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International Scientific Cooperation Networks of Top Universities in the CEE Region

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Abstract
Competitiveness of higher education institutions depends highly on the ability of universities to interact with the national and international scientific community. Publishing with researchers from other countries can greatly improve the scientific and economic performance of universities and can increase international visibility. This is the reason why building international collaboration links with other countries' research and higher education institutions has become priority for most universities, colleges. International publication links of the top universities in Central and Eastern Europe (CEE), although showing a growing trend, are still lagging behind Western European or North American higher education institutions. The aim of this research is to identify the main characteristics of the international publication network of the top universities of Poland, Slovenia, Slovakia, Hungary, Romania and Bulgaria. The study focuses solely on international publication links. Data were retrieved from the Scopus database. Higher education institutions were chosen using the QS Emerging Europe and Central Asia University Rankings (2018). A map containing publication links for the best universities in Central and Eastern Europe can be drawn using network theory tools. Higher education institutions in the CEE region prefer Western European or North American research partners than build publication links with scientists from neighbouring countries. A higher number of publication links can indicate a deeper integration in the international scientific community. Decision makers should support the formation of international scientific cooperations, as these can not only improve the institutions' economic and scientific performance, but can also enhance international visibility and attract national and international students.

Keywords: higher education, publication networks, CEE countries.

JEL classification: I23, F15, C45, D85.

1. Introduction

International competitiveness and visibility of higher education institutions depends greatly on their ability to interact with the national and international scientific community. The aim of this study is to analyze the publication links of top higher education institutions from six Central and Eastern European countries, Bulgaria, Hungary, Poland, Romania, Slovakia and Slovenia. The focus is on the scientific collaboration of these universities measured through publications. Do they tend to cooperate more with institutions from neighbour countries or prefer to collaborate with researchers from Western Europe or the USA, the leaders of the global scientific market?

Scientific cooperation can greatly influence the scientific performance of researchers, higher education and research institutions or even countries (see for example Chen et al., 2016; Zhou et al., 2013; Ding, 2011). Glänzel (2001) has shown that co-authored publications tend to get more citations than one-authored publications. Less developed countries can increase the quantity and quality of their scientific performance by cooperating with researchers from developed countries (see for example Vogel, 1997; Wagner et al., 2001; Harris, 2004; Zhou-Lv, 2015). For example, a researcher coming from an African country has more chance to publish in an internationally known journal if she or he has as co-author a researcher from the USA or Western Europe. According to Zhou-Lv (2015), developed countries can also take

advantage from these kinds of collaborations. It can counterbalance the decrease of the number of their young researchers.

Higher education institutions such as universities can increase their scientific competitiveness by cooperating with other countries' higher education or research institutions. Khor and Yu (2016) analysed the effect of international co-authorship on the impact of publications of some selected well established and young universities. They concluded that both young and old universities benefitted from these type of collaborations.

2. Methodology

This study focuses on the scientific cooperation of the top higher education institutions of Bulgaria, Hungary, Poland, Romania, Slovakia and Slovenia. Scientific collaboration is measured through publications. For identifying the best universities in the analysed countries, the QS EECA (Emerging Europe and Central Asia) University Ranking was used. Several international university rankings are published every year. The most known are the Academic Ranking of World Universities (ARWU) or the Times Higher Education World University Ranking. Very popular are also the rankings published by Webometrics and the university rankings by Quacquarelli Symonds (QS) (QS Rankings). The QS EECA ranking was chosen for this analyses as universities from the CEE region are almost invisible in other international university rankings. For example the first higher education institution from this region in the ARWU ranking is the Charles University ranked 201-300.

The international scientific cooperation of the top universities was analysed. As this study focuses only on international links, all national collaborations were excluded from the analysis. Publication and affiliation data for all research fields were retrieved from the Elsevier, Scopus database (all publications until June, 2018). Publication links are defined as publications where in the affiliation, besides one top university analysed, there is at least another institution mentioned from a foreign country. This means that not only co-authored papers are regarded as scientific links, but all those one-author publications are taken into consideration where the author has mentioned in the affiliation, besides the university analysed, at least one more institution from a foreign country.

3. Main Findings

Network theory tools were used to analyse the international publication links of the top universities of Bulgaria, Hungary, Poland, Romania, Slovakia and Slovenia. Countries with which the universities had been mentioned together in publication affiliations are the nodes. Edges represent the publication links between higher education institutions and countries. The width of these show the number of links. The greater is the size of an edge, the more the university and country have published together. Red nodes represent countries of the CEE region, the yellow ones show countries from Western Europe and Scandinavia (Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Great Britain). Countries from Western Europe and Scandinavia were grouped together as their scientific performance is very similar (see for example the EU Commission's SRIP Report, 2018). Blue nodes are for countries from North America (USA and Canada), while BRICS (Brazil, Russia, India, China, South Africa), Japan and Turkey are represented by green nodes. The latter group entails the main emerging markets (both economically and scientifically) and Japan. Gray nodes represent all other countries with which the analyzed universities had scientific connection measured through publications.

According to the QS EECA Ranking (2018), the top university in Bulgaria is the University of Sofia (rank 47), in Hungary it is the University of Szeged (rank 27), in Poland it is the

University of Warsaw (rank 6), in Romania it is the University of Bucharest (rank 39), while the top universities in Slovakia and Slovenia are the Comenius University in Bratislava (rank 43) and the University of Ljubljana (rank 32).
The publication network of University of Sofia can be seen on Figure 1. It contains 111 nodes. This means that there were 111 countries with which it had scientific cooperation measured through publications. The total number of publication links was 7 899. This shows how many times the university was mentioned in an affiliation of a publication together with other institutions belonging to countries other than Bulgaria.

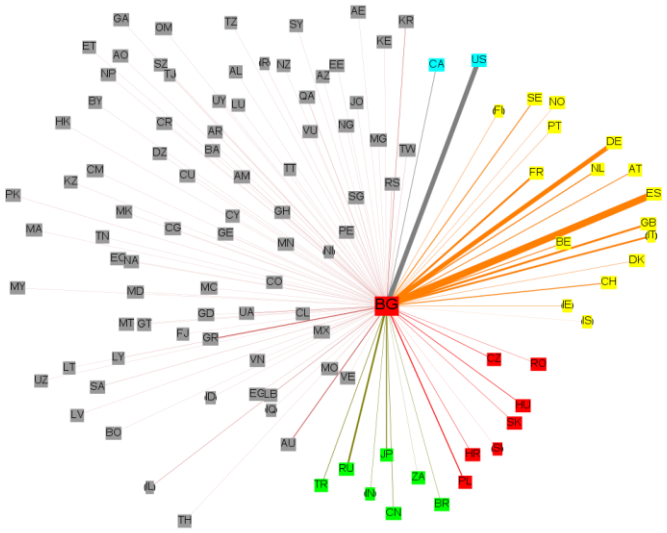

Figure 1. International publication links of University of Sofia (Bulgaria)
Source: Scopus, own editing

The highest number of links was with countries from North America, Western Europe and Scandinavia (12.21% and 57.02%). It is interesting to see that more than half of scientific cooperations analyzed were with countries from the yellow group. The country with which it had the most links is not the USA or Germany, but Spain. The university most have some special scientific collaboration program with this country as the links with Spain gave more than 16% of the total number of collaborations (1 334).
From the green group, Russia seems to be the most popular publication partner. Important publication partners from the gray group are Greece, Australia and South Korea. In total, this group had only 12.93% of the total number of links, while the number of countries belonging to this cluster was 79. The publication links with other countries from the CEE region made up only 7.47% of the total number of connections.
The international publication links of the top university in Hungary can be seen on Figure 2. The publication network of University of Szeged has 116 nodes, which means that it had scientific cooperation with 116 countries. The quantity of nodes is very similar to that of University of Sofia. The amount of publication links was 14 817. This number is almost double than that of the top higher education institution of Bulgaria. This means that although the number of countries with which these two institutions have built scientific cooperation is very similar, the quantity of links varies significantly.

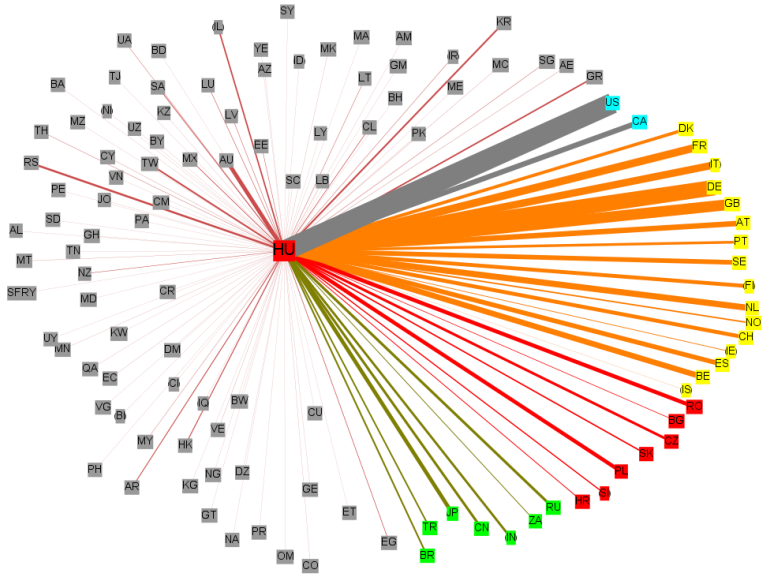

Figure 2. International publication links of University of Szeged (Hungary)
Source: Scopus, own editing

Question arises, whether the distribution of publication links for the top university of Hungary shows similar characteristics than that of University of Sofia. The link ratios for the five country groups are almost identical to the previous one. North America, Western Europe and Scandinavia are the ones with the highest number of links (15.80% and 51.34%). BRICS, Japan and Turkey hardly reach 10% (9.38%), while the CEE region holds less than 10% from the total number of publication links (8.84%). The 'other' category (the gray group), although it entails 84 countries, has only 14.64%. It seems that, as seen by the Bulgarian higher education institution, the University of Szeged prefers to have Western European, North American or Scandinavian than CEE research partners. The very wide edge linking the university to the USA shows a great interest of the university towards scientists from the North America.
The network of international publications for the University of Warsaw can be seen on Figure 3. The total number of links was 66 940, while the nodes representing partner countries was 156. Both the quantity of links and nodes are very different from the University of Sofia or University of Szeged. This means that the Polish higher education institution has almost six times greater number of publication links than Hungary or Bulgaria, and also it built scientific cooperation with almost half as much countries than did the previously analyzed two universities. Looking at this data, the University of Warsaw seems to be much more open when it comes to international publications than does the top university from Hungary or Bulgaria.

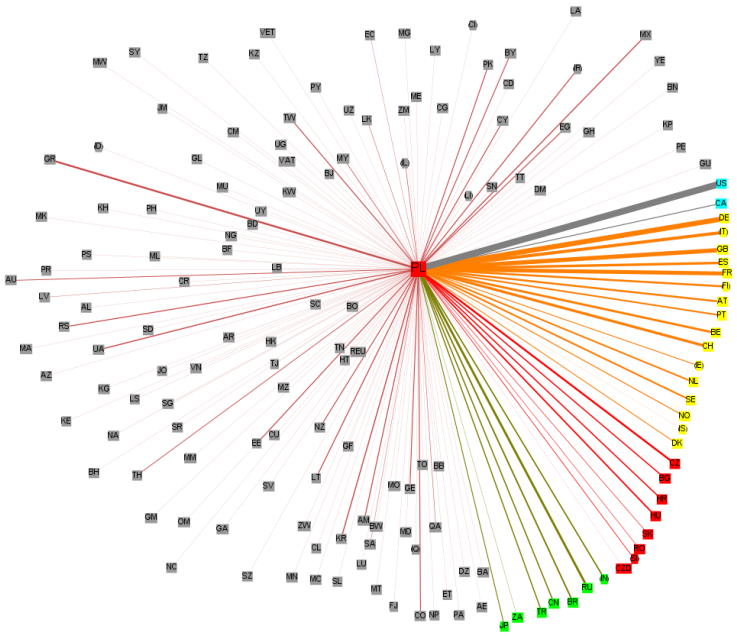

Figure 3. International publication links of University of Warsaw (Poland)

Source: Scopus, own editing

It is interesting to see how the geographical distribution of publication links differs from the previous ones. Is it different at all? Looking at the publication network of the university, one can see, that the groups with higher ratios are the same as for the other top universities. Countries denoted with yellow and blue color are the ones with the highest number of links. The only difference is that the distribution is a little more even then seen by the other higher education institutions. The data outlines this observation. The Western European and Scandinavian countries have a ratio of less than 50% (43.04%). The North American region has also a smaller proportion from the total publication links, 9.144%. The big difference is at the gray group, which entails 28.48% from all scientific collaborations analyzed. This is greater with more than 10% than by the universities of Hungary and Bulgaria. The number of nodes (countries) belonging to this group is also higher (123 compared to 79 and 84). Interestingly, the only feature which is almost identical with the other two higher education institutions, is the ratio of CEE countries, 8.91%. It seems, that, although the University of Warsaw has some differences regarding its geographical link distribution, its publication partner preferences are the same as for the University of Sofia or University of Szeged. It tends to publish more with partners from Western European, Scandinavian or North American countries than with scientists from the CEE region.

The geographical distribution of publication links of University of Bucharest is shown on Figure 4. The total number of nodes and links are similar to those seen by the University of Sofia and University of Szeged (110 nodes and 17 869 links).

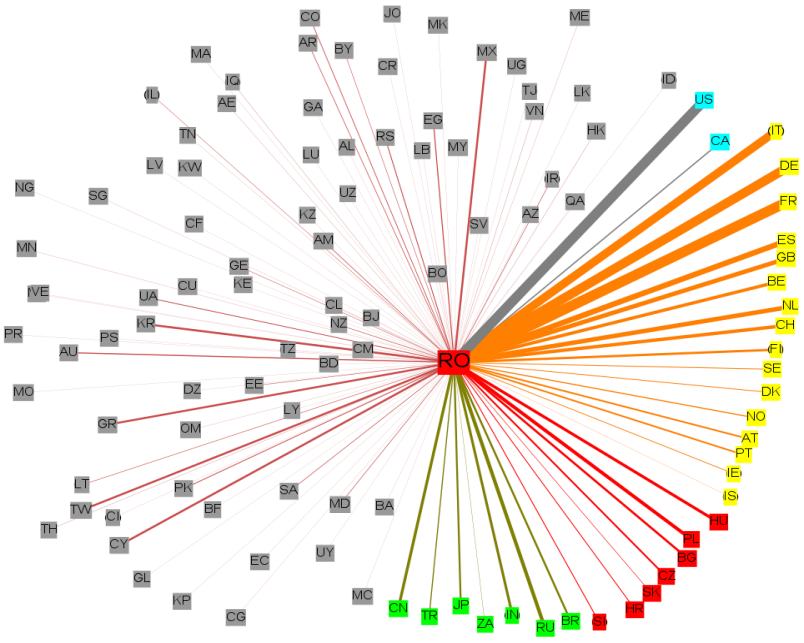

Figure 4. International publication links of University of Bucharest (Romania)
Source: Scopus, own editing

The dominance of the USA, Germany and France comes as no surprise, although the country with the most publication links is not the USA or Germany (as by Poland or Hungary), but France. This can be explained with the very strong economic, political and scientific relationship between Romania and France.

The distribution of publication links between the five regions shows no major surprises. The Western European and Scandinavian countries entail almost 50% of the total number of links (49.17%), while the ratio for North America is below 10% (9.1%). For the gray group a 20.23% ratio and a smaller proportion for the green cluster (11.20%) can also be observed. The 'other', gray group entails 110 countries. A somewhat greater cooperation with the CEE countries compared to the others can be seen when analyzing the publication links of the University of Bucharest (10.3%). This reaches 10%, while by the universities of Sofia, Szeged and Warsaw this was less than 9%. Even so, it still can be concluded that the preferred countries for publication cooperation by the University of Bucharest are Western European, Scandinavian or North American rather than CEE countries.

The international publication links of the Comenius University can be seen on Figure 5. The total number of nodes and links is relative high compared to the top universities from Bulgaria, Hungary or Romania (151 nodes, 65 059 links). The quantitative characteristics of the network are quite similar to the publication network of University of Warsaw.

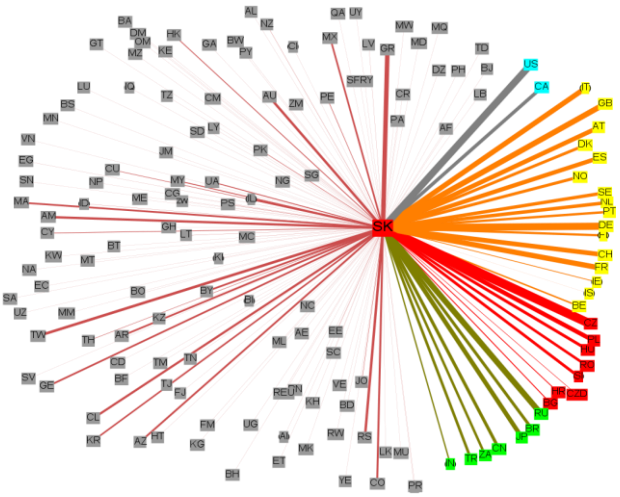

Figure 5. International publication links of Comenius University in Bratislava (Slovakia)
Source: Scopus, own editing

The geographical distribution of publication links, however, shows a relative different picture compared to the other universities analyzed. The ratio of Western European and Scandinavian countries is less than 40% (37.37%) and for North America is 6.64%. A very low value compared to the ones analyzed before. Interestingly, the green group's ratio of the total links reaches almost 15% (14.21%). The gray group has a value similar to the one seen by the University of Warsaw (26.1% for 151countries). Surprisingly, the ratio for the CEE region is also quite high, 15.68%. Looking at the links with Central and Easter European countries, one can see that the 'collaboration' is relatively high with Czechoslovakia. This is a methodological issue as this study deals only with international publication links. Slovakia and the Czech Republic were part of Czechoslovakia until end of 1992. The high ratio of links with Czechoslovakia (and through it with the CEE region) should be interpreted with caution as this might also entail links with institutions which are now part of Slovakia.

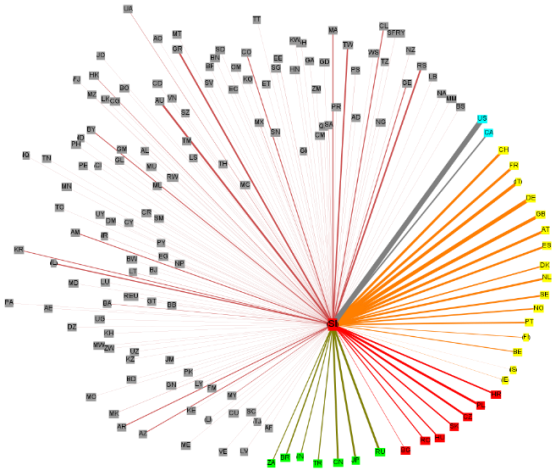

Figure 6. International publication links of University of Ljubljana (Slovenia)
Source: Scopus, own editing

The publication links for the top university of Slovenia can be seen on Figure 6. It contains 157 nodes and 72 058 links. The University of Ljubljana has the most scientific collaboration links from all top higher education institutions analyzed. The number of countries (nodes) with which it has scientific cooperation is roughly the same as seen by the University of Warsaw.
The question is whether there are major differences in the geographical distribution of its publication links compared to the others. The dominant countries are from Western Europe, Scandinavia (40.46%) and North America (8.82%). The distribution is very similar to the one seen by the Comenius University. The gray group has a relatively high ratio (24.87%), while the countries denoted with green entail 12.73% from the total number of links. Interestingly, the ratio of the CEE region is also quite high (13.11%). The almost 15% ratio by the Comenius University was mainly due to the high number of links to Czechoslovakia (a methodological problem). Slovenia in the other hand had significant number of publication links with the Czech Republic (2.66% from the total number of links), with Poland (3.07%) or Croatia (2.09%). It seems that the University of Ljubljana has the most scientific collaborations with other countries from the CEE region measured through publications, although, the major scientific partners - here also - come from Western European, Scandinavian or North American countries.
Simple network theory tools have been also used to analyze the publication networks of the University of Sofia, University of Szeged, University of Warsaw, University of Bucharest, Comenius University and University of Ljubljana. In graph theory, the degree of a node is the number of edges incident to the node. The average degree shows the average number of links per nodes (Barabási, 2004). The highest average degree belongs to the top universities from Poland, Slovakia and Slovenia (1.987), while the lowest are for higher education institutions of Bulgaria and Romania (1.982) and Hungary (1.983). The average weighted degree is the average of sum of weights of the edges of nodes (here countries) (Ouyang-Reilly, 2015). There is a great difference between the average weighted degree of the top universities from Bulgaria (141.054), Hungary (253.282), Romania (321.964) and Poland (852.739), Slovakia (856.039), Slovenia (912.127). These outline the previous findings, namely, that the later higher education institutions are internationally more open compared to the other analyzed universities when it comes to international publications. This can be also seen on Figure 7., where the geographical distribution of publication links for the six universities is presented together.

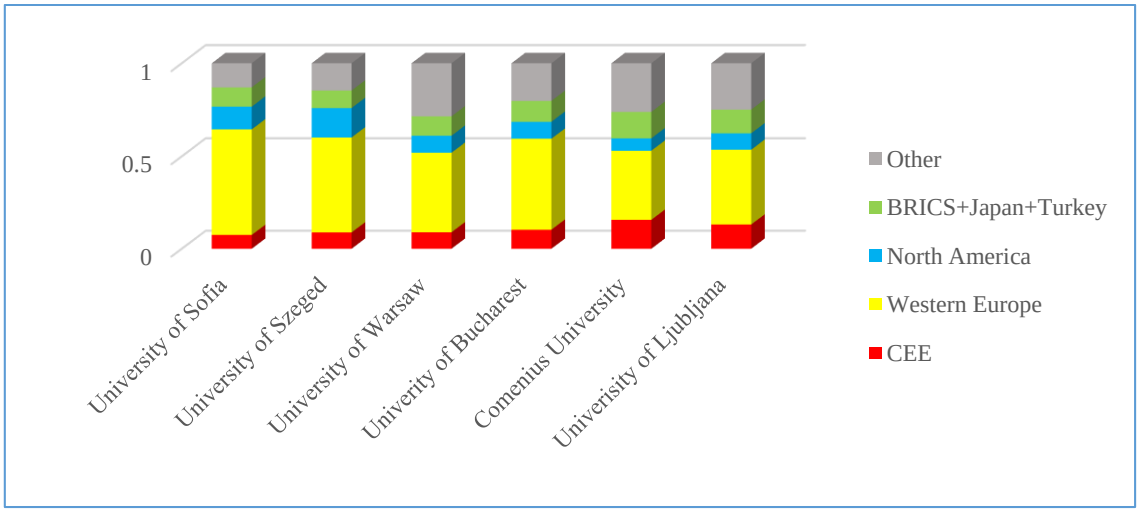

Figure 7. Geographical Distribution of Publication Links for the Analyzed Universities
Source: Scopus database, own editing.

The top 5 countries with which the universities had the most publication links was also examined. It has been found that, except the Comenius University, no other higher education institution had countries from the CEE region in the top 5. The countries with which all universities had the most links are the United States and Germany. Great-Britain, Italy, France and Spain were also among the preferred ones. All these show that higher education institutions from the CEE region prefer publishing with scientists from Western Europe or Norther America rather than with researchers from neighboring countries. The Comenius University (the exception) had the most publication links with the Czech Republic. This, however, comes as no surprise, as Slovakia and the Czech Republic for many years were part of the same country, Czechoslovakia.

It seems that all six universities analyzed show a very similar geographical distribution regarding their publication links. They prefer countries from Western Europe, Scandinavia or North America rather than neighboring countries from the CEE region. One reason for this is the belief that collaboration with well-known institutions may facilitate international visibility.

4. Conclusion

The competitiveness of higher education institutions depends greatly on their scientific ability and performance. Scientific collaborations can positively influence scientific achievements. This study focuses on the publication links of the top universities of Bulgaria (University of Sofia), Hungary (University of Szeged), Poland (University of Warsaw), Romania (University of Bucharest), Slovakia (Comenius University in Bratislava) and Slovenia (University of Ljubljana). Using simple network theory tools, it has been shown that the most important publication partners for the analysed universities are Western European, Scandinavian countries, the USA and Canada. Geographical distance does not seem to have a significant role when it comes to choosing international scientific partners.

This study argues that decision makers should try to enhance the scientific cooperation of higher education institutions from the CEE region. This could improve the participants' scientific performance, which in turn would lead to a higher international visibility for Central and Eastern European universities.

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