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The Innovation Development of the European Union: Regional Clustering[1]

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Abstract

Innovative development is one of the political priorities of the European Union countries. The Commission of the European Communities recommends that countries pursue innovation policies at the regional level. The regional development of innovations is possible only in conditions of openness. It is important to understand in which conditions the regions will support each other, and in which they will become competitors pulling over limited resources.

The strength of mutual influence is determined by economic, technological and geographical distances. In this paper the goal is to understand how patent activity in one region effects the number of patents of other neighboring territories in the European Union regions. The research methodology of this study consists of the calculation of spatial autocorrelation (global and local Moran index I) by the number of patents in 2018-2021 in 169 regions of Europe.

Among the regions four groups were identified: innovation cluster centers, innovation agglomerations, the neighbors of innovative cores and the territories outside the influence. The dynamics of development is also analyzed. Among the results, it is shown that most regions of the EU regions have the low level of patent activity. However, in some cases regions form technological clusters (in Germany, Belgium, the Netherlands) or pull assets from neighbors to more innovative regions (in France, Austria, Denmark). Moreover, it is obtained that there are potential innovation centers such as Castile-Leon (Spain), Masovian voivodeship (Poland). Understanding the emerging innovation blocs in the European Union will allow to implement more focused and effective policy.

Keywords: regional innovation development, regional clustering, the European Union, global and local Moran I

JEL Codes: R11, R12, O31, O5, C21

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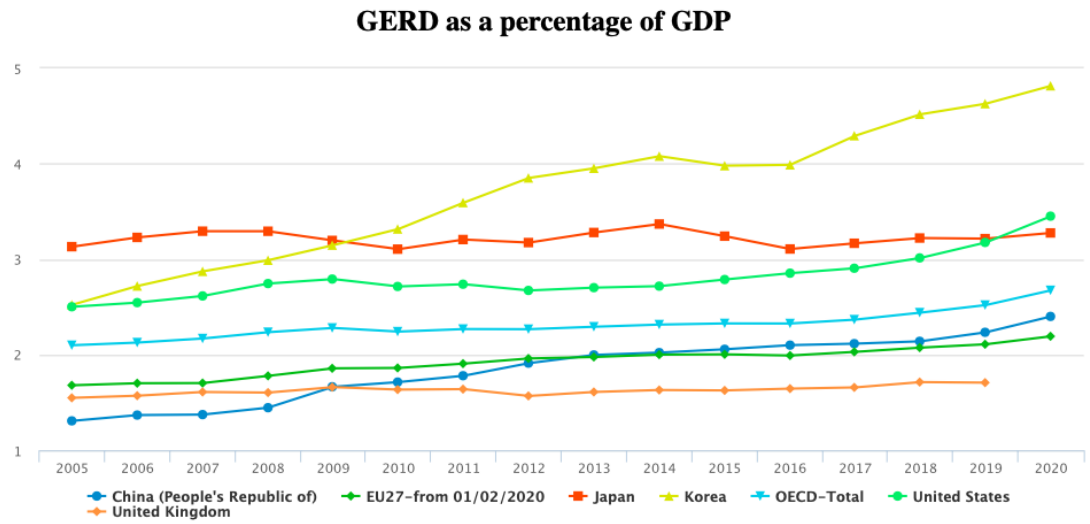
Introduction

Nowadays the European Union has lost the significant share of the innovation on the world market (Leijten, 2019). Figure 1 shows that China, Japan, South Korea, United States have taken the leading positions in the gross domestic expenditure on R&D as a percentage of GDP in recent years and have displaced the European countries and regions.

Figure 1. The gross domestic expenditure on R&D as a percentage of GDP in 2005-2020



But science and innovation are still main factors contributing to the development of technological and organizational conditions (Leijten, 2019). Innovation development is one of the key drivers of economic competition, which significantly affects the employment rate and national and regional economic prosperity. Furthermore, innovations influence the advancement of the knowledge economics, an economics where knowledge is the main component of the growth and development of countries where new information is actively included in production (Rosario et al., 2019).

The innovation engine in the spatial context is formed under the influence of above-mentioned factors not only within the region, but also outside its area. The resulting external effects depend on technological, economic, and geographical distances between firms and regions (Moreno et al., 2005). A significant role is also played by the regional innovation system, which creates an upward spiral of the technological process “research-production”, leading to the growth in the efficiency and the quality of products and services (Kolesnikova, 2012).

As a result, innovative ecosystems, clusters, megaregions with high research costs, large companies, research centers and universities, where highly qualified human capital is concentrated, become factors influencing the spread of innovative agglomeration and polarization (Moreno et al., 2005).

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

Literature review

Urbanization is an important condition that stimulates not only economic development of regions, but also innovation activity of them (Chen et al., 2020). The relationship between economic growth, urbanization and technological development is doubtless (Baldwin & Martin, 2004). Urbanization, as well as the concentration of innovations in a certain area, contributes to the accumulation of resources such as labor and capital, and therefore creates profitable conditions for rapid economic growth.

Innovation activity is even more prone to concentration than manufacturing, and the technological concentration of companies is observed in or around large cities (Audretsch & Feldman, 1996). For city residents, company employees, scientists, researchers, teachers and officials, there are more opportunities for direct informal communication, which enhances the dissemination of new ideas, deepens accumulated knowledge. The concentration of economic and especially innovative activity in a city or region leads to positive technological externalities, further rapid knowledge and information dissemination.

Urban development through secondary (not primary) knowledge dissemination (Wang & Sun, 2009) contributes to the creation of new innovative behaviors (Rosenthal & Strange, 2004). Urbanization increases the regional innovation potential, but negatively affects innovation activity in neighboring territories (Chen et al., 2020). The ideas that spatial agglomerations contribute to more effective innovative behavior take place in the works of Krugman, Fujita and other economic geographers (Krugman, 1991; Fujita et al., 1999).

From the companies' point of view, the relationship between urbanization and innovation development is not so unambiguous. In this regard, the concentration occurs up to a certain

point, and then disperse. Such ideas were studied by different researchers (since Krugman, 1999), but without an obvious conclusion. According to the concept of differentiation, direct competition separates companies from their competitors, while the benefit of complementary differences brings organizations closer to their dissimilar competitors. Nowadays the number of inter-firm technological alliances soars not only in the regional economy, but also in international business (e.g., Nooteboom et al., 2007). However, firms are still reluctant to share their key competencies with others as there is a serious risk of knowledge leakage to competitors. But, in accordance with the provisions of new economic geography, the externalities of concentrating competitors in one place bring more benefits than companies' costs and risks. We believe that the power balance largely depends on the economic sector because innovative companies in some industries receive more effects from agglomeration than others. Depending on the nature of innovation, organizations in some industries tend to concentrate, while others prefer to keep their distance from competitors.

Another interesting block of research on the causes of regional innovative development is to assess the endowment of the territory with natural resources and, more importantly, the policy of using this factor of production. Regions are different in the availability of natural factors. Moreover, their presence or nature does not guarantee successful economic and even more innovation development. The rent cycle theory states that when the ratio of "rent to the share of natural resources in GDP" is high, the country's political aims will be to distribute rent, not to achieve economic prosperity (Auty, 2005). This state of affairs definitely does not contribute to regional innovative development. Empirical evidence of the negative relationship between natural resources and regional innovation is observed in several papers (e.g., Zhang & Wu, 2017, the example of China; Papyrakis & Gerlagh, 2007, the example of the USA).

Dependence on natural resources displaces physical and human capital, thereby hindering innovation. At the same time, rich natural resources do not directly hinder economic growth, but cause the redistribution of capital through the management of a resource-based economy, displacing investments in technological innovations. It is obvious that the problem is more political, so proper management aimed at long-term development and achieving economic prosperity can solve it.

Based on the study of European regions, such a phenomenon as "cluster agglomeration of innovation activity" has emerged. In other words, technologically specialized clusters are emerging in certain territories (Moreno et al., 2005). Moreover, radical changes in IT, innovations create the preconditions for the regional clustering as a competitive advantage of the territories. The tasks of researchers here include determining the factors, conditions, and other incentives for the emergence of such a concentration of innovation activity.

There is a high differentiation among the regions of the European Union, both in terms of the level of innovation activity (by the total number of patent applications) and by spheres of activity. An important stage in the analysis of innovative development is the determination of spatial correlation to assess the mutual influence of regional innovation potential.

Thus, in 175 European regions in 1978-2001, it was revealed that innovation specialization positively and strongly depends on the specialization of the region in production activities. At the same time, innovation activity is more likely to be concentrated in those regions that are adjacent to highly technological specialized regions (Moreno et al., 2005). A significant impact on regional innovation potential was proved by the example of 30 regions of China in 2005-2018 (Chen et al., 2020).

Methodology

Based on the literature review, most researchers have concentrated on the investigation of spatial distribution of innovation in the regions of Europe until the 1990s (Paci & Usai, 1999) and until 2001 (Moreno et al., 2005). However, there are fewer papers focused on the spatial distribution of innovations in the European Union regions in 2018–2021. To address this gap in the literature review, the purpose of this study is to analyze the spatial distribution of patent activity in the European Union in 2018-2021.

14 courtiers of the European Union, including Switzerland, and their 169 regions were selected for the research. The database was the accumulated statistics of the European Patent Office. The key indicator for assessing regional innovation activity was the number of European patent applications. The "technological output indicator" included direct European applications (resident) and international applications (non-resident, PCT), which entered the European phase in 2018-2021.

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The degree of regional 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.

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. Then, the data was standardized, each element was divided into the total number of rows because there are more borders than the number of analyzed regions.

The spatial interdependence assumptions are made based on the comparison of the expected value of Moran index I (E(I)) defined as $\frac{-1}{n-1}$, and the actual Moran index I.

When the actual I is more than E(I), positive spatial autocorrelation is observed. It indicates the similarity of the values of observations in neighboring analyzed territories.

When the actual I is less than E(I), negative spatial autocorrelation is observed. It indicates a difference in the values of observations in neighboring analyzed regions.

When the actual I is equal to E(I), there are no correlations. The values of observations in adjacent regions are randomly located.

To assess the mutual influence, the scattering map in 169 regions and its changes during the 4 years should be also analyzed. This map shows how the regions are divided into 4 groups.

The first group includes areas that have a low number of patent applications, but are adjacent to regions with high values. It is called the LH (low-high) group. There is a negative local spatial autocorrelation (local Moran index I (LISA))[3] because regions with high values influence the neighbors with low indicator values. Therefore, this group is called the "periphery – zone of influence".

[3]It allows to assess the mutual influence between the area and its neighbors.

The second group includes areas that have a high number of patent applications and are neighbors of regions also with high values of PA. It is called the HH (high-high) group. Positive LISA is observed. This group can be called "counterbalance satellites" as there is a mutual influence on the cores.

The third group includes areas that have a low number of patent applications and are neighbors of regions with low values of the indicator. It is called the LL (low-low) group. Positive local autocorrelation is observed. This group can be called "territories that are not affected". If these regions have a significant number of the patent applications and LISA which are comparable in modulus with the values of the cores, it can be concluded that there are new "points of growth" – potential centers of innovation clusters.

The fourth group includes areas that have a high number of patents and are adjacent to regions with low values of the indicator. It is called the HL (high-low) group. There is a negative local spatial autocorrelation. This group can be called "cores" as there are centers of innovation clusters.

Findings

The analysis of Global Moran I 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 obvious that the global Moran I index has declined over 4 years. It indicates a divergence trend in the innovation development and activity of the EU regions.

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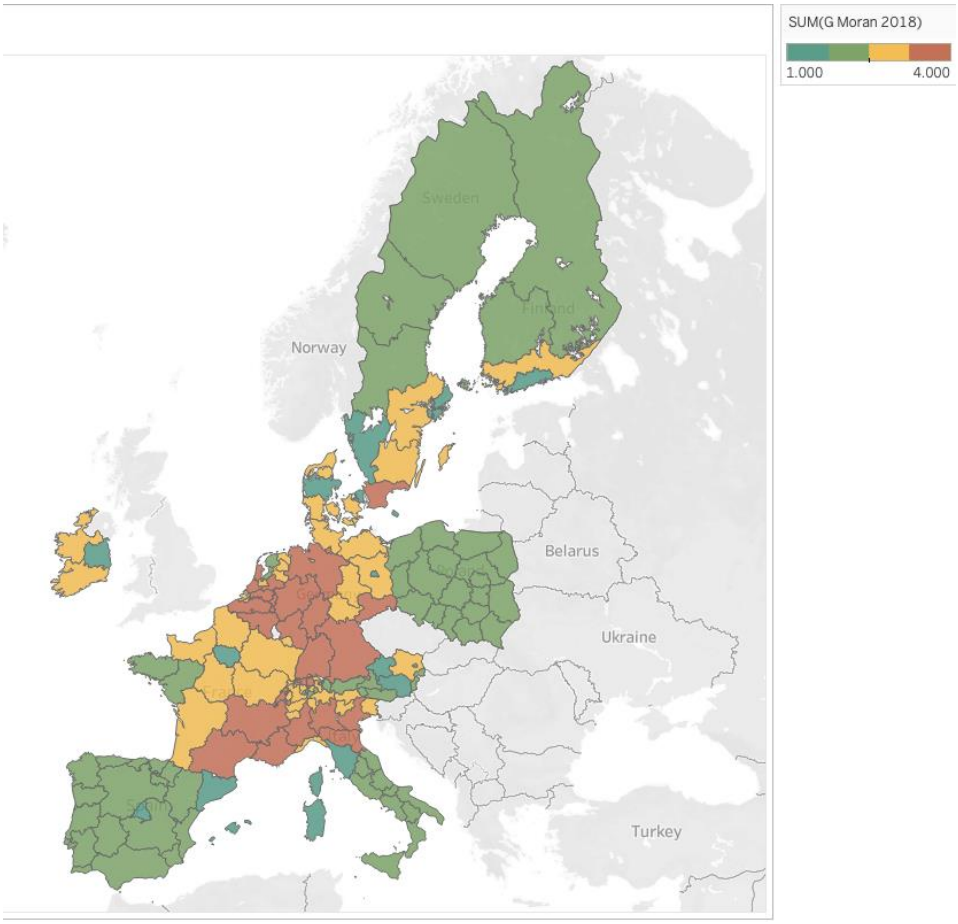
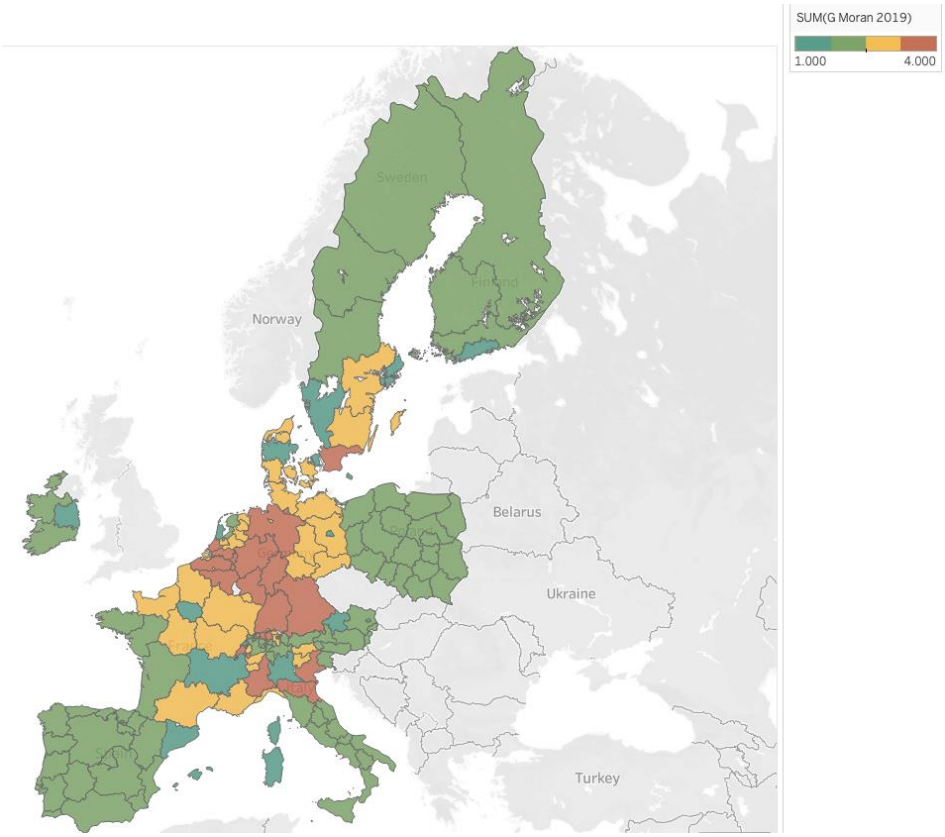
Figure 2. Map of innovation clusters in European regions by number of patent applications in 2018



According to the above-mentioned grouping, 14 "cores" (the current centers of innovation clusters) were observed in 2018. Most regions with high values of PA and the adjacent regions with low values are located in Austria, Denmark, Spain and Sweden. There is the main innovation cluster center of France, it is Ile-de-France, the number of patents of which is much higher compared to neighboring areas and other cores of the European Union. The high mutual influence of this region demonstrates that innovative activity "flows over", so Ile-de-France becomes a kind of innovative agglomerate. "Counterbalance satellites" became 33 regions, mainly in Belgium, Germany, the Netherlands and Switzerland. The German regions such as Bavaria, Baden-Württemberg and North Rhine-Westphalia have the highest number of patent applications. They strongly influence the neighboring areas, stimulating them to create and develop innovations and increase innovation activity. The "periphery-zone of influence" includes 42 regions, which are located in those countries where "counterbalance satellites" predominate. Centre Val-de-Loire (France), Thuringen (Germany), Burgundy-Franche-Comté

(France), Zealand (Netherlands) and Thurgau (Switzerland) are the regions strongly influenced by counterbalance satellites or cores. 66 regions became "territories outside the influence". However, there are new "points of growth" among them. It is Polish regions (Masovian, Greater Poland, Świętokrzyskie, Lodz, Kuyavian-Pomeranian voivodeships) and Spanish ones (Castile-Leon, Castile-La Mancha and Extremadura). They have the potential to become "cores" or "counterbalance satellites". It means that a high number of patent applications and, furthermore, a high level of technological activity can be concentrated in these EU regions.

Figure 3. Map of innovation clusters in European regions by number of patent applications in 2019



It can be observed that 15 regions became innovative "cores" in 2019. Among these regions, Auvergne-Rhone-Alpes (France), Lombardy (Italy), North Holland (Netherlands) and Neuchatel (Switzerland) were added to the group with a high number of patent applications that have neighboring regions with low values of the indicator. These EU regions were in the high-high stimulating innovation development group. Due to the overall increase in the average number of PA the values of the indicator declined among the neighbors of the group, as a result 15 territories became the members of the HL group. Such "cores" as Styria (Austria), Tuscany

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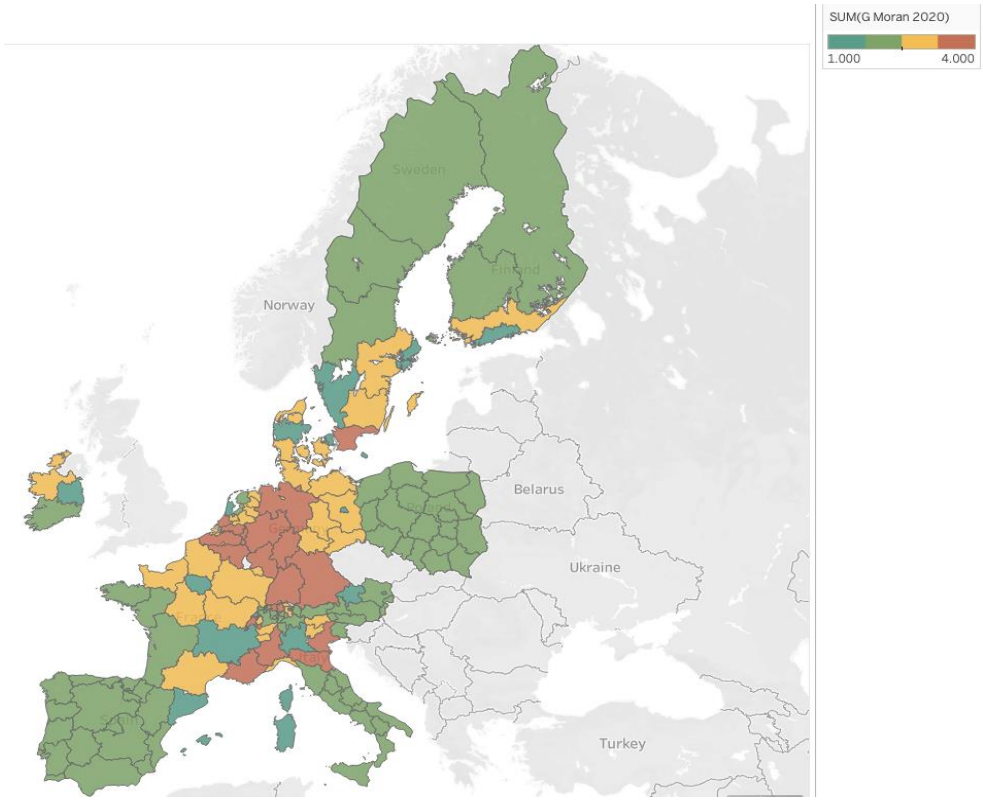
(Italy), Madrid (Spain), became "periphery – zone of influence" due to a decline in eigenvalues. Ile-de-France has maintained a leading position relative to the "cores" of other countries. The number of regions with their own high values of patent applications and a high number of neighboring territories decreased to 22. The majority of regions moved to the low-high group, in which the number of the EU regions also declined to 36. The main reason for the transition is that the number of patent applications from neighboring territories has decreased, so these 36 regions have become low-low territories. Besides, it is worth noting that the group of low-high regions, which are strongly influenced by "cores" and "counterbalance satellites", remained unchanged, only the Grand Est (France) was added. Finally, the number of LL regions has increased to 82 due to a decrease in the number of patent applications both from themselves and from their neighbors. The territories "points of growth" are still the same regions of Spain and Poland.

Figure 4. Map of innovation clusters in European regions by number of patent applications in 2020



The same 15 regions of the EU countries were the "cores", the innovation centers, in 2020. Despite the significant superiority of the Ile de France in this group, Lombardy and Stockholm (Sweden) also have a high number of patent applications. The number of "counterbalance

satellites" has increased to 23 territories, where Provence-Alpes-Côte d'Azur (France) has become a new member of the group. The main transition reason is an increase in the number of patent applications of the neighboring core, Auvergne-Rhône-Alpes. The group of regions "periphery-zone of influence" expanded to 37, where Southern Finland and Northern and Western Ireland were added. In both cases, the reason is an increase in the number of patents of neighbors, Helsinki-Uusimma and Eastern and Central (Middle) Ireland. 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 declined to 80 regions, 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 Extremadura) and Poland (Masovian, Greater Poland, Świętokrzyskie, Lodz, Kuyavian-Pomeranian voivodeships).

Figure 5. Map of innovation clusters in European regions by number of patent applications in 2021

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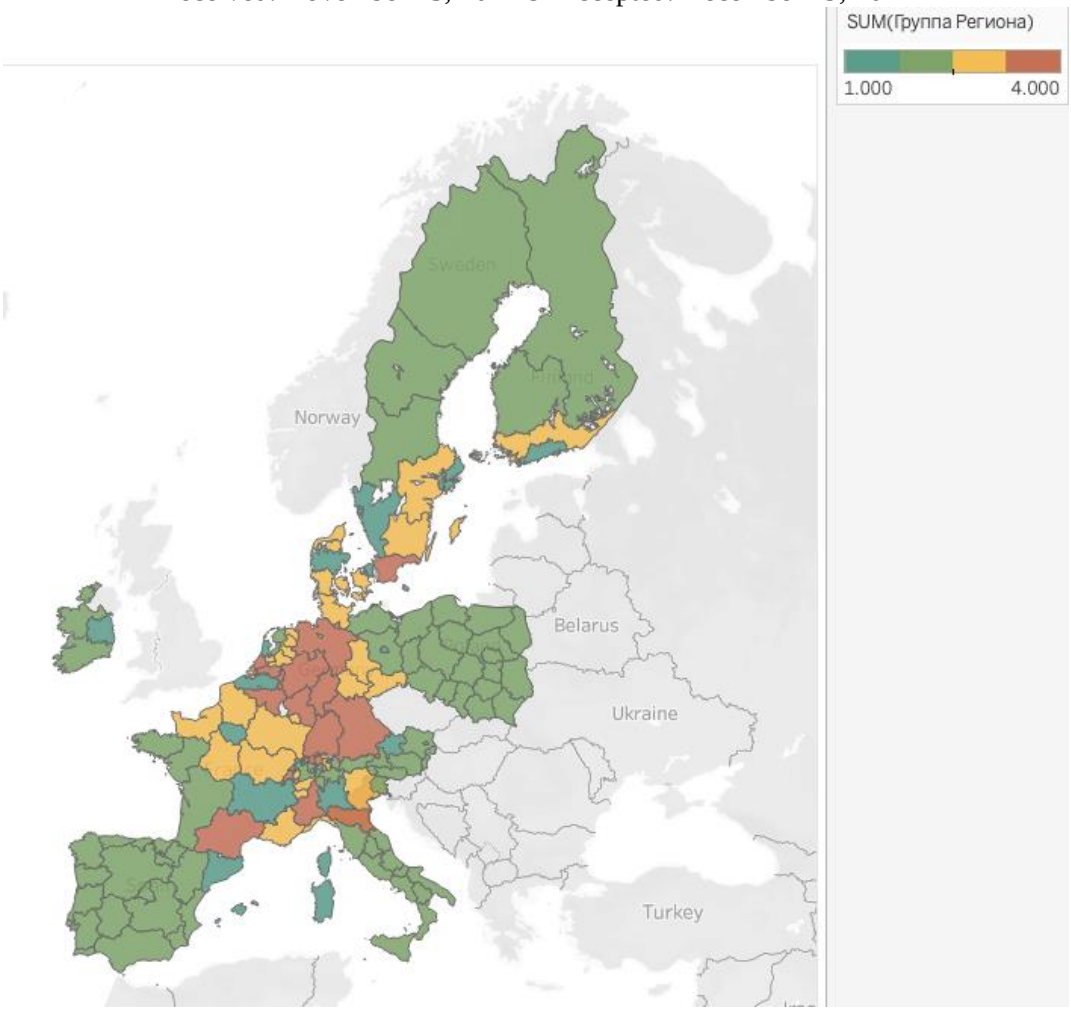


New data showed that in 2021 the group of 15 regions of the "core" expanded to 16. The Flemish region (Belgium) from the HH group was added. The Ile-de-France remains the leader in the number of patent applications in this group. The number of "counterbalance satellites" decreased to 22, where Provence-Alpes-Cote d'Azur (France) moved to the "periphery - zone of influence" group due to a reduction in the number of patents. However, the group of regions "periphery-zone of influence" decreased by 3 territories to 34 due 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 because of 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 "points of growth" 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 (LISA), which does not allow us to unambiguously conclude about their development as future innovative "cores" or "counterbalance satellites".

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. Moreover, most regions with low number of patent applications are located in the south of the European Union that correspond with the results of Moreno R., Paci R., & Usai S. (2005).

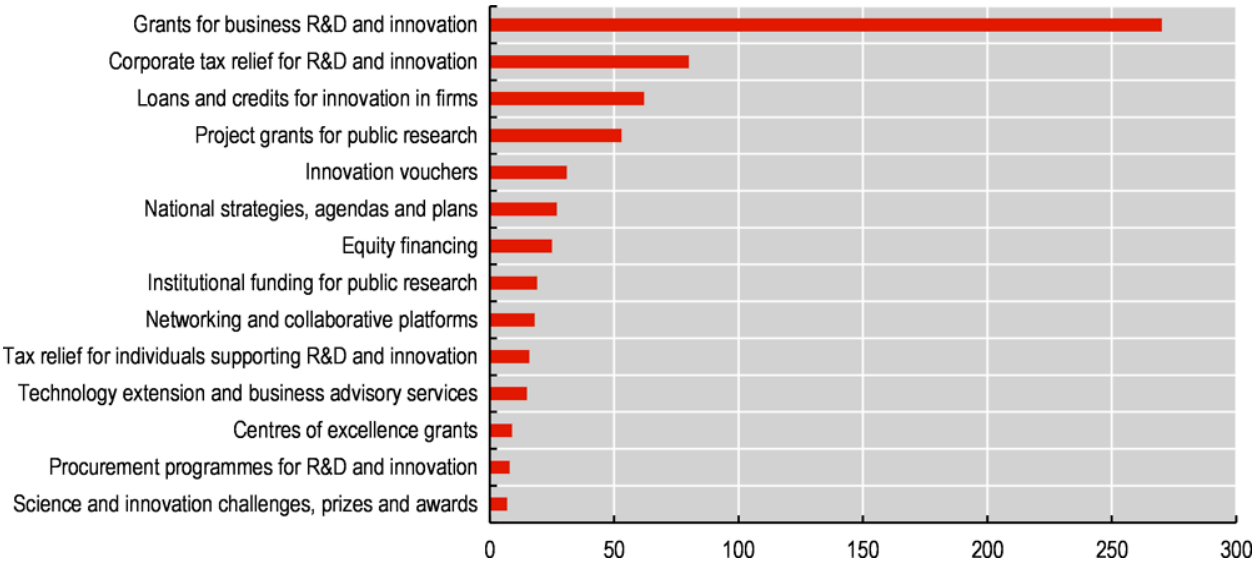
Figure 6. The distribution of the EU regions according to their patent activity

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 patent applications is the University of Valladolid, in the Masovian voivodeship it is the transport company "Babik", the supplier of audio and video equipment "HEM". In Kuyavian-Pomeranian voivodeship it is the manufacturer and supplier of hygienic, cosmetic and medical products "Materialow Opatrunkowych Spolka Akcyjna", agro-industrial company "ANWIL", cosmetic company "La Rive Spolka Akcyjna". In Lodz voivodeship, it is the pharmaceutical company "Aflofarm Farmacja Polska". In Velikopoljska voivodeship there is the Pepco Poland trading network. The growth of these companies and an increase in the number of goods and

services patented by them, can directly affect the innovation development of clusters in the European Union countries and regions.

Furthermore, regional clustering and the development of "points of growth" will depend on the policy instruments providing financial support for business R&D and innovations. Figure 7 shows financial policy tools supporting R&D in the private sector in OECD countries. One of the most popular tools is grants for business R&D and innovation as the public direct forms of support. Specifically, today in Poland two tools are used. There is the deduction of R&D expenditures (200% of R&D expenditures can be deducted) and R&D grants (Deloitte, 2020). In Spain the national authorities provide companies with R&D grants, R&D tax credit, partial exemption of withholding tax and social security contributions for R&D staff and patent box (Deloitte, 2020). Thus, we can see that Spanish "points of growth" can have more potential to become the centers of innovation clusters than Polish voivodeships as more policy instruments providing financial support for R&D and innovations are introduced.

Figure 7. Number of active policy initiatives reported by OECD countries, top 14 instruments



Conclusion

Innovations are still one of the main factors that influence economic and technological prosperity not only in the private sector, but also in the public one, in regions and nations. Particularly regions do not innovatively grow or decline in isolation. It can be outlined that

there is some influence of territories on each other, and the strength of this impact depends on economic, technological and geographical distance.

Based on the results of calculating spatial autocorrelation (global and local Moran I indices), it is observed a divergence trend in the regional innovation development of the European Union countries and regions.

Moreover, the scattering maps of the EU regions according to their high or low number of patent applications in 2018-2021 show 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. Their development will depend on the organizations and businesses which patent innovation products and services in the regions. Besides, new "points of growth" will have more potential to become the centers of new innovation clusters where regional, and national innovation policy and financial incentives offered by the governments are introduced and expanded.

Acknowledgments

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