country, the publication count by inventor is slightly higher for each group of countries. The number of citations by European citing and cited countries highlights the fact that, although CEECs have very similar statistics by inventor, their citing country position is less than half their cited country position by applicant. These proportions are very different from those of the EU-17, a finding that requires further investigation if we are to draw any serious conclusions.

Within the CEEC group, three countries (the Czech Republic, Poland and Hungary) represent 72% of the publications counted by applicant and 68% by inventor. The relatively strong presence of these countries in patent filing might be an inheritance from their recent socialist past. Examples might include their established structure of disciplines, the existence of patenting-related businesses, and the presence a patenting tradition. When measured against the EU-27, these three high-performing countries have publication levels of 0.3% by applicant and 0.6% by inventor, which means that they perform well only inside the group of CEECs. The degree of internal and external citations of CEECs shows their participation in knowledge flows and linkages. The citation linkage pattern by region is very similar by applicant and inventor, although the number of publications counted shows differences similar to the average (Table 4).

Europe as a whole is characterised by a relatively low intensity of citation among member states. This is because of the relatively low patent output of certain CEE countries and southern Europe. However, the relatively low level of intra-ERA citation to the citation of US documents in EU patents cannot be explained only by the weaker patenting of European countries. North America is the most important cited region (except for Lithuania, which has a very low citing rate), while the second most important cited region is the EU-17. The other large regions are much less

Table 4. Frequency of citations of Central and East European countries (CEECs) by large regions, 1996–2005 (inventors).

		Cited country or large region							
Citing country	**Self-citation**	**North America**	**EU-17**	**Other European**	**Others**	**Other CEECs**	**Japan**	**Total**
Rank	5	1	2	3–4	3–4	6–7	6–7	
1) Czech Republic	1	14	8	1	3	1	1	29
2) Poland	2	13	6	2	2	-	-	25
3) Hungary	-	15	4	-	1	-	-	20
4) Slovakia	-	7	2	-	-	-	-	9
(5–6) Romania	-	4	2	-	-	-	-	6
(5–6) Estonia	-	3	2	1	-	-	-	6
(7) Slovenia	-	3	1	-	-	-	-	4
(8–10) Latvia	-	2	-	1	-	-	-	3
(8–10) Lithuania	-	-	2	1	-	-	-	3
(8–10) Bulgaria	-	2	1	-	-	-	-	3
Total	**3**	**63**	**28**	**6**	**6**	**1**	**1**	**108**

Source: Author's compilation from background to Ranga, Inzelt *et al.*, 2009.

important. It is noteworthy that not all of the EU-17 countries are cited; the most important cited countries are Germany, the UK and Belgium. There is only one CEEC region (Mazovieckie in Poland) among those cited by four regions from the Czech Republic. Although the citing performance of these countries is very limited, it may be considered a sign of slow progress from isolation towards ERA performance networking. Intellectual linkages are still weak both within CEECs and between CEECs and the EU-17.

CEECs in the citations

It is also worth looking at the other side of the coin; that is, how is knowledge produced by CEECs cited in patent documents? Which countries and large regions are paying the most attention to CEE universities and research organisations, and who is citing them? CEE scientific products are cited by the EU-17 in roughly 100 cases, either by applicant or by inventor (Ranga, Inzelt *et al.*, 2009). The most cited country is the Czech Republic (36), followed by the largest CEE country, Poland (32), while Hungary (11) is third and lags far behind. All others have less than 10 citations. Poland, the Czech Republic and Hungary are the most cited countries not only by number of citations, but also by number of citing countries. At the other end of the rank are Bulgaria, Latvia and Lithuania, which are cited only once, by one country.

Citation linkages of the CEE sub-regions

Country-level data clearly show that CEECs play a minuscule role in citing/cited publications in patent documents. However, an analysis at the regional level allows us to identify the more influential regions in this group of countries. Classifying the CEE regions by their citing and/or cited performances may give an overview of the presence and absence of CEE regions on the patent literature map. A region is shown on the map if it had one 'hit' as having a useful publication for patents.

Of 54 CEE regions, 24 are among the European regions cited. All the CEE regions cited are low cited compared with those of the EU-17. The number of cited publications lies between 23 and 190 among the top-ranking 50 European regions. Except for Praha (Prague), all other CEE regions are far below Europe's highly cited regions. Praha, as the most-cited region (ranked 35th), had 36 hits by application and 59 by inventor. For cited publications in patents, Praha has almost 20% of the corresponding figure for the top region, the Vlaams-Brabant province in Belgium. Even if the citation level is low in CEECs, the regional concentration is strong in the mid-sized countries. The citing/cited differences among CEE regions are striking. Only five regions (four of these central regions in their own countries) are embedded in international circulation; 11 other regions are on the track towards active participating and 21 are on the periphery of embedding. The remaining 17 regions are some distance from where knowledge is circulating.[12]

To summarise briefly the results from 54 CEE NUTS2 regions, 20 show citing by inventors (only eight by applicants).[13] Besides the low-performing regions, there are also a goodly number of untouched regions in Poland, Romania, Hungary and Bulgaria. Of 30 non-cited CEE regions, 13 are citing, but 17 are untouched by citing/cited activities. There are various reasons for these differences as many factors influence patent citation – the economic orientation of the region, the type of HE institutions and the quality of research. Relatively isolated research organisations are always less likely to be cited than networked organisations. Citing activity also depends on access to knowledge.

The ratio of R&D personnel to employees in a region is an important factor not only in producing knowledge that is cited by others, but also in citing knowledge that is produced by the region. According to the Pearson correlation coefficient, the correlation between the fraction of R&D personnel and the citing index is 0.63 (more than satisfactory, but not very strong). This may be interpreted as indicating that while the number of R&D personnel is important in knowledge absorption, other factors (internationalisation, networking, openness of access to outside knowledge) also play a role. In respect of knowledge production capabilities, when measuring by cited patents the Pearson correlation coefficient index is higher (0.79), indicating that the correlation between fractions of R&D personnel and cited publications is strong.

Cited academic organisations

Taken together, citation hits express the importance of the scientific product, the novelty of technology output and the visibility of these findings. They indicate that the cited organisations and regions are able to find some means of disseminating their knowledge products. Citation hits also mean that the developers and producers of new technology are paying attention to these organisations and regions. Even if the presence of CEECs is almost negligible in citing/cited publications, some CEE academic organisations may appear among top European affiliations ranked by the number of cited/citing publications. There is only one organisation from CEECs in the top 50 cited universities/research organisations, the Ceskoslovenská Akademie, ranked 23rd.[14] There are 43 CEE academic organisations (8%) among the 509 European cited affiliations. Poland has the largest number of listed affiliations (19), followed by Hungary (six), Romania (five) and the Czech Republic (four).

Conclusions

The novel databank used for this study revealed the key characteristics of the recent performance of CEECs. It also allowed us to explore a new perspective on innovation in CEE countries and on knowledge exchange between regions. The analysis highlighted the relevance for policy-making of investigating further the connections between the production and exploitation of new knowledge in order to identify whether knowledge producers and users are separated in space by globally open innovation system. Framing regional policies, the TH mode can contribute to nurturing regional innovation organisers. Universities are not the sole candidates for this function. However, the transformation of HE institutes, regaining their right to engage in basic research and doctoral training, has created new opportunities for universities to function as regional innovation organisers. Certainly, performing this function is time consuming, and requires both inventive and entrepreneurial skills.

The CEEC now have modern legislative and administrative structures, as well as well-functioning patent laws. Establishing new legal frameworks to break out of the historical trap of the sovietised countries was essential. However, new IPRs and regulations are only one part of the transformation. The other, much more time-consuming, task is to build up patent awareness at universities among professors and students as potential inventors, to set up competent technology transfer organisations, and to change the old habits and behaviour of the actors. At all levels of patenting, professional skills are still generally insufficient as a result of several decades of being detached from market-economy IPR systems, and this is still affecting the patent performance of CEECs. Patent indicators illustrate the invention-producing capabilities of these countries, their patenting culture and their ability to patent inventions.

Undoubtedly, there is an enormous gap in patent-production capabilities between the CEE regions and leading patenting countries and regions in the EU. All types of patent data clearly show major differences among the various ERA countries and regions. A low level of patent activity is clearly visible in most CEECs and their regions. The patenting patterns reflect the industrial and technological advance of these countries and their specialisations. The structures of R&D investment and R&D organisations still differ from those in the old member states. Innovation habits and innovation performance are both causes and consequences of low patent intensities in these countries. The presence and role of foreign investors in CEECs explain the differences in inventor–applicant indices, but do not explain the gap between old and new member states in patent inventor intensity.

For the transition economies, domestic invention and foreign ownership of patents are important signs of collaboration in the global open innovation system. Inventor–applicant relationships contribute to the evaluation of domestic innovation capabilities and FDI-related international research, development and innovation (RDI) linkages. The position of countries or regions is different if patents are counted by inventor or applicant country. CEECs have a better position in international ranking as inventors than as applicants. It also seems that the penetration of FDI in CEECs has resulted in a strong headquarters phenomenon, which characterises not only the foreign-owned companies, but also the relationship between these and public research organisations.

Embeddedness is a delicate issue for transition economies. One of the important features inherited from the former centrally planned economies, which were closed economies, was that their knowledge-producing organisations were somehow isolated in the bipolar world system. Some benefits have been gained through the opening of these countries, and through national and EU programmes, but it is a very long journey to achieve integration into the networks – although the citing performance of CEECs is very limited, and this may be a sign of slow progress from isolation towards ERA networking. Intellectual linkages are still weak both inside CEECs and between CEECs and the EU-17. CEE publications cited by EU-17 countries suggest that the Europeanisation process has a positive effect in exploiting CEEC-produced knowledge for the advancement of Europe. CEE publications are becoming more visible, at least inside the EU-17.

The citation pattern clearly shows the importance of outside knowledge for CEE countries. Citing–cited linkages in terms of self-citation and highly localised citation indicate weak scientific impulses from the immediate environment to patenting activities. Very low self-citation may be indicative of not only low knowledge production capabilities, but also of weak knowledge dissemination and absorption capabilities. The latter may have a negative impact on the former. Another reason might be the slow emergence from isolation caused by obstacles to entry into existing networks. Greater embeddedness could strengthen further knowledge production capabilities through interaction and cross-fertilisation.

We can only speculate about whether the knowledge production capabilities of these countries are stronger than their knowledge absorption capabilities, and whether inventor capabilities are better than their knowledge management counterparts. How will EU RDI programmes and knowledge demand from current MNCs influence discipline structure and the international filing of patents over time? On the basis of this study, the conclusion must be that existing TH models in CEECs and in their regions are still unbalanced, and that many regions have scarcely been touched.

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Notes

1. The database was developed for a study commissioned by the European Commission Institute for Prospective Technological Studies (ECIPTS) (contract 150176-2005-F1SC-BE), *Production of Data to Analyse University References Found in Patent Documents by Geographic Origin* by the Erawatch Network. The aim of this study was to produce data on the relations among the components of the European Research Area (ERA), with special focus on the links between universities and other actors.
2. We refer to the CEEC-10 in this short form as meaning either the CEE area or the countries themselves. The CEEC-10 are: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The two other new member states, Cyprus and Malta, are non-transition economies, never having undergone the Soviet experience. They are also, of course, outside the CEE geographical area.
3. The separation of scientific research, education and teaching was never as pronounced in Poland as in other countries, as the Polish Academy did not have the monopoly status of academies in other countries.
4. A better translation for 'certificate of authorship' would be 'inventor's certificate'.
5. The Soviet Union invaded the Baltic countries in 1940, but one year later Germany occupied them. The Soviet Union reoccupied the Baltic States in 1944, and so the constitutional metamorphosis, the sovietisation of the system, started at the end of the war.
6. These countries established and/or renewed their legal institutions. It was also crucial to accumulate experience and qualified specialists through training and retraining of R&D managers, managers of liaison offices, IPR specialists and patent attorneys. The European Union had a special programme for transition economies relating to the IPR regime (Inzelt *et al.*, 1996).
7. The databank used in this paper is based on an ECIPTS contracted study, and was produced by three organisations: Managerial Economics, Strategy and Innovation, Faculty of Economics and Applied Economics, KU Leuven; the research division of Incentim; and Steunpunt O&O Statistieken. Methodological details are presented in Lecocq *et al.*, 2008.
8. The EU-27 comprises all the EU member states between 2007 and 2013. The EU-17 is the old EU-15 member states and two new member states, Malta and Cyprus, that are not transition economies.
9. Comparison between EU old and new member states is based on Ranga, Inzelt *et al.* (2009) and Ranga, Looy *et al*. (2009).
10. NUTS stands for Nomenclature of Territorial Units for Statistics in the EU. NUTS classification is a hierarchical system for dividing the territories of the EU for a variety of economic categorisation purposes.
11. Another analytical option is to use patent citation relationships for building interactive overlay maps, as is done by Leydesdorff *et al.* (2014).
12. Analysing regional R&D activities in Swedish Triple Helix practice, Danell and Persson (2003) also observed significant performance differences among regions. The

domination of the main (Swedish) urban areas remained strong despite decentralisation of the academic system. The main urban areas have been performing better in patenting and citation activities, and there are better balances among the three sectors of the TH model. The main problematic difference is the frequency of internationally well-embedded regions between CEECs and Sweden.

13. Although Slovenia is divided into two NUTS2 regions, related data are frequently available only at the country level. In our databank, Slovenian data are available only at the country level as a citing country (NUTS level-1, S10 Slovenia). When Slovenia is the country cited, data are divided into two NUTS2 regions (S101 Vzhodna Slovenija and S102 Zahodna Slovenija).
14. The name of this organisation is an old one which existed before Czechoslovakia was divided into the Czech Republic (and Czech Academy) and Slovakia (Slovak Academy). As the first reference year is 1996 (priority year), the past performance of affiliation during the socialist period and the transition period in patenting activities/opportunities may influence these data. Other information is crucial to evaluate the real value of the data.

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