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Patterns of Added Value and Innovation in Europe — With Special Regards to Metropolitan Regions of CEE[1]

The increasing territorial inequalities are raising a huge challenge for the European Union. There are significant differences among the given parts of Europe in terms of gross domestic product (GDP) per capita. Innovation and added value are also important indicators of regional economic development, and competitiveness. For example, improving innovation performance can enhance the national competitiveness. This research analyses the patterns of gross value added (GVA) and innovation (with special regards to the patent applications) in the European NUTS3 (county level) regions. The aim is to identify the major tendencies of concentration in the European spatial structure and to see the trends of change in the indicators. Metropolitan regions were analysed as special areas. The research question was whether the values of gross value added and the patent applications are concentrating in metropolitan areas, or there are significant hot spots outside them. It is hypothesised that because of the concentration of capital, most patent applications are also concentrated in the metropolitan areas of Europe. This hypothesis was tested using spatial econometric methods. The results show that the metropolitan regions have a significant contribution to GVA and patent applications of the European Union. In 2015, 65.7 % of all GVA and 57.1 % of all patent applications were concentrating in the metropolitan regions of Europe. The spatial autocorrelation is a significant factor in the case of both indicators. The complex (economic and innovation) index shows great Western-eastern, Northern-southern differences, the best position of South Germany, and the peripheral situation of CEE (Central and Eastern Europe) metro regions. Basic shortcomings/limitations of research can be found in the innovation data, as the number of patent applications is not published every year.

Keywords: spatial econometrics, spatial autocorrelation, metropolitan regions, Central and Eastern Europe, inequalities, gross value added, innovation, patent applications, European Union, NUTS3

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Структура добавленной стоимости и инноваций в Европе: на примере агломераций Центральной и Восточной Европы

Растущее территориальное неравенство представляет серьезную проблему для Европейского союза. Регионы Европы существенно отличаются друг от друга по показателю валового внутреннего продукта (ВВП) на душу населения. Инновации и добавленная стоимость также являются важными характеристиками регионального экономического развития и конкурентоспособности. В частности, развитие инновационной деятельности приведет к повышению национальной конкурентоспособности. Данная статья рассматривает структуру валовой добавленной стоимости (ВДС) и инноваций с учетом патентных заявок в европейских регионах NUTS3 на уровне округов. Цель исследования — выявить основные тенденции их концентрации в европейском пространстве и проследить динамику изменения показателей. В качестве особых территорий проанализированы агломерации. Исследована зависимость концентрации показателей валовой добавленной стоимости и патентных заявок от их расположения (в мегаполисах или центрах деловой активности за пределами агломераций). Предполагается, что большинство патентных заявок также сосредоточено в европейских метрополиях с высокой концентрацией капитала. Эта гипотеза была проверена с помощью пространственных эконометрических методов. Результаты показали, что мегаполисы значительным образом влияют на показатели ВДС и патентные заявки Европейского союза. В 2015 г. 65,7 % всей валовой добавленной стоимости и 57,1 % всех патентных заявок были сосредоточены в городских агломерациях Европы. Пространственная автокорреляция значима для обоих показателей. Комплексный (экономический и инновационный) индекс демонстрирует существенные различия между западом и востоком, севером и югом. Высокие показатели наблюдаются в южной части Германии. Значительное влияние на показатели оказывает периферийное положение метрополий Центральной и Восточной Европы. Ограничением исследования являются недостаточные данные об инновациях, поскольку информация о количестве патентных заявок не публикуется ежегодно.

Ключевые слова: пространственная эконометрика, пространственная автокорреляция, мегаполисы, Центральная и Восточная Европа, неравенство, валовая добавленная стоимость, инновации, патентные заявки, Европейский союз, NUTS3

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1. Introduction

The territorial social and economic inequality is one of the most fundamental characteristics of spatial economics (Nemes-Nagy, 1990; Nagyné Molnár, 2007). There are not two points in the space, which have the same characteristics, because their economic, social and cultural parameters are different (Nagyné Molnár, 2007; Benedek, Kurkó, 2011). The economic and social inequalities are critical problems also for the European Union, as by each enlargement the regional differences were becoming even more evident. The Eastern enlargement of the European Union (EU) has resulted in increasing inequalities of gross domestic product (GDP) per capita at the interregional and intra-regional level.

Taking a closer look at the spatial disparities of the GDP per capita, it can be seen that there is a huge difference between the richest Inner London (UK) region and the poorest Severozapaden (BG) region (see Figure 1). (In the case of the NUTS3 territories, these territories are Camden and the City of London (UK) and Silistra (BG). The intra-country level differences are also dominant across the European countries, mostly between the capital regions and the peripheries. If we look at the situation without the UK, the differences are a bit modest, as the richest Inner London region is a quasi-outlier area.

We can see that the biggest intra-country differences can be identified in the case of the United Kingdom, Belgium, Slovakia and France. Simultaneously, the smallest gaps between the richest and poorest regions are observed in Slovenia, Bulgaria and Finland. In most of the cases, the capital region is the richest one inside the EU, except Germany and Italy which have historic traditions (West Germany: Wolfsburg and

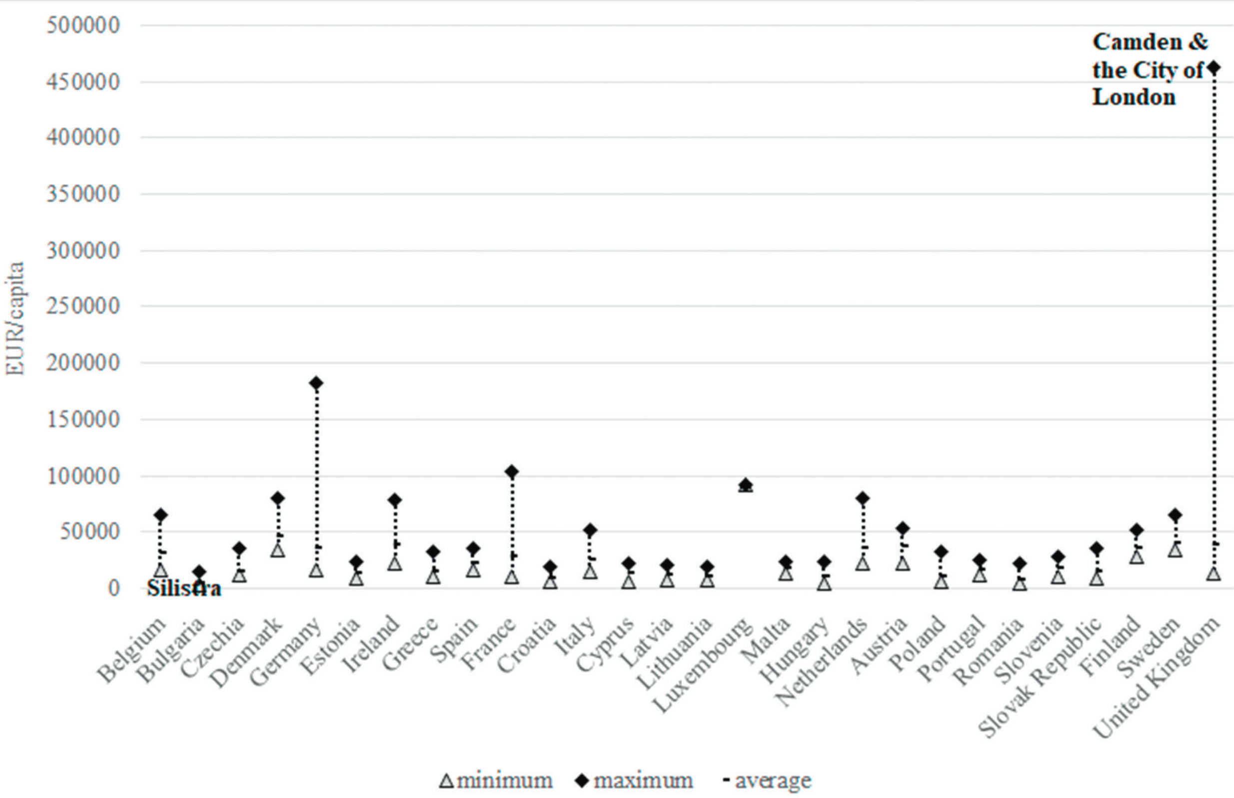


Fig. 1. *Intra-country differences of the GDP/capita (EUR/capita) in the EU (2017) (source: compiled by the author based on the Eurostat data. Eurostat Database. Retrieved from: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10r_3gdp&lang=en (Date of access: 03.02.2019))*

Ingolstadt; Northern Italy: the case of Milan, Bolzano, Bologna).

That is why scientists have examined several times the status of spatial inequalities and tried to find solutions to enhance the convergence processes. Generally, some researchers have found that the peripheral regions and countries of the EU tend to grow faster than the richer ones (e.g. (Paas, Schlitte, 2007; Matkowski, Próchniak, Rapacki, 2016; Alcidi et al., 2018), instead of this, there is rather a divergence across the territories in the long run (Alcidi et al. 2018). So the income convergence is taking place within the EU as a whole, contrasting trends emerge when looking within one country. This is especially the case for Central and Eastern European countries (Alcidi et al., 2018, p. 3).

2. Literature Review — the Role of Innovation

Innovation is aimed at increasing productivity and gaining competitive advantage, thereby leading to an increase in the level of economic development of countries and regions (Paas, Vaahi, 2012; Iammarino, Rodríguez-Pose, Storper, 2018). In the last few years, several articles have appeared on the topic of innovation, examining either the classical mechanical innovation (e.g. (Paas, Vaahi, 2012; Lee, Rodríguez-Pose, 2013; Ciocanel, Pavelescu, 2015; Guastella, Timpano, 2016; Sabatino, Talamo, 2017)), or the recently emerged social innovation (Howaldt et al., 2016; Rehfeld et al., 2015; Terstriep et al., 2015; Szendi, 2018).

In the economic history, some researchers have concluded that the innovation is a critical factor in regional development. For example, first Schumpeter has noted that 'the innovation is the engine of growth for individual firms, regions and nations' (Lim, 2006, p. 4). According to Romer's endogenous growth model, economic development is dependent on the investment in human capital, knowledge and innovation (Romer, 1994).

By analysing the connection between innovation and economic growth, Lee and Rodriguez-Pose have made a statement that the 'innovation is a crucial driver of urban and regional economic success. Innovative cities and regions tend to grow faster and have higher average wages' (Lee, Rodríguez-Pose, 2013, p. 1). The reason for this can be found in the high technologies, several patent applications, and more research and development (R&D) expenditures. Others emphasise that 'innovative regions tend to have higher productivity and income levels, which leads to differences in regional levels of economic development'

(Paas, Vaahi, 2012, p. 118–119). Therefore, it is a quasi-fact that the regional development and convergence process depend on innovation, but there can be also other influential factors (Paas, Vaahi, 2012).

In the European Union, the European Commission analyses the regions' innovation potential and its contribution to competitiveness. In 2019, the 9th version of the Regional Innovation Scoreboard was created to compare the innovation capacities across the EU. Based on the previous version of the study, there is a strong and positive connection between regional innovation performance and regional competitiveness, and 'even regions with similar innovation capacity have different economic growth patterns' (European Commission, 2017, p. 6). Based on these findings, there are clusters among the regions of the EU according to their innovation potential. 'The first group of Innovation Leaders includes 38 regions with performance more than 20 % above the EU average' (European Commission, 2019a, p. 14); they are territories from the northern and north-western part of the continent. There are another 73 regions with strong innovation potential (between 90 and 120 % of the EU average). Another statement indicates that although the most innovative regions can be found in the most innovative countries, there are 'some regional 'pockets of excellence' in some Moderate Innovator countries (for instance, Praha (Prague) in the Czech Republic (Czechia), Kriti (Crete) in Greece, and Friuli-Venezia Giulia in Italy' (European Commission, 2019a, p. 4). 'The most innovative region in the EU is Helsinki-Uusimaa in Finland, followed by Stockholm in Sweden and Hovedstaden in Denmark' (European Commission, 2019a, p. 4). I have also checked the correlation of the economic development (characterised by the GDP per capita) and the innovation capacity (characterised by the patent applications) of the regions in the members of the EU for 2017. I have found medium-strong positive connection (0.6454) for the whole EU, but it is varying from country to country. I have also checked the special category of metro-regions, which can be the major driving centres of development, and in their case I found strong and positive connection of the two indicators (0.7154).

In my former analyses, I have focused on the spatial patterns of the innovation in the European Union in the 2005–2013 time period. Based on the patterns of innovation data, a western-eastern slope can be outlined in the distribution of R&D expenditures and patent applications in the European Union, e.g. the developed areas of blue banana (London-Milan-Madrid axis), can be identified. The trend of innovation indicators showed that 'although the gap between the Western and Eastern European Member States is relatively small in terms of innovation data in NUTS2 level, but there is still a significant gap between the two sides' (Szendi, Papp, 2017, p. 157).

From the above it is possible to conclude that the innovation is a key factor in regional economic development, and it is important to analyse the tendencies and connections. The basic aim of this research is to analyse the patterns of the innovation (with special regards to R&D expenditures and patent applications) and gross value added in the European NUTS3 regions. I would like to identify the major tendencies of concentration in the European spatial structure and to see the trends of change in these indicators.

The analysis focuses on the metropolitan areas, which are concentrating the major economic and social functions. The main research question is whether the values of gross value added and the patent applications are concentrating in the metropolitan areas or there are significant hot spots outside them.

Therefore, it is hypothesised that because of the concentration of capital, the majority of patent applications is also concentrating in the metro areas of Europe. The metropolitan regions have the highest share of the operating enterprises, the biggest part of working capital, and they are called as the steering centres of the EU. Because of this concentration of capital and enterprises, the inputs of research and development potential (researchers and expenditures) belong mainly also to these areas, so it is expected that they accumulate the highest share of the outputs (patent applications, publications), as well. The hypothesis was tested using two separate methods, the classical pattern analysis (with distribution ratios) and the local spatial autocorrelation analysis that was applied to validate it.

3. Data and Methodology

In this research, I would like to analyse the patterns and distribution of three indicators which are deemed critical by analysing the innovation potential of given territories. I have checked the dates of R&D expenditures, the patent applications, and gross value added across the European NUTS3 regions. The research focuses on the metropolitan regions of the European Union (Table 1).

For selecting metro regions, I have applied the methodology and definition of the European Commission. Based on their methodology and the Urban Audit classification, a 'metropolitan area is

Table 1

Number of NUTS3 regions and the metropolitan areas in the member states of the EU

	EU member state	No. NUTS-3 areas	No. metropolitan regions		EU member state	No. NUTS-3 areas	No. metropolitan regions
1	Austria	35	5	15	Ireland	8	2
2	Belgium	44	5	16	Italy	110	21
3	Bulgaria	28	4	17	Lithuania	6	2
4	Cyprus	1	1	18	Luxemburg	1	1
5	Czechia	14	4	19	Latvia	10	1
6	Germany	401	68	20	Malta	2	1
7	Denmark	11	4	21	the Netherlands	40	13
8	Estonia	5	1	22	Poland	73	19
9	Greece	52	2	23	Portugal	25	3
10	Spain	59	23	24	Romania	42	9
11	Finland	19	3	25	Sweden	21	4
12	France	101	34	26	Slovenia	12	2
13	Croatia	21	2	27	Slovakia	8	2
14	Hungary	20	5	28	United Kingdom	179	40

Source: own compilation based on the Eurostat data (Eurostat. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual_-_metropolitan_regions#Classes_for_the_typology_and_their_conditions (Date of access: 15.04.2019))

Table 2

Applied data sources of the analysis

Indicator	Measure	Time period	Spatial level	Data source
Patent applications per 1 million inhabitants	number	2004, 2012, 2015	NUTS3	Eurostat regional database
		2004, 2012, 2015	Metropolitan areas	Eurostat Metropolitan regions database
R&D expenditures per capita	Euro	2005, 2013	NUTS3	Eurostat regional database
Gross value added per capita	Euro	2005, 2015	NUTS3	Eurostat regional database
	Euro	2004, 2005, 2015	Metropolitan areas	Eurostat Metropolitan regions database

Source: own compilation.

a NUTS3 region, or a combination of NUTS3 regions, which represents all agglomerations of at least 250 000 inhabitants' (European Commission, 2019b). The analysis has applied the metropolitan regions classification of the European Commission; based on the NUTS2013 system, there are 267 metro regions in this classification.

From my narrower region, the Visegrad countries (Hungary (HUN), Slovakia (SVK), Czechia (CZE), Poland (POL)) have 31 metro regions:

— Hungary (5): Budapest, Miskolc, Pécs, Debrecen, Székesfehérvár;

— Slovakia (2): Bratislava, Kosice;

— Czechia (5): Praha, Brno, Ostrava, Plzen, Liberec;

— Poland (19): Warszawa, Lódz, Kraków, Wroclaw, Poznan, Gdansk, Szczecin, Bydgoszcz — Torún, Lublin, Katowice, Bialystok, Kielce, Olsztyn, Rzeszów, Opole, Czestochowa, Radom, Bielsko-Biala, Tarnów.

In my research, I have performed a comparative analysis for the above-mentioned indicators in different times, where I had all of the dates available. My basic data source was the database of the Eurostat (Table 2).

To analyse spatial patterns and autocorrelation, I have used different methods like the correlation analysis and the methods of spatial econometrics (global and local spatial autocorrelation). In this part of my research, I only mention spatial autocorrelation methods as the methods for analysing the neighbourhood relations across the territories. The spatial autocorrelation should be examined based on various causes, but one of the most typical is the First Law of Geography summarised by Tobler: 'All things are related, but nearby things are more related than distant things' (Tobler, 1970, p. 236). Autocorrelation means that 'high or low values for a random variable tend to cluster in space (positive spatial autocorrelation), or locations tend to be surrounded by neighbours with very dissimilar values (negative spatial autocorrelation)' (Anselin, Bera, 1998, p. 241).

In my research, first I have focused on the global spatial autocorrelation measured by Moran's I, which was first introduced in 1950 by Patrick

Alfred Pierce Moran. This index is one of the most often-used measurement methods of spatial autocorrelation. It can be calculated with the help of the following equation:

$$I = \left(\frac{N}{\sum D_{ij}} \right) \sum \sum \left(\left(x_i - x \right) \left(x_j - x \right) \right) \frac{D_{ij}}{\sum \left(x_i - x \right)^2}, \quad (1)$$

where $(x_i - x)(x_j - x)$ is the product of the regions' values and the difference of the means. D_{ij} is the contiguity matrix and N is the number of territories. The maximum of the index is 1, while the minimum is zero. If $I > -1 / N - 1$, then there is a positive and if $I < -1 / \mathrm{N} - 1$, then there is a negative spatial autocorrelation (Dusek, 2004). Critical question is the selection of the neighbourhood matrix, hence, it defines the weight structure. The most common used types of neighbourhood matrices are the row-standardised ($n \times n$ matrix with zeroes on the diagonal), the distance based matrices and the k nearest neighbours method (Abdulhafedh, 2017).

Compared to this, the local spatial autocorrelation measures whether the spatial distribution of the dates is stochastic or there are kinds of patterns in the space. That is why I have applied this method to examine the patterns of different indicators. From the tools of local spatial econometric methods (LISA indicators, like Local Moran's I, Local Geary C, Local G indicator), I have used the Local G_i^* indicator, which is the tool of Getis and Ord (1992). The G_i statistic is an indicator for local spatial autocorrelation for each data point (Abdulhafedh, 2017). There are two types of G_i statistics in the literature: the G_i and the G_i^*. Basic difference of the two types, that the G_i^* counts with the interaction of a zone with itself ('i. e. the G_i statistic does not include the value of Xi itself, but only the neighbourhood values, but G_i^* includes X_i as well as the neighbourhood values'; (Abdulhafedh, 2017, p. 212)). In my analysis, I have used this type, which can be calculated based on the following equation:

$$G_i^* \left(d \right) = \frac{\sum_{j=1}^{n} w_{ij} x_j}{\sum_{j=1}^{n} x_j}, \quad (2)$$

where d is the neighbourhood distance, and w_{ij} is the weight matrix which is a queen contiguity matrix. The G statistic can vary between 0 and 1 (Abdulhafedh, 2017). The positive G_i^* means the local clustering of high values (hot spots), while the negative G_i^* means the local clustering of low values (cold spots). Important note, that the G statistics do not consider spatial outliers (Anselin, 2016).

4. Empirical Results and Discussion

In this research, I am analysing the disparities of the innovation-related indicators in the European Union, as the innovation can be a driving force of further development and can enhance the convergence of regions. In the last years, there was an increasing innovation activity across the EU, as from 66,616 pc in 2010 the total number of patent applications was increasing to 72,615 pc until 2019 based on the dates of the European Patent Office (EPO). The share of Visegrad countries is relatively small but increasing in this dimension, as in the same time it was increasing from 0.76 to 1.11 % (809 pc patents, Figure 2). Most of the EU patents are related to Germany, France and the Netherlands: these countries are concentrating more than 60 % of all patent applications.

I have tested the distribution of patent applications among the NUTS3 counties of the EU, mainly relying on the dates of the European Patent Office, and have compared the dates for two years: 2004 and 2015 (Figure 3) because of the data availability.

By analysing the patent applications' distribution, I can conclude that only minor changes happened in the distribution of the dates from 2004 to 2015, and mainly the Central and Eastern European (CEE) region has showed great improvement in this indicator; hence, there were more hot spots in the area for 2015. In the CEE region, not only the capital cities are getting big emphasis by the patent application, but also some other big cities are increasing their role. It could be seen most clearly in the case of Poland, Czechia and the Baltic states. The most intensive patent activity (biggest hot spots) can be verified in the Benelux states (Belgium, the Netherlands, and Luxemburg), in southern and south western Germany (in the area of Bavaria, Baden-Württemberg and the Ruhr area), and in northern Italy (in the territory of the Milan — Turin — Genova triangle). In contrast, the biggest cold spots can be identified in three countries: Greece, Bulgaria and Romania. Here the patent activity per 1 million inhabitants is very weak. In these countries, there are several territories with zero patent applications (e.g. Vidin, Sofia in Bulgaria, or Botosani, Vaslui or Arges in Romania). The results are quite similar to the former analysis of Runiewicz-Wardyn (2013). There are some well-known spatial structures in the European Union, which can be verified also by the patent applications, like the blue banana territory (highly urbanised and developed area from London to Milan; mentioned by Hospers (2003), Gorzelak (2012)

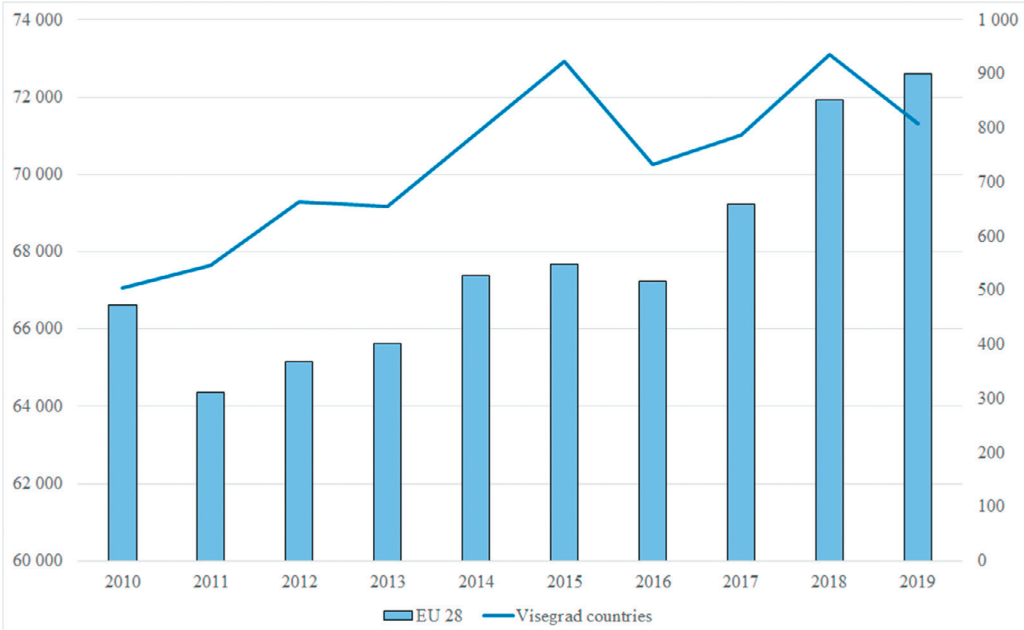


Fig. 2. *Evolution of the registered patent applications in the EU and the Visegrad countries (2010–2019) (source: compiled by the author based on the EPO data. EPO Statistics. Retrieved from: http://documents.epo.org/projects/babylon/eponet.nsf/0/4CAF4F386D2F9911C1258526002F14EA/$File/European_patent_applications_per_country_of_residence_of_the_applicant_2010–2019_en.xlsx (Date of access: 21.09.2020))*

or Kincses, Nagy and Tóth (2014), or the Central European Boomerang (Gorzelak (2012) or Kincses, Nagy and Tóth (2014)), or the red octopus of van den Meer (1998), or the blue star of Dommergues (1992). These are highly developed centres also in the case of the patent applications. I can conclude similarly to Acs, Anselin and Varga (2002, p. 1070) that 'production of new scientific and technological knowledge has a predominant tendency to cluster spatially'.

I have also examined the spatial patterns of R&D expenditures across the European regions. Because of the availability of the data, the analysis was made for 2005, 2013 (last full year) and 2017 for NUTS2 (regional) level. The research and development expenditures data shows that from 2005 to 2017 there was an increasing R&D activity across the regions of the EU, which was the most intensive in Belgium, France and in the CEE region, where besides the capital regions also other hot spots emerged. The biggest hot spots can be found in the south of Germany, and in the northern countries of Scandinavia. Concerning the spatial structures of Europe, the highly developed sunbelt-zone can be seen as a significant hot spot. This sunbelt-zone is the territory of the northern shore of the Mediterranean Sea from Valencia in Spain to northern Italy, Bologna region (Kunzmann, 1992). The sunbelt zone is mainly built on the services sector, and besides it a dominant high-tech

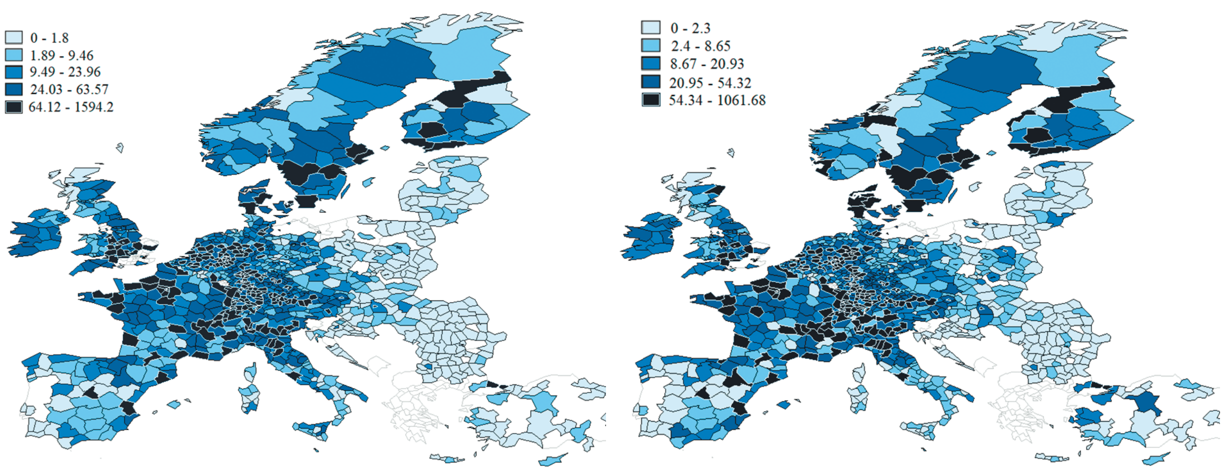
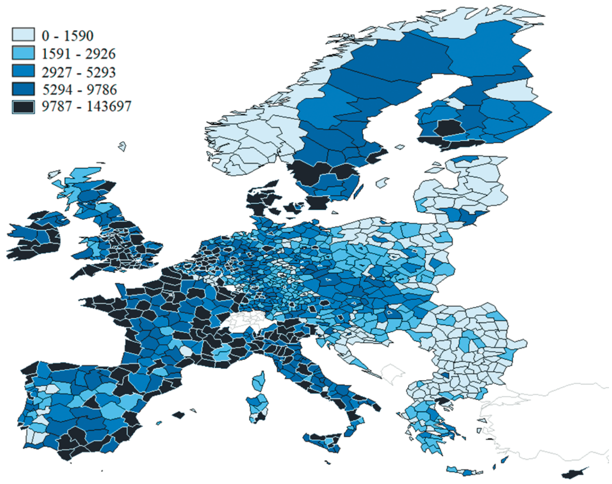


Fig. 3. *Disparities of patent application across the EU (NUTS3) — 2004 (left) and 2015 (right) (source: own compilation based on Eurostat and EPO data)*



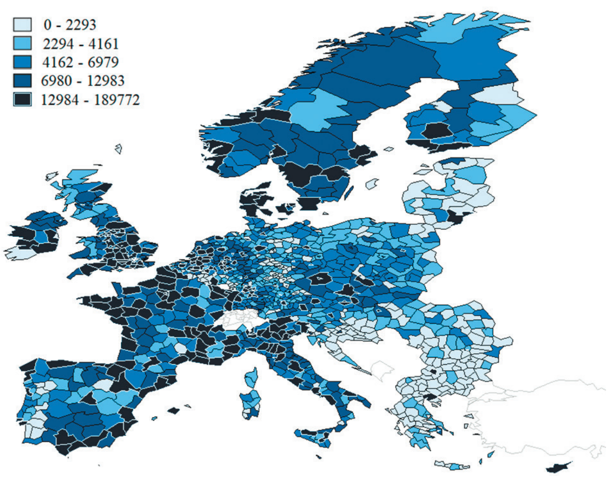


Fig. 4. *Disparities of gross value added across the EU (NUTS3) — 2004 (left) and 2015 (right) (source: own compilation based on Eurostat data)*

sector can be observed in the area. The lowest intensity of R&D expenditures can be realised in the eastern and southern part of the continent, where the territories have lower R&D intensity.

The analysis of gross value added across the NUTS3 (county level) territories is presented in Figure 4 for 2004 and 2015.

According to the gross value added data, the most significant changes happened in the eastern part of the EU, mainly in the territory of the new member states. There was a great improvement in some Polish and Romanian regions. The most developed areas can be identified, similarly to the patent applications, along the blue banana and the sunbelt zone, while in the eastern part of the continent the capital regions are the biggest hot spots. The least developed areas can be found predominantly in Romania, Bulgaria and the Baltic states.

I have examined the spatial interconnections in the European Union across the territories focusing on the economic activity (based on gross value added) and the innovation activity (patent applications) for 2015. First, I have calculated Moran's I for the NUTS3 territories as the indicator of the global spatial autocorrelation, and have stated that for both indicators (gross value added and patent applications) there is a significant spatial autocorrelation (Table 3).

As it can be seen on Table 3, in the case of gross value added there is a positive, weak spatial autocorrelation, which means that there is a clustering tendency among the dates, and for the patent applications, the spatial autocorrelation is positive, but medium-strong. Therefore, the local spatial autocorrelation analysis can be made for drawing up the main clusters of the indicators.

In my analysis, I have used the above-mentioned local G_i^* indicator for the estimation, and have calculated the clusters. This indicator shows the hot and cold spots of the two indices, without mentioning the spatial outliers. The distribution of clusters is summarised in Figure 5.

Table 3

Global spatial autocorrelation of the indicators (NUTS3, 2015)

	Gross value added per capita	Patent applications per 1 million inhabitants
Moran I	0.2076**	0.4137***
pseudo-*p*	0.021	0.034
z-score	4.358	4.127

Source: Author's results. * indicates significance at 0.10 level, ** indicates significance at 0.05 level, *** indicates significance at 0.01 level.

Taking a closer look at the local G_i^* clusters of gross value added (GVA), I can state that the biggest hot spots can be found in five areas: 1. northern and southern France (in the broader area of Paris, in Upper-Normandy and Rhone Alpes and Cote d'Azur region), 2. southern Scandinavia (Stockholm in Sweden, Uppsala region in Finland, and the region Midtjylland in Denmark), 3. central and north-eastern Spain (Segovia, Guadalajara, Toledo, Comunidad de Madrid, Avila, Cuenca, Girona and Tarragona), 4. northern and central Italy (in the larger area of Piemonte, Genova, Savona, Aosta and Rome), 5. the Netherlands. The greatest cold spots are in the eastern part of the continent, mainly in the new member states (in the Baltic countries, Poland, Romania, Bulgaria and Croatia), in Greece and in eastern Germany. In the case of Romania and Bulgaria, almost the whole country is a cold spot.

Based on the patent applications, the hot spots are in three areas. The first is in southern Germany (Bavaria and Baden-Württemberg region is a hot spot area regarding the patent appli-

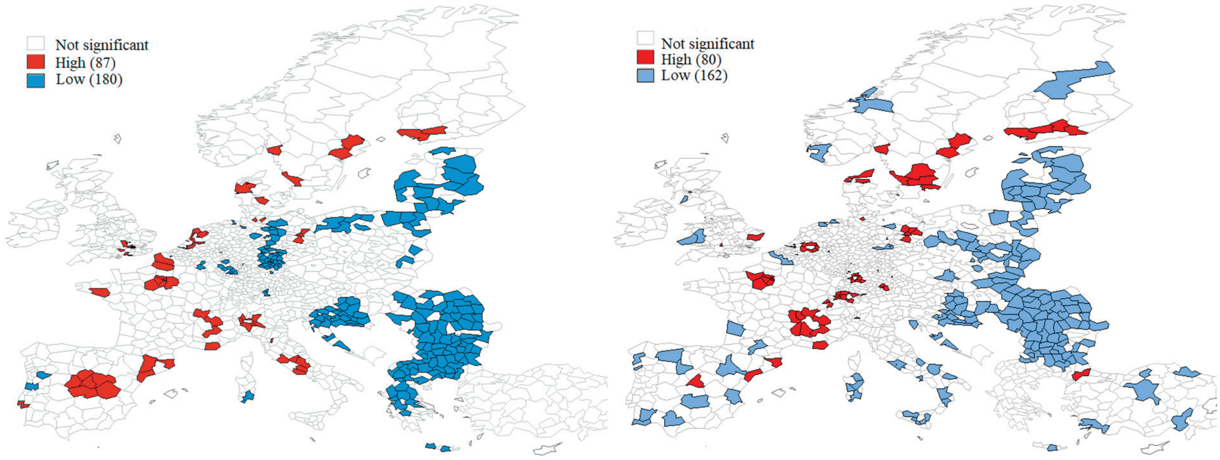


Fig. 5. *Local G_i^* clusters (NUTS3, 2015) of gross value added (left) and patent applications (right) (source: own compilation based on Eurostat data)*

Table 4

Share/Role of metropolitan regions for some indicators

		European Union	Metro regions	Share (%)
GVA (million Euro)	2004	9 966 551.8	6 571 468.68	65.9
	2008	11 737 012.0	7 760 879.31	66.1
	2012	12 060 224.7	8 022 409.02	66.5
	2015	13 246 377.0	8 702 128	65.7
industrial GVA	2004	2 022 906.2	1 159 450.46	57.3
	2008	2 325 358.8	1 323 885.79	56.9
	2012	2 329 477.3	1 333 848.35	57.3
	2015	2 573 679.8	1 417 102.45	55.1
Population	2004	492 555 798	270 223 402	54.9
	2008	500 297 033	281 415 770	56.2
	2012	504 047 964	290 377 482	57.6
	2015	508 540 103	294 582 078	57.9
Patent applications	2004	55 479.68	39 214.1	70.7
	2008	57 049.74	40 013.37	70.1
	2012	56 771.67	32 424.88	57.1
	2014	56 752.99	n/a	n/a

Source: own compilation based on the Eurostat data.

cations), second hot spot is in southern Sweden, while the third is in France (broader area of Paris, and Upper-Normandy, as well as in Rhone Alpes and Languedoc Roussillon regions). The dispersion of the cold spots is a bit heterogeneous compared to GVA, as they can be found in almost every part of the continent. The biggest concentration areas can be identified in the Baltic states, in the Visegrad countries (eastern Poland, Hungary), in Romania, Bulgaria, and in southern Italy.

It should be noted that about nearly 35 and 40 % of the metropolitan areas of Europe can be ruled into the significant clusters of local spatial autocorrelation in the case of the GVA and patent applications. That is why I have examined them a little bit more precisely. With the enhancing globalisation, the role of cities is increasing all over the world. The role of metropolitan regions is significant also in the European Union, as they have significant contribution to GVA and patent applications of the European Union. In 2015, 65.7 % of all GVA, and 57.1 % of all patent applications were concentrating in the metropolitan regions of Europe. Besides, the 267 metro regions are concentrating more than half of the European Union's population (Table 4).

In Central and Eastern Europe, the situation is a bit different: in the Czech Republic, Hungary and Poland the metropolitan regions show similar values in the above-mentioned indicators as the European average, while in Romania, Slovakia or Slovenia they represent lower values (Table 5), but their role is significant.

Regarding the high-tech sector based patent applications, the concentrating function of the metropolitan areas is more current, as these types of activities are strongly capital-intensive. Inside the European Union, 75 % of all high-tech patent applications are realised in the metropolitan areas, while this ratio is a bit lower, about 64 % in Central and Eastern Europe. Also, it is remarkable that only the 1.3 % of metropolitan areas high-tech patents are created inside CEE countries, so the role of this region is relatively weak (at regional level it is only 1.5 %).

From the sectoral distribution of the dates, we can conclude that the variation of patent applications among the different sectors (human necessity, chemistry, performing operations and transporting, textiles and papers, fixed constructions, mechanical engineering, physics, electricity) is not big across the metropolitan areas of the EU. Comparing the metro regions of CEE with the others, the weight of different sectors is quite similar, with some inequalities. In the cities of CEE, the share of chemistry, and mechanical engineering

Table 5

Share/Role of metropolitan regions for some indicators in the Visegrad countries

		Czech Republic	Hungary	Poland	Slovakia
GVA (million Euro)	2004	63.3	60.9	60.3	37.8
	2008	64.7	63.1	60.7	38.1
	2012	64.7	63.2	61.0	38.8
	2015	65.3	62.1	61.5	40.0
industrial GVA	2004	55.9	54.5	55.4	27.9
	2008	56.9	52.7	54.4	28.8
	2012	57.2	53.1	53.2	30.1
	2015	56.6	50.0	54.1	30.9
Population	2004	55.5	48.9	47.7	25.4
	2008	55.9	49.5	47.8	25.6
	2012	56.4	50.1	49.5	25.9
	2015	56.7	50.5	49.7	26.2
Patent	2004	61.2	86.2	61.7	43.4
	2008	59.4	75.2	75.4	62.1
	2012	46.7	61.8	68.0	59.3
	2014				

Source: own compilation based on the Eurostat data.

sectors' patents (12.2 and 13.4 % from the total respectively) is a little higher than in other parts of Europe, while in the case of the textiles and paper, and fixed constructions sector (5.5 and 6.7 %) the shares are significantly higher than in Western Europe.

In the case of the metropolitan areas, I have checked the differences in the distribution of the economic (GVA) and innovation (patent applications) indicators. I have checked the dispersion of the two data series for 2015 based on the dates of the Eurostat Metropolitan region database (Figure 6).

Figure 6 reveals that the patterns of the two indicators show quite similar hot and cold spots at the regional level. In both cases, western-eastern and northern-southern differences can be underlined. The biggest hot pots regarding gross value added can be found in the Paris region, in London, in the Benelux states (Brussels, Antwerp, Gent, Amsterdam, Rotterdam, Utrecht), in western Germany (München, Köln, Frankfurt am Main, Stuttgart, Düsseldorf, Hannover, Nürnberg, Bonn, Karlsruhe, Braunschweig, Mannheim, Ingolstadt) and Denmark (Copenhagen, Arhus, Odense, Aalborg). GVA is the lowest in the metro regions of Poland, Romania and Bulgaria. For patent applications, the hot spots are concentrating in the northern and north-western part of the EU, mainly in Belgium, northern Germany and Denmark. The cold spots can be found similarly to GVA, in Poland, Romania and Bulgaria.

Regarding the research hypothesis (because of the concentration of capital, the majority of patent applications is also concentrating in the metro areas of Europe), we can state that it can be accepted. The spatial autocorrelation analysis has showed medium-strong positive local spatial autocorrelation of the patent applications in Europe. Therefore, the data are concentrating in some larger areas of the EU, and the graphical test implies that the metropolitan areas are the biggest hot spots. In 2004 and 2008, more than 70 % of patent applications were created in these areas; this value a bit decreased in 2012 to 57 %. In the case of the Visegrad countries, this share is a bit higher, about 59 % in 2012.

After checking the spatial patterns of the indicators, I have calculated an index based on the two indicators and examined the different categories of metro regions. I have created three basic groups

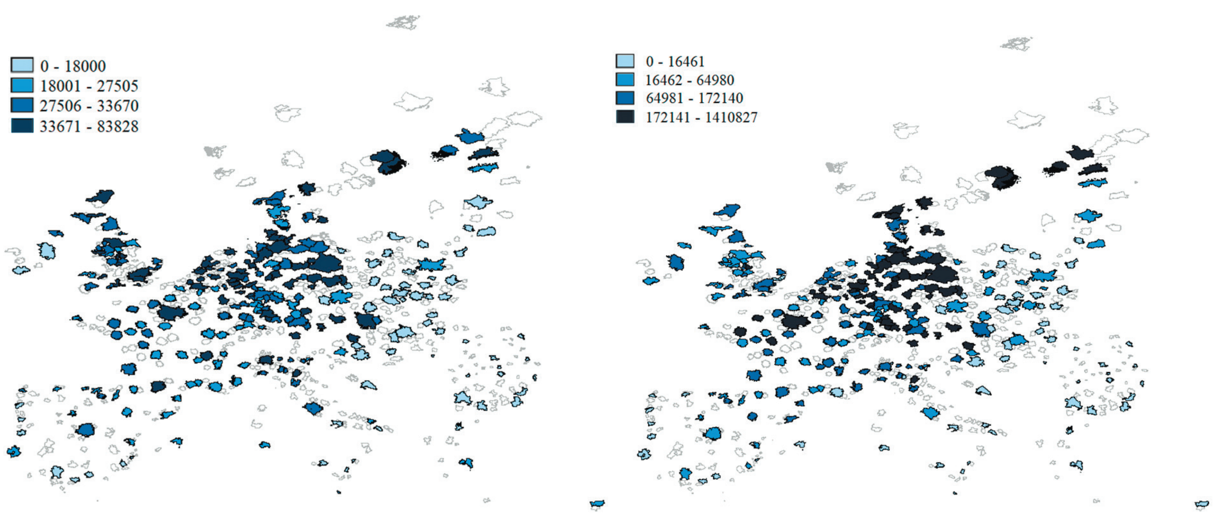


Fig. 6. *Patterns of GVA (left) and patent applications (right) across the metro regions (2015) (source: own compilation based on Eurostat data)*

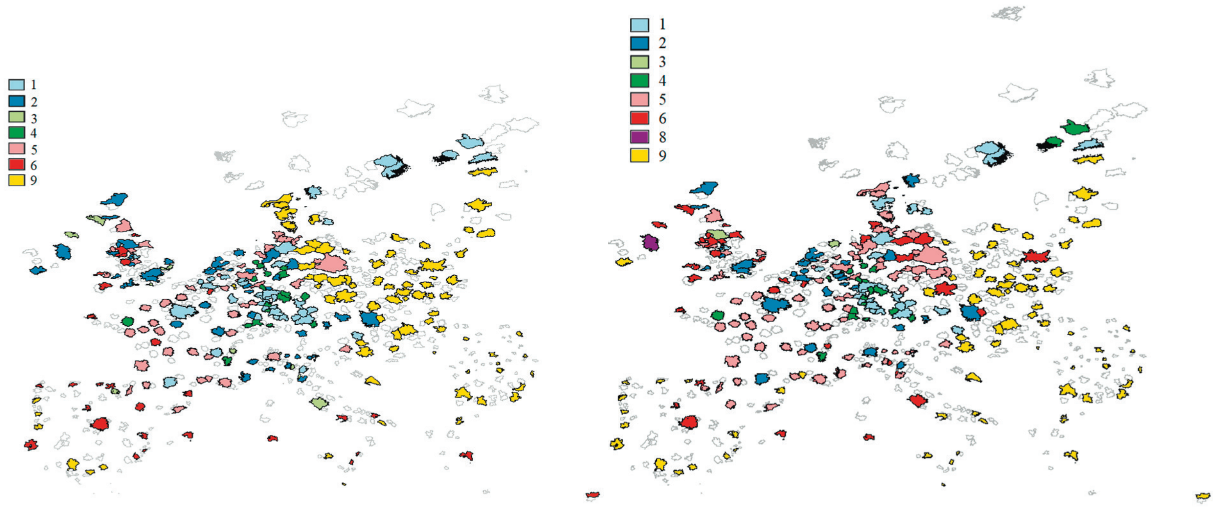


Fig. 7. *Change in the pattern of metro regions — 2004 (left), 2015 (right) (source: own compilation)*

Table 6

Categories of metropolitan regions

Category	Code	Description
(2) (2)	1	high GVA — high patent
(2) (1)	2	high GVA — medium patent
(2) (0)	3	high GVA — low patent
(1) (2)	4	medium GVA — high patent
(1) (1)	5	medium GVA — medium patent
(1) (0)	6	medium GVA — low patent
(0) (2)	7	low GVA — high patent
(0) (1)	8	low GVA — medium patent
(0) (0)	9	low GVA — low patent

Source: own compilation.

regarding the size of indicator value with the following notes: high (2), medium (1) and low (0). Based on it, nine clusters can be created, which are listed in Table 6.

In this classification, the first cluster members are the most developed in both indicators, while the ninth cluster contains territories with the worst conditions. I have checked the distribution of the data for two years (2004 and 2015). Based on the results (Figure 7), two types of territorial differences can be identified. There are a western-eastern and a northern-southern slope in the values. The best position (code 1) areas are, except some cases, in southern Germany and Sweden, where both indicators demonstrate outstanding results. The cluster members are: Graz, Hamburg, München, Frankfurt am Main, Stuttgart, Düsseldorf, Hannover, Nürnberg, Darmstadt, Regensburg, Karlsruhe, Mainz, Mannheim, Heilbronn, Ulm, Ingolstadt, Reutlingen, Helsinki, Eindhoven, Stockholm, Malmö, Uppsala and Nottingham. Compared to this, the worst cluster members are in Central and Eastern Europe, southern Italy and southern Spain, characterise by multiple disadvantaged situations (e.g. in Hungary all of the analysed metro regions (Budapest, Székesfehérvár, Miskolc, Pécs and Debrecen) belong to this category). The fifth cluster concentrates the territories with average position; it and the worst cluster have the most elements.

In the two examined years, there were only small changes in the clusters of the territories; some areas could improve their positions. In the northern part of the continent, the metropolitan areas of Denmark were able to improve significantly, e.g. Copenhagen and Arhus made a step forward from the 9th to the 1st category (from the worst to the best situation), while Odense and Aalborg from the 9th group to the average 5th cluster. On the northern part of the continent, two Finish areas (Tampere and Turku) were losing their positions from the best category to the 4th cluster (which was the result of decreasing GVA activity in the area). Great improvement happened in the case of some north-German areas (like Rostock and Schwerin), where the development was the result of the enhancing patent activity.

In the Central and Eastern European region, the Polish capital Warsaw were able to improve the position, with the increasing GVA activity. The cause for it can be found in the development of the foreign direct investment (FDI) activity in the capital, which shows also that in the first quarter of 2017 the most jobs through the FDI was created in Warsaw in the whole Europe.

Two great loser areas can be identified in Europe, first Northern-Italy with Torino, Genova, Firenze, Verona, and Padova, where the GVA was decreasing from 2004 to 2015 significantly. The second great loser area is Ireland, where Dublin and Cork suffered great fall-back, from the 2nd to the 8th category as a result of the dynamically decreasing GVA activity.

5. Conclusion

It can be concluded that there are huge territorial differences across the EU in terms of economic and innovation indicators. Innovation has a significant role in the convergence process of peripheries, as by the NUTS3 patterns there was a small convergence across the territories both in GVA and patent applications. There was an increasing patent activity of Central and Eastern Europe, which has resulted in a small convergence.

Based on the patent application dates, there are identifiable spatial patterns like the blue banana, the red octopus, the blue star or the Central European boomerang. R&D expenditures also draw up the highly developed sunbelt zone in the Mediterranean area. The analysis of spatial autocorrelation showed significant neighbourhood effects in terms of both patent applications and GVA.

In the case of the metropolitan regions, it can be concluded that they have significant contribution to GVA and patent activity in Europe, and their analysis is important. The complex index shows great western-eastern, northern-southern differences, while south Germany is in the best position, and the peripheral situation of CEE metro regions can be verified.

Based on the conclusion of the study, a new research question has been formed. Further research should answer exactly what kind of processes and trends are happening among the created clusters (based on GVA and patent applications), how the cluster membership is changing in time, and whether there is a convergence process across and inside the clusters. It is also interesting to study whether the given clusters of metropolitan areas show some similarity based on other economic and social indicators. Furthermore, the formed clusters give a better insight on the development differences of Western and Eastern Europe, and the deeper analysis of them could answer the question what typical development paths can be differentiated based on the distribution of GVA and R&D activity. This latter can be highly significant for the CEE region, as it can give hope for convergence.

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