Global shifts in world science base? A comparative analysis of Central and Eastern Europe with the world's regions

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Abstract. This paper explores the changing role of world regions (CEE, EU15, South EU, Former USSR, North America, Latin America, Asia Pacific and the Middle East) in science base with special reference to EU15 (developed EU) and Central and Eastern Europe (CEE) in 1981-2011 period based on bibliometric data. The data are extracted from Thomson Reuter's National Science Indicators (2011) for 21 broad disciplines in science and social sciences. We investigate over time changes in descriptive indicators such as publications, citations, impact as well as scientific specialization measured by revealed comparative advantage (RCA) applied to citations and papers, in three periods – i.e. 1981-1989, 1990-2000 and 2001-2011. Multidimensional scaling and hierarchical clustering are used to comment on divergence/convergence among world regions. In view of common historical legacy in science we are particularly interested in process of divergence within the post-socialist world as well as in the process of the EU convergence in terms of specialization in major scientific disciplines.

First, our results show that there is global shift in science largely in terms of quantity (papers) and much less in terms of impact (citations). We argue that this should be interpreted as shift in terms of absorptive capacity of science but not necessarily in terms of knowledge generation at world science frontier. Science systems are characterised by strong inertia and by long lasting historically inherited advantages and disadvantages.

Second, three major changes at regional level have been the loss of the excessive specialization of South EU in applied sciences; excessive specialization of CEE and Former USSR in fundamental sciences that has been followed by reduced specialization of the CEE and continuous excessive specialization of the Former USSR and its de-specialization in life sciences; excessive specialization of North America and the Middle East in social sciences (albeit for opposite reasons) that has been followed by reduced specialization of the Middle East and by continuous high specialization of North America.

Third, CEE has shown strong comparative advantages particularly in fundamental sciences and has been catching up in the last decade in applied sciences. This is accompanied by a divergence from the former-USSR and a convergence towards EU15 from 1981-89 period to 2001-2011 period. Together with the Former-USSR region CEE continue to be specialized in fundamental sciences when compared to other world regions which suggest that these regions are facing disproportionally higher problem of (ir)relevance of their science base for technological and industrial bases. Changes in the CEE science systems have been largely in terms of their absorptive capacity rather than in terms of the world frontier activities.

1. Introduction

Knowledge intensive growth is not any more confined to developed countries (Hollander and Soete, 2010). The importance of scientific knowledge has increased for absorptive capacity of countries and is likely to increase further. This historically unprecedented diffusion of codified knowledge through rapid diffusion of Internet in the South will have enormous effects on absorptive capacity of catching up economies. However, increase in generation of scientific knowledge will not necessarily lead to diffusion of technological knowledge. Inequalities in patenting are much higher as patents denote potentially commercialized and proprietary knowledge. Also, this may not lead to automatic diffusion of industrial knowledge. The linkages between scientific, technological and industrial knowledge are not automatic. They are actually becoming increasingly difficult to couple for nation states which have been increasingly fragmented by operations of MNCs and their value chains.
In catching up economies science system is improving not only in terms of science outputs but also in terms of disciplinary profile of science output. This profile shifts towards new growing areas of science which represent the knowledge base of new technologies. We do not have theory of industrial / technology upgrading but we could hypothesize that science system is also upgrading during catching up process both in terms of number of outputs, their impact as well as structure. This upgrading can evolve from absorptive to knowledge frontier generation function of science.

In this paper we focus on scientific capabilities and explore issues of falling behind and catching up in world regions with special reference to countries of Central and Eastern Europe (CEE). We explore long-term changes in world science by differentiating between science as world frontier knowledge activity and as activity which denotes absorptive capacity. We explore this dual face of science through changes in world regions and countries disciplinary structures. We explore dynamics of changes by distinguishing between increase of absorptive capacity through number of papers and increase in world frontier knowledge through impact of papers.

We are primarily focused on CEE but in the comparative framework of the EU including South EU as well as other world regions, especially former-USSR regions which share socialist legacy with the CEE. In fact, our research is motivated also by our previous finding on surprisingly strong homogeneity of science systems of the post-socialist countries in terms of their disciplinary structure which is explained to a large extent by the communist legacy (Kozlowski et al, 1999). Hence, we want to explore the extent to which there has been convergence or divergence in disciplinary profiles of the European countries, especially European East and West, and the extent to which science systems of the CEE have diverged from the science systems of the former-USSR. As our analysis is comparative and global we also explore the differences between the disciplinary structures of the world's main regions placing CEE in the core of the analysis.

CEE countries have undergone a radical economic and industrial restructuring accompanied by significant institutional change. We want to explore whether this process has affected the CEE science base in terms of its dynamics and its disciplinary profile, especially in relation to other world regions. We want to explore whether this region has fallen behind in this respect and whether science has been more absorption capacity oriented or was able to maintain its world frontier knowledge activities. As many CEE countries have become members of the EU we also want to explore whether institutional convergence towards EU has led to convergence in terms of disciplinary profile of science base – i.e. is there co-evolution of research base and institutions? If yes, in which direction?

EU integration is a rare 'natural experiment' where we observe a large scale integration of science systems of countries of very different levels of development. In that context it is interesting to explore whether institutional convergence in science systems lead to convergence in 'outcomes' in terms of disciplinary profiles of their science systems. Or, science systems may have a large degree of autonomy which is not directly responsive to changing institutional set up even when it is as radical as it has been shift from socialism to post-socialism.

CEECs/Former-USSR countries are catching up economies and their technology upgrading has been focused largely around improvements in production capability (Kravtsova and Radosevic, 2011). R&D has played the role in productivity improvements primarily by facilitating 'absorptive capacity'. Their further upgrading will increasingly depend on whether they are building R&D beyond its absorptive capacity and towards R&D as one of drivers of growth. Hence, we are interested to observe whether it is possible to detect in bibliometrics data a shift from largely absorptive function of science knowledge towards more world knowledge frontier generation. Bibliometric analysis is a quantitative method, which analyzes information from the scientific literature database and can provide valuable insight to explain, predict and plan patterns of technology today and in the future (Martin, 1995; Debackere and Glanzel, 2004; Sommer, 2005: Chuang et al., 2010; Lee et al. 2012). Publication state of scientific literature is also seen as a core indicator for assessing scientific capabilities (Okubo, 1997). Therefore, information acquired from bibliometric analysis provides very useful complementary knowledge and it is in itself a useful tool for the purposes of science and technology policy.

In the next section we explain dataset and method of analysis. Section 3 reports major findings on comparative position of CEE in terms of quantity (publications) and impact (citations) of bibliometric output. We also, explore whether differences in impact between the CEE and EU15 are due to differences in disciplinary structure due to strong differences among disciplines towards citations or due to across-the-board national differences. We also, undertake comparative revealed comparative advantage analyses of world regions with special reference to CEE and present results graphically through cluster and MDS analyses. Conclusions summarize major results.

2. Data and Methods

In general, bibliometric measures are useful tools to investigate the research-based knowledge and thus make it possible to map the structure and changing shape of knowledge resources in the economy and society as a whole. The conventional measures are published research papers in academic journals to represent published output of research activity; citation counts, that is, the number of references to a publication to represent qualified research activity and the impact measure[1] calculated as the citation counts per paper published. Publication counts refer to the

[1] 'Impact' is citation impact in a field divided by published papers in that field (C1/P1). 'Impact relative to world' is citation impact in a field divided by citation impact for the world (all fields) (C1/P1)/ (Cw/Pw). This is a baseline comparison to the world.

‘quantity’ of knowledge resources in the economy and society. Whether citation counts refer to the ‘quality’ of knowledge resources is a matter of debate. On specifically this issue, Garfield (1979: 361) notes that “What do citation counts measure? While it is theoretically possible that a high citation count could be produced by publishing low-quality work that attracted a lot of criticism, the apparent reluctance of scientists to go to the trouble of refuting inferior work makes such a situation very unlikely.” Conversely, some other scholars are unambiguous in saying “citation counts, that is, the number of references to a publication, cannot tell us about the "quality" of a piece of research. ... [they] can only give us an indication of the "impact" research has had on work that follows.” (Katz, 1999: 2). HEFCE (2009) highlights that the robustness of the bibliometrics varies across the fields of research covered by the pilot, lower levels of coverage decreasing the representativeness of the citation information and in areas where publication in journals is the main method of scholarly communication, bibliometrics are more representative of the research undertaken. Therefore, although citation counts are sometimes used as a proxy for ‘quality’ in the bibliometrics literature, they are more appropriately used as a measure of ‘impact’.

The above-mentioned measures and their transformed measures as share of world publications, citations and relative impact (citation impact relative to world), are very useful for descriptive purposes and for international comparison. However, they cannot tell us if the country has relative advantage over others in one specific field of science. In that sense, the ‘Revealed Comparative Advantage’ measure, originally created by Balassa (1965) to show export specialization, is much more appropriate. Here we use it to create indices of revealed comparative advantage for published papers (RCAPAP) and revealed comparative advantage for citations (RCACIT). It has been first introduced into patent analysis by Soete and Wyatt (1983) as RTA – Revealed Technological Advantage index and since then has been successfully used in the patent analysis to examine specialisation in technology fields (Pavitt and Patel, 1988; Meyer, 2006; Frietsch and Schmoch, 2010; Chen, 2011; Zheng et al, 2011) and in the bibliometrics literature as well to examine specialisation in scientific fields (Barre, 1991[2]; Kozlowski et al, 1999; Chuang et al. 2010 Tang and Shapira, 2011; Lee et al., 2011; Lee et al., 2012).

In a bibliometrics context the algebra for the index is set up as follows for citations and published papers (Kozlowski et al, 1999):

$$RCACIT_j^i = \frac{\left(\frac{Cit_j^i}{TotCit_j}\right)}{\left(\frac{Cit_{world}^i}{TotCit_{world}}\right)} \qquad (1)$$

where

$RCACIT$ = Revealed Comparative Advantage index based on citations;

Cit_j^i = citations in field i of country j;

$TotCit_j$ = total citations in all fields of country j;

Cit^i_{world} = world citations in field i;

[2] Barre (1991) named it as Revealed Scientific Advantage calculating the index for published papers and hence examining the matter from quantity perspective only. In this study, we approach the matter both from quantity and impact perspectives and thus distinguish between published papers and citations. We prefer to use the term as Revealed Comparative Advantage for papers (RCAPAP) and for citations (RCACIT) separately.

$TotCit_{world}$ = world citations in all fields.

$$RCAPAP_j^i = \frac{\left(\frac{Pap_j^i}{TotPap_j}\right)}{\left(\frac{Pap_{world}^i}{TotPap_{world}}\right)} \quad (2)$$

where

$RCAPAP$ = Revealed Comparative Advantage index based on papers;

Pap_j^i = papers in field i of country j;

$TotPap_j$ = total papers in all fields of country j;

Pap^i_{world} = world papers in field i;

$TotPap_{world}$ = world papers in all fields.

The RCA index, thus, allows for a comparison of regional/national scientific specializations across different scientific fields. When RCA equals 1 for a given scientific field in a given region/country, the percentage share of that field is identical with the world average. When RCA is above 1 the region/country is said to be specialised in that scientific field and vice versa where RCA is below 1. From a methodological point of view, the RCA index was originally formulated to compare relative specialisation in different sectors nation-wise and to allow comparison of the dominance of different sectors of a given nation within a larger group of countries. It should be kept in mind that these indices (RCA, RTA etc.) are indicators of relative structures and an indicator for 'international competitiveness' (Dalum et al., 1996: 7).

Data. We extracted data from National Science Indicators (Thomson Reuters 2011), Standard Edition. This is a database of summary publication and citation statistics taken from over 10,000 peer-reviewed journals indexed by ISI during the years 1981-2011. The database covers 180 countries and geographical/political regions of Asia Pacific, European Union (separately for EU15 and EU27), Nordic (Scandinavia), Latin America, the Middle East and OECD. The dataset contains information on fields in the sciences, social sciences, and arts and humanities. The database is available in two versions: a Standard dataset with 21 broad fields in the sciences and social sciences, and a Deluxe dataset of 249 narrower fields in the Sciences, Social Sciences, and Arts and Humanities corresponding to Thomson Reuters's *Web of Science*® (*WoS*) categories.

Regions and Countries Studied. We selected Asia Pacific, European Union (EU15), Latin America and the Middle East from Thomson database. In addition to these regions we formed data for Central and Eastern Europe (CEE), North America, Former USSR and South EU. Table 1 shows the list of countries included in each group.

Table 1. World regions studied in this research.

CEE	Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia + Czechoslavakia and Yugoslavia
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
South EU	Cyprus, Greece, Italy, Malta, Spain, Portugal
Former USSR (exc. EU	Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine,

members)	Uzbekistan
North America	Canada, USA
Latin America	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Columbia, Costa Rica, Cuba, Dominican Republic, Equador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Surinam, Trinidad & Tobago, Uruguay, Venezuela.
Asia Pacific	Australia, Bangladesh, Brunei, China, Hong Kong, India, Indonesia, Japan, Laos, Macau, Malaysia, Micronesia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Vietnam
Middle East	Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen

Scientific Fields. Thomson provides a Standard dataset with 21 broad fields in the sciences and social sciences. These are Agricultural Sciences, Biology & Biochemistry, Chemistry, Clinical Medicine, Computer Science, Economics & Business, Engineering, Environment/Ecology, Geosciences, Immunology, Materials Science, Mathematics, Microbiology, Molecular Biology & Genetics, Neuroscience & Behaviour, Pharmacology & Toxicology, Physics, Plant & Animal Science, Psychiatry/Psychology, Social Sciences-general, Space Science. We have further grouped these broad fields into four major fields as Social Sciences (Social Sciences-general and Economics & Business), Fundamental Sciences (Chemistry, Geosciences, Mathematics and Physics), Applied Sciences (Computer Science, Engineering, Materials Science and Space Science) and Life Sciences (the remaining fields).

Periods. We study three periods in a total duration of thirty years: 1981-89, 1990-2000, 2001-2011.

Methods. Apart from the descriptive analysis of indicators related to publications, citations and impact; we use multidimensional scaling (MDS) and hierarchical cluster analysis based on RCACIT and RCAPAP to investigate convergence and divergence in four major scientific fields in world regions.

3. Main Findings

3.1. Region Level Analysis

3.1.1 Publications, Citations and Impact in World Regions

Table 2 shows summary changes in world science in between 1981-2011 in terms of publications, citations, impact and impact relative to world. As pointed earlier our perspective is of the CEE within the wider Europe and global changes. From that perspective there are several important trends.

First, there is important catching up of CEE after decline in 1990s which reflects turbulent transition period. Unlike CEE, during the 1990s the South EU has been catching up and increased its world share which slowed down significantly before the current Euro zone crisis. While CEE has been recovering and catching up during the 2000s the former-USSR science systems were falling behind indicating serious structural crisis of their R&D systems. Despite economic recovery after 1998 their science systems have continued to decline in terms of relative share of world publications though this decline seems to be slowing down. These trends were taking place on the background of relatively unchanged position of the EU15. The relative stagnation of EU15 could have been deeper if it were not for the South EU. On the other hand, there has been a remarkable catch up of Asia Pacific which indicates potential for forging ahead i.e. if these trends continue we may see this region overtaking EU15 and North America in relative share of publications. There has been convergence of EU15 and North America in relative shares. However, this convergence in the case of North America took place from very high relative shares of 44% to 35% while in EU15 this is increase from 31% in 1980s to 35% in 1990s and than stagnation at achieved level in 2000s. The sign of global shift in world science is also very strong catch up of Latin America and the Middle East.

In terms of world share of citations North America continues to lead while EU15 grows but at moderate pace; South EU has been growing strongly as well as the Middle East and Latin America while remarkable catch up of Asia Pacific is still behind growth of its relative growth in terms of quantity (papers). In overall, changes in citations suggest also global shift but of much more complex nature as rise of publications is not automatically accompanied by proportional increase in terms of recognition or relevance of papers to world knowledge frontier. This further reinforces distinction between absorptive vs. world knowledge frontier dimension of science.

Table 2. Percentage of world publications, world citations, impact and relative impact in all fields.

	% of world publications				% of world citations				Impact				Impact relative to world			
	1981-89	1990-2000	2001-05	2001-11	1981-89	1990-2000	2001-05	2001-11	1981-89	1990-2000	2001-05	2001-11	1981-89	1990-2000	2001-05	2001-11
CEEC	3.34	3.28	3.96	4.31	1.27	1.72	2.58	2.83	7.87	11.64	11.92	7.10	0.38	0.52	0.65	0.66
EU-27	33.24	37.08	38.53	37.22	30.35	36.58	40.16	40.33	18.83	22.00	19.06	11.71	0.91	0.99	1.04	1.08
EU-15	31.26	34.96	35.90	34.33	29.66	35.70	38.86	38.96	19.56	22.78	19.79	12.26	0.95	1.02	1.08	1.13
South EU	4.07	6.80	8.88	9.40	2.97	6.16	8.86	9.53	15.06	20.20	18.23	10.95	0.73	0.91	1.00	1.01
FORMER USSR	7.17	5.19	3.80	3.35	1.21	1.35	1.51	1.50	3.49	5.82	7.25	4.83	0.17	0.26	0.40	0.45
ASIA PACIFIC	13.80	18.75	25.15	28.29	10.14	13.71	19.44	21.13	15.15	16.31	14.13	8.07	0.73	0.73	0.77	0.74
LATIN AMERICA	1.48	2.34	3.66	4.28	0.84	1.52	2.55	2.76	11.65	14.48	12.75	6.97	0.57	0.65	0.70	0.64
MIDDLE EAST	1.62	2.10	3.28	4.06	1.35	1.67	2.45	2.66	17.16	17.76	13.62	7.08	0.83	0.80	0.75	0.66
NORTH AMERICA	43.48	40.90	37.15	35.24	61.00	57.26	52.20	51.09	28.93	31.22	25.69	15.67	1.40	1.40	1.41	1.45
OECD	84.51	86.34	84.14	80.12	95.82	95.53	92.51	91.05	23.38	24.68	20.10	12.28	1.13	1.11	1.10	1.14

Source: Thomson Reuter's 2011 National Indicators_Standard ESI.

Notes: Data for CEEC incorporates data for Czechoslavakia and Yugoslavia as well.

With regard to impact[3], countries where absorptive capacity is the major driver of investment in science should be expected to have much lower quality or impact when compared to countries

[3] 'Impact' is number of citations in a field divided by number of published papers in that field (C1/P1). It is important to notice that for impact to take place requires some time and hence impact in the last decade is lower for all regions as it takes time for publications to generate impact i.e to be cited. Hence, we confine our conclusions on period 1981-2000 though in later analyses we assume that it is correct to take relative position of region in terms of impact as presumably there should not be significant regional differences in speed of generation of impact.

where science is contributing more to knowledge generation at world frontier rather than to absorptive capacity. Their science systems are largely oriented towards following world frontier knowledge and their research is largely locally oriented. In that respect, North American science seems to generate much more impact when compared to other regions and its impact seems to have increased together with the EU15 which suggest that these are regions that operate at world knowledge frontier. From the perspective of distinction between absorptive capacity and world knowledge frontier it is interesting to observe whether regions that have been catching up in terms of papers have also been catching up in terms of impact. Surprisingly, the biggest increase in impact took place in South EU suggesting that science in these countries have possibly shifted from absorptive to knowledge frontier contributory role. South EU impact factor has increased from average factor of 15 in 1980s decade to factor of 20 in 1990-2000. Also, it is surprising that Asia Pacific science systems have increased impact by only 1 point (from 15 to 16 in this period) which suggests that science in these largely catching up economies is still mainly focused on its absorptive role. The former-USSR is a region with the lowest impact factor which suggests their systems are relatively isolated from world science. CEE has recorded significant increase in impact which is somewhat behind the South EU. It is remarkable that this has been achieved during transition decade, a period when its actual share of papers has declined. This is also case with the former-USSR which suggests that top science results of post-socialist regions have become more recognised with their opening.

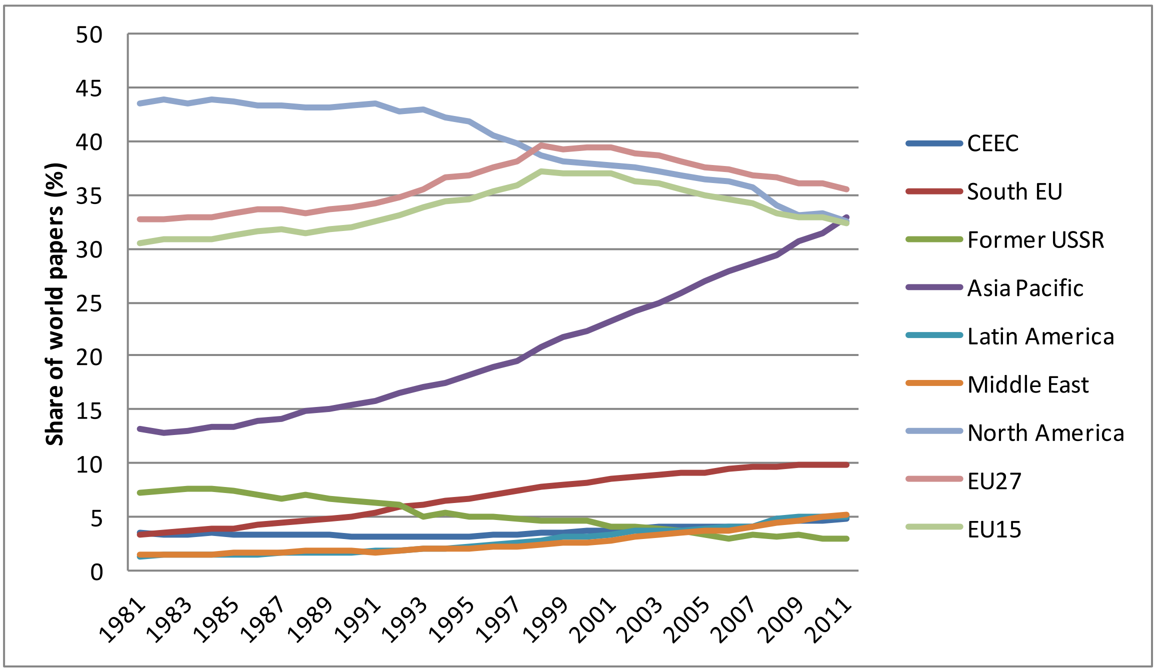
In terms of relative impact[4] world excellence in science is still located in North America followed by EU15 and in that by the EU South. A remarkable rise of Asia Pacific in both papers and citations is not accompanied by improvements in relative impact which remains almost unchanged for the last 30 years. This again reinforces relevance of distinction between sciences in its absorptive and its world frontier knowledge dimension. A distinctly high gap in terms of lower relative impact of the former-USSR science has been gradually closed but still top layers of science in this part of the world remains isolated and seem to be on average of low relative impact.[5]

In the rest of this section we present data from Table 2 in graphical form and by years. In this way we hope to convey in acceptable form the major trends that are not easily discernible from Table 2, especially turning periods which are not detectable when compressing data into decades. Graphs 1 to 3 are based on average values of percentage papers published and share of world citations for the stated periods.

[4] 'Impact relative to world' is citation impact in a field divided by citation impact for the world (all fields) (C1/P1)/ (Cw/Pw).

[5] Later on we show that former-USSR is also region with the most uneven RCA indexes which suggest that pockets of former-USSR science are much more developed than others.

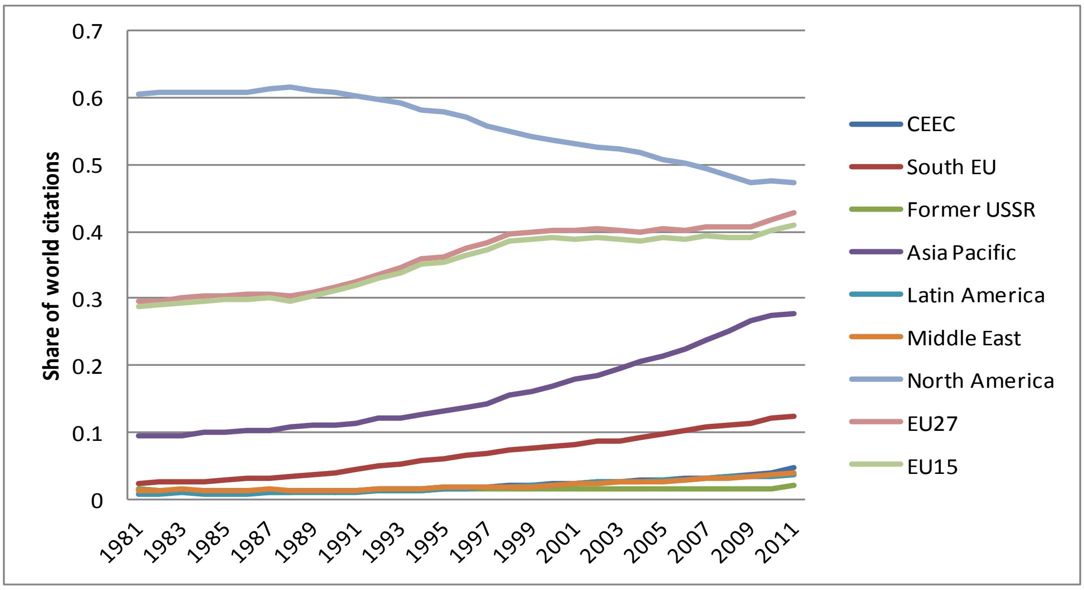
Graph 1. Share of world papers by regions, all fields, 1981-2011.



Graph 1 shows falling behind of the US followed by recent falling behind of EU15 which took place from the late 1990s. This global shift (OECD, 2010) took place due to rise of Asia Pacific, a rise of Middle East and Latin America. However, the rise of the CEE took place with continuing decline of the former-USSR. Also, stagnating growth dynamics of the South EU in the years before Eurozone crisis indicate a looming structural crisis of their science systems.

However, we argue that this global shift in science is more complex and cannot be properly interpreted by using only papers as indicators. In fact, this shift should be interpreted as shift in absorptive capacity globally as research base is proxy not only for world knowledge frontier but also proxy for capacity to absorb external knowledge. In that respect, Asia Pacific (where China, India, Korea and Taiwan make 45% of papers in 2003) is clear gainer with the South EU trailing at much lower pace. Moreover, it seems that with the onset of global financial crisis and Eurozone crisis as its toxic derivative South EU has exhausted its further potential for growth. There is remarkable catching up of Middle East to also gradually improving pace of the CEE. However, North America, EU15 and the former-USSR research bases, though at very different levels, have been gradually losing their dynamism. In that respect, profile of global research base has profoundly changed in the last 30 years in favour of newcomers led by Asia. However, given dual role of R&D this is largely shift in absorptive role of science but not yet shift in knowledge frontier generation shares.

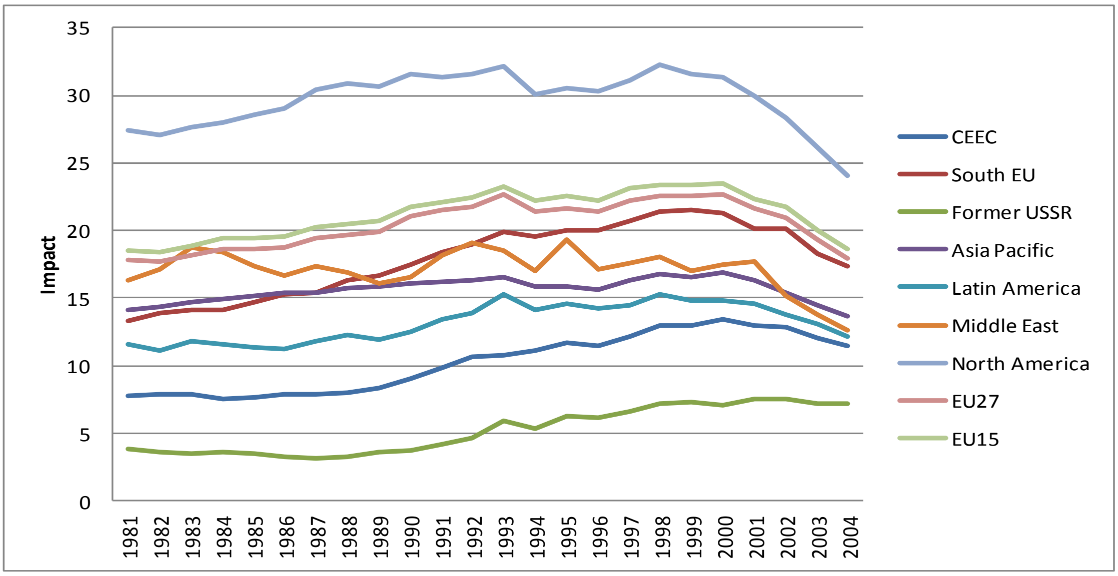
Graph 2. Share of world citations by regions, all fields, 1981-2011.



Citations are proxy of improved impact in science, not mere quantity. In overall, in citations a global shift has been taking place similar to publications: a further decline of North America; slowing down of the EU; stagnation of the former-USSR and very similar gradual increase of the CEE and Middle East (Graph 2). However, we do not see in citations stagnation of South EU which points to 'response effect' which goes from publications to citations and which can be expected only with some delay. Also, catching up of Asia Pacific is somewhat slower but it seems that it is only an issue of time before quantity in terms of papers get converted into impact growth in terms of citations.

With respect to impact (Graph 3) we do not observe global shift which reinforces our point that global shift in science is still largely about shift in absorptive capacities.

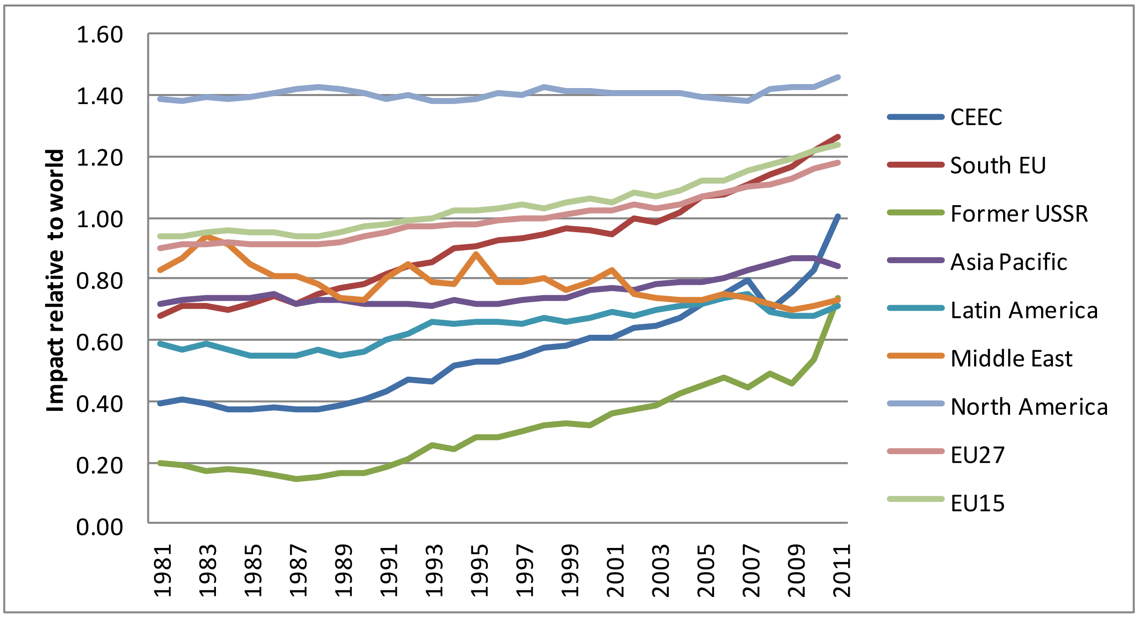
Graph 3. World regions by impact factors, all fields, 1981-2011.



The absence of global shift is visible through a huge gap in terms of impact between North America and the rest of the World. Also, there is remarkable catching up of South EU in terms of impact which is compatible to trends in citations. So, increased share of South EU in terms of papers has been accompanied also by increase in terms of both citations and even more in terms of impact. In other words, improved absorptive capacity of science has been accompanied by increased contribution to world science knowledge frontier. This raises interesting issues of the relations between science, technology and industry knowledge in South EU. Why improved absorptive and knowledge generation dimension of science did not translate in economic growth? Is part of structural problems in this part of the EU related to gaps between developed science knowledge and absence of demand for its use in terms of technology and especially industry knowledge?

A stagnant impact of Asia Pacific and Middle East shows again that global shift is largely about shift in absorptive, not so much about shift in world knowledge frontier activities. If we exclude countries that are leaders in both regions (Japan with 40% of citations, and Israel with 54.8% citations in 2003) this may suggest that science in these regions is largely oriented towards absorptive capacities. A majority of these countries are still deeply in absorptive capacity building stage which underpins their economic growth.

Graph 4. World regions by impact factors relative to world, all fields, 1981-2011.



Also, when we plot impact relative to world we do not observe global shift which is detected by looking at papers only. However, relative impact trends show towards convergence which are quite revealing. There seems to be tendency of EU15 including South EU to converge towards North America in terms of relative impact. However, there are also convergence processes among the remaining world regions towards relative impact of 0.8 of world average. This possibly conditional convergence is especially strong for the CEECs and the Former-USSR, and is absent in the Middle East which actually has declining relative impact. Asia Pacific has gradual increase in relative impact but much less discernible when compared to ex-socialist world. It also shows that despite decline of overall science systems in terms of relative shares of papers (quantity) in former-USSR systems there are areas of science in this region that continue to excel in terms of impact. Growth of the CEE in terms of relative impact is much more reflection of its growth in terms of relative shares of papers rather than differentiation between quantity and quality as it seems to be the case in the former-USSR region.

Summary. Global shift in science is largely in terms of quantity (papers) and much less or not yet in terms of impact. Hence, global shift is much more about absorptive capacity of science and much less about regional shifts in world science frontier. CEE is region that is catching up region both in terms of quantity (papers) as well as citations and impact. This process is taking place in the context of a shift of world science in terms of quantity gradually towards Asia and other non-North Atlantic regions and in the context of decline of the former-USSR science systems in terms of quantity (papers). EU15 trends reveal catching up of South EU both in terms of quantity and impact but also the lack of further dynamics. These trends may affect the overall EU27 distribution of science knowledge at least in terms of quantity (papers) i.e. in terms of absorptive capacity of science.

3.1.2 Scientific Specialization in World Regions by Four Major Fields

In this step of analysis we use RCA indexes for papers and citations to explore changes of the relative position of the CEE in relation to other world regions. In terms of citations, the CEE has RCA in fundamental sciences which during the last decade (2001-11) have been supplemented by RCA in applied sciences largely due to shift to computer and materials sciences (Table 3). A high bias towards fundamental sciences during the 1980s has been characteristics of both CEE and former-USSR. RCA coefficients for both papers and citations for fundamental sciences in post-socialist world have been by far the highest when compared to other world regions. This has been accompanied by low priority given to life sciences and to social sciences. This reflects belief at the time of 'science as the basis of technological progress' which has been highly skewed towards fundamental and applied areas. This orientation has remained largely unchanged during the post-socialist period. RCA coefficients remain the highest in this area in both post-socialist regions. In former-USSR it has actually further deepened. So, post-socialist world continue to excel relatively at the highest level in fundamental sciences when compared to other world regions. This would suggest that these regions face disproportionally higher problem of (ir)relevance of its science base for technological and industrial bases. This picture equally applies to papers which suggest that 'quantity' breeds 'impact' which again brings to attention the issue of trade off between excellence and relevance (Radosevic and Lepori, 2009) – i.e. whether continuous orientation towards old areas of excellence is the best strategy to ensure also relevance of science activities to changing technological and industrial knowledge.

Table 3. RCACIT and RCAPAP by region, major field and period.

	Asia Pacific		CEE		EU15		Former USSR		Latin America		Middle East		North America		South EU	
RCA-CIT	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11	1981-89	2001-11
Life sciences	1.00	0.85	0.69	0.80	0.97	1.00	0.26	0.36	1.15	1.18	0.89	0.90	1.01	1.05	0.81	0.93
Fundamental sciences	1.22	1.26	1.95	1.61	1.08	1.05	2.44	2.61	1.23	1.18	1.32	1.16	0.93	0.85	1.29	1.15
Applied sciences	1.16	1.33	1.35	1.35	0.97	1.03	1.09	1.59	1.47	1.33	1.31	1.33	1.04	0.94	1.21	1.28
Social sciences	0.32	0.51	0.15	0.31	0.40	0.79	0.06	0.12	0.51	0.47	1.41	0.76	1.44	1.33	0.16	0.46
RCA-PAP																
Life sciences	0.97	0.83	0.84	0.83	1.00	1.03	0.41	0.38	1.20	1.29	0.96	0.88	1.10	1.16	1.04	1.00
Fundamental sciences	1.19	1.16	1.44	1.41	0.96	1.01	1.78	2.24	0.94	0.96	1.06	0.95	0.88	0.84	1.03	1.10
Applied sciences	1.04	1.21	0.96	1.17	0.99	1.04	1.20	1.43	1.01	0.97	1.05	1.00	1.05	0.94	2.22	1.26
Social sciences	0.43	0.53	0.52	0.59	0.61	0.98	0.09	0.21	0.60	0.64	1.15	0.70	1.66	1.48	0.43	0.69

In the context of EU it is remarkable how South EU has been oriented during the 1980s towards applied sciences within which largely towards computer sciences. Its index of 2.2 for papers is by far the biggest specialization index recorded of all regions. However, this shift towards quantity has not been accompanied by equal shift towards impact as its RCA for citations has increased from 1.21 only to 1.28 between two periods. It seems that shift in sciences has not been accompanied by shift in terms of technology knowledge which would generate further pull towards industrial knowledge based on areas around applied sciences.

In order to systematically explore shifting comparative advantages of world regions with special reference to CEE we design matrices which compare RCA both in terms of papers and citations in two periods: 1981-1989 and 2001-11.

First, regional advantages and disadvantages are quite persistent features of world science. In 30 year period only 3 regions have seen newly gained advantages in terms of RCA PAP. EU15 has gained RCA in fundamental and applied sciences and CEE in applied sciences. This was followed by loss of RCA by North America and Latin America in applied sciences and by loss of Middle East RCA in fundamental and social sciences. At aggregate level science systems operate with high inertia and in areas of their historically inherited advantages and disadvantages.

Figure 1. Shifting areas of RCA in papers 1981-89/2001-11.

	RCA PAP >1 (1981-89) (old advantages)	**RCA PAP <1 (1981-1989) (old disadvantages)**
RCA PAP >1 (2001-11) (new advantages)	**Areas of continuous advantages** CEE: fundamental EU15: life Former USSR: fundamental, applied North America: life, social South EU: life, fundamental, applied Latin America: life Asia Pacific: fundamental, applied Middle East: applied	**Areas of newly gained advantages** CEE: applied EU15: fundamental, applied
RCA PAP <1 (2001-11) (new disadvantages)	**Areas of lost advantages** North America: applied Latin America: applied Middle East: fundamental, social	**Areas of continuous disadvantages** CEE: life, social EU15: social Former USSR: life, social North America: fundamental South EU: social Latin America: fundamental, social Asia Pacific: life, social Middle East: life

Second, persistence of regional advantages and disadvantages is even more pronounced in terms of citations and impact. In 30 year period only 2 regions have seen newly gained advantages in terms of RCA CIT. Only EU15 has increased RCA CIT in life and applied sciences and only 3 regions have seen lost relative advantages. CEE newly gained relative advantages in papers in applied sciences has not yet been followed by RCA in terms of citations. From global perspective it is interesting to note loss of North America in applied sciences and in Asia Pacific of life sciences. Former-USSR region has not gained now major areas of comparative advantage and remain at aggregate level specialized in fundamental and applied sciences and de-specialized in life and social sciences. This suggests that scientific specializations are historically rooted and highly path dependent even in regions which have undergone major changes in terms of economic regime and openness of science system.

Figure 2. Shifting areas of RCA in citations for world regions 1981-89/2001-11.

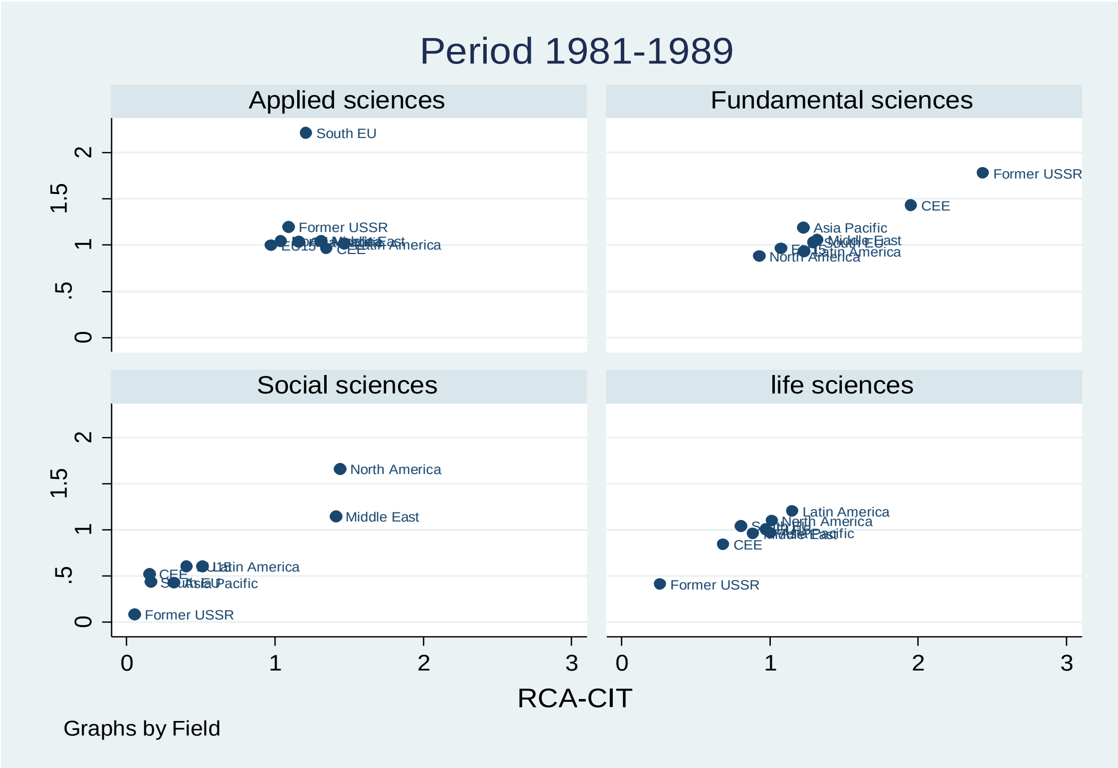
	RCA CIT >1 (1981-89) **(old advantages)**	**RCA CIT <1 (1981-1989)** **(old disadvantages)**
RCA CIT >1 (2001-11) **(new advantages)**	**Areas of continuous advantages** **CEE:** fundamental, applied **EU15:** fundamental **Former USSR:** fundamental, applied **North America:** life, social **South EU:** fundamental, applied **Latin America:** life, fundamental, applied **Asia Pacific:** fundamental, applied **Middle East:** fundamental, applied	**Newly gained advantages** EU15: life, applied
RCA CIT <1 (2001-11) **(new disadvantages)**	**Areas of lost advantages** North America: applied Asia Pacific: life Middle East: social	**Areas of continuous disadvantages** CEE: life, social EU15: social Former USSR: life, social North America: fundamental South EU: life, social Latin America: social Asia Pacific: social Middle East: life

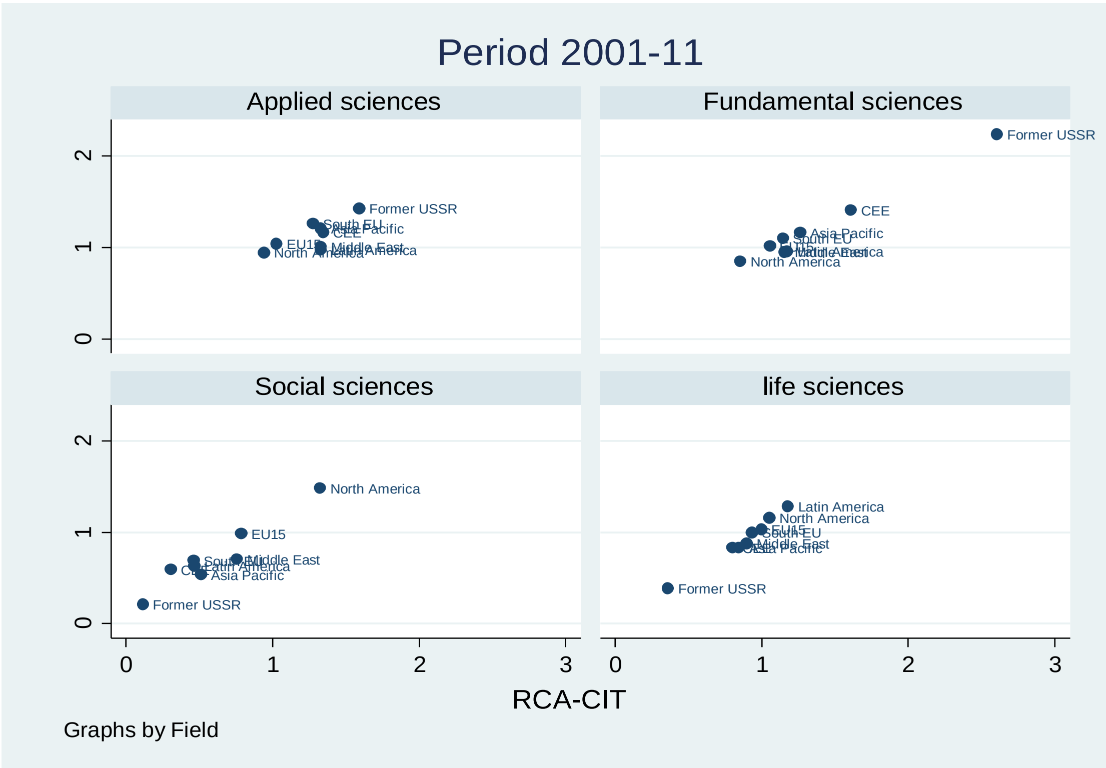
RCA data at aggregate level suggest that there have not been significant changes in disciplinary structures of regional science systems. This suggest that despite significant institutional and political changes sciences systems in the world operate with relatively high degrees of autonomy which may be explained probably less by institutional differences but much more by nature of scientific capabilities which are highly localised, cumulative and path dependent. So, global shift in science has taken place in terms of shares of overall papers (absorptive dimension of science) but not in terms of disciplinary specializations. Finally, amid strong persistence of disciplinary structures it is significant to note that relatively small region as CEE has shifted excessive specialization from RCA PAP in fundamental sciences towards applied sciences. For detailed graphic presentation of RCA changes in between two periods see Annex 1.

Graph 5 is based on the scatter diagrams of RCACIT and RCAPAP for world regions by four major areas of sciences in two periods. In 1981-89 period we can clearly see the strong specialization of

CEE and former-USSR in fundamental sciences, strong specialization of South EU in applied sciences, strong specialization of North America and Middle East in social sciences and strong de-specialization of former-USSR in life sciences and in social sciences.

Graph 5. Scatter diagrams for RCA PAP and RCA CIT by four major fields by world regions and by periods 1981-89 and 2001-11.





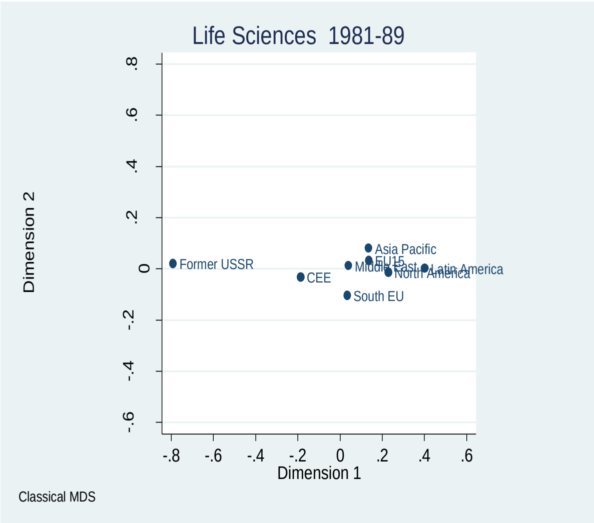
In 2001-11 period as suggested by Figures 1 and 2 there has been limited shift in RCA among regions. However, a few features remain pronounced. First, former-USSR continued to specialize in fundamental sciences and its science system has become extremely unbalanced as it continues to de-specialize in life sciences and is de-specialized in social sciences. CEE has reduced its excessive specialization in fundamental sciences and has shifted more towards applied sciences. On the other hand, very strong specialization of South EU in applied sciences in the first period led to strong de-specialization in 2001-11 period. North America continued to be specialized strongly in social sciences while the Middle East has clearly de-specialized from that area. In overall, this would suggest that the EU science specializations have become more homogenous while former-USSR continued to be outlier in terms of RCA.

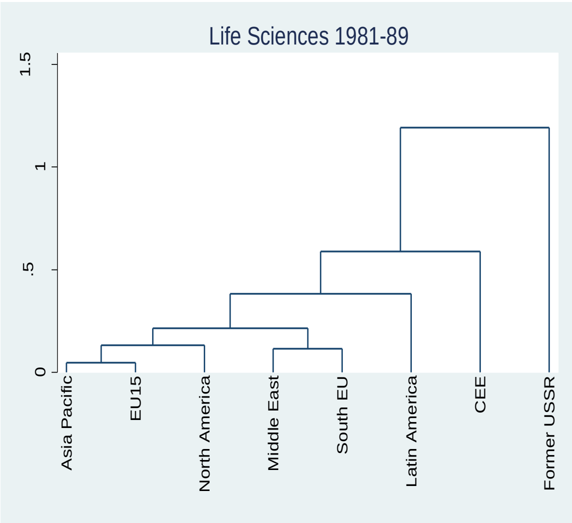
In continuation, we present data in form of multidimensional scaling (MDS) and hierarchical cluster analysis based on RCACIT and RCAPAP to investigate convergence and divergence in four major science areas.

These two forms of analyses enable us to visually easily detect distances between regions in terms of similarity or dissimilarity in terms of RCA in papers and citations.

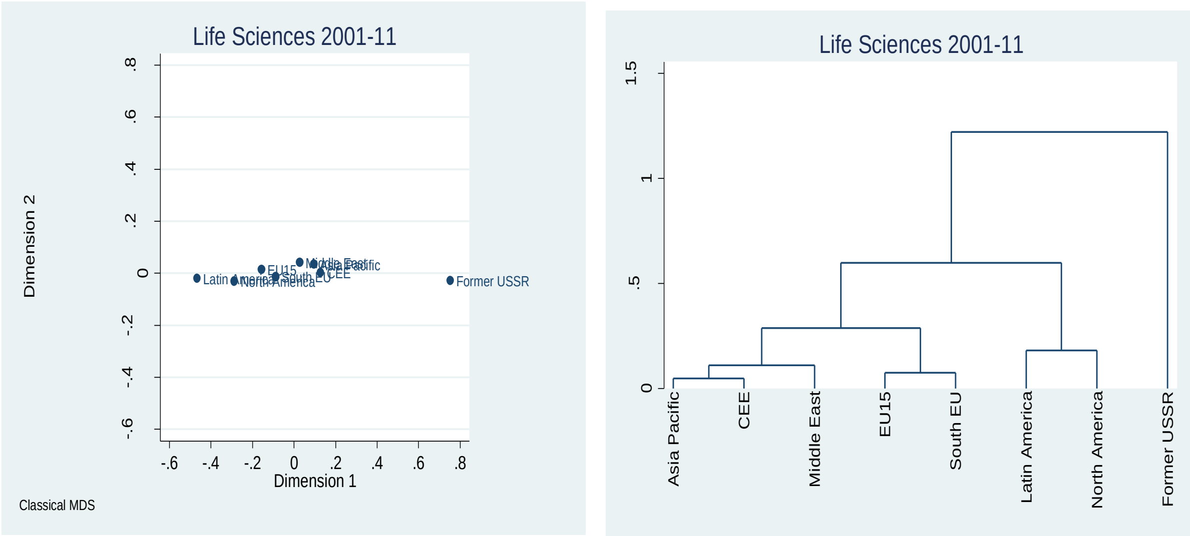
In life sciences (Graph 6 and 7) former-USSR and CEE have been clearly de-specialized in this area which is also visible in dendogram. In 2001-11 period CEE has clearly moved towards other regions while former-USSR remains outlier which poses issue of how these countries can respond to raising environmental and other challenges related to life sciences. South EU has moved closer to the EU15 and to other regions in second period.

Graph 6. Multidimensional scaling (MDS) and hierarchical clustering of world regions in life sciences 1981-89 (based on RCAPAP and RCACIT)



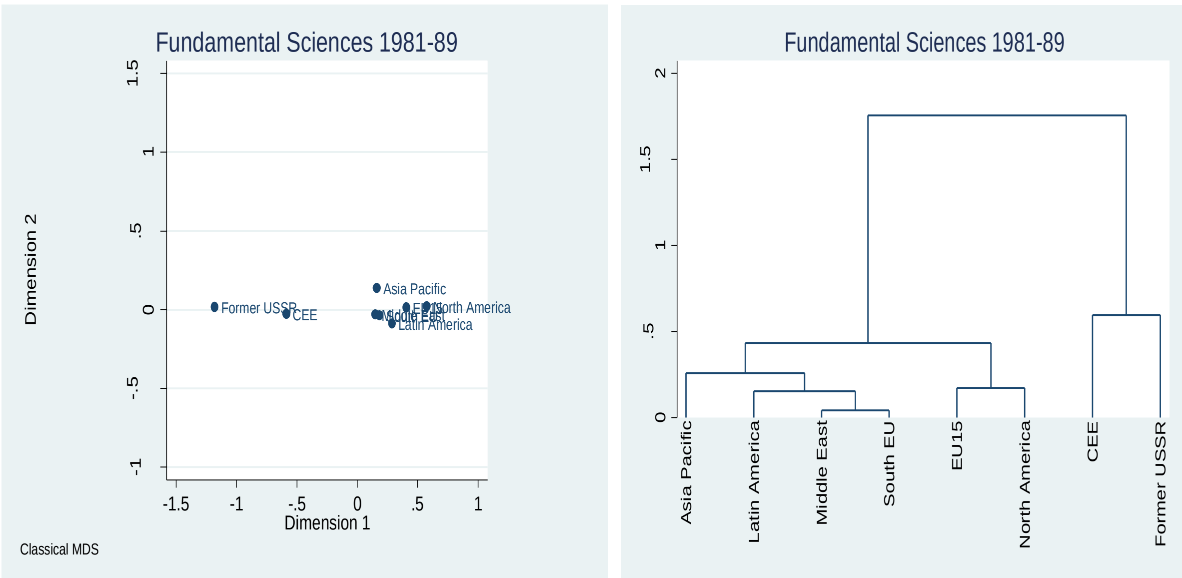


Graph 7. Multidimensional scaling (MDS) and hierarchical clustering of world regions in life sciences 2001-11 (based on RCAPAP and RCACIT)



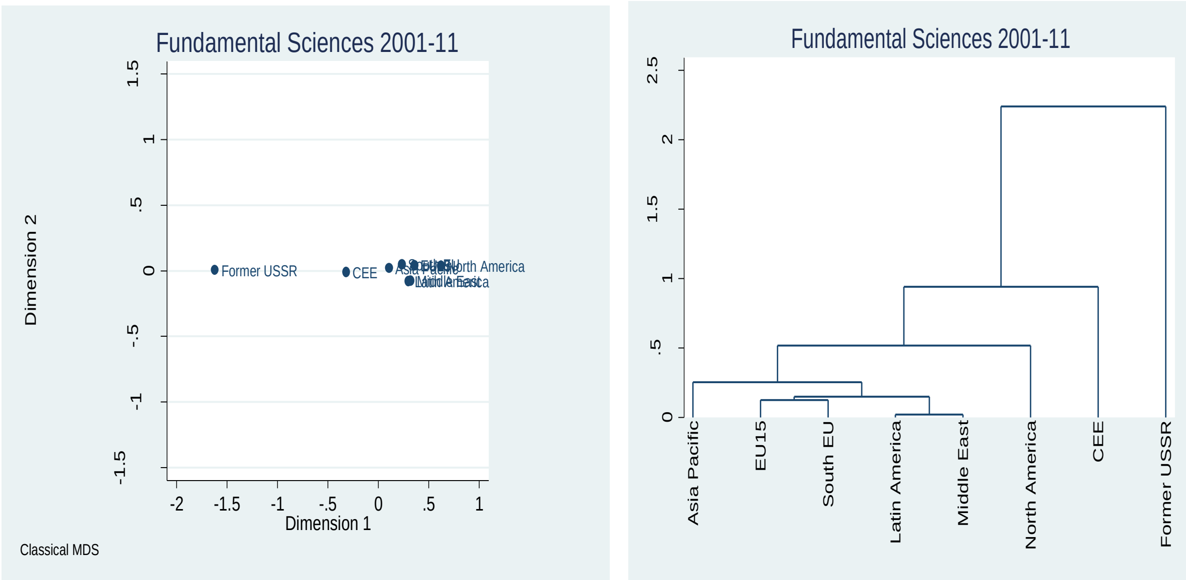
Very high RCA in fundamental sciences in terms of both papers and citations for Former-USSR and CEE suggest that they have been clearly outliers in 1981-89 period . This is clearly visible in dendogram (Graph 8) where these two regions are distant from other regions.

Graph 8. Multidimensional scaling (MDS) and hierarchical clustering of world regions in fundamental sciences 1981-89 (based on RCAPAP and RCACIT)



Graph 9 shows that these two regions continue to be distant but CEE has been strongly converging to other regions while former-USSR remain strongly specialized in fundamental sciences. Other regions have even further came closer to each other in terms of RCA in CIT and PAP in fundamental sciences which suggest that there has been increasing integration of world fundamental sciences.

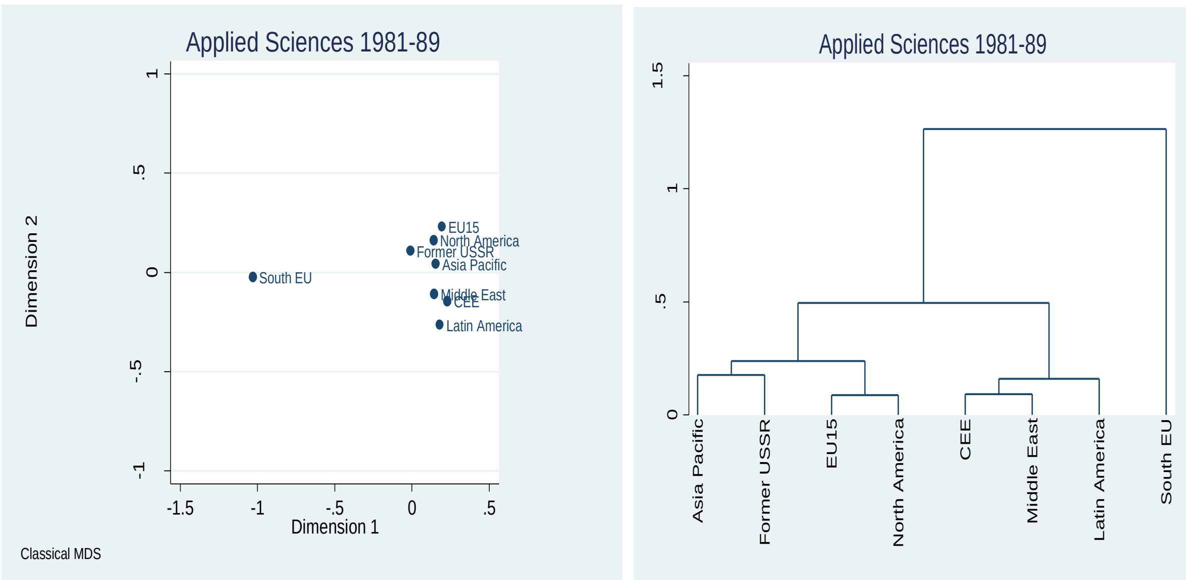
Graph 9. Multidimensional scaling (MDS) and hierarchical clustering of world regions in fundamental sciences 2001-11 period (based on RCAPAP and RCACIT)



In applied sciences South EU has been clearly outlier in terms of strong specialization in applied sciences where it has been largely specialized in space research and in computer sciences (Graph 10). However, there has been clear shift of de-specialization of the South EU in 2000-11. South EU has been the most specialized with RCAPAP>2. However, it did not manage to keep its old advantages at 1981-89 level at least for RCAPAP, but kept it for RCACIT. We assume that this came due to decreasing demand of local technology providers for new research in this area in South EU. In other words, South EU science systems continued to decline in terms of absorptive dimension of applied sciences although its quality in terms of citations has remained unchanged.

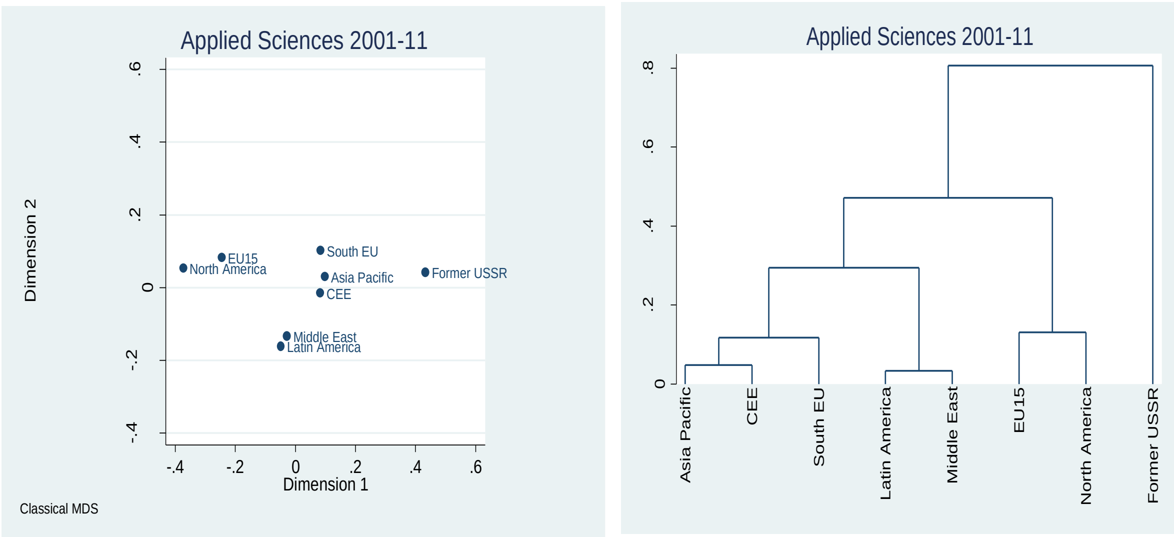
Unlike trend towards increasing global integration national specializations in fundamental sciences (Graph 9) there has been trend towards global diversification in applied sciences in terms of RCA (Graphs 10 and 11).

Graph 10. Multidimensional scaling (MDS) and hierarchical clustering of world regions in applied sciences 1981-89 (based on RCAPAP and RCACIT)



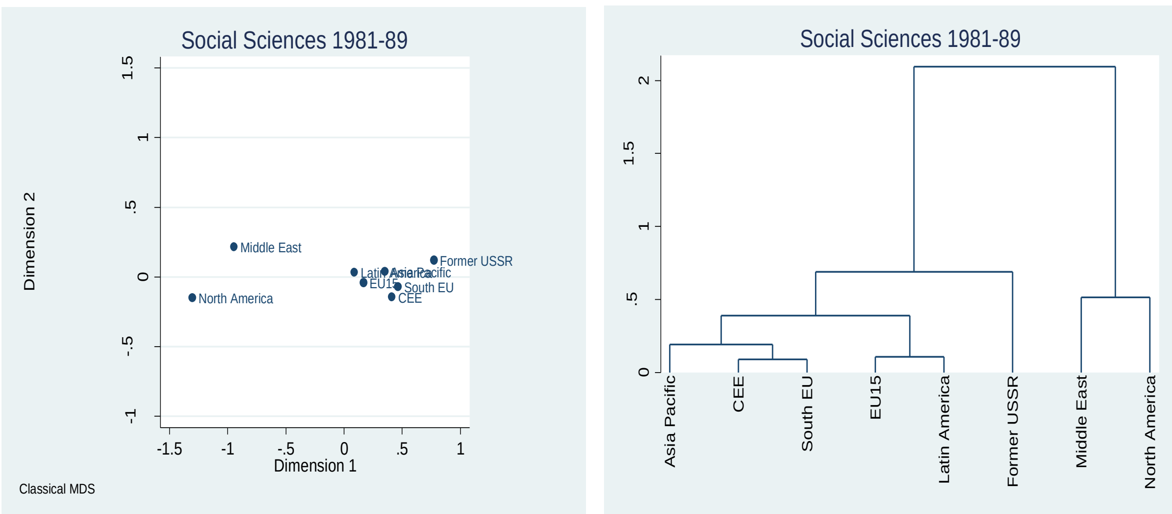
There have emerged three groupings in applied sciences in terms of RCA CIT/PAP. First, EU15/North America, second, South EU, Asia Pacific and CEE, and third, Middle East/Latin America while former-USSR has actually diverged in this area in terms of RCA. Former-USSR has become increasingly specialised in applied sciences through its renewed interest in space research which is for the time being reflected in high RCA in papers.

Graph 11. Multidimensional scaling (MDS) and hierarchical clustering of world regions in applied sciences 2001-11 period (based on RCAPAP and RCACIT)



Finally, in social sciences during the 1980s North America and Middle East have been hyper-specialized in social sciences when compared to other regions (Graph 12). This puzzling result possibly shows two extreme cases. In the case of North America we observe expected process of increasing reflexivity or research based scrutiny of social processes while in the case of Middle East this hyper-specialization is largely the outcome of weak development of other areas – i.e.. it is not reflection of development of social sciences *per se* but of weak development of other sciences.

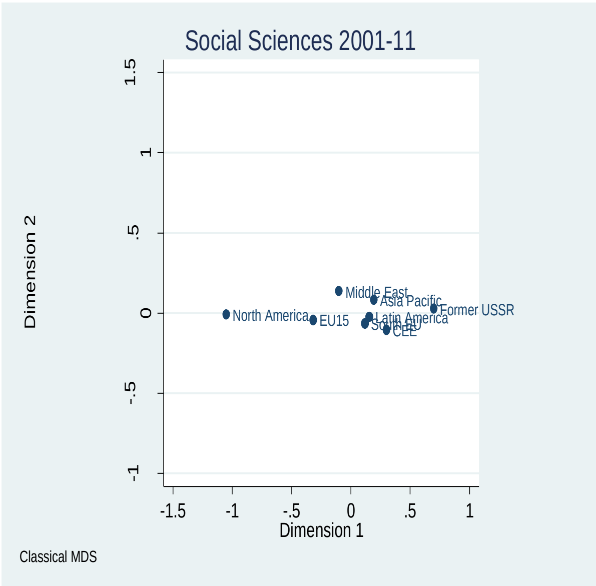
Graph 12. Multidimensional scaling (MDS) and hierarchical clustering of world regions in social sciences 1981-89 (based on RCAPAP and RCACIT)

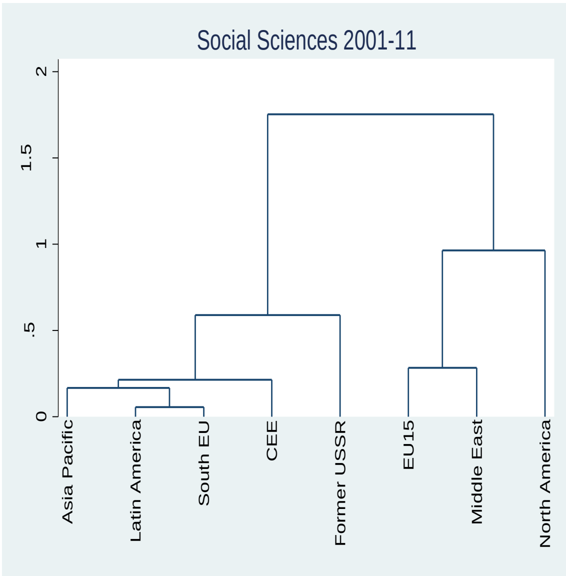


North America continues to have strong RCA in social sciences in 2001 -11 period. Its RCA continue to be well above 1 in both RCAPAP and RCACIT. Middle East has lost its RCA in social sciences but largely due to increased importance of other areas as these countries have developed science capacities in technical and natural sciences areas.

It is surprising that the socialist world (former-USSR and CEE) has not been strongly de-specialized in this area. Dendograms show that in terms of both RCA they were closer to other regions than two outliers (North America and Middle East). In second period CEE has doubled its RCACIT from 0.15 to 0.31 from period 1 to period 3. However, in terms of RCA in 2001-11 period CEE is only better than former-USSR, the worst performer among all regions in both periods. This is not surprising as local capacity for self-reflection and research approach to social processes has been sorely lacking in post-socialist world in transition period and onwards.

Graph 13. Multidimensional scaling (MDS) and hierarchical clustering of world regions in social sciences 2001-11 period (based on RCAPAP and RCACIT)





In summary, use of MDS and cluster analysis confirmed that scientific specializations in the world science among world regions in the last 30 years have been quite persistent. In fact, changes can be reduced to the following three major trends. First, South EU has lost its excessive specialization in applied sciences. Second, CEE and Former-USSR had excessive specializations in fundamental sciences and Former-USSR continues to be excessively specialized in this area and de-specialized in life sciences when compared to other regions. Third, North America and Middle East had excessive specialization in social sciences but for opposite reasons and North America continued to be highly specialized in this area.

Summary. Even though producing 4% of world papers and 2.5% of world citations during 2001-2011 period, CEE shows strong relative comparative advantages, both in published papers and citations, particularly in fundamental sciences and is catching up in applied sciences. This is accompanied by a divergence from the Former-USSR and a convergence towards EU15 from 1981-89 period to 2001-2011 period.

3.2 Country Level Analysis by 21 Scientific Fields

In this section we break our analysis down to country level and further to investigation of 21 scientific fields in terms of RCAPAP and RCACIT.

3.2.1 Publications, Citations and Impact

The low share of world publications and citations of the CEE in general is rooted in the low share of these conventional bibliometric indicators per country. The country level analysis, thus, reflects very much the analyses conducted for the regions. Table 4 illustrates that there is more or less some homogeneity among the CEECs in terms of their individual share of publications, citations in world and the relative impact measures. It also shows that Poland is the most productive country in terms of publications and citations among the CEECs, which can largely be attributed to being the most populated country in the region. These figures, however, are well below that of EU15 and BRIC countries, though they show an increasing trend over time. Relative impact of the science base in CEECs, in particular during the 2001-11 period, are comparable to BRICs and depict a considerable existence when compared to most of the EU15 countries.

Table 4. Share of papers, citations and impact relative to world for all fields in CEE and selected countries by periods.

	% Papers in the world			% citations in the world			Relative impact		
	1981-89	1990-2000	2001-11	1981-89	1990-2000	2001-11	1981-89	1990-2000	2001-11
BULGARIA	0.26	0.23	0.19	0.07	0.09	0.13	0.27	0.41	0.68
CROATIA	_	0.15	0.22	-	0.07	0.15	_	0.47	0.65
CZECH REPUBLIC	_	0.35	0.68	-	0.20	0.60	_	0.51	0.86
ESTONIA	0.04	0.06	0.09	0.02	0.04	0.10	0.44	0.67	1.06
HUNGARY	0.58	0.49	0.51	0.28	0.33	0.49	0.49	0.67	0.97
LATVIA	0.06	0.05	0.04	0.01	0.02	0.03	0.22	0.39	0.68
LITHUANIA	0.05	0.05	0.12	0.01	0.03	0.08	0.20	0.50	0.62
POLAND	1.03	1.09	1.55	0.45	0.58	1.04	0.43	0.52	0.67
ROMANIA	0.19	0.18	0.37	0.05	0.07	0.20	0.25	0.35	0.53
SLOVAKIA	_	0.27	0.24	-	0.12	0.17	_	0.44	0.70
SLOVENIA	_	0.14	0.24	-	0.09	0.18	_	0.63	0.75
AUSTRIA	0.64	0.79	0.97	0.45	0.81	1.25	0.71	1.02	1.28
BELGIUM	0.98	1.18	1.40	0.93	1.32	1.91	0.95	1.12	1.36
GERMANY	7.75	8.13	8.03	6.27	8.17	10.17	0.81	1.00	1.27
SWEDEN	1.70	1.88	1.82	2.33	2.43	2.50	1.37	1.29	1.38
UK	8.57	8.88	8.28	10.14	10.66	11.39	1.18	1.20	1.38
ITALY	2.53	3.66	4.37	2.06	3.54	5.04	0.81	0.96	1.15
SPAIN	1.14	2.29	3.44	0.65	1.96	3.71	0.56	0.84	1.07
USA	38.81	36.33	30.96	55.76	51.85	44.28	1.44	1.43	1.43
RUSSIA	5.18	4.09	2.70	1.03	1.14	1.23	0.20	0.28	0.46
CHINA	0.73	1.97	7.55	0.26	0.83	5.51	0.35	0.41	0.70
INDIA	2.71	2.29	2.95	0.79	0.89	1.86	0.29	0.39	0.62
SOUTH KOREA	0.14	0.91	2.85	0.08	0.54	2.16	0.58	0.58	0.75
TAIWAN	0.22	0.93	1.80	0.13	0.55	1.32	0.61	0.59	0.73
BRAZIL	0.49	0.92	2.11	0.27	0.58	1.42	0.54	0.63	0.68
TURKEY	0.10	0.41	1.53	0.05	0.21	0.84	0.49	0.50	0.56

Source: Thomson Reuter's 2011 National Indicators_Standard ESI.

Notes: 2nd period is 1993-2000 for Croatia and Slovenia; 1990-2000 for Czech Republic and 1994-2000 for Slovakia;

3.2.2 Scientific Specialization in CEE by 21 Scientific Fields

In section 3.1.2, where we analyzed scientific specialization of the CEE with regard to four major fields, applied sciences emerged as area of newly gained advantages in RCAPAP and applied and life sciences emerged so in RCACIT. When broken down to 21 scientific disciplines (see Figure 3), it seems that space science has been the driving scientific field playing the major role in gaining relative advantages both in papers and citations from 1981-89 period to 2001-11 period among all other disciplines classified under applied sciences. Likewise, agricultural sciences, plant and animal sciences (and in these two fields CEE held continuous advantages in papers in both periods) and environment/ecology have been the scientific fields driving the gain in relative advantages in citations in life sciences for the whole of the CEE region. In categories of life sciences related to human beings, CEE did not improve its relative advantages – either in papers or in citations– from

1981-89 to 2001-11 period. Maths, chemistry, physics as branches of fundamental sciences and engineering sciences and materials science as branches of applied sciences have always been the continuous advantage areas of the CEECs.

Figure 3. Shifting areas of RCA in papers and citations in CEE (21 bibliometric fields) 1981-89/2001-11.

	RCA PAP >1 (1981-89) **(old advantages)**	**RCA PAP <1 (1981-1989)** **(old disadvantages)**
RCA PAP >1 **(2001-11)** **(new advantages)**	**<u>AREAS OF CONTINUOUS ADVANTAGES</u>** Agricultural sciences Plant and animal sciences Biology and biochemistry Engineering Materials science Chemistry Mathematics Physics	**<u>AREAS OF NEWLY GAINED ADVANTAGES</u>** Environment/ecology Space science
RCA PAP <1 **(2001-11)** **(new disadvantages)**	**<u>AREAS OF LOST ADVANTAGES</u>** Microbiology Pharmacology and toxicology	**<u>AREAS OF CONTINUOUS DISADVANTAGES</u>** Clinical medicine Immunology Molecular biology and genetics Neuroscience and behaviour Psychiatry/psychology Computer science Geosciences Economics Social sciences
	RCA CIT >1 (1981-89) **(old advantages)**	**RCA CIT <1 (1981-1989)** **(old disadvantages)**
RCA CIT >1 **(2001-11)** **(new advantages)**	**<u>AREAS OF CONTINUOUS ADVANTAGES</u>** Pharmacology and toxicology Engineering Materials science Computer science Chemistry Mathematics Physics	**<u>AREAS OF NEWLY GAINED ADVANTAGES</u>** Agricultural sciences Plant and animal sciences Environment/ecology Space science
RCA CIT <1 **(2001-11)** **(new disadvantages)**	**<u>AREAS OF LOST ADVANTAGES</u>** **-**	**<u>AREAS OF CONTINUOUS DISADVANTAGES</u>** Clinical medicine Biology and biochemistry Microbiology Immunology Molecular biology and genetics Neuroscience and behaviour Psychiatry/psychology Geosciences Economics Social sciences

3.2.3 Country Level Scientific Specialization in CEE by 21 Scientific Fields

When analysed separately, CEE countries show different patterns in relative comparative advantages by 21 scientific fields. In this section we aim to identify CEE countries which diverge from the regional trend and investigate the disciplines in which countries developed comparative advantages in papers and citations over time. Annex 1 provides more detailed information for the Table 5 and Table 6.

Table 5. Shifting areas of RCA (21 bibliometric fields) in papers (RCAPAP) in CEE countries from 1981-89 to 2001-11.

⇧ Continuous Advantage ⇩ Continuous Disadvantage ⇘ Lost Advantage ⇗ New Advantage

	Bibliometric field	Country											Number of countries where technology experinces a			
		BG	HU	PL	RO	HR	CZ	EE	LT	LV	SK	SI	⇩	⇘	⇗	⇧
Life sciences	Clinical medicine	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
	Immunology	⇩	⇗	⇘	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	8	1	2	0
	Neurology and behaviour	⇩	⇧	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	9	0	1	1
	Psychiatry/Psychology	⇩	⇩	⇩	⇩	⇩	⇘	⇩	⇩	⇩	⇘	⇩	9	2	0	0
	Biology and biochemistry	⇧	⇧	⇗	⇩	⇧	⇧	⇘	⇘	⇩	⇘	⇘	2	4	1	4
	Molecular biology and genetics	⇘	⇧	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	9	1	0	1
	Microbiology	⇩	⇩	⇩	⇩	⇩	⇧	⇗	⇩	⇗	⇧	⇩	7	0	2	2
	Pharmacology/Toxicology	⇘	⇧	⇘	⇩	⇩	⇘	⇩	⇩	⇩	⇘	⇩	6	4	0	1
	Plant and animal science	⇗	⇧	⇗	⇩	⇧	⇗	⇗	⇗	⇩	⇗	⇘	2	1	6	2
	Agricultural sciences	⇗	⇧	⇩	⇩	⇗	⇧	⇩	⇗	⇩	⇘	⇗	4	1	4	2
	Environment/Ecology	⇩	⇩	⇗	⇗	⇗	⇗	⇗	⇗	⇩	⇗	⇩	4	0	7	0
Fundamental Sciences	Chemistry	⇧	⇧	⇧	⇧	⇘	⇧	⇘	⇘	⇘	⇧	⇧	0	4	0	7
	Physics	⇧	⇗	⇧	⇧	⇘	⇗	⇧	⇧	⇧	⇗	⇧	0	1	3	7
	Mathematics	⇧	⇧	⇧	⇧	⇧	⇧	⇩	⇗	⇩	⇧	⇧	2	0	1	8
	Geosciences	⇗	⇩	⇩	⇩	⇩	⇗	⇗	⇩	⇩	⇗	⇩	7	0	4	0
Engineering sciences	Computer sciences	⇩	⇩	⇘	⇗	⇘	⇩	⇩	⇩	⇩	⇩	⇧	7	2	1	1
	Engineering sciences	⇩	⇩	⇧	⇧	⇧	⇩	⇩	⇗	⇗	⇩	⇧	5	0	2	4
	Materials science	⇧	⇩	⇧	⇗	⇗	⇧	⇩	⇧	⇧	⇧	⇗	2	0	3	6
	Space science	⇧	⇗	⇗	⇩	⇩	⇗	⇧	⇧	⇘	⇗	⇩	3	1	4	3
Social sciences	Economics and business	⇩	⇩	⇩	⇩	⇩	⇧	⇩	⇗	⇩	⇧	⇗	7	0	2	2
	Social sciences	⇩	⇩	⇩	⇩	⇗	⇩	⇗	⇩	⇩	⇩	⇗	8	0	3	0

Table 6. Shifting areas of RCA (21 bibliometric fields) in citations (RCACIT) in CEE countries from 1981-89 to 2001-11.

⇧ Continuous Advantage ⇩ Continuous Disadvantage ⇘ Lost Advantage ⇗ New Advantage

	Bibliometric field	Country											Number of countries where technology experinces a			
		BG	HU	PL	RO	HR	CZ	EE	LT	LV	SK	SI	⇩	⇘	⇗	⇧
Life sciences	Clinical medicine	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
	Immunology	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
	Neurology and behaviour	⇩	⇧	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	10	0	0	1
	Psychiatry/Psychology	⇩	⇩	⇩	⇩	⇩	⇘	⇩	⇩	⇩	⇘	⇩	9	2	0	0
	Biology and biochemistry	⇩	⇗	⇩	⇩	⇩	⇩	⇩	⇘	⇩	⇗	⇘	7	2	2	0
	Molecular biology and genetics	⇩	⇘	⇩	⇘	⇗	⇩	⇗	⇩	⇩	⇩	⇩	7	2	2	0
	Microbiology	⇩	⇩	⇩	⇩	⇩	⇧	⇩	⇗	⇗	⇧	⇗	6	0	3	2
	Pharmacology/Toxicology	⇧	⇧	⇧	⇩	⇘	⇩	⇩	⇩	⇩	⇗	⇗	5	1	2	3
	Plant and animal science	⇗	⇧	⇩	⇩	⇧	⇧	⇧	⇩	⇗	⇧	⇘	3	1	2	5
	Agricultural sciences	⇩	⇘	⇗	⇩	⇗	⇗	⇩	⇗	⇩	⇗	⇗	4	1	6	0
	Environment/Ecology	⇩	⇩	⇩	⇩	⇧	⇗	⇗	⇗	⇗	⇗	⇧	4	0	5	2
Fundamental Sciences	Chemistry	⇧	⇧	⇧	⇧	⇧	⇧	⇘	⇘	⇘	⇧	⇧	0	3	0	8
	Physics	⇧	⇗	⇧	⇧	⇧	⇗	⇘	⇧	⇧	⇗	⇧	0	1	3	7
	Mathematics	⇧	⇧	⇧	⇧	⇧	⇧	⇘	⇧	⇧	⇧	⇧	0	1	0	10
	Geosciences	⇗	⇩	⇩	⇗	⇩	⇗	⇧	⇩	⇩	⇩	⇩	7	0	3	1
Engineering sciences	Computer sciences	⇩	⇗	⇘	⇗	⇘	⇩	⇩	⇧	⇘	⇗	⇧	3	3	3	2
	Engineering sciences	⇧	⇩	⇧	⇧	⇘	⇧	⇩	⇗	⇗	⇘	⇧	2	2	2	5
	Materials science	⇧	⇩	⇧	⇧	⇘	⇧	⇘	⇗	⇧	⇧	⇧	1	2	1	7
	Space science	⇗	⇗	⇗	⇩	⇗	⇗	⇘	⇧	⇘	⇩	⇗	2	2	6	1
Social sciences	Economics and business	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇩	10	0	1	0
	Social sciences	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	⇩	⇩	10	0	1	0

LifeSciences. In terms of RCA in papers (see Table 6), in line with earlier findings even though the majority of CEE countries display continuous disadvantages in most of life sciences. However, particularly in plant and animal sciences, agricultural sciences and environment/ecology disciplines a considerable number of CEECs gained advantages from 1981-89 period to 2001-11 period. Among these countries, in environment/ecology Poland, Romania, Croatia, Czech Republic, Estonia, Lithuania and Slovakia gained advantages whereas none of the countries had sole continuous advantages. Bulgaria, Hungary, Latvia and Slovenia had continuous disadvantages over 30 years period. RCA CIT follows more or less the same pattern as RCA PAP (Table 6). Croatia and interestingly Slovenia had continuous advantages in citations in environment/ecology discipline implying that Slovenia certainly had an impact in this field compared to quantity of its publications. In plant and animal sciences Bulgaria, Poland, Czech Republic, Estonia, Lithuania and Slovakia gained advantages from first period to the third. Hungary and Croatia have been holding continuous advantages over time. With regard to RCACIT, these countries have also been holding continuous advantages or gained advantages over time, with the exception of Poland whose impact has been lower than the quantity of publications. In agricultural sciences Bulgaria, Croatia, Lithuania and Slovenia show having gained advantages, whereas Hungary and Estonia have been holding continuous advantages over time. In terms of RCACIT six countries, namely Poland, Croatia, Czech Republic, Lithuania, Slovakia and Slovenia gained advantages over 30 years' time indicating a progress in this field. Apart from these three fields, only in biology/biochemistry, which is indeed considerably associated with fundamental sciences, is a strong field among the life sciences for the CEECs. Bulgaria, Hungary, Croatia and Czech Republic already held continuous advantages over time in this field, whereas

Poland gained advantages. In terms of impact, though, only Hungary and Slovenia show progress over time. By means of the remaining disciplines in life sciences, particularly the ones related to human beings, CEECs seem to be very weak both in terms of comparative advantages in publications and papers. None of the countries have any advantages in clinical medicine. Czech Republic and Slovakia lost their advantages that they had in psychiatry/psychology both in terms of quantity and impact. In Pharmacology/toxicology Bulgaria, Hungary, Czech Republic and Slovakia lost their comparative advantages in publications, even though advantages in impact show an ambiguous pattern among the CEECs. Even though majority of the CEECs remain in weak human being related life sciences some countries managed to gain comparative advantages. Hungary and Estonia have gained advantages in immunology in publications, but this did not reflect to impact. Estonia gained advantages in neurology and behaviour in terms of publications and Hungary always had continuous advantages both in publications and citations. Estonia and Latvia gained advantages in microbiology in papers, but this did not reflect to impact, whereas Latvia, Lithuania and Slovenia showed progress in developing advantages in citations.

Fundamental Sciences. In chemistry, physics and mathematics branch of fundamental sciences, 7-10 out of 11 CEECs had strong continuous comparative advantages both in publications and in citations throughout the 30 years period studied. Contrary to the former three fields, CEECs seem to be weak in geosciences. They all had disadvantages in publications and citations with regard to this discipline during 1981-89 period. Four CEECs, Bulgaria, Czech Republic, Estonia and Slovenia gained new advantages in this field during period 2001-11. Bulgaria and Czech Republic managed to gain advantages in terms of citations as well, whereas Estonia already had continuous advantages.

Applied Sciences. Especially in engineering and materials science, majority of the CEECs already had continuous advantages both in publications and citations from 1981-89 to 2001-11 period. Poland, Romania, Croatia and Slovenia had continuous advantages in publications in engineering sciences; while Bulgaria, Poland, Romania, Czech Republic and Slovenia had continuous advantages in citations. The Baltic States of Lithuania and Latvia gained new advantages in this field both in publications and citations over time. Bulgaria, Hungary, Czech Republic, Estonia and Slovakia could not progress and stayed with continuous disadvantages in publications; while as for citations continuous disadvantages prevailed only for Hungary and Estonia. Therefore, historically, even though not all CEECs showed comparative advantages in publications in engineering sciences, a considerable majority had continuous and newly gained advantages in impact. As largely connected to engineering sciences, materials science follows the same pattern with 6 -7 of the 11 CEECs having already continuous advantages in the field both in publications and citations. Among them are, Bulgaria, Romania, Poland, Czech Republic, Slovakia, Lithuania, Latvia. Over time, Croatia and Slovenia gained advantages. Space science displays an intermediate position among the branches of applied sciences. Even though it has been a vastly invested area in the Soviet Union, it seems that only few of the periphery were influenced. Bulgaria, Lithuania and Estonia had continuous advantages in publications and only Lithuania in citations as well. It is interesting to note that Hungary, Poland, Czech Republic and Slovakia gained new advantages in publications from 1981-89 period to 2001-11 period; whereas alongside them Bulgaria and Croatia gained advantages in citations. Contrary to the central eastern European countries, the Baltics which were in the Soviet Union, lost their advantages in space science, i.e. Latvia both in publications and citations and Estonia in citations. Lastly, computer science has been a weak field in terms of publications, i.e. 7 out of 11 countries had continuous disadvantages, but it depicts an ambiguous picture in terms of citations throughout the CEECs. Only Slovenia had continuous advantages in publications and Romania gained it over time; whereas Croatia and Poland lost advantages. As for advantages in citations Slovenia and Lithuania had continuous advantages; Hungary, Romania and Slovakia gained new advantages; Poland, Croatia and Latvia lost their advantages, whereas Bulgaria, Czech Republic and Estonia had continuous disadvantages from 1981-89 period to 2001-11 period.

Social Sciences. Both branches of social sciences analysed in this research, i.e. social sciences in general and economics and business were and remain to be weak areas in the CEECs. Only Slovakia and Czech Republic had continuous advantages in publications in economics and business, but this does not reflect to their advantages in citations. Their impact remains to be weak. Although Latvia and Slovenia gained advantages in publication in economics and business and Croatia, Estonia and Slovenia gained advantages in social sciences in publications over time; in terms of citations only Latvia in economics and business and Croatia in social sciences managed to reflect it onto their impact.

4. CONCLUSONS

In this paper we have explored the changing role of world regions in world science with special reference to the EU15 and CEE regions. We have used 30 years long data series of bibliometrics data and specifically have explored changing shifts in terms of papers and citations. In addition to descriptive statistics we have used RCA indicators applied to citations and papers as well as their graphic derivates in form of MDS and hierarchical clustering.

First, we show that there is global shift in science largely in terms of quantity (papers) and much less or not yet in terms of impact. This shift is characterised by gradual shift in papers towards Asia and other non-North Atlantic regions and by decline of the former-USSR science systems.

Second, at aggregate level science systems operate with high inertia and in areas of their historically inherited advantages and disadvantages. Nevertheless, within largely unchanged areas of regional advantages and disadvantages EU15 has gained RCA in fundamental and applied sciences and CEE in applied sciences while only EU15 has gained RCA in citations in life and applied sciences. Other world regions have not gained advantages in new areas. North America has lost advantages in applied sciences in both papers and citations; Middle East has lost in fundamental (papers) and social sciences (both) and Asia Pacific in life sciences (citations).

Third, at more detailed level we show that three major changes have been the loss of the excessive specialization of South EU in applied sciences; excessive specialization of CEE and Former USSR in fundamental sciences that has been followed by reduced specialization of the CEE and continuous excessive specialization of the Former USSR and its de-specialization in life sciences; excessive specialization of North America and the Middle East in social sciences (albeit for opposite reasons) that has been followed by reduced specialization of the Middle East and by continuous high specialization of North America.

Fourth, CEE is region is catching up both in terms of quantity (papers) as well as citations (impact) while it has reduced its excessive specialization in fundamental science and has shifted more towards applied sciences. This has been accompanied by a divergence from the former-USSR and a convergence towards EU15 from 1981-89 period to 2001-2011 period. While former-USSR continues on its divergent path when compared to other regions, CEE region has clearly been converging. However, great imbalance between deficits in life sciences and specialization in fundamental sciences continue to characterize CEE science systems.

Finally, together with the Former-USSR region CEE continue to be specialized in fundamental sciences when compared to other world regions which suggest that these regions are facing disproportionally higher problem of (ir)relevance of their science base for technological and industrial bases. Changes in the CEE science systems have been largely in terms of their absorptive capacity rather than in terms of the world frontier activities.

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Appendix A. RCA changes in terms of citations and papers across four major science areas by world regions.