Clusters of regions in the innovative development of the European Union

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Regions do not develop in isolation. It is assumed that there is some influence of neighboring regions on each other, and the strength of such interaction depends on technological, economic and geographical distance. The diffusion and location of innovative activities, new technologies and knowledge have their own specifics. More innovative regions are able not to drag development on themselves, but on the contrary, to spread innovative influence through institutions and information and communication technologies to neighboring regions and further, increasing the level of their involvement in innovative development. At the same time, companies, patenting their inventions, still make a choice between regions, which means that competition factors remain.

We assessed the relationship between the territorial concentration of innovation and spatial dependence and determined how technological innovation activities in one region are related to those in neighboring regions.

Key words: Clusters of regions, regional innovative development, territorial concentration of innovation, global and local Moran I, regions of the European Union

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Today Europe has lost a significant part of the innovation supply on the world market. China, South Korea and the Southeast Asian countries have displaced European regions and taken leading positions [3, p.1]. However, science and innovation are still key factors contributing to the development of technological and business conditions [3, p.1]. Innovation is a main driver of economic competition, which significantly affects the level of employment and economic prosperity of regions and countries. In addition, they influence the development of the knowledge economy, an economy where knowledge is the main component of the growth and development of countries where new information is actively included in production [5, p. 414].

The innovation engine in the spatial context is formed under the influence of factors not only within the region, but also outside its area [4, p.716]. The resulting externalities

depend on technological, economic, and geographical distances between firms and regions [4, p.716]. An important role is also played by the regional innovation system, which creates an upward spiral of the technological process “research-production”, leading to an increase in the efficiency and the quality of goods and services [2, p.108].

Thus, innovative ecosystems, clusters, megaregions with high research costs, large firms, research centers and universities, where highly qualified human capital is concentrated, become factors influencing the spread of innovative agglomeration and polarization [4, p.716].

To assess this impact, it is necessary to consider the relationship between the territorial concentration of innovations and spatial dependence. In other words, it is important to find out how technological innovation activity in one region is related to activities in neighboring ones.

14 countries of the European Union (with Switzerland, which was included for a more accurate analysis of regional influence) and 169 regions were selected for the study. This study is based on the information of the European Patent Office. The main indicator for assessing innovation activity was chosen "technological output indicator". It is the number of European patent applications, including direct European applications and international applications (PCT), which entered the European phase in 2018- 2021 [4, p.716].

The degree of territorial innovation interdependence can be estimated due to spatial autocorrelation (global Moran index I), defined as:

$$I = \frac{N}{S_0} \frac{\sum_i^N \sum_j^N w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^N (x_i - x)^2}$$

where x_i and x_j are the number of patent applications in regions i and j, x is the average number of applications, N is the number of selected regions, $S_0 = \sum_i \sum_j w_{ij}$ is a standardized value – a matrix of spatial weights [4, pp. 725-726].

The land border of adjacent regions was taken as an element of the spatial matrix, where 1 is its presence and 0 is its absence [4, pp.725-726]. Further, the data was standardized, each element was divided into the total amount of rows because there are more borders than the number of analyzed regions.

Assumptions about the spatial interdependence are made based on a comparison of the expected value of E(I), defined as $\frac{-1}{n-1}$, and the actual I [1, p.97].

When I > E(I), positive spatial autocorrelation is observed, which indicates the similarity of the values of observations in neighboring analyzed regions.

When I < E(I), negative spatial autocorrelation is observed, which indicates a difference in the values of observations in neighboring analyzed regions.

When I = E(I), there are no correlations, the values of observations in adjacent regions are randomly located [1, p.97].

The analysis revealed positive spatial autocorrelation in 2018, 2019, 2020 and 2021: with E(I) = -0.005952 and I = 0.7704, 0.6564, 0.2544 and 0.2273, respectively. It is clearly seen that the global Moran I index has decreased over 4 years, which indicates a divergence trend.

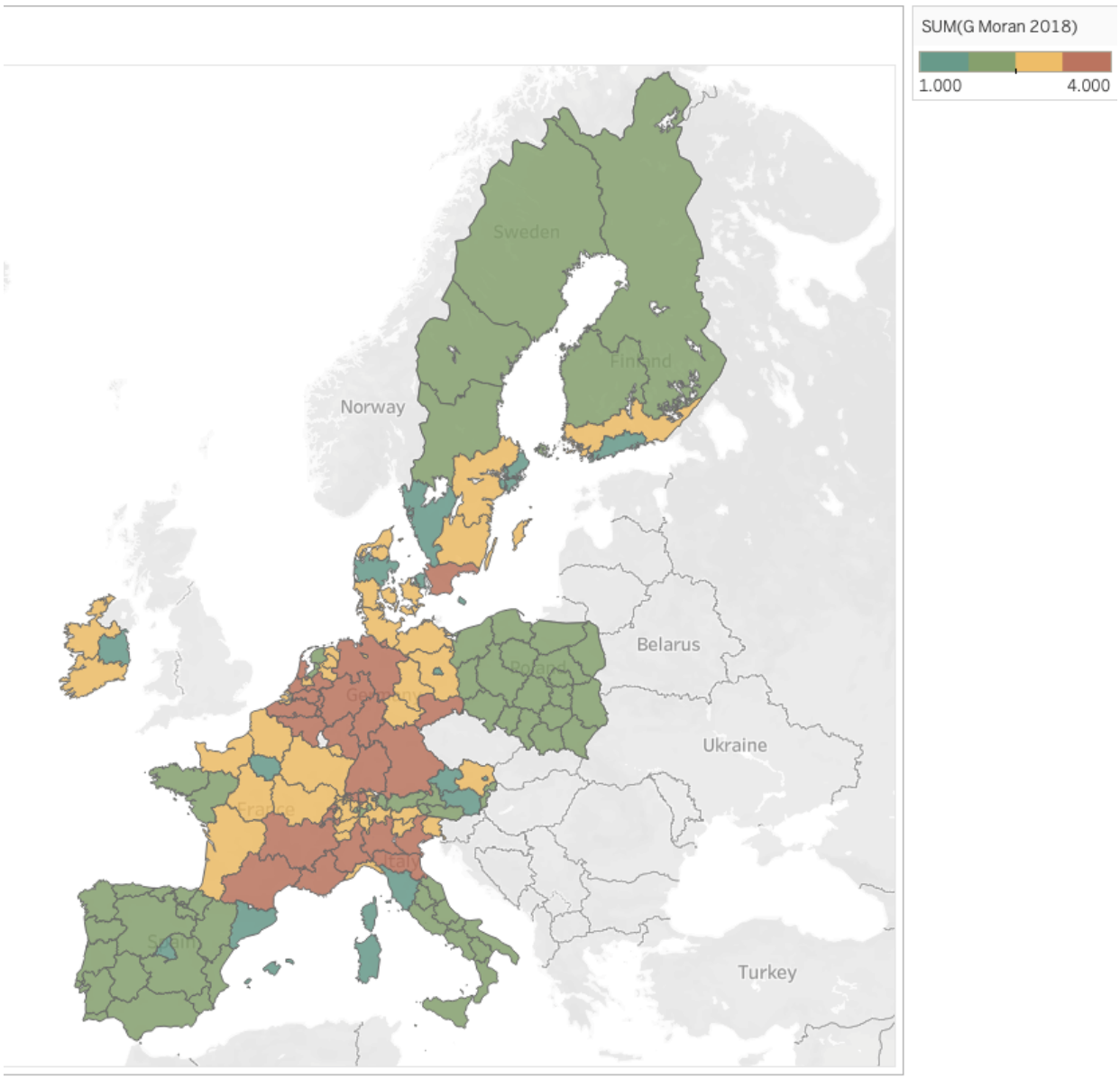
To assess the mutual influence, the scattering map in 169 regions and its changes during the 4 years were also analyzed. Meanwhile, it is necessary to indicate that the map shows how the regions are divided into 4 groups:

1. HL (high-low) – areas that have a high number of patents and are adjacent to regions with low values of the indicator. There is a negative local spatial autocorrelation (local Moran index I (LISA), which allows us to assess the mutual influence between the area and its neighbors). This group, according to Y.V. Pavlov and E.N. Koroleva, can be called “cores”, centers of innovation clusters [1, p.97, 101].

2. LL (low-low) – areas that have a low number of patent applications and are neighbors of regions with low values of the indicator. Positive local autocorrelation is observed. This group can be called "territories that are not affected". With a significant number of the analyzed indicator and LISA values comparable in modulus with the values of the cores, it can be concluded that there are new "growth points" – centers of innovation clusters [1, p.98, 104].

3. LH (low-high) – areas that have a low number of patent applications, but are adjacent to regions with high values. Negative local autocorrelation is observed, which indicates the influence of regions with high values. Therefore, this group is called the "periphery – zone of influence" [1, p.98, 102-103].

4. HH (high-high) – areas that have a high number of patent applications and are neighbors of regions also with high values of the indicator. Positive local autocorrelation is observed. This group can be called "counterbalance satellites", mutually influencing the cores [1, p.98, 101-102].



Calculated by the authors according to the European Patent Office: https://www.epo.org (accessed 30.03.2021)

Fig. 1. Map of innovation activity clustering in selected European regions by number of patent applications in 2018

14 cores-centers of innovation clusters were indicated in 2018. The largest number of regions with high values, which are adjacent to regions with low values, are seen in Austria, Denmark, Spain and Sweden. Here it is worth paying attention to the main innovation center of France – Ile-de-France, the number of patents of which is much higher compared to neighboring areas and other cores of Europe. The high degree of mutual influence of this region indicates that innovative activity "flows over", as a result of which the region becomes a kind of innovative agglomerate. 33 regions, mainly in Belgium, Germany, the Netherlands and Switzerland, became "counterbalance satellites". Germany

has the regions with the highest number of patent applications – Bavaria, Baden-Württemberg and North Rhine-Westphalia. They have a strong influence on the nearest areas, stimulating them to increase innovation activity. The “periphery-zone of influence” includes 42 regions, which, obviously, are located in those countries where “counterbalance satellites” predominate. The regions that are strongly influenced by counterbalance satellites or cores – Centre Val-de-Loire (France), Thuringen (Germany), Burgundy – Franche–Comté (France), Zealand (Netherlands) and Thurgau (Switzerland). Finally, 66 regions are territories outside the influence. However, among them there are new "growth points" – Spanish regions (Castile-Leon, Castile-La Mancha and Extemadura) and Poland ones (Masovian, Greater Poland, Świętokrzyskie, Lodz, Kuyavian-Pomeranian voivodeships). They can become “cores” or “counterbalance satellites”. A high number of patents and, moreover, a high level of technological activity can be concentrated in them.

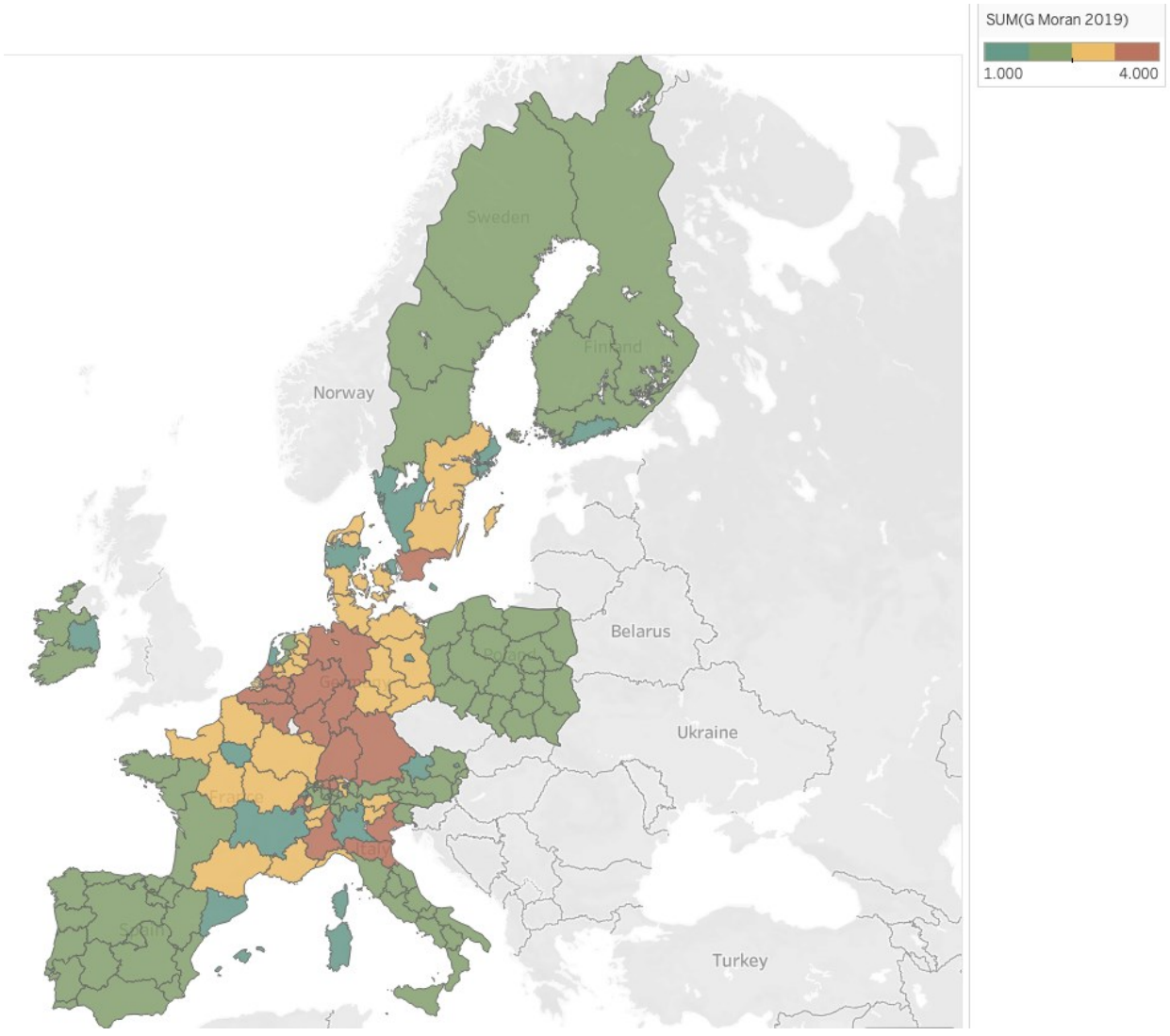


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Fig. 2. Map of innovation activity clustering in selected European regions by number of patent applications in 2019

It can be seen that 15 regions became innovative cores in 2019. Among these regions, Auvergne-Rhone-Alpes (France), Lombardy (Italy), North Holland (Netherlands) and Neuchatel (Switzerland) became new members of the group with a high number of patent applications that have neighbors with low values. These regions were in the HH stimulating innovative development group. But due to the general increase in the average number of patent applications the values of the indicator decreased among the neighbors of this group, so 15 territories moved to the HL group. Also, some cores, Styria (Austria), Tuscany (Italy), Madrid (Spain), have become periphery due to a decrease in eigenvalues. Ile-de-France has maintained a leading position relative to other cores. The number of regions with their own high values and a high number of neighboring areas decreased to 22. The majority of regions moved to the LH group, in which the number of regions also decreased to 36. In most cases, the reason for the transition is that the number of patent applications from neighboring territories has decreased, so these 36 regions have become LL territories. Meanwhile, it is worth noting that the group of low-high regions, which are strongly influenced by cores and counterbalance satellites, as a whole remained unchanged, only the Grand Est (France) was added, but the degree of influence decreased. Finally, the number of low-low territories has increased to 82 due to a decrease in the number of patent applications both from themselves and from their neighbors. The areas "growth points" remained unchanged.

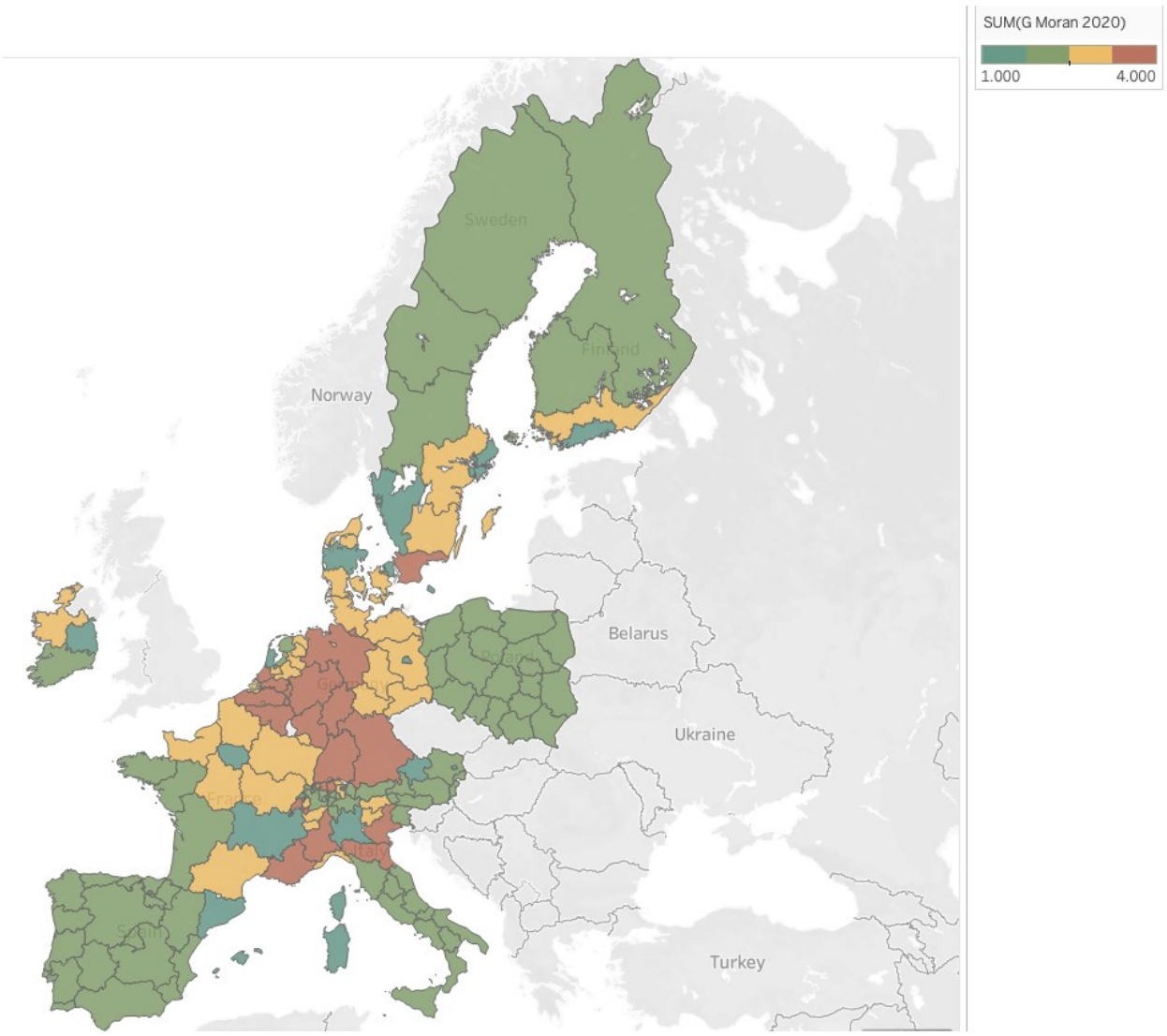

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Fig. 3. Map of innovation activity clustering in selected European regions by number of patent applications in 2020

The same 15 regions were the core innovation centers in 2020. It is worth paying attention to the fact that despite the significant superiority of the Ile de France in this group, Lombardy and Stockholm (Sweden) also have a high number of patents. The number of counterbalance satellites has increased to 23, where Provence-Alpes-Cote d'Azur (France) has become new. The main reason is that an increase in the number of patent applications from the neighboring core - Auvergne-Rhone-Alpes. The group of regions "periphery-zone of influence" increased by two regions to 37, where Southern Finland and Northern and Western Ireland were added. In both cases, the reason is an increase in the number of neighbors, Helsinki-Uusimma and Eastern and Central (Middle) Ireland. It is worth

mentioning that the regions “zones of strong influence” have not changed, but the indicator of mutual influence (LISA) has become smaller. Finally, the number of territories outside the influence has decreased to 80, which is due to the transition of one region of Finland and one region of Ireland to the low-high group. The areas, new "points of growth", still the regions of Spain (Castile-Leon, Castile-La Mancha and Extemadura) and Poland (Masovian, Greater Poland, Świętokrzyskie, Lodz, Kuyavian-Pomeranian voivodeships).

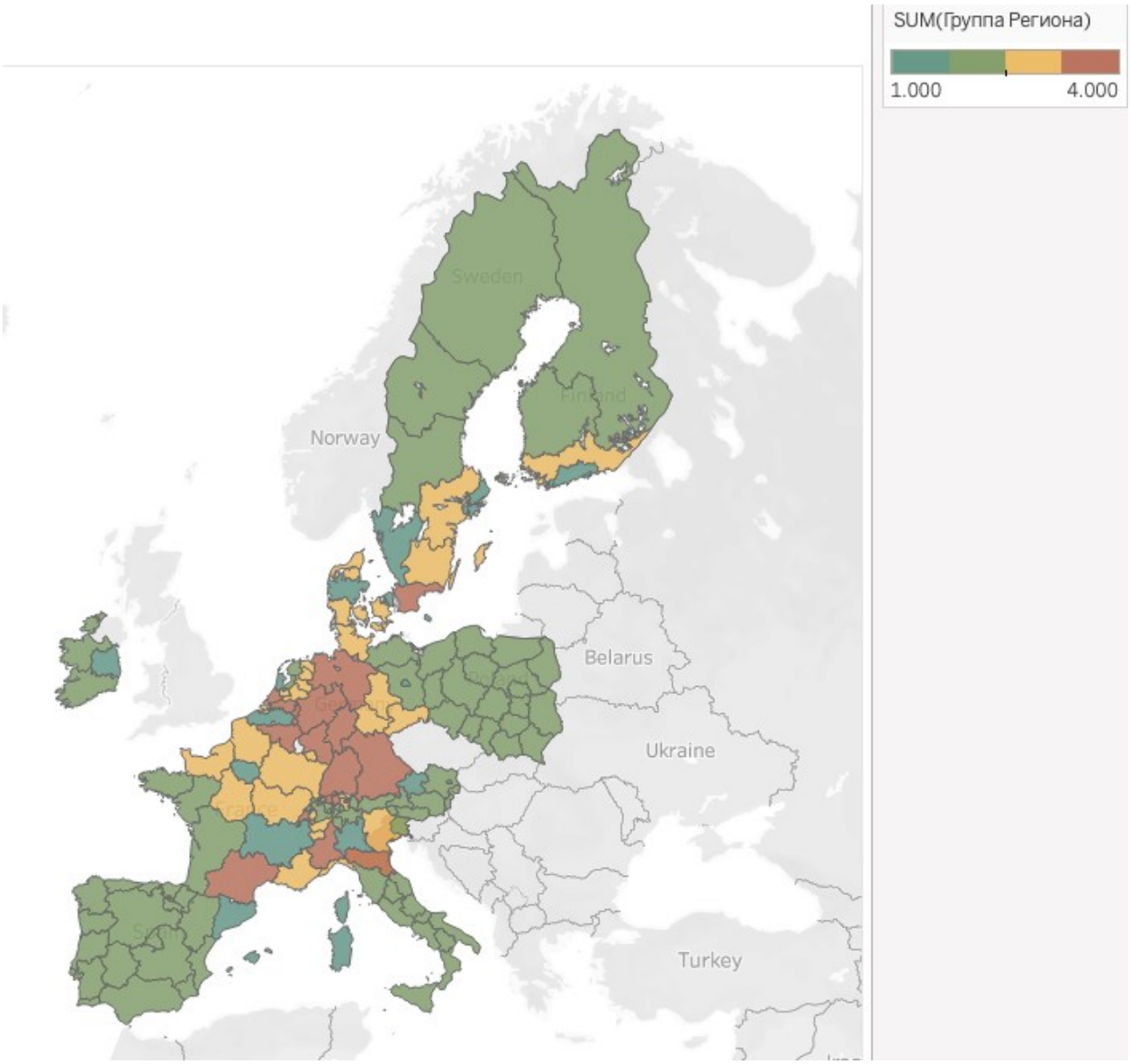

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Fig. 4. Map of innovation activity clustering in selected European regions by number of patent applications in 2021

New data showed that in 2021, the group of 15 regions of the core innovation centers, expanded to 16. The Flemish region (Belgium) from the HH group was added. The Ile de

France remains the leader in the number of patents in this group. The number of counterbalance satellites decreased to 22, where Provence-Alpes-Cote d'Azur (France) moved to the "periphery - zone of influence" group due to a reduction in the number of patent applications. The group of regions "periphery-zone of influence" decreased by 3 territories to 34 dues to the transition of Occitania (France), Brandenburg (Germany), Northern and Western Ireland to other groups. The number of territories outside the influence has increased to 83, which is due to the transition of Brandenburg (Germany), Mecklenburg-Vorpommern (Germany), Northern and Western Ireland. The reason is a reduction in the number of patent applications of neighboring regions. The territories – the new "growth points" - still include the regions of Spain (Castile-Leon, Castile-La Mancha and Extemadura) and Poland (Masovian, Greater Poland, Sventoshish, Lodz, Kuyavian-Pomeranian Voivodeships). However, during 2018-2021, their own value, the number of patent applications, fluctuated, as well as the values of mutual influence with neighboring territories, which does not allow us to unambiguously conclude about their development as future innovative cores or counterbalance satellites.

The potential innovative clustering of "growth points" depends on the development of companies located in the regions. In Castile-Leon, the institute registering a sufficient number of patents is the University of Valladolid, in the Masovian voivodeship it is the transport company "Babik SP. Z O.O.", the supplier of audio and video equipment "HEM SP. Z O.O. In Kuyavian-Pomeranian voivodeship it is "Materialowopatrunkowych Spolka Akcyjna" (manufacturer and supplier of hygienic, cosmetic and medical products), agro-industrial company "ANWIL S.A.", cosmetic company "La Rive Spolka Akcyjna". In Lodz voivodeship it is pharmaceutical company "Aflofarm Farmacja Polska SP. Z O.O.". In Velikopolsky voivodeship there is the Pepco Poland SP. Z O.O. trading network. The growth of these organizations, an increase in the number of goods and services patented by them, can directly affect the development of innovation clusters in the European Union.

Based on the results of calculating spatial autocorrelation (global and local Moran I indices), it can be concluded that most regions of Europe have low innovation activity, ceasing to be in a zone of strong influence or being completely outside it from the centers of innovative development, cores that form innovation clusters, or counterbalance satellites that technologically stimulate neighbors. However, among the zones outside of influence, a group of regions stands out. It is new "growth points", which in the future (that cannot be

unambiguously estimated in 4 years) can become innovation clusters. These clusters can increase the level of technological activity in the countries of the European Union. It is obvious that this should happen through the development of innovation policy at the national and international levels.

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