Working Paper Series
GRINCOH
Growth-Innovation-Competitiveness
Fostering Cohesion in Central and Eastern Europe

Serie 3
Knowledge, Innovation, Technology

Paper No. 3.06

Running faster or measuring better? How is the R&D sector in Central and Eastern Europe catching up with Western Europe?

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2015

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This paper was funded under the FP7 project "Growth– Innovation – Competitiveness: Fostering Cohesion in Central and Eastern Europe (GRINCOH)" under the Programme SSH.2011.2.2-1: Addressing cohesion challenges in Central and Eastern Europe; Area 8.2.2 Regional, territorial and social cohesion. Project Nr. 290657

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Please cite as:
Płoszaj A., Olechnicka A, (2015), 'Running faster or measuring better? How is the R&D sector in Central and Eastern Europe catching up with Western Europe?', GRINCOH Working Paper Series, Paper No. 3.06

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Abstract

This paper explores the development of the science sector in Central and Eastern European (CEE) countries and convergence with 'old' European Union countries. The aim is to better understand the observed development processes in the science sector in CEE by the use of data concerning research outcomes in the form of articles indexed in the Web of Science (WoS) database. The Authors put forward the hypothesis that changes in the list of journals, particularly in the number of periodicals published in specific CEE countries, have a significant impact on bibliometric indicators and, consequently, on the convergence levels they are used to measure.

The analyses presented in the article support the argument that countries from Central and Eastern Europe, despite showing fairly consistent convergence trends, achieve noticeably weaker results than Western Europe in terms of research and development and scientific activity. The evident impact made by inclusion of numerous CEE journals in WoS on the values of the indicator analysed, directly supports the hypothesis put forward in this article. The results of the study are important because data on the number of publications and citations in the Web of Science are increasingly used as development indicators of national R&D sectors. By showing how modifications in these databases influence the results obtained, we can better understand and thus make better use of data from these sources. The article concludes with listing the possibilities for furthering and deepening selected themes pointed out in the paper.

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Introduction

Central-Eastern Europe (CEE) is often portrayed in contrast to Western Europe. Due to a wide variety of economic, social, institutional and historical factors, this region exhibits a lower level of socio-economic development, lower levels of innovation as well as a less advanced information society (etc.). The successive entry of CEE countries to the European Union (EU) and their adoption of cohesion policy instruments brought positive economic consequences. As stated in the Sixth Report on economic, social and territorial cohesion: "*Between 2000 and 2011, all the regions in the central and eastern Member States recorded an increase in GDP per head in PPS relative to the EU average*" (EC 2014b, p. 5).Thus, in the case of CEE countries, we can talk about economic convergence on a European level. Statistics given in the report show that the crisis caused a slow-down in these processes from 2009, yet this is taken to be of a transitional nature, and the convergence process is expected to continue. This optimistic picture of convergence on the European scale is undermined by the internal divergence that can be observed within countries – that is, the increasing difference among regions of CEE countries (Smetkowski, Wojcik 2012). A deepening internal divergence could lead to a slow-down in convergence processes on the European scale, although so far the increased development gap among countries has been attributed to the economic crisis of recent years (Kozak 2014).

One of the elements allowing CEE countries to catch up with Western Europe in socio-economic terms is the development of science and innovation. In this area CEE countries stand out visibly from their western neighbours, although even here we can observe a (slow) process of convergence (Vinkler 2008; Must 2006; EC 2014a; Abbott, Schiermeier 2014; Radosevic, Yoruk 2014; Kozak, Bornmanz, Leydesdorff 2015). On one hand, this is the consequence of economic growth, and on the other it is the result of EU policy and closely related national policies. We would expect that incorporating CEE countries into EU structures and thereby allowing them to make use of EU instruments to support science sector development, including Framework Programme grants, should help reduce the distance dividing CEE from Western Europe in terms of both expenditure as well as research outcomes, including the number of articles and citations.

Grounds for analysis, aim and hypothesis

The development of the science sector in CEE countries and, in consequence, convergence with 'old' EU countries is unquestionable (although the rate of this convergence, particularly in terms of development policy, is still unsatisfactory) and is easy to elaborate (open borders, ease of cooperation, substantial EU funds available for supporting research work and innovation in new member states). Why, then, it is worth paying further attention to this issue? Firstly, because the decisive majority of analyses in this area are based on widely available statistical data, while in this article, we draw on seldom used data concerning research outcomes in the form of research articles indexed in the Web of Science (WoS) database. WoS is a bibliographic database containing bibliographic descriptions and indexes of citations from scientific publications. This database is one of the products created and made available by the Institute of Scientific Information, a commercial research institute that is part of the Thomson Reuters Corporation. WoS, from among many databases of this kind, boasts extensive coverage, with a total file count of 90 million records, which includes over a billion cited references[1]. For the purposes of this study, data on research articles

[1] http://wokinfo.com/citationconnection/realfacts/#regional, access: 14.01.15.

derived from WoS has been elaborated to show not only the number of publications in specific years, but also their citations, language, country of publication of the journal in which they appear as well as declared international collaboration with authors from various countries. The presentation of data from different perspectives allows for a better understanding of the dynamics of emerging processes in the science sector in CEE and to differentiate among countries in the region.

Secondly – and most more importantly – our analysis serves to show a phenomenon that has up till now been largely overlooked: the way in which modifications to the coverage of bibliometric databases influence observable trends, in our case the process of scientific convergence of CEE countries with Western Europe. In order to conduct such an analysis, we make use of detailed data from the Web of Science database. The usual analyses conducted are based on the overall number of articles attributed to a given country. From this angle, the growth and convergence of CEE countries are as clear as day. However, this approach ignores the fact that the list of journals in the WoS database is not permanent but, quite the contrary, changes significantly in some periods. We put forward the hypothesis that changes in the list of journals, particularly in the number of periodicals published in specific CEE countries, have a significant impact on bibliometric indicators and, consequently, on the convergence levels they are used to measure. In a broader sense, our analysis aims to show that observed trends in scientific output sometimes result not only from intensified research activity, but may also be the effect of elements being accounted for which were not previously included, in short, they derive from more precise (or simply different) measures. This viewpoint is also important because data on the number of publications and citations in the Web of Science are increasingly used as development indicators of national R&D sectors (EC 2014a). By showing how modifications in these databases influence the results obtained, we can better understand and thus make better use of data from these sources.

Data

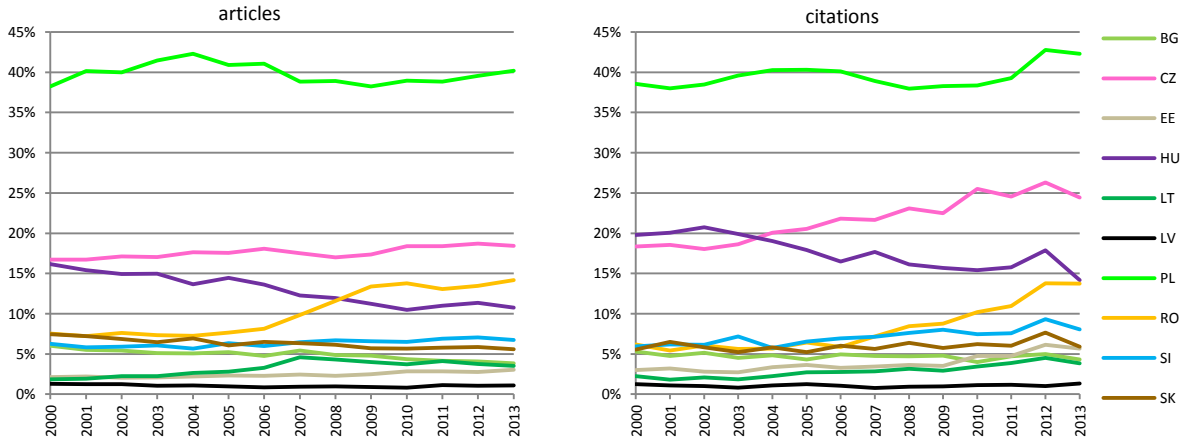
The spatial scope of the study was defined as the ten countries of Central and Eastern Europe (EU10) which acceded to the EU as part of expansion in 2004 and 2007. These are: the Czech Republic, Estonia, Lithuania, Latvia, Poland, Slovakia, Slovenia, Hungary, Bulgaria and Romania. In the article their situation is outlined against the background of the so-called 'old' member states, also referred to as 'the fifteen' (EU15) as well as in reference to the situation of the whole European Union (EU27, i.e. without Croatia that entered the EU on 1 July 2013).

In the study, alongside widely available data concerning expenditure and employment in research and development, bibliometric data was used that was generated from the Web of Science database. Detailed data, on the level of individual articles, was retrieved from the database in June 2014. The sample created from this source contains in total 547,050 articles affiliated to Central and Eastern Europe (EU10) published in the years 2000-2013. These constitute 10.9% of articles affiliated to EU27 countries (5,034,893).

The EU10 group of countries is very diverse in terms of the size and structure of publication output due to the disparate sizes of individual economies as well as the specificity of their scientific sectors. Almost 40% of all the publications in the region published in the years 2000-2013 are affiliated to Poland (217,288), 18% in the Czech Republic (97,012) 13% in Hungary (68,713) and 11% in Romania (59,175). It is interesting that the share of the Czech Republic and Hungary in the EU15 citation pool is higher than in the publication pool, which is the reverse in the case of Romania. This means that

the publications affiliated to this country are cited much less often. For our analysis it is important that the dominant role of Polish publications in the publication output and citations of the EU10 means that processes affecting Poland determine the results obtained for the whole group of CEE countries.

Figure 1. Countries' share in articles and citations of EU10



Source: own study based on data from the Web of Science.

The share of individual countries in the joint publication output of CEE countries hardly changed during the analysed period; the greatest change took place in Hungary, whose share fell from 16% in 2000 to 11% in 2013, as well as Romania, where there was a four-fold increase in the number of articles, and whose share rose from 8% to 14% in the study period. Meanwhile, Romania came in third place among the EU10 in terms of its share in the general publication pool. Only Lithuania noted a higher uninterrupted growth in the number of articles affiliated there, although due to the small scale this did not translate into a spectacular rise in its share in EU10 output (by 2 pp.) (Figure 1).

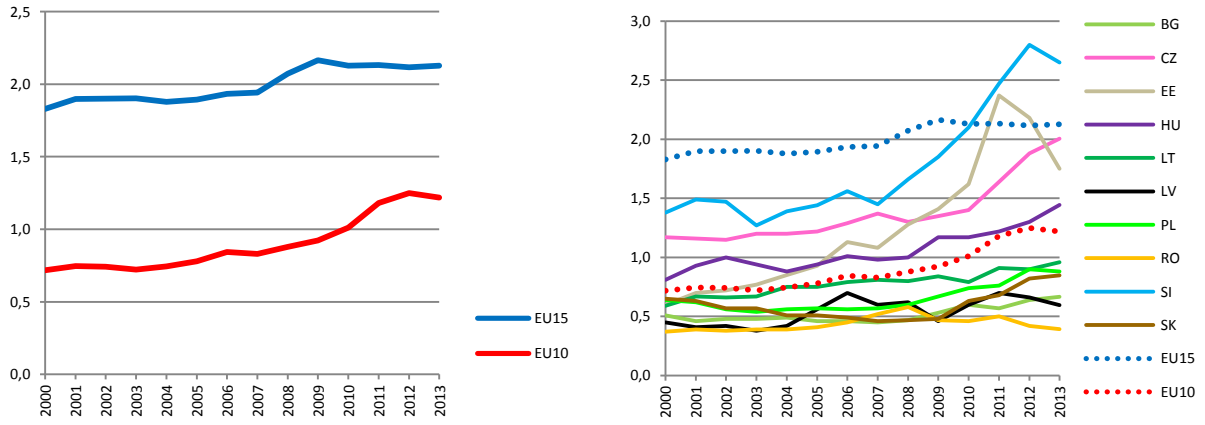
Results

Expenditure on R&D and employment in R&D

Convergence of the scientific systems of the EU10 and EU15 is visible in terms of expenditure as well as outcomes of R&D activity. The basic indicators which can be traced in this respect are the level of expenditure on R&D with reference to GDP as well as the indicator of employment in R&D relative to population size.

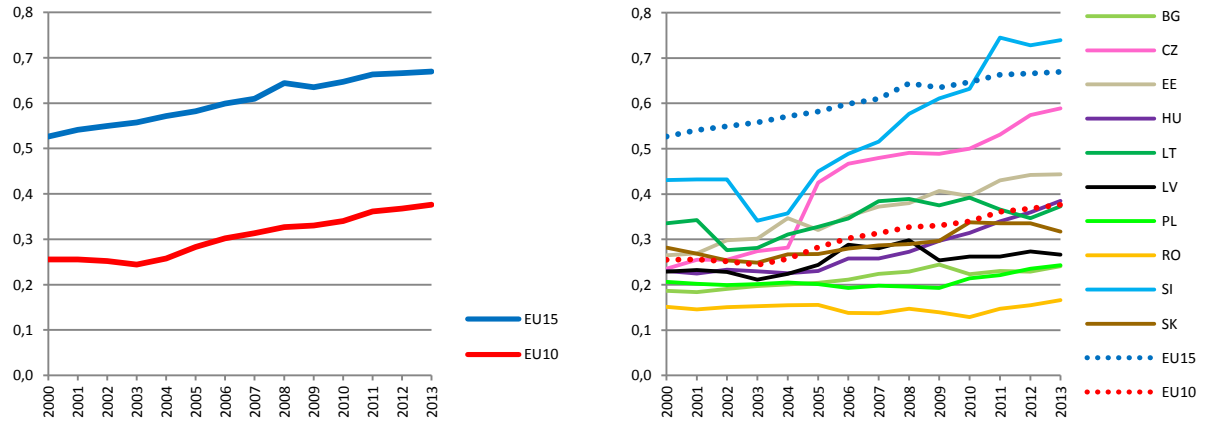
Data on R&D expenditure and employment lead us to several conclusions. Firstly, in the years 2000-2013 both groups of countries display an increase in expenditure on R&D measured in relation to GDP as well as a growth in the indicator of employment in science in relation to population size. Interestingly, during the crisis period (starting in 2009), there was no fall in the level of investment in research and development in relation to GDP; quite the contrary, a growth in the value of this indicator was noted (Figure 2, Figure 3).

Figure 2. GERD as % of GDP



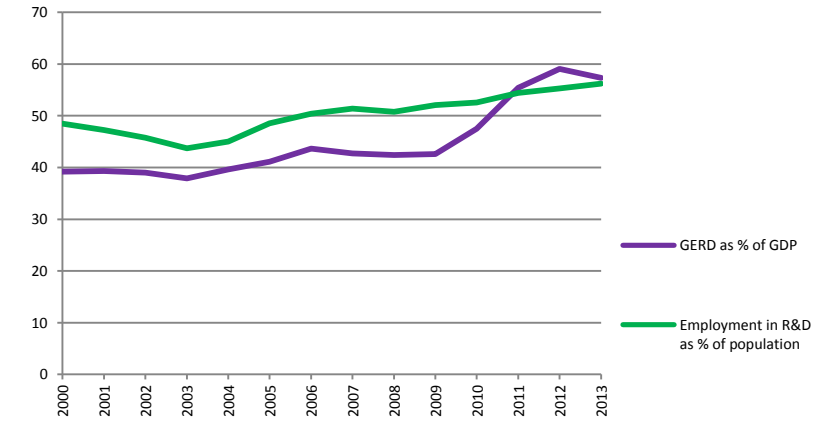
Source: own study based on data from the Web of Science.

Figure 3. Employment in R&D as % of population



Source: own study based on data from the Web of Science.

Figure 4. GERD in % of GDP and Employment in R&D as % of population in EU10 in relation to EU15 (EU15=100)



Source: own study based on data from the Web of Science.

Secondly, there are important differences among the EU10 countries. In recent years, Slovenia and Estonia achieved a level of expenditure exceeding the EU15 average. In the former country this was a

permanent upward trend as from 2011, while in the latter nation, spectacular growth in the years 2010-2012 was followed by a dramatic drop in value of the said indicator. Besides the above mentioned countries, only the Czech Republic and Hungary achieved a level of expenditure exceeding the EU10 average. Slovenia confirmed its strong position equally in terms of employment in R&D – after 2011 this indicator reached levels exceeding the EU15 average. However, the Czech Republic, Estonia and Lithuania noted higher levels of employment in R&D than the EU10 average in the study period. Romania and Bulgaria are in the weakest position in this respect, and Poland is marked out by weak values for this indicator in relation to its population size (Figure 2, Figure 3).

Thirdly, as we might have anticipated, the gap in values for expenditure and employment between CEE countries and the 'fifteen' is significant. In 2000, expenditure on R&D as % GDP in the EU10 came to only 39% of that in the EU15, rising to 57% in 2013. Meanwhile, employment taken as % inhabitants in EU10 countries was 48% in 2000, rising to 56% at the end of the study period. All things considered, despite the significant disproportion between the EU10 and EU15, a visible convergence of results can be seen to take place on the European scale (Figure 4). More and more resources in the science sector can contribute to subsequent growth in the scientific output of CEE countries (Vinkler 2008; Lin, Chen, Yang 2014).

Journals published in CEE

The Web of Science does not include all scientific articles published worldwide. It contains only articles from selected journals. In principle, the choice of journals is meant to be content-based – the intention is to include the most prominent (the best) periodicals. However, other factors also play a role. One of these is the desire to achieve a spatially balanced database, by including journals that are not only important on the world scale, but also those whose scope is more regional (i.e. a group of countries) or even national (Testa 2011). This approach is particularly important in the case of periodicals in the field of social science and humanities, as the research problems they deal with are often of a national, linguistic or even local nature. However, journals relating to the exact sciences which are clearly of a national character (supported by the fact that they are published in non-congress languages) can also be included in WoS, such as the journal "Przemysł Chemiczny" (Chemical Industry) which is published in Poland and mostly in the Polish language (there is a fraction of articles in English).

Inclusion in the database is not indefinite. If a journal does not fulfil the criteria determined by WoS, it is simply removed. The criteria include formal requirements (e.g. regular issue) as well as content requirements (a suitably high Impact Factor)[2]. When a given journal is removed from the index, the 'space' becomes available to new titles. The scope for considering new titles depends both on the engagement of publishers who apply for entry, as well as of the database administrators who, apart from respecting the overriding principle of listing the most important journals, must to some extent be guided by business sense. We should also remember, that WoS is a commercial product, and its creators (owners) are guided by economic outcomes. It follows that, in aiming to include journals from different countries (markets), we can perceive that WoS does not only strive to provide an adequate representation of the diversity of worldwide research, but also seeks to reach new potential clients. Moreover, an important question remains unanswered as to whether the Thomson

[2] http://wokinfo.com/essays/journal-selection-process/, access: 14.01.15.

Reuters' selection criteria are consistent and rigorous or whether some countries are favoured and overrepresented in WoS (Kosanovic and Sipka 2013).

In recent years we have witnessed a fairly important expansion in the spatial range of the WoS database. This growth has been markedly more intense than in previous decades. In the years 1980-1990, the number of journals in the database rose from 6130 by 654 titles (10.7%) In the decade 1990-2000, a further 1444 journals were added (21.3%). In the years 2000-2010 the increase was visibly steeper: in 2000 there were 8228 titles, and as many as 11793 in 2010. The increase of 3511 journals meant that the list of titles grew by 42.7%. This radical expansion of the database is described by Thomson Reuters as "The Globalization of the Web of Science" (Testa 2011). Apart from the routine analysis of journals for inclusion in the database – in recent years around 2.5 thousand applications annually, of which around 10% are accepted – in the years 2007-2009 action was undertaken to increase the database's representation of journals outside the 'centre' of world research:

> *[…] from 2007 to 2009 the Editorial Development Department at Thomson Reuters focused on a collection of more than 10,000 regional journals (these are journals published outside the US or UK that contain the scholarship of authors from a particular region or country, and cover topics of regional interest or topics studied from a regional perspective). Sixteen hundred (1,600) of these 10,000 journals met Thomson Reuters standards and were selected for coverage* (Testa 2011, p. 2)

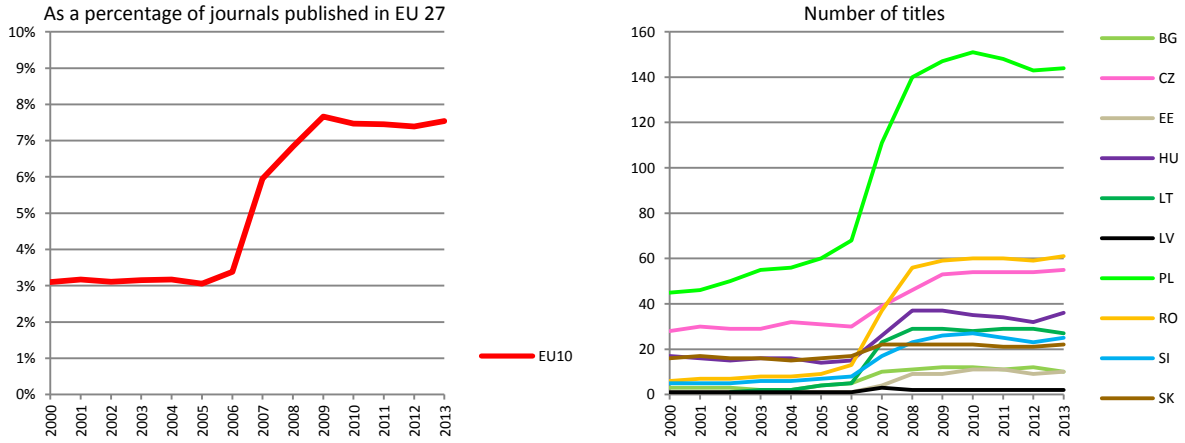
In consequence the number of journals published in some countries and listed in WoS grew significantly between 2005 and 2010. The steepest growth in absolute numbers was recorded in: Spain (112 new titles; growth of 207%), Brazil (105; 389%), Australia (97; 105%), Poland (85; 149%), Turkey (68; 971%), Italy (68; 56%), France (62; 28%), China (62; 75%), South Korea (62; 168%), Japan (61; 35%), India (60; 113%), Romania (52; 650%), Croatia (47; 336%), South Africa (41; 152%) (Testa 2011, p. 4).The increase in the number of journals naturally leads to an increased number of indexed articles in WoS. This should be remembered when performing time analyses. The growth in the number of articles are, after all, not only the result of increased research activity, but also the effect of more extensive monitoring of scientific production - in this case, the greater number of journals included in WoS.

The greater openness of WoS to journals outside the global research centre is clearly visible in Central and Eastern Europe. In the years 2000-2006 published titles in CEE constituted barely more than 3% of all journals published in the entire EU27. As a consequence of the database's expansion, in the years 2007-2009 this percentage rose by around 3.5% and in subsequent years (2010-2013) maintained a level of around 7.5% (see Figure 5, left).This growth in the number of journals affected all the CEE countries analysed (see Figure 5, right), although the scale varied due partly to the size of country as well as to the number of journals from a given country that were listed in WoS before the 'global expansion' of 2007-2009. When we compare figures for 2000 and 2013, the greatest growth in journal numbers in WoS was noted in Romania and Estonia – where the number of titles increased 10-fold. To a large extent this results from the low starting point (i.e. a low number of journals from these countries in 2000). A spectacular 5-fold increase was recorded in Slovenia. In the case of Poland and Bulgaria, growth was just over 3-fold. Meanwhile Poland is the clear leader in the group of countries analysed in terms of absolute numbers of titles – one in three journals from the EU10 in

the database is a journal published in Poland. Hungary, Lithuania and the Czech Republic doubled the number of journals in WoS and Slovakia increased its share by 40%. Meanwhile, Latvia is a very unusual case, as in 2013 only two journals from this country were present in WoS, and its entire growth is attributed to the addition of just one title in 2007. Another specific case is Lithuania: in the years 2000-2001 not a single journal published in this country appeared in WoS while, as a result of the expansion, as many as 29 titles had been included by the end of the decade.

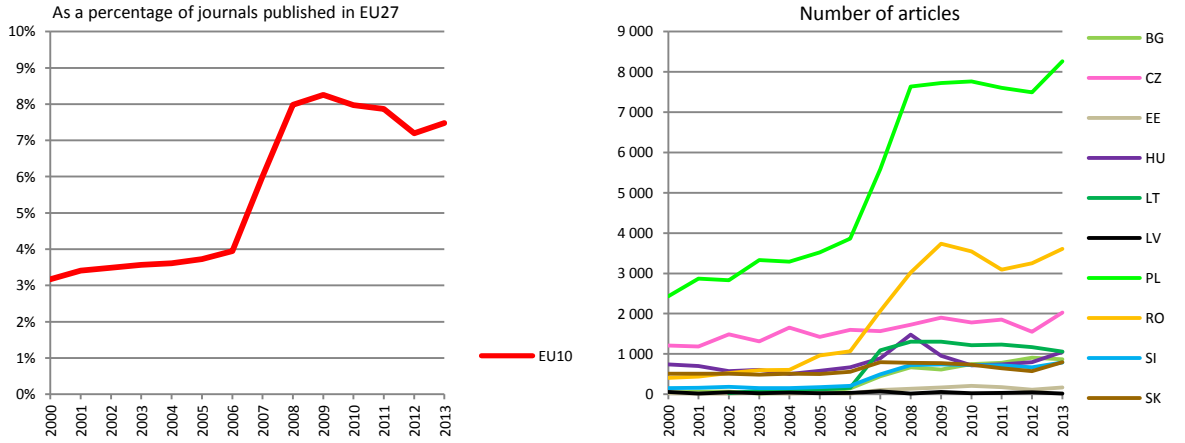
Analysis of the number of articles appearing in journals published in EU10 countries and included in WoS results in a similar picture to that given by analysis of the number of journal titles. Equally in this case, there is a clear leap in the years 2007-2008 (Figure 6).

Figure 5. Articles published in EU10 countries and indexed in WoS



Source: own study based on data from the Web of Science.

Figure 6. Articles in journals published in EU10 countries indexed in WoS

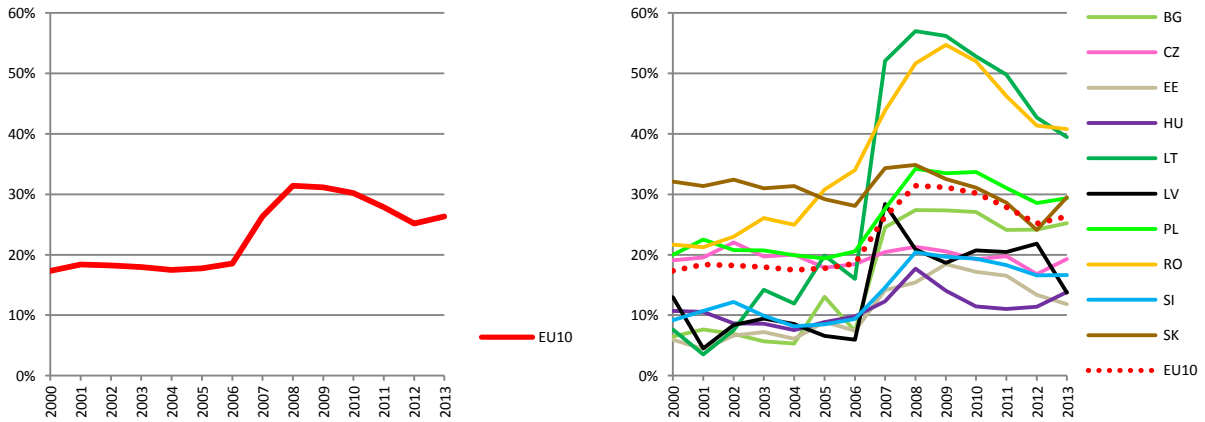


Source: own study based on data from the Web of Science.

One of the effects of including such a large number of national journals in WoS is the noticeable increase in the percentage of articles affiliated to EU10 countries and appearing in journals published by institutions in this part of Europe. In the years 2000-2006 these constituted 17-18% of all articles affiliated to these countries and indexed in WoS. However, in the years 2008-2009 this percentage increased to 31%. Subsequent years saw a fall in numbers and in the years 2012 and 2013 only around one in four articles from the EU10 in WoS came from journals published in this region. Despite this drop, the figure is still higher than a decade earlier. The significance of national journals

in the number of articles is very diverse in CEE. In the case of Lithuania and Romania, in the years directly following the expansion of WoS to include a large number of titles from these countries, more than half the articles in WoS came from journals published in the EU10 (which is almost equal to the number of journals from these countries – it is very rare that articles affiliated to the EU10 appear in journals published in other countries). However, the Czech Republic presents a completely different scenario. In this country, despite the number of journals in WoS doubling, the percentage of articles appearing in journals published in the EU in the years 2000-2013 (this also differs from national journals) remained at a level of 20% (see Figure 7).

Figure 7. Percentage of articles affiliated to EU10 appearing in journals published in EU10



Source: own study based on data from the Web of Science.

The difference in the share of articles appearing in journals published in countries in the region could testify to the differing levels of internationalization of publishing activity. A high percentage of publications in journals of a particular country (region) can be interpreted as indicating a lower level of internationalization in the science sector of this country. Meanwhile, a dominance of articles published in journals outside the country (region) in question indicates a greater presence in international research circles.

Citations

Information on citations from scientific journals are often used to gauge the quality of these publications and/or their impact factor (see Hoekman et al. 2008, van Raan 2004). However, citations are not a perfect measure, as they do not allow for context, that is, they assign weight to a given publication, even if the citation is negative – for example to show misconceptions or incorrect methods. Moreover, the most recent studies are often cited in preference to earlier ones which relate to a given issue (citation amnesia) or overlook studies included in the canon of research because their influence is regarded as obvious (oversight due to incorporation). This measure also fails because studies are produced by large teams of researchers recruited to study new, popular issues (see de Bells N. 2009; Moed 2005; Andrès 2009; Kamińska-Włodarczyk, Siwiec-Kurczab 2003). The weakness of citations is the fact that they are derived from (imperfect) bibliometric databases which do not encompass all citations appearing in all publications worldwide, but only those indexed in a given database. Moreover, in researching citations, we should allow for the time lapse in relation to publication (Schneider 2009; Moed 2005).

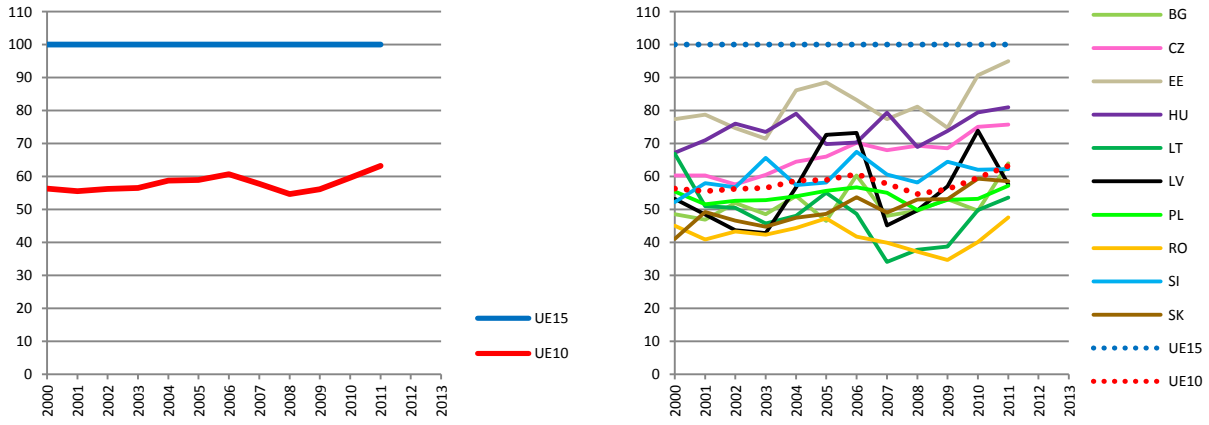
This analysis of 'citability' is based on the normalised citations, that is, the number of citations from articles affiliated to a given country and published in a given year is compared with the average number of citations from articles in the EU15 in that year. This allows us to compare citability over time. This is essential, as information on article citations is obtained at the moment of retrieving data from the WoS database, i.e. mid-2014. Therefore more recent articles have decidedly fewer citations than older articles, not because they are of inferior quality, but above all because the more time passes, the greater likelihood of a larger number of citations. This is also the reason why the data presented here relates to the period 2000-2011 (as opposed to the remaining analyses in this article which relate to the period 2000-2013). Information on article citations where only a short time has lapsed since publication is less reliable than articles published some distance in the past (Research Evaluation and Policy Project 2005). This stems from the fact that usually, from the moment of publication to the moment of citations appearing, at least a few or several months pass, or often even many years[3].

Analyses relativized to the EU27 values for average article citation shows that publications affiliated to EU10 countries are much less frequently cited than those affiliated to the EU15, although this difference can be seen to be lessening over time. The average number of citations per publication affiliated to the EU10 constituted 56.3% of the EU average in 2000, while in 2011, 63.3% - a growth of 6.9 pp. (Figure 8, left). However, as with the number of articles, convergence can be seen to be much stronger when we exclude from the publication sample those titles which were published in CEE countries. The relative increase in normalised citations in the EU10 for this newly defined sample of articles is 16 pp. (from 64.9 in 2000 to 80.9 in 2013) (Figure 8, left). This means that publications which appeared in CEE journals are generally less often cited and the normalised citations of these articles increases on average at a slower rate. This leads us to the practical conclusion that, if researchers from CEE wish to be more frequently cited, they should try to have their work published in journals outside their country and region.

The EU10 group is diverse in terms of the indicators discussed above. In both respects (all articles and only those published outside CEE) values above the EU average are achieved by the Czech Republic, Hungary and Estonia. In 2010 and 2011 this last country exceeded even the EU15 average in the case of articles published in journals outside CEE. Poland and Slovenia noted values close to the EU10 average or slightly below it (although the trend observed in Poland reflects the EU10 average – Poland, as the country with the largest number of articles in the region, has the greatest influence on this average). On the other hand, Romania and Lithuania are countries which fall farthest below the EU10 average (with considerable fluctuation from year to year). The values for Latvia are the most unstable – this is due to the relatively small number of articles affiliated to this country: the fewer articles, the more sensitive the average number of citations to the influence of one or two frequently cited articles (see Figure 8, right; Figure 9, right).

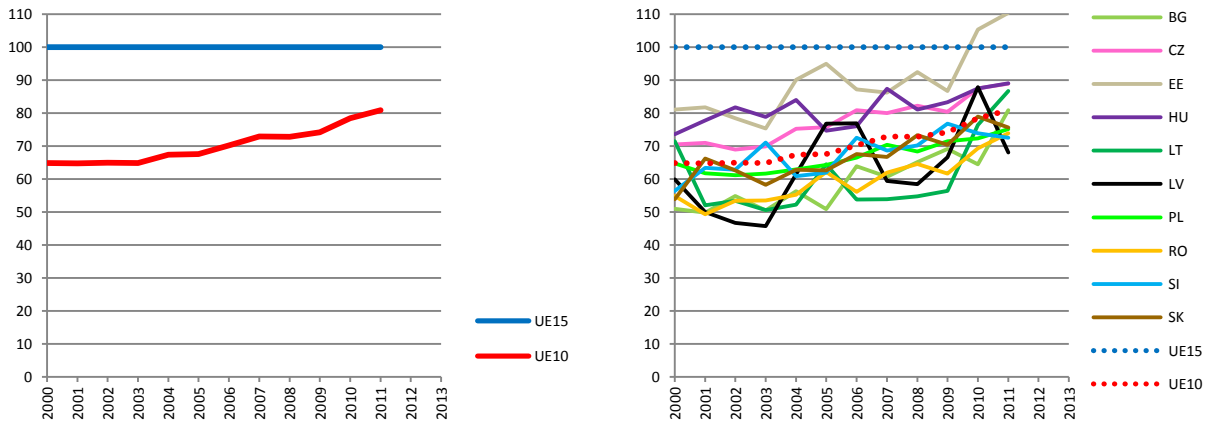
33 In order for an article to be cited it must first be read, then the citation must be included in an article submitted for publication; this is then followed by a review process that may last several months or even years leading to amendment or further review, etc.

Figure 8. Citations per article in EU10 and EU15 in relation to EU27 (UE27=100)– all journals



Source: own study based on data from the Web of Science.

Figure 9. Citations per article in EU10 and EU15 in relation to EU27 (UE27=100) - journals published outside EU10



Source: own study based on data from the Web of Science.

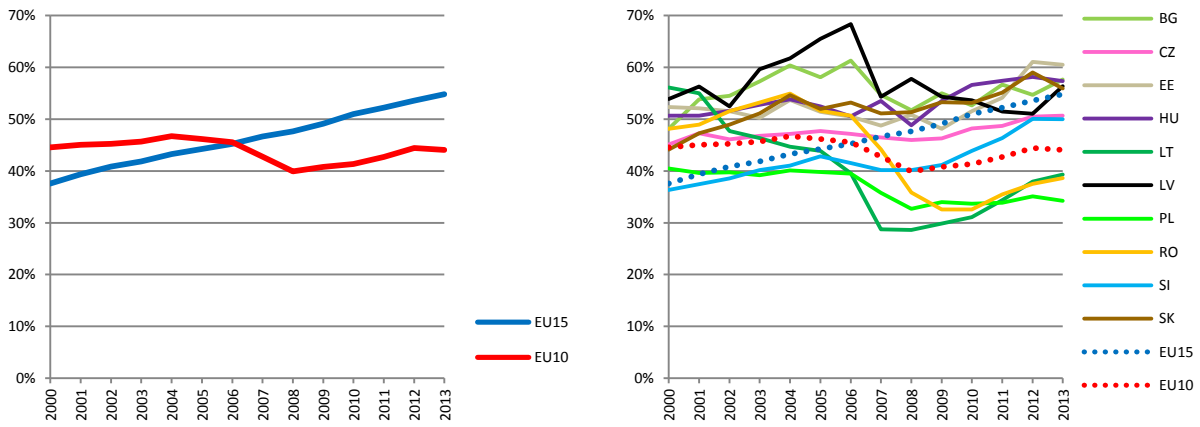
International Collaboration

Modern day science is increasingly globalized. This is evidenced by the growing intensity of international collaboration among researchers from different countries and continents. In terms of scientific publications this has led to a growing number of articles with multiple authors from various institutions and countries (Glänzel, Schubert, Czerwon 1999; Glänzel, Schubert 2004; Wagner, Leydesdorff 2005, Tijssen 2008). A synthetic indicator of the internationalization of publications can be the percentage of articles affiliated to a given country which have at least one foreign author, in the overall number of publications from that country. In 2013 over half the publications from the EU15 were produced in cooperation with co-authors from abroad. Moreover, the value of the discussed indicator has grown in recent years. In 2000, international articles constituted 37.6% of those published in the EU15, while as many as 54.8%in 2013. In this context, Central and Eastern European countries give a different picture. In the years 2000-2006, the share of international articles in the overall publication output of the EU15 maintained a fairly stable level of between 44.5 and 46.7%. In the years 2007-2008 there was a noticeable drop to a level of 40%. In subsequent years the value of this indicator gradually rose, but did not exceed the level of 2000-2006. Thus, despite the fact that in the first half of the analysed period the share of international publications in the EU10

was greater than in the EU15, in subsequent years Western European countries began to noticeably overtake CEE countries in this respect (Figure 10, left).

As with other aspects discussed in this article, the group of CEE countries is diversified in terms of the share of articles with foreign co-authors. In many cases we can also see major changes in the values of this indicator. Generally speaking, we can distinguish three groups of countries. The first group is formed of countries in which the share of international articles in the period 2000-2013 noticeably fell. The steepest drop was noted in Lithuania (-16.9%), while it was slightly less steep in Romania (-9.6%) and in Poland (-6.3%). Finally, at the end of the analysed period, only these three countries had a share of international articles below the EU10 average. The second group constitutes countries with a clear growth in the share of international articles. The most spectacular growth was witnessed in Slovenia (13.7 pp) and Slovakia (11.8 pp).Significant growth could also be observed in Bulgaria (9.5 pp), Estonia (8.2 pp), Hungary (6.7 pp), as well as in the Czech Republic (5.6 pp). A distinct case is represented by Latvia, in which the indicator began to rise dramatically, from 53.9% in 2000 to 68.3%, and then subsequently fell dramatically. Thus at the end of the discussed period, Latvia noted only insignificant growth in the share of international articles (2.5%). This dramatic fluctuation in Latvia's case is the result of the relatively small number of articles affiliated to this country (Figure 10, right).

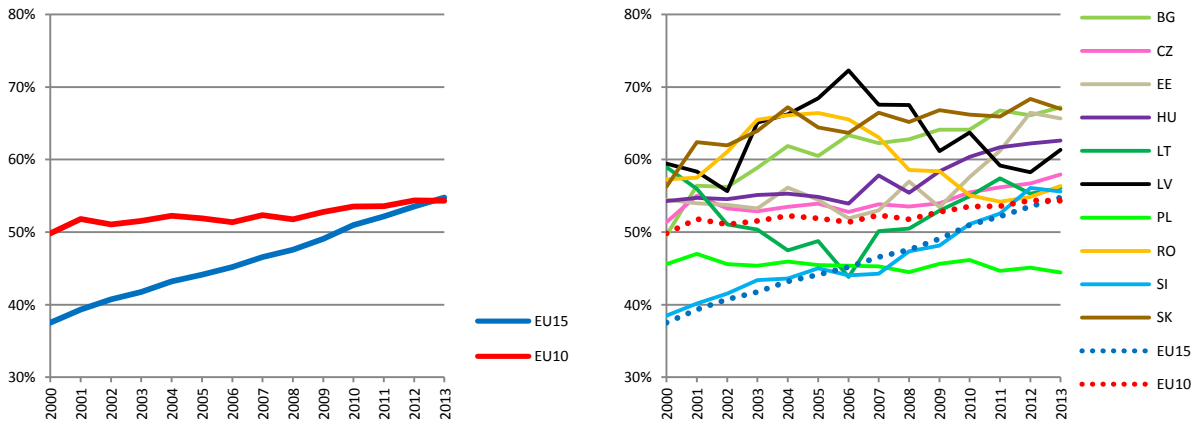
Figure 10. Percentage of articles with at least one foreign affiliation – all journals



Source: own study based on data from the Web of Science.

We can presume that changes in the share of international articles in the EU10 were influenced by the expansion of the WoS database to include journals published in these countries. This is shown by the fall in the number of international publications produced in the years 2007-2008, exactly when WoS started to index a large number of journals published in CEE countries (see above). This presumption is further supported by analysis of the share of international articles appearing only in journals published outside Central and Eastern Europe. From this angle we do not see a fall in the value of the indicator, but quite the contrary, we can observe constant – although slight – growth (see Figure 11, left).

Figure 11. Percentage of articles with at least one foreign affiliation – journals published outside EU10



Source: own study based on data from the Web of Science.

Moreover, it appears that the share of international articles appearing in journals published outside CEE in the case of the EU10 was noticeably higher for many years than in the case of articles from the EU15. However, considering the much more dynamic growth of the indicator in the EU15 than in the EU10, the levels for both these groups of countries at the end of the period balanced out. On a national level, Poland stands out noticeably. This is the only country which experienced a constant fall in the number of international articles appearing in journals published outside CEE. Thus Poland is clearly falling behind the EU10 and EU15 averages, and in 2013 was the only CEE country which came in below these averages (see Figure 11, right).

Productivity and Effectiveness

Comparing information on articles and their citations to data regarding expenditure on scientific activity and human resources in science allows us to estimate the scientific productivity and effectiveness of individual countries. The average number of articles and average number of citations per researcher can be used as a productivity indicator (generally understood as the relationship between output volume to the level of resource input). Meanwhile, the level of expenditure per article or citation is an indicator of effectiveness (the relationship of outcomes achieved to costs incurred).

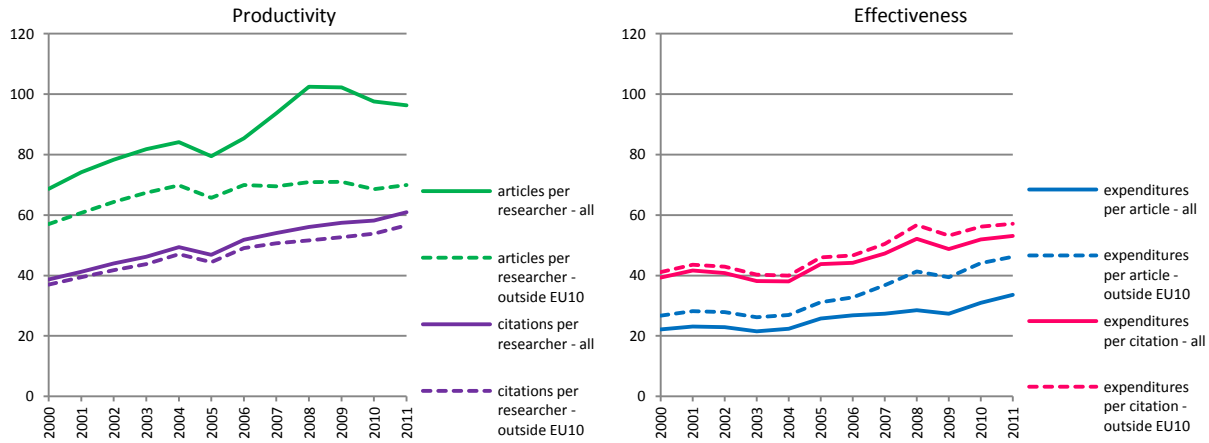
The advantage of this approach is that it is a relatively simple way of achieving a general comparison of countries. However, this method of presenting data also has limitations, which should be remembered when interpreting results. The fundamental drawback is the fact that, in order to calculate these indicators, information is used on the total employment in research and development as well as data on the total expenditure on R&D in a given country. Thus, in calculating values, not only publishing researchers are included, but also those who do not have their work published, for example those that perform research for enterprises in order to obtain patents etc. The situation is similar in the case of expenditure. It is not possible to identify from public statistics what level of expenditure is designated to activities resulting in scientific publications and accordingly, what level of expenditure is designated to other activities. Thus, this type of calculation is not sufficient to claim that the costs of 'production' of scientific articles in a given country are 'X', or that the number of

articles per researcher is 'Y'. Nevertheless, the proposed approach allows us to spot some interesting differences among countries and between groups of countries.

Firstly, the convergence of EU10 countries is stronger in terms of productivity indicators than effectiveness measures. While the indicator for the number of articles per researcher at the end of the analysed period came close to the EU15 average (in the years 2008-2009 it even exceeded it slightly) and the citation indicator per R&D worker reached 60% of the EU average, at the same time expenditure on R&D per article or citation oscillated between 53% and 34% of the EU15 average. This phenomenon is linked to the above-mentioned greater convergence of CEE in employment in R&D than in expenditure on research and development activity (see Figure 12).

Among the indicators of effectiveness, the disparity between the scale of convergence calculated for the whole publication pool and for the sample of publications appearing in Western European journals is three times greater in the case of the cost of articles compared to the cost of citations (60% versus 20%). This means that the rate of growth in the cost absorption of articles published in foreign journals is greater than for those published in CEE. A similar conclusion can be drawn from the indicator of citations, with the exception that here, differences relating to the place of publication are less significant. Meanwhile, in the case of citations per researcher, the disparity is also visible, but decidedly less pronounced. This may indicate that the inclusion of journals from the EU10 in WoS had an impact on the number of publications from this region indexed in WoS, but did not influence (at least for the time being) growth in the normalised citations of researchers from Central and Eastern Europe (see Figure 12, left).

Figure 12. Productivity and effectiveness measures in EU10 in relation to EU15 (EU15=100)

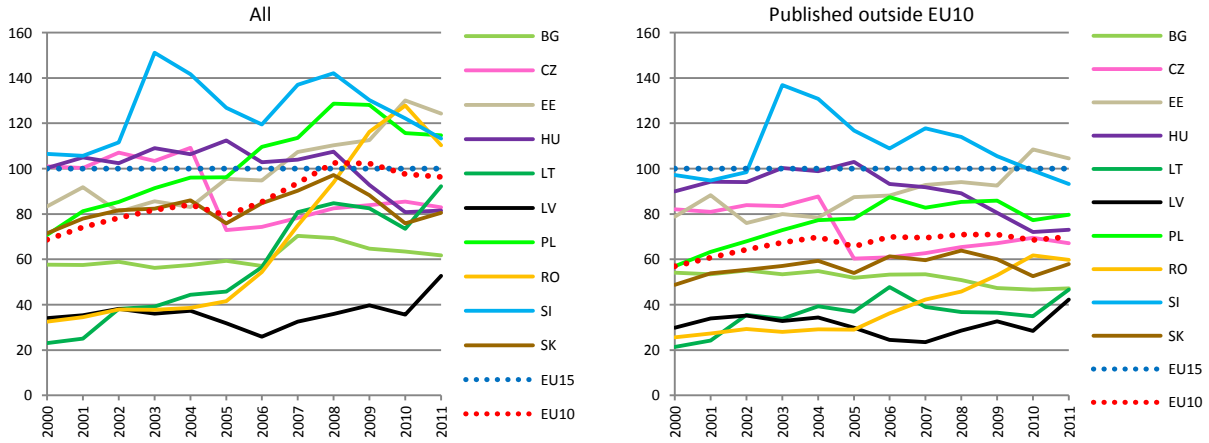


Source: own study based on data from the Web of Science.

Diversity among CEE countries regarding output, measured as the number of articles per researcher, is very great. We only need to notice that while many countries with the highest level of convergence, such as Estonia, Slovenia, Poland and Romania, achieved values that exceed the EU15, countries such as Bulgaria and Latvia achieved levels of no more than 50-60% of the EU15 average. This disparity is visible in both the levels and rates of convergence. The clear leader is Romania, where the index of articles per researcher in relation to the EU15 grew in the study period from a level of one third to a level exceeding the EU15 average. This fast rate of convergence also distinguishes Estonia, Lithuania and Poland. However, the Czech Republic and Hungary show a fall in productivity measures in terms of articles. As a result, while starting at a high level – close to the

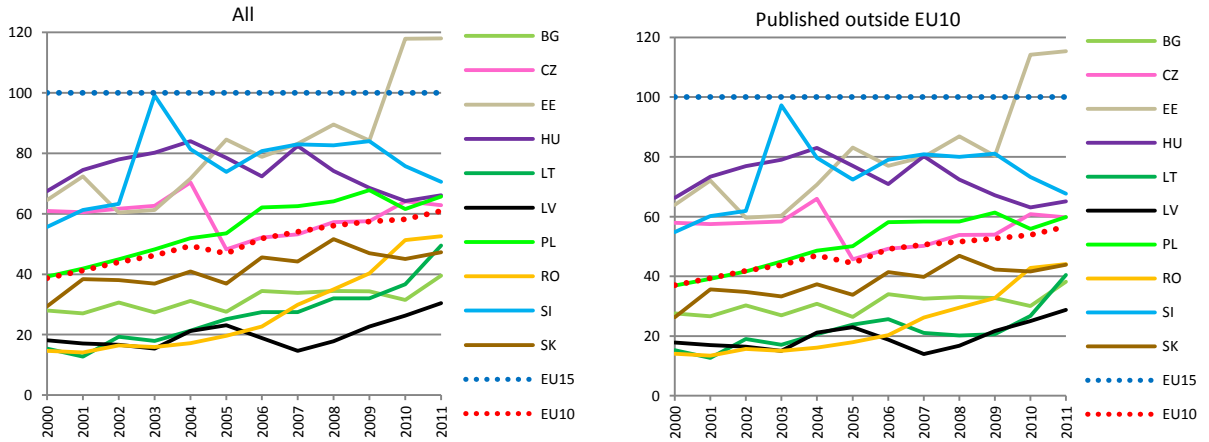
EU15 average – at the beginning of the study period, they have clearly lost ground in recent years, distancing themselves both from the EU15 and even the EU10 average (Figure 13, left). However, by limiting the pool of articles and citations to journals published outside CEE, we arrive at significantly revised values for the discussed indicators. The observed convergence is decidedly less pronounced (e.g. Estonia, Lithuania, Romania) or non-existent, and we can even notice a departure from the EU15 (Bulgaria). In the case of the Czech Republic and Hungary, this divergence is plainly visible (Figure 13, right).

Figure 13. Number of articles per researcher in EU10 in relation to EU15 (UE15=100)



Source: own study based on data from the Web of Science.

Figure 14. Number of citations per researcher in EU10 in relation to EU15 (UE15=100)



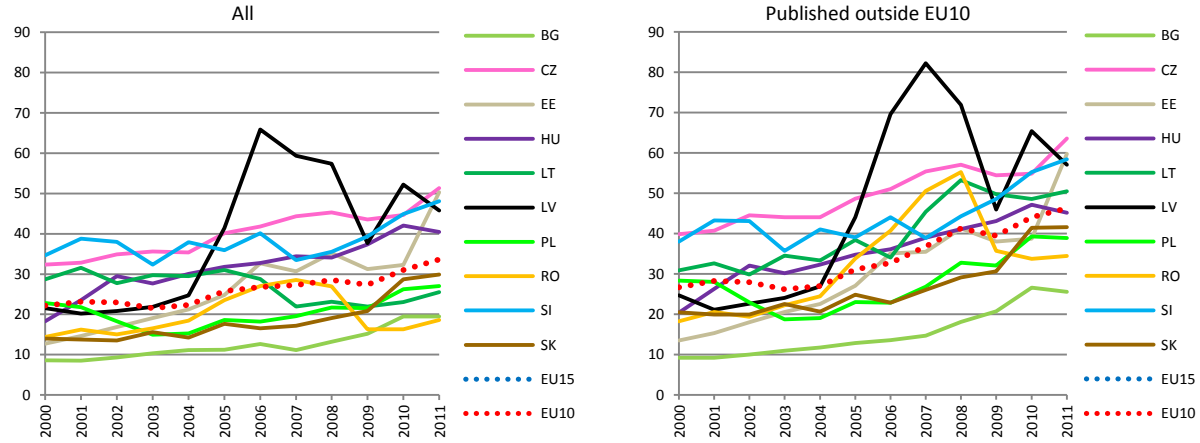
Source: own study based on data from the Web of Science.

While in the case of articles per researcher some CEE countries achieved the EU15 average, or even significantly exceeded it, in the case of citations per researcher the distance dividing EU10 countries from the EU15 average is still enormous. Apart from a few exceptions (Slovenia in 2003 and Estonia in 2010 and 2011) none of the analysed countries came close to the EU15 average. However, we should point out that certain countries noted constant improvement (e.g. Poland, Romania, Slovakia and Lithuania). Meanwhile, the Czech Republic and Hungary, which also began in a relatively high position in this respect, did not achieve significant convergence (Figure 14, left). It is interesting to note that in the case of citations, the inclusion of articles appearing in journals published outside CEE in the citation sample analysed has little influence on the shape of these trends (Figure 14, right).

This may stem from the fact that articles published in journals outside CEE are cited more often than those from CEE.

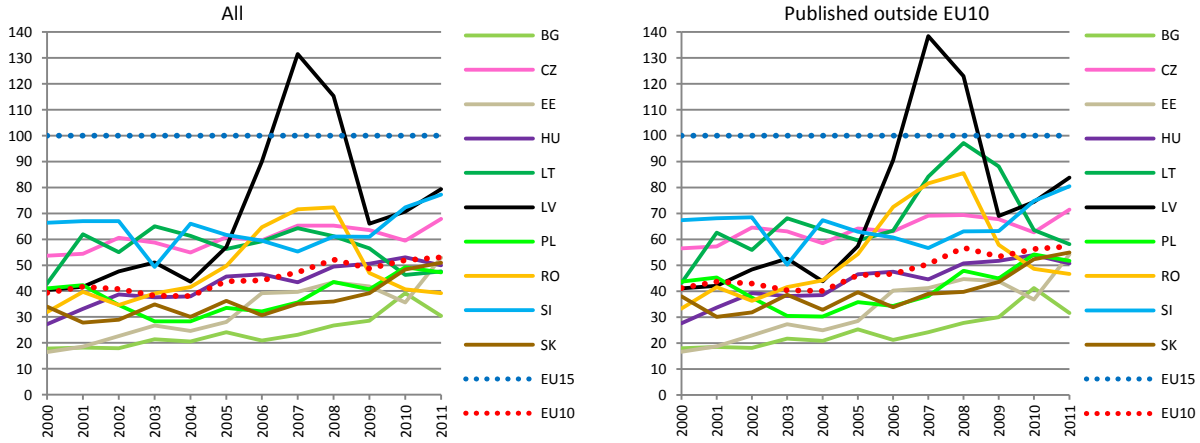
The situation looks completely different regarding effectiveness within the region (Figure 15, Figure 16). Firstly, none of the CEE countries in the entire study period noted output levels that exceeded the EU15 average. In the case of Latvia, the EU15 average was exceeded incidentally in 2007 in terms of the average expenditure on citations. Secondly, the scale of diversity among CEE countries is decidedly less than in the case of productivity (around 30 pp versus 100 pp). Moreover, the group of countries which stand out in terms of convergence levels is also somewhat distinct. Countries with a cost absorption indicator exceeding the EU10 average are the Czech Republic, Slovenia, Hungary and Latvia. However, the countries with the lowest cost absorption of articles in relation to the EU15 average are Romania and Bulgaria, thus the economies which have the lowest level of GERD in % GDP. Thirdly, the rate of convergence is weaker than that for output levels. The cost of articles is growing fastest in Estonia, Latvia, the Czech Republic and Hungary, while the slowest in Lithuania, Poland and Romania. Similar tendencies affect expenditure relative to citation numbers (Figure 16, left).

Figure 15. R&D expenditures per article in EU10 in relation to EU15 (UE15=100)



Source: own study based on data from the Web of Science.

Figure 16. R&D expenditures per citation in EU10 in relation to EU15 (UE15=100)



Source: own study based on data from the Web of Science.

Comparison of trends calculated for all journals, as well as for a sample excluding journals published in the EU10, generally gives similar results. Of course, the average cost of an article in all the countries appears greater than when we include all articles, which is a natural consequence of excluding a group of articles (e.g. those appearing in journals published CEE). The differences in the case of expenditure on citations are less pronounced, due to the above-mentioned fact that articles from journals published in CEE are much less often cited (i.e. citations from these articles constitute a sufficiently small proportion of total citations that their exclusion from the analysis does not significantly influence results, since they combine the same level of expenditure with a slightly lower number of citations).

Discussion

The analyses presented in this article support the argument that countries from Central and Eastern Europe, despite showing fairly consistent convergence trends, achieve noticeably weaker results than Western Europe in terms of research and development and scientific activity. The distance separating CEE countries from the Western European average is lesser or greater depending on which indicators are analysed. Moreover, EU10 countries also differ considerably from each other. However, none of them exceeds the EU15 average in all analysed contexts. Generally speaking, the best runners up behind Western Europe are Estonia, Slovenia, the Czech Republic and Hungary. The first two of these countries are relatively small economies which in recent years took up a comprehensive, knowledge-based approach to economic growth. Meanwhile, the Czech Republic and Hungary possess a strong scientific tradition, which in recent years they have been able to maintain and even develop. The middle of the Central European league table for science and R&D is taken by Lithuania, Latvia, Poland and Slovakia. The weakest results are shown by Romania and Bulgaria (see Figure 17). We can see here quite a clear relationship between the level of economic growth of a country (measured e.g. by GDP per capita), or the wider level of socio-economic development (assessed using e.g. the Human Development Index created by UNDP), and indicators of R&D development. However, this relationship is two-way. It is true to say that development of the science sector influences socio-economic development, but the fact is that wealthier countries invest more in the R&D sector.

Traditional measures of research and development activity – expenditure on R&D relative to GDP as well as employment in R&D as a percentage of the population – show that, in 2013, the EU10 average reached over half the EU15 average (57% and 56% of the average, respectively). In terms of the number of articles listed in WoS per inhabitant, this distance is somewhat greater: the EU10 attained a level of 48% of the EU15 average. However, if we set the number of publications against the number of researchers, it turns out that the EU10 comes up equal with the EU15 average. Thus we can assume that further growth in the number of publications in the EU10 is unlikely without an increase in human resources in science. Scientists from Central and Eastern Europe have similar levels of output to their Western European colleagues, but there are proportionately less of them (relative to population potential). They have decidedly less funds at their disposal with which to finance research. This is also the reason why the relationship between expenditure on R&D and the number of articles and citations differs to such an extent between the EU10 and EU15.In the EU10 this amounts to 34% (expenditure per article) and 53% (expenditure per citation) of the EU15 average. In very simplified terms, we can say that Central European articles are relatively 'cheaper' than those from Western Europe, which can certainly be attributed to the fact that less costly

research areas are dealt with, but also to the fact that remuneration for research in CEE countries is significantly less.

Figure 17. R&D in EU10 in relation to EU15 average

		UE10	BG	CZ	EE	HU	LT	LV	PL	RO	SI	SK
GERD as % of GDP (2013)		57	31	94	82	68	45	28	41	18	125	40
Employment in R&D as % of population (2013)		56	36	88	66	58	56	40	36	25	110	47
Articles per inhabitants (2013)	*All*	48	23	78	102	48	52	24	46	31	146	46
	Non-EU10	35	18	63	90	42	32	21	33	19	122	33
Citations per article (2011)	*All*	63	64	76	95	81	54	58	57	48	62	59
	Non-EU10	81	81	89	110	89	87	68	75	74	73	76
Share of international articles (2013)	*All*	80	105	93	110	105	72	103	63	70	91	102
	Non-EU10	99	123	106	120	114	102	112	81	103	102	122
Articles per researcher (2011)	*All*	96	62	83	124	82	92	53	115	110	113	81
	Non-EU10	70	47	67	105	73	47	42	80	60	93	58
Citations per researcher (2011)	*All*	61	40	63	118	66	49	30	66	53	71	47
	Non-EU10	57	38	60	115	65	40	29	60	44	68	44
Expenditures per article (2011)	*All*	34	19	51	50	40	26	46	27	19	48	30
	Non-EU10	46	26	64	60	45	50	57	39	34	58	42
Expenditures per citation (2011)	*All*	53	30	68	53	50	48	79	47	39	77	51
	Non-EU10	57	32	71	54	51	58	84	52	47	81	55

Source: own study based on data from the Web of Science and EUROSTAT.

While in terms of articles per researcher, Central and Eastern Europe has caught up with the EU15 average, as regards the average number of citations per article as well as the number of citations per researcher, this convergence is decidedly less pronounced. The average number of citations from articles affiliated to the EU10 in 2011 amounted to 63% of the EU15 average, and the number of citations per researcher constituted 61% of this average. This shows that convergence in science is taking place to a greater degree in terms of quantitative outcomes (number of articles) than in qualitative terms (citations). Scientists from CEE publish increasingly more articles which are listed on WoS, but they are still much less often cited than their Western European colleagues. The reasons for this are complex. We certainly cannot ignore the significance of lower expenditure on science in comparison to the West, the lesser importance of CEE languages for scientific communication, and the generally weaker scientific traditions of these countries (resulting from their isolation in finding themselves on the 'wrong' side of the iron curtain following World War II, see eg.: Kozak, Bornmanz, Leydesdorff 2015).

Nonetheless, in this article we would like to pay particular attention to one factor alone: the place in which journals are published. It happens that if we exclude from our analysis those journals published in CEE, then the average number of citations from articles written by authors from EU10 countries comes much closer to the EU15 average, attaining a level of 81% - that is 18 pp more than if we include journals published in CEE. This suggests that reasons for the weaker citability of CEE scientists should also be sought in the characteristics of journals published in these countries (this finding is in line with that of Pajic (2015), who analysed the impact of national journals on citations inhumanities and social sciences). For some reason the articles they publish are less likely to be cited. This partly stems from the national language they are published in. However, this factor does not have great impact since only 6% of articles in the years 2000-2013 affiliated in the EU10 were published in a language other than English. Therefore, we can assume that a major role is played by factors which are hard to capture, such as the prestige of a journal, its international recognition, its availability on the internet in full-length form and finally – even harder to assess – the quality of the articles published. For authors affiliated to EU10 countries it may be easier to publish articles in national journals (even English-language ones), than in international titles. A whole range of factors contribute to this situation including, among others, poorer knowledge of publication standards and publication strategies as well as inadequate levels of proficiency in English, but also perhaps poorer standards of research resulting, inter alia, from weaker international collaboration. We can suppose that publishing in CEE journals, even for authors of the region, is a second choice, particularly if the article has valuable content. This aspect requires further detailed analysis based on the experiences and opinions of scientists in this part of Europe.

Conclusion

The development of scientific and R&D activity in Central and Eastern European countries, and consequently their progressing convergence towards the old EU member states, is easily observable. Even basic data from EUROSTAT testifies to this phenomenon and it is also quite easy to explain. On one hand, convergence has been caused by the opening of borders, the incorporation into EU structures, the growing wealth of society, the implementation of scientific policies, and also to the substantial EU funding designated to support the research and development sector and innovation in general in these countries. On the other hand, the purely statistical aspect is also important, that is, the so-called low-base effect. It is easier to achieve a high rate of development if you start from a low ceiling.

The aim of this article is to show that there is also a third factor, which influences the observable (but real?) convergence in term of research and development outcomes, in the form of publications in scientific journals. This factor is the wider inclusion of research articles from journals published in Central and Eastern European countries in worldwide bibliometric databases. To illustrate this we used the Web of Science, which has for decades been the main reference source for international bibliometric comparisons. The evident impact made by inclusion, in 2007-2008, of numerous CEE journals in WoS on the values of the indicator analysed, directly supports the argument put forward in this article. The growth in the number of articles from individual countries in WoS thus not only testifies to the organic growth of the science sector in these countries, but also results from decisions made by the managing bodies of these commercial databases. Changes in the database are doubtless content-driven, and are prompted, for example, by the desire to better reflect the state of world research. But we cannot reject other, non-content related motives, such as the wish to make the

database more attractive to potential clients in countries with 'developing' science sectors and who have a great need to evaluate their research achievements (which in many countries goes hand in hand with reforms in higher education and science). However, irrespective of the reasons for expanding the database, it has led to better visibility in the European arena (Vanecek2014) and easier access to the research outcomes of CEE countries. And in the context of scientometric studies and international comparisons, we can say that the state of research in CEE countries is also being better measured.

Without a doubt, this article has many limitations and – thanks to these limitations – possibilities for furthering and deepening selected themes. Firstly, the analyses conducted are based on a single bibliometric source. Conducting similar analyses on other source materials would help verify our theories. An obvious line of research would be to investigate data from the SCOPUS database, as the main rival database for bibliometric analyses. The unquestionable advantage of SCOPUS over WoS is its wider inclusion of publications from the social sciences and the arts. Secondly, this article is based only on descriptive and comparative statistical analyses. More detailed analyses using more advanced statistical instruments could help give a more precise understanding of the nature and scale of differences as well as the incidence of co-variance and causal relationships. Thirdly, we can point to several content-related areas for pursuing the given approach: (a) An important area would be to analysed more precisely the influence of the language of publication on the normalised citations of articles; (b) A very important factor – completely overlooked in this article –is the differentiation of research fields. This is important because in certain countries the range of research fields in the publication pool varies, and each field has a very different approach to publishing, internationalization, the number of co-authors, the average number of citations and the speed at which (citations of) articles are included into intellectual circulation in a given field (see van Raan 2004). Initial analysis shows that the field structure of articles in the EU10 countries differs significantly to that in the EU15. In particular, there is a much higher percentage of publications from natural science fields, while the share of articles from medical sciences is much less. This is largely a result of their historical legacy (Kozlowski, Radosevic, Ircha 1999). Fourthly, a potentially interesting aspect for further analysis would be to analysed in detail international collaboration, taking into consideration not only the share of articles from foreign authors, but also the directions of this collaboration (from national and regional perspectives), as well as national collaboration. Fifth, it would be worth carefully analysing indicators of productivity and effectiveness, e.g. paying attention to division of expenditure on public and private R&D, as well as employment in R&D in government and enterprise sectors.

Acknowledgments

This work was supported by the Polish National Science Center under grant "Polish scientific centres in the European cooperation network - characteristics, determinants, mechanisms" and European Union's 7th Framework Programme under project "GRINCOH—Growth-Innovation-Competitiveness: Fostering Cohesion in Central and Eastern Europe".

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