# Innovative ecosystems behind regional smart specializations: The role of social, cognitive and geographical proximity

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## Abstract

*The article shows how regional smart specializations that are currently considered as the most essential tool of European innovation policy may be assessed if they form innovative ecosystems based on social, cognitive, and geographical proximity. The article presents the concepts of smart specializations and innovative ecosystems, as well as the concept of proximity and its aspects being of reference to smart specialization ideas. The concept of innovative ecosystems is presented from the perspective of its foundations and relations to other concepts and theories. Cooperation in the innovation process by varied actors is considered a significant feature of innovative ecosystems and the manifestation of social proximity. Related diversity of smart specialization areas indicates their cognitive proximity, and embeddedness in a particular administrative region shows their geographical proximity. The results of research carried out in the Subcarpathian region prove that firms in smart specializations are more Research & Development and innovation-intensive and more prone to cooperation than other companies, which determines their social proximity. The research also shows that smart specializations have positive effects on regional development, which indicates the efficiency of their innovative ecosystems. Related diversity of Subcarpathian Regional Smart Specializations (RSS) is also measured to show their cognitive proximity. Analysis of the locations of RSS companies indicates that they are characterized not only by regional but often even by local geographical proximity. The applied methods are desk research, web site queries, a literature review, statistical data analysis, as well as direct research based*

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on a survey and econometric analysis of the results of the survey. The article responds to the lack of studies on smart specializations in the context of proximity.

## INTRODUCTION

Regional smart specializations (RSS) in the EU have been indicated as stimulants of the innovative development of regions. They reflect areas of not necessarily the highest technological advancement but in which the region specializes and has a comparative advantage, and implements innovations based on research. Strategies for smart specializations assume the joint implementation of projects by enterprises and scientific entities, and thus the existence of cooperation of these sectors in the regions for the development of innovative solutions. This means that smart specializations should reflect innovative ecosystems characterized by links between enterprises and between sectors (like business-science links) in the research and innovation process. These ecosystems should have business, technological and knowledge layers – subsystems – and thus be capable of generating new value together, both inventing and commercializing it. At the same time, this interdependence in the innovation process determines the competitiveness of individual organizations within the ecosystems of smart specializations, that is, the appropriate cooperation and occurrence of particular types of partners will determine whether other members of the ecosystem can be effective, as in biological ecosystems. The reasons for the occurrence of innovative ecosystems arise from the features of modern economies, the complexity of technology and the turbulent environment to which organizations adapt by adopting flexible, agile, organizational forms. The complexity of technology and products/services, and at the same time, hyper-competition means that no organization is able to have all the resources needed in-house and often needs complementary products/ services/materials that will condition its achievements. As a result, a well-functioning innovation ecosystem will determine the competitiveness of its members, and at the same time, translate into effects in the field of regional development based on innovative processes.

Accurately indicated regional smart specializations are based on actual innovative ecosystems characterized by social proximity reflected in interactions in the innovative process. They are also characterized by cognitive proximity through a common knowledge base due to the related diversity of their industries. Moreover, as regional smart specializations were indicated

by particular administrative regions at the second level of the Nomenclature of Territorial Units for Statistics (NUTS 2), they consist of entities located in the same geographical territory, which indicates geographical proximity. The article presents the concepts of smart specializations and innovative ecosystems, as well as the concept of proximity and its aspects being of reference to smart specialization ideas.

The hypothesis of the research for the article is that well indicated Regional Smart Specializations reflect efficient, innovative ecosystems based on social, cognitive, and geographical proximity. The purpose of the article is to develop a tool for the analysis of innovative ecosystem effectiveness in terms of these types of proximities and to test the tool in the Subcarpathian voivodship in Poland. The assumptions for the developed tool are as follows:

1) Cooperation in the innovation process and network structure may be perceived as the main common features and are the basis for the concepts of RSS and innovative ecosystems. These are also manifestations of social proximity.
2) Embeddedness of RSS in a given knowledge base indicates cognitive proximity. The characteristic of innovative ecosystems is the crucial role of a knowledge base, which constitutes part of the innovative potential determining the ability of a system to introduce new products based on mixing different but related competences to create new value. Cognitive proximity is reflected in the related diversity of innovative ecosystems of RSS areas.
3) Embeddedness of RSS in a specified territory indicates geographical proximity. Analysis of the location of RSS companies allows one to check if they are based not only on regional but also local geographical proximity, which might further stimulate more intense social interaction and proximity due to easier tacit knowledge flows.
4) Efficiency of innovative ecosystems based on social, cognitive and geographical proximity is visible in positive spill-overs of them in terms of quicker regional development.

The proposed tool may be used to check if the RSS areas were indicated in a proper way, that is, whether they form actual innovative ecosystems.

Over 400 articles related to smart specialization concept are in the Scopus database, but none of them have the keyword proximity. Only nine Scopus indexed articles also refer to the concept of innovative ecosystem and they stress the collaborative aspect of innovative ecosystems in terms of an open innovation model or collaboration crossing administrative boundaries (Carayannis, Meissner, & Edelkina, 2017; Woronowicz, Boronowsky, Wewezer, Mitasiunas, Seidel, & Cotera, 2017). A tool to analyze the cells of a business ecosystem is offered by Vlados and Chatzinikolaou (2019). In the article, the tool for assessing if regional smart specializations are based on actual

innovative ecosystems is proposed consisting of a theoretical approach, and methods and sources of data that may be used to check the presence of social, cognitive and geographical proximities as characteristics of innovative ecosystems of RSS. Smart specialization strategies enhance the effects of such proximity-based joint activities in the innovative ecosystems of RSS.

The subsequent parts of the article consist of a literature review presenting the concept of regional smart specializations, the concept of innovative ecosystem and its foundations, as well as the concept of proximity and its different types. A data and methods section presents the empirical strategy based on theory, as well as the sources of data and methods used for the development of the tool. The results section is divided into sub-sections reflecting social, cognitive, and spatial as well as geographical proximity. Conclusions complete the text.

## LITERATURE REVIEW

Smart specializations are science-related areas of economies that have been selected by individual regions for the smart specialization strategies that form the 3rd generation of regional innovation strategies in the EU. These areas can receive regional support for research under the Structural Funds. Their selection results from the necessity to prioritize and concentrate resources on research in areas which, in a given region, can bring the best results in terms of the implementation of innovative and internationally competitive solutions, and which derive from the existing structure and development of regions. In addition, smart specialization strategies indicate areas that may be promising for regions in the future. These strategies are designed to support entrepreneurial discovery in regions, especially in phases, when it requires some protection through public support to bring about the desired return on private and public investment (OECD, 2013).

In addition, the strategy of smart specialization should lead to the technological modernization of an existing industry, including the development of specific applications of the main technology in a given sector as a traditional one. For example, the Finnish pulp and paper industry perceives nanotechnology as a source of valuable innovations. Smart specialization policies must be rooted in local conditions and guarantee access to external knowledge through strong and vital links with the supra-regional environment (Capello & Lenzi, 2013). Foray (2017) sets the following economic fundamentals of SS strategies: specialization in the area of R&D and innovation, transformative activities of existing sectors and creating new sectors, and an entrepreneurial discovery process.

According to McCann and Ortega-Argilés (2016), the basic argument of the smart specialization strategies is that policy resources must be spent on those activities, technologies or sectors where a region has the most realistic chances to develop internationally competitive products, based on many different local and inter-regional linkages and connections. This approach requires that many of these activities are already embedded in the region's existing industrial fabric and that as many local actors are engaged in the policy design and delivery process as possible. This involves an entrepreneurial ecosystems' type of approach in which the role of entrepreneurship in driving local innovation is seen as critical for enhancing regional competitiveness. This type of thinking implies that policies may target any of the technological, financial, institutional, or skill-related elements within the ecosystem, to enhance certain features of the local business system, to overcome constraints, or to bridge missing links. Modernizing traditional specialties through entrepreneurial discovery refers to the collective nature of the process of learning in territories through interpersonal interactions and achieving synergetic effects. This is characteristic of industrial districts/clusters/innovation environments, or cities where the learning process is rooted in a developed sector of small and medium-sized enterprises and in the local labor market (Wojnicka-Sycz, 2020). The rapidly changing conditions in which enterprises operate, and especially the critical importance of knowledge and innovation for the success of modern organizations, have created new organizational forms such as virtual and network organizations that create more or less dependent and formally related entities within their environment which are business or innovation ecosystems. This also reflects the growing importance of the systemic paradigm in science, technology, and the economy.

The concept of an innovative ecosystem reflects a shift towards a systemic paradigm from a mechanistic approach in the case of innovation processes in an organization that is increasingly interdependent with its environment. The systemic paradigm is based on the theory of systems, the essence of which is the holistic approach to reality. The concept of the open system of Ludwig von Bertalanffy (1968) is the basis of the theory of systems, and especially the systems' school in management theory. Von Bertalanffy's concept is based on the perception of living organisms as organized wholes with a dynamic character. This means that individual parts of the body can only be determined by knowing their place in the whole. At the same time, these organized entities are "open systems" because they collect and render the material substance into the environment (Hammond, 2010, p. 112).

The business ecosystem, on the other hand, is a term proposed by J.F. Moore, who said that a company could not be seen as a representative of one industry but as a part of a business ecosystem that crosses industry

boundaries. In the business ecosystem, the partners work together to develop competitive products and services and develop skills and innovations together, but they are also competitors. The business ecosystem includes the organization, its clients, competitors, market intermediaries, companies selling complementary goods, and suppliers, as well as regulators or media that may have a less direct, but significant, impact on the operations of an organization. The ecosystem works together, partly deliberately, organizes itself, and is characterized by decentralized decision making. According to Moore, the business ecosystem should replace the term industry, because currently, it is challenging to assign a given organization to a specific industry. Linking an ecosystem's actors means that they have an impact on each other. Organizations in the business ecosystem are trying to implement innovations and use the skills of other ecosystems' participants. At the same time, however, they function in a turbulent environment, so they constitute a dynamic structure (Moore, 2016).

Organizations nowadays increasingly function as entangled organizations that depend on their environment and perceive that business is not war, and its goal is to create value, which means a non-zero-sum game. Creating value is a common goal that connects organizations. In a modern economy, no organization is able to perform all activities on its own – the benefits of specialization encourage the outsourcing of all functions that do not belong to the core business. Cooperation is the main factor shaping the relationships between organizations, and the basis of economic life is symbiosis, not aggression. Companies want to focus on a narrow area of their key competences and key processes, so they try to pass on as many side activities as possible to external subcontractors. The more companies specialize, the more they become dependent on other companies and need formal mechanisms to harmonize their activities. Continued partnership will be fostered by the balance of anticipated benefits and the required work input (de Wit & Meyer, 2017).

Business ecosystems can contain key and niche organizations. The key organizations control the most critical organizational resources – distribution, technology, or brand, but the organization becomes more resilient when these resources and related organizations are more diversified. Therefore, key organizations should, instead of gaining more control in the ecosystem, try to have a greater share in distribution and joint value creation with partners, which will also increase their resilience. An example of building an efficient ecosystem in recent years with partners is, for example, Cisco, or the ecosystem of music publishing houses and others selling their songs through the iTunes platform created by Apple. Platforms are creating an entirely new blueprint for competition that puts ecosystems in head-to-head competition.

The utility of almost any platform is shaped more and more by the ecosystem that surrounds it. Take Apple's iOS platform that includes the iPhone, iPod, and iPad. Its value to its users comes largely from the 800,000 complementary apps over which Apple has little ownership. The emergence of such platform ecosystems is relocating the locus of innovation from the firm to a massive network of outside firms. The goal is to develop new capabilities and foster innovations unforeseeable by the platform's designers (Tiwana, 2013).

The concept of a business ecosystem is derived from the definition of a biological ecosystem, and thus, the system of organisms dealing with a given habitat, along with those aspects of the physical environment in which they interact. The ecosystem must adapt to the changing environment, so there must be a large variety of species so that the entire ecosystem survives in a changing situation (Peltoniemi & Vuori, 2016). Rothschild (1990) sees the economy as an ecosystem that continues and develops thanks to copying information and thus increasing the knowledge base, which speeds up the development. According to Rothschild, the main difference between natural and economic systems is a much faster process of changes in economic systems, while the basic mechanism is the same. The economic change is based on copying, exchange, and development of technological knowledge, just like genetic information in nature.

In terms of innovativeness, the concept of an innovative ecosystem exists. It consists of all partners of a company whose knowledge the company uses or in cooperation with which it develops innovations and conducts research and development (R&D). The term ecosystem is also related to the national systems of innovation concept  (Lundvall, 1990). The main components of innovation ecosystems are other enterprises, but also the R&D sphere, universities, intermediary institutions, such as technology transfer centers or knowledge-based business services, as well as administration creating the right conditions for the development of innovation, or directly creating the demand for innovative products in public procurement. From the perspective of the quadruple helix or the demand-driven approach to innovation, apart from business, science and administration, users – society – are also an important subsystem of innovative systems. Recently, the environmental dimension has also been added to this model – a quintuple helix. Among the elements of such an ecosystem, there are direct interactions, like the joint implementation of all or some elements of the R&D and innovation process on a partnership basis or in the form of subcontracting, and also indirect interactions based on technology transfer or tacit knowledge flows through the mobility of personnel (Wojnicka-Sycz, Sycz, Walentynowicz, & Waśniewski, 2018; Teixeira & Lopes, 2012).

The idea of networks and interdependent ecosystems is also reflected in theories emphasizing the positive effects of agglomerations for local and regional development, such as the concept of Marshall's territorial production systems from 1899 or clusters based on Porter's diamond, for example, clusters of a given industry and related industries (suppliers and customers) and supporting institutions in a given area, as well as relevant resources – production factors. Nowadays, clusters are mainly perceived as innovative ecosystems, especially those that, in addition to companies, also include the knowledge subsystem like universities or research institutes. According to Andersen (2011), innovative ecosystems are successful agglomerations in geographical, economic, industrial or entrepreneurial terms, and therefore, particularly innovative regions/territories such as Silicon Valley, Bangalore, or successful ICT platforms like the iPhone or Android, as well as new industries such as calculations in the cloud.

Xua, Wub, Minshallc, and Zhoud (2018) believe that an innovation ecosystem consists of a knowledge ecosystem driven by research and development, and a business ecosystem driven by market forces. In addition, in the definition of an ecosystem, the knowledge created as a public good and technological knowledge covered by the protection of intellectual and partly private property should be distinguished. Thus, in the innovative ecosystem, they distinguish the business, technological and scientific layers. There are interactions between the business ecosystem and the knowledge ecosystem that may lead to their evolution, for example, through spillover effects from basic knowledge or value propositions for the knowledge sector from business partners. However, the knowledge and business subsystems differ in goals and organization, and hence their cooperation may be difficult. However, this cooperation may be facilitated by various instruments in the field of innovation or market policy, like pro-innovation institutions such as technology transfer centers, technology parks, or consulting companies.

It is thus possible to summarize the concept of an innovative ecosystem as deriving from:
1)  In terms of theoretical foundations:
    a) systems theory – open systems theory, systems school in management, engineering – systems design;
    b) innovation theory – innovative systems based on interactions within a quadruple/quintuple helix: business, science, administration and society/environment, innovative networks, clusters – based on the benefits of agglomeration from clusters of a given industry and related industries together with scientific institutions supporting a given sector, open innovations based on cooperation of the company with the environment in implementing innovations, which allows the lowering of the costs of this process.

2)  At the mezzo and macro level, the concept of an innovative ecosystem is related to the concept of a business ecosystem and the perception of the economy as having similar features to biological ecosystems. This also results in the increasingly frequent phenomenon of coopetition, which is the capitalism of allies instead of perceiving competition as a zero-sum game. Moreover, it means competition between ecosystems, not individual companies.

3)  At the micro-level, the concept of an innovative ecosystem reflects a systemic approach to the organization as well as the concept of an entangled organization and networked and virtual organizations (Figure 1).
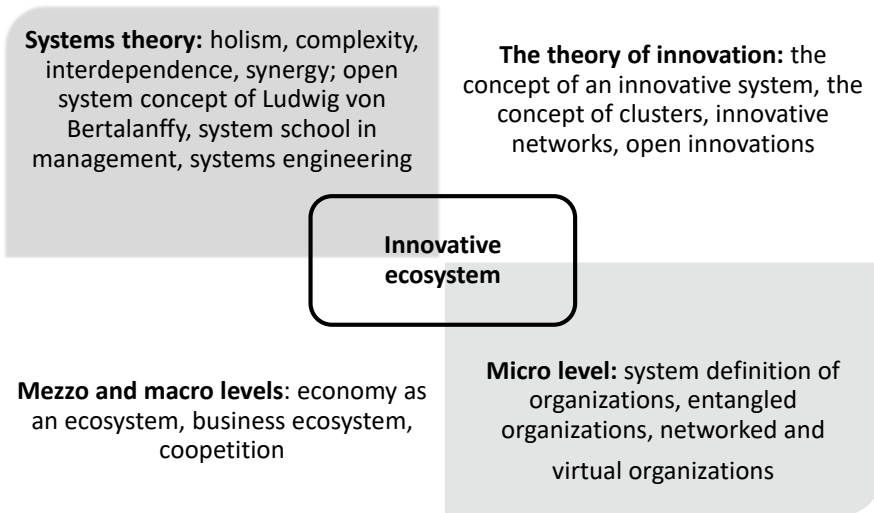


**Figure 1.** The foundations of the innovative ecosystem concept
**Source**: Wojnicka-Sycz & Sycz (2018).

Proximity, in the simplest terms, means similarity of the organization's attributes (Boschma & Frenken, 2009). More broadly, proximity refers to the similarity "of physical space, psychological and social relations as well as shared cultural values or similarity of institutional operating conditions" (Czakon, 2010). External proximity can be seen through the prism of belonging of market participants to the same circle of friends, community, family, professional group, organization, or institution (Torre & Rallet, 2005). Individual authors emphasize the multidimensionality of proximity by listing various components (Klimas, 2011 p. 16).

Social proximity refers to the issue of strength of interpersonal relationships, in particular to what extent people know each other and interact in a private or professional context (Huber, 2011). The traditional

belief is that strong relationships based on trust facilitate the exchange of knowledge (Gertler, 2004, p. 156). However, the existing literature on social proximity, sometimes also called relational proximity or personal proximity, is dominated by the slightly loose use of this idea (Amin & Cohendet, 2004).

Broadly understood cognitive proximity means similarity in the way people perceive, interpret, understand, and evaluate the world (Wuyts, Colomb, Dutta, & Nooteboom, 2005). Cognitive proximity is essential for mutual understanding and effective communication with each other. Existing empirical studies do not distinguish between dimensions of cognitive proximity, which seems important for understanding the complexity of the broad concept of cognitive proximity (Nooteboom, Van Haverbeke, Duysters, Gilsing, & Van Den Oord, 2007).

The similarity of knowledge bases, patents, and technologies used is perceived as a factor determining and accelerating the processes of knowledge generation and commercialization of innovation. The implementation of joint learning processes is effective because entities close to each other in cognitive terms tend to understand the same phenomenon or process (Lagendijk & Lorentzen, 2007). Common interests reduce the risk of opportunistic behavior and focus on combining complementary resources and technologies to eliminate information gaps and knowledge gaps (Klimas, 2011, p. 17).

Geographical proximity is the proximity based on the same physical space, which means that the agents are located not far from each other. This proximity depends on the type of geographical scale taken into account. In the case of regional smart specializations, what is essential is regional space, understood as being located in the same administrative region on the NUTS 2 administrative level and being covered by the same Regional Smart Specialization Strategy that is Regional Innovative Strategy of the 3rd generation. However, local geographical proximity is also important as the logic of smart specializations stresses concentration of resources on R&D and innovative activity, which may be amplified by local concentration of companies and institutions stimulating tacit knowledge flows during direct, often informal, meetings of employees of RSS agents.

Proximity helps explain such important processes as building a competitive advantage, increasing efficiency and effectiveness, making strategic choices, and organizational collaboration (Czakon, 2010). Economic geography literature and endogenic regional development theory find proximity and networking as determinant factors for explaining local and regional development (González-López, Dileo, & Losurdo 2014). Recently, most attention has been focused on linking proximity with innovation, acquisition, and diffusion of knowledge (Boschma, 2005), especially quiet and difficult to codify (Gertler, 2004). Moreover, some indicate that properly close inter-organizational interactions allow the realization of full and multidimensional learning (Crevoisier &

Jeannerat, 2009) and the use of the effect of knowledge diffusion. The closer the organizations are, the greater the likelihood of knowledge transfer in the inter-organizational network and the higher external effects of its functioning. Enterprises striving to optimize cooperation and maximize their results, strive to reduce the distance between them (Klimas, 2011, p.17). Obtaining the most favorable effects of proximity requires the appropriate configuration of several of its dimensions. Optimal configuration of proximity types refers to providing the right structure and level of proximity (Boschma, 2005). A proper structure of proximity shall consider interrelationships and couplings between dimensions and the effects that the organization plans to achieve through cooperation. The right level of proximity means a good balance between a lack of closeness and its completeness. Large proximity provides many positive effects, but on the other hand, too high a level can be harmful to the organization and cause counterproductive effects. Then occurs the so-called paradox of proximity (Boschma & Frenken, 2010), consisting in the fact that too close inter-organizational relationships can lead to inertia, loss of flexibility, bureaucracy and economic inefficiency, and what is important to limit access to innovation and new knowledge outside the network (Boschma, 2005). The proximity paradox reflects the parabolic nature of the relationship between proximity and the benefits of maintaining it (Czakon, 2010; Klimas, 2011, p. 17).

## DATA AND METHODS

The literature analysis presented in the article showed that a systemic approach and networks of cooperation, as well as innovativeness, are crucial both for the concept of smart specializations and innovative ecosystems. The concept of innovative ecosystems is different from the original concept of national innovation systems, mainly in the stressing of the dynamic rather than institutional aspects of the system. It also makes it more difficult to indicate the borders of an ecosystem as they evolve similarly to natural, biological ecosystems. The linking mechanism of innovative ecosystems, as well as smart specializations, are interactions between agents, which often take the form of less or more formal cooperation complementing competition. Such competition of allies is characterized by the emergence of networked organizations with their breeding environment, occurrence of platform-type business ecosystems, as well as by the importance of knowledge exchange for learning and innovation processes in the era of complexity and knowledge-based economies.

These types of proximity: social, cognitive and spatial, which are characteristics of an innovative ecosystem and a regional smart specializations

concept, are interrelated and enhance their own importance reciprocally for the smooth and value-adding operation of RSS areas as innovative ecosystems. Cognitive proximity, in the form of a common knowledge base and complementary capabilities reflected in the related diversity of RSS areas and subareas, is important from the perspective of an innovation ecosystem concept as it means a mixture of different capabilities that are crucial for cooperation-based innovations and for the creation of new value in a systemic way.  This also resembles the way of operation of platform-based ecosystems where, often spontaneously, varied companies produce applications that may be used with particular platform type software.  The related diversity of RSS is measured in a regional context, so it refers to complementary capabilities present in a particular geographical space of location of RSS companies. Concentrations of RSS companies in local territories make tacit knowledge flows more probable and this is crucial for innovative ecosystems like, for example, clusters. Tacit knowledge flows, as well as more direct and formal types of cooperation, involve social interactions between people, which are based on or create social proximity. These types of proximity, based on social interactions, knowledge flows and formal cooperation agreements, make the diffusion of knowledge and innovation possible as well as the creation of new value in the form of innovations by companies cooperating with academia, administration, society, and the environment. This subsequently leads to the quicker development of a region thanks to the diffusion of growth from innovative ecosystems of regional smart specializations to the other regional industries (Figure 2). The above relations derived from theory are the basis for the empirical analysis in the article.

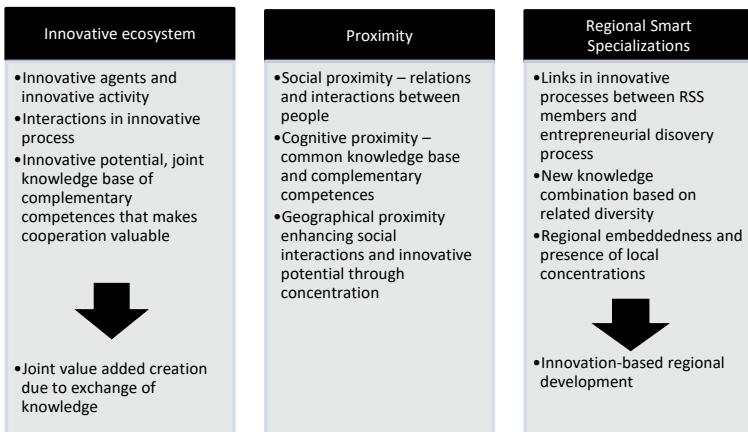| Innovative ecosystem | Proximity | Regional Smart Specializations |
|---|---|---|
| • Innovative agents and innovative activity<br>• Interactions in innovative process<br>• Innovative potential, joint knowledge base of complementary competences that makes cooperation valuable | • Social proximity – relations and interactions between people<br>• Cognitive proximity – common knowledge base and complementary competences<br>• Geographical proximity enhancing social interactions and innovative potential through concentration | • Links in innovative processes between RSS members and entrepreneurial disovery process<br>• New knowledge combination based on related diversity<br>• Regional embeddedness and presence of local concentrations |
| ⬇ | | ⬇ |
| • Joint value added creation due to exchange of knowledge | | • Innovation-based regional development |

**Figure 2.** Innovative ecosystem's and RSS's concepts and related with them types of proximity

The analysis in the article is carried out for the Subcarpathian voivodship in Poland. The Subcarpathian region is located in south-eastern Poland, and it is one of the poorer regions at the NUTS 2 level of Poland and the European Union. GDP per capita in the Subcarpathian region in 2017 was 49% of the average for the EU-27 in PPS, while in relation to the average for Poland, it was 71%. The population of this region was 2.13 million people in 2018. The Subcarpathian Region is characterized by a high share of industry in the economy, as 39% of the added value was generated in industry and construction in 2016, compared to 35% on average in Poland. The Subcarpathian region is also characterized by a relatively high share of employment in agriculture, forestry, and fisheries – 11.6% (similar to the average for Poland), however, agriculture is not very productive, as this sector had only 1.5% share in the added value generated in the region in 2016. However, the region is the seat of the Aviation Valley industrial cluster, and many international companies are present here. As a result, the Subcarpathian region distinguishes itself in terms of the share of R&D expenditures of enterprises in GDP (BERD), which in 2017 amounted to 0.86% here compared to 0.67% of the total GDP in Poland. The total share of expenditure on R&D in the region's GDP in 2017 was 1.03%, and it was equal to the Polish average.[4]

In 2015, the value of exports from the region was 37% higher than the value of imports and in 2016 exports from the region grew by 10,6 % in comparison with 2015. Calculated for one exporting company, it amounted to PLN 14 million, which was the eighth-highest value in the country. From 2010, exports from the region increased by 89.4%, a figure higher than the average for the country, which amounted to 69.9% (Klimczak, Miller, Wojnicka-Sycz, Sycz, & Piróg, 2017). Therefore, the region is an example of a poorer EU region due to the large share of traditional industries such as agriculture and tourism, but also with strong innovative and exporting industrial companies, and the choice of priorities for smart specialization strategies reflects the duality of this region. The aviation and space industries, along with the automotive industry and industries related to them as well as smart specialization "Quality of Life" and the horizontal ICT specialization, were indicated as smart specializations here.

The industrial specializations and ICT were indicated as bundles of related industries: end-product producers, suppliers, complementary products and services as well as R&D for the RSS. However, the RSS "Quality of Life" is too diversified often in an unrelated way. In detail, the specialization "Quality of Life" includes the following activities: passive construction, systems for smart houses, energy-saving construction materials, biodegradable plastics, cognitive tourism, leisure tourism, ecotourism, agrotourism; qualified tourism like hiking, skiing,

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4   Data of Eurostat and the Central Statistical Office (CSO).

biking, motor, canoeing, sailing; health tourism; business tourism; religious tourism, culinary tourism, wine tourism, renewable energy, organic food, care for the elderly, preventive medicine and natural medicine. The Quality of Life specialization is meant to reflect the endogenic potential of the region.[5]

The analysis in the article is based on several aspects. There is a literature review and a statistical data analysis based on the OECD Input-Output trade tables and the data of the Rzeszow Statistical Office. In addition, there is an analysis of data gathered from website queries on companies that represent areas of Subcarpathian smart specializations. Finally, there is an analysis of the results of the CAWI (Computer Assisted Web Interview) survey carried out on 200 innovative enterprises that embrace the subgroup of firms of smart specializations in the Subcarpathian region of Poland in 2017 (for a research project commissioned by the Subcarpathian Marshall Office (Klimczak et al., 2017)). The respondents were selected in a targeted sampling from the database of smart specialization firms created from website queries and the database of innovative enterprises of other industries identified in a representative survey of 600 enterprises in the region, as well as the databases of economic entities that received support for innovations. Websites for the queries were found by searching varied firms' databases through keywords connected with particular subdomains of RSS areas. Moreover, we investigated the websites of firms indicated on the websites of clusters and associations connected with RSS. The CAWI research was done into those firms of RSS that indicated on their websites some kind of innovative activity.[6] CAWI research was used for testing the hypothesis formulated for logistic regression and for determining the internal related diversity of RSS areas. In the CAWI research, the companies self-assessed varied aspects, which were reflected in questions about conducting activity in a particular subarea of smart specializations, conducting R&D activity, cooperation with universities or other scientific institutions, membership in clusters and declaring the year of their origin. Industrial smart specializations were specified on the basis of the indicated subareas of RSS falling into the Aviation and Automotive RSS.

The econometric method that was used for the analysis of the results of the survey was logistic regression. Logistic regression, also called a logit

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5   Regional Innovation Strategy of Podkarpackie Voivodship 2014-2020.

6   In particular the following websites were investigated: ICT clusters - http://www.klasterict.org.pl/, http://www.klasterit.pl, Eastern Automotive Alliance. http://eaa-wsm.pl/, http://www.automotivesuppliers.pl, Aviation Valley: http://www.dolinalotnicza.pl/, Aviation Cluster http://www.klasterlotniczy.pl/, Ecological housing: http://www.pasywny-budynek.pl/, https://lipinscy.pl/województwie podkarpackie, Oenology: http://www.naszewinnice.pl/polskie-winnice/prezentacja-winnic/woj-województwie podkarpackie?start=20, http://województwie podkarpackiszlakwinnic.pl/winnice/, Preventive medicine: http://www.sanatoria.org/pl/wojewodztwa/województwie podkarpackie.html; Cluster of Plastics Producers http://www.poligen.pl/, Energy providers http://energia.rzeszow.pl/, Ecological Valley http://www.dolinaeko.pl/, Regional products-http://www.smaki.województwie podkarpackie.pl, http://www.baza-firm.com.pl (searching with keywords as: computers, databases, Internet, electronics, telecommunication services, automotive: production and accessories, motorcycles, engines, smart houses, real estate developers, wooden houses, renewable energy, wind farms, fotovoltaic, solar panels, water power plants, ecologic food, healthy food, natural medicine, care for the elderly, medical care), BISNODE database.

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model, is used to model dichotomous outcome variables. In the logit model, the log odds of the outcome are modeled as a linear combination of the predictor variables. Logit regressions show the probability that an explained variable will be 1 or 0 with given parameters and values of explanatory variables. The logit models in the article take the form of:

$$P(Y_n = 1|X = \Lambda(X\beta) = \frac{\exp(X\beta)}{1 + \exp(X\beta)} \tag{1}$$

Where: $\Lambda(X\beta)$ is a logistic cumulative distribution function, $Y_n$ are variables reflecting the R&D and innovation activity of firms or other explained variable, with n=1,..., N firms, X is a vector containing a set of determinants like belonging (or not) to smart specializations, and $\beta$ is a vector of parameters.

The hypothesis checked in the article with the usage of logistic regression were if the fact of activity of the surveyed enterprises in the areas of smart specialization increased the probability of their higher propensity to cooperate and conduct R&D activity reflecting social proximity and innovative potential as the characteristics of an innovative ecosystem.

To compare the strength of related diversity, based on the spatial proximity of particular industries of regional smart specialization areas, the following index was constructed.

$$RDSS_i = \sum_{j=1}^{PIio_j} PIio_j \sum_{i=1,j=1}^{Iss,Iio} \left( \frac{SIio_j}{SIss_i} \right) \tag{2}$$

Where: $RDSS_i$ – related diversity of a particular industry of the particular regional smart specialization area,

$PIio_j$ – proportion of a particular important (over 1.5% share) suppliers' industry according to the OECD Input-Output tables in total expenditures of the particular industry of smart specializations, without supplies coming from the same industry,

$SIss_i$ – percentage share of a particular industry of regional smart specialization areas in the total average employment in the region,

$SIio_j$ – percentage share of a particular important suppliers' industry in the total average employment in the region.

In this index, the analysis of intra industrial suppliers was omitted, which is suppliers from the same industry as the RSS industry. This index shows how big the pool of complementary competences is, in terms of employed

people in a given region, in comparison with competences related directly with a particular RSS industry. Hence, it is a measure of the external-related diversity of RSS areas, reflecting their cognitive proximity in the value chain of the region of location.

Moreover, based on the CAWI results, contingency tables and a Chi-square Pearson test was calculated between varied subdomains of RSS areas represented by the firms that indicated more than one subdomain of RSS as their field of activity. The variables here were dichotomous – 0 if a firm does not act in a specific subdomain of RSS and 1 when it does act. This reflects the internal-related diversity and internal cognitive proximity of particular RSS areas. A location quotient was also calculated to find local concentrations of RSS companies in the Subcarpathian region, reflecting geographical proximity on which innovative ecosystems of RSS are based. It was calculated on data from the Register of National Economy REGON and on data on companies of RSS gathered from website queries. The used indexes were (3) and (4).

$$LQ_R = \frac{P_{ip}}{P_{iv}} \tag{3}$$

Where: $P_{ip}$ – percentage share of registered entities of a given RSS industry in all registered entities in a county (poviat in Poland),
$P_{iv}$ – percentage share of registered entities of a given RSS industry in all registered entities in a voivodship.

$$LQ_{WQ} = \frac{P_{piWQ}}{P_{piRv}} \tag{4}$$

Where: $P_{piWQ}$ – percentage share of a given poviat (county) in companies of a given RSS industry identified from website queries of the Subcarpathian RSS firms,
$P_{piRv}$ – percentage share of a given poviat (county) in all registered companies in the Subcarpathian voivodeship.

These indicators show the relative concentration of companies of a given RSS industry in a given county in relation to the voivodship average (3) or average share of a county in regional companies. It was assumed that if it was higher than 1.25 it meant a significant concentration of entities of a given RSS industry in a given county.

## RESULTS

### Social proximity of innovative ecosystems and Subcarpathian SS

Innovative networks and cooperation in the innovation process are the glue of an effective innovative ecosystem. According to the quintuple helix concept, these interactions embrace interactions between academia, business, administration, society, and the environment. Cooperation means social interactions during joint projects, working in teams, often virtual, meetings, or talks with the usage of electronic tools. They may be formal or informal. Social interactions may sometimes lead to an unintended spread of tacit knowledge during informal meetings, which is enhanced by geographical proximity. To enhance cooperation and knowledge flows, varied publicly co-financed initiatives are implemented that create platforms of dialog like clusters and specifically designed financial instruments, like the improved assessment of applications from consortia instead of just single organizations (see Svare & Gausdal, 2017). Smart specializations are also an example of such cooperation-based tools and tools enhancing cooperation and, especially, social interactions between academia, business, and administration. However, companies searching for new ideas will often use new, innovation management methods like demand-driven innovation and engage users in innovation processes. Cooperation with the environment may be enhanced by the necessity to be environment friendly in order to get public grants, which stimulates social interaction with people in firms/institutions who are specialists in environmental protection technologies.

The preparation of strategies for smart specializations in the Subcarpathian region was based on extensive direct research, as well as workshops/meetings with stakeholders, so it embraced social interactions. The concept of RSS embraces not only innovative networks but also the entrepreneurial discovery process. Entrepreneurial people, who are well prepared to look for new niches, often do not have sufficient external connections to enable the commercialization of new ideas and seek sources of financing. The presence of specialized support systems for searching for new activities is important (OECD, 2013) and the implementation of smart specialization strategies offer support systems like bridging tools between entrepreneurs and sources of finance (grants, venture capital funds, business angels) which are a form of socially interactive, institutionalized platforms. In the Pomeranian region of Poland, a competition for the label of smart specialization was held during which consortiums of business and academia had to prove that they could introduce internationally competitive innovations based on regional research, which stimulated entrepreneurial discovery and social networks

(Wojnicka-Sycz, 2018). Smart specialization strategies hence offer tools that stimulate the efficiency of innovative ecosystems of the areas of regional smart specializations, based on innovative interactions and entrepreneurial discovery processes being the earlier phase of innovation processes. These interactions are based on the social interactions of people from RSS entities: firms, institutions, academia, but also society and the environment in which RSS operates, creating social proximity.

For Poland, it was noticed that innovative networks promote innovations in companies, which determine their higher profitability. On the other hand, companies' income is a component of GDP. A series of analyses using logit regression based on a study of approximately 2,500 enterprises and 58 scientific units in Poland in the period 2003-2017, as well as analyses based on statistical data, showed the significant importance of cooperation in the innovation process for innovation and efficiency at the micro and macro levels. Business surveys have shown that cooperation in the innovation process, and in particular the cooperation between enterprises and science, increases their innovativeness in terms of novelty on the market scale, as well as their profitability and international competitiveness. Voivodships and industries, where more enterprises cooperate with science in the innovation process, develop more successfully. Scientific projects implemented by scientific units in partnership with a larger number of enterprises, bring better results in terms of the development of innovative solutions and increases in the entity's revenue, than those where scientific units dominate (Wojnicka-Sycz & Sycz, 2018).

Clusters are cooperative associations of firms aiming at enhancing their cooperation especially in innovation process. In the case of the Subcarpathian region, they embrace enterprises of the major and related sectors, scientific units as well as bridging institutions like technology parks, technology transfer centers, and consulting firms. One of the members of the main cluster of the Subcarpathian region's Aviation Valley is also a regional development agency as a representative of public administration.

All RSS priority areas of the Subcarpathian region have their cluster organizations. Entities connected with the aviation and automotive industries (e.g., from the metal industry) mostly belong to the Aviation Valley association. The Eastern IT Cluster also operates in the region, which includes 81 enterprises, 3 foundations and associations, and 3 universities. In the automotive industry, the cooperation platform is the Eastern Automotive Alliance, which consists of 22 enterprises, regional development institutions, and the Rzeszow University of Technology. The region also has the Subcarpathian Cluster of Pure Energy, Cluster of Good Tastes (organic food), the Bieszczady Cross-Border Tourist Centre, and the Spa Cluster of the Pearls of Eastern Poland. Each of the specializations, therefore, has its own

cluster organization. The CAWI results also confirmed a high propensity of RSS firms belong to clusters. One of the reasons is the possibility of obtaining a favorable assessment of applications for co-financing from structural funds when the enterprise belongs to a cluster initiative. At the same time, these clusters often include entities from other regions of the country, as well as from abroad, together with universities as supporting institutions. Therefore, they constitute an important platform for cooperation in the innovative and supra-regional system.

Using the logit regression, based on data from the survey of 200 innovative companies, the dependencies between the affiliation of enterprises to smart specializations and their R&D activity and cooperative attitude were examined. The analyzed hypothesis was if the fact of activity of innovative firms in the areas of smart specializations increased the probability of firms conducting research and development, and the probability of cooperation in innovative ecosystem. Table 1 shows the structure of answers of 200 innovative firms from the sample in the case of variables taken into account in logit models.

**Table 1.** Structure of answers in CAWI of innovative firms (n=200)

|  | Number of firms | Percentage of innovative firms (%) |
|---|---|---|
| R&D activity | 100 | 50 |
| Cluster membership | 82 | 41 |
| Cooperation with science | 61 | 30.5 |
| Activity in the areas of smart specialization | 137 | 68.5 |
| Company set up before 2000 | 94 | 47 |
| Activity in the areas of industrial smart specialization | 69 | 34.5 |
| Profit in the previous year | 171 | 85.5 |
| Planning of R&D results implementation in 2 years | 54 | 27 |

**Source**: own elaboration on the basis of the CAWI research.

Based on this analysis, it can be concluded that:
- the company's affiliation to industrial smart specializations increased the chance of the companies conducting R&D activities; at the same time, for R&D activity, the cooperation of companies with scientific units proved significant;
- the activity of the surveyed enterprises in the areas of smart specializations increased the chance of the enterprise belonging to a cluster, as well as increased the chance of them planning the implementation of R&D results in the next two years (Table 2).

**Table 2.** Results of estimations with the usage of logistic regression (n=200)

| Explanatory variables | R&D activity | Cluster membership | Planning of R&D results implementation in 2 years |
|---|---|---|---|
| Constant | -0.76*** | -0.75** | -2.71*** |
| Cooperation with science | 2.06*** | | |
| Industrial smart specialization | 0.57* | | |
| Smart specialization | | 0.92*** | 0.78** |
| Set up before 2000 | | -0.58* | 0.61* |
| Profit in the previous year | | | 0.96* |
| $R^2$ McFadden's | 0.15 | 0.04 | 0.05 |

**Notes:** * - significance on 0.1 level, *** - significance on 0.01 level.
**Source**: own elaboration based on CAWI.

## Cognitive and spatial proximity of Subcarpathian SS

The related diversity, defined by Boschma and Iammarino (2009) as "sectors of industry that are similar in terms of common or complementary competences," is also mentioned as an important element of the smart specialization strategy. These may be end producers and their suppliers or industries based on a common knowledge base like engineering competences. Common or complementary competences mean a common knowledge base making possible a mutual understanding on which different new niche areas may be created, for example, based on innovations transforming traditional industries with the usage of new technologies like General Purpose Technologies and leading to the formation of a new related industry. To some extent, aviation may be considered an automotive industry of a newer generation. Hence, related diversity is based on the cognitive proximity of companies and, if firms and sub-industries in RSS areas can be defined as based on related diversity, they represent cognitive proximity. RSS areas in the Subcarpathian region were indicated as bundles of interrelated industries. The industrial RSS and ICT embrace end-product producers and their suppliers as well as research and development activity for these sectors. Moreover, broadly understood engineering competences are also the basis of both the Automotive and Aviation RSS. These competences have been developing in the region since the beginning of industrialization in the 19th century, with the oldest company in the automotive industry being founded in 1838. The construction of the Central Industrial District originates from the beginning of the 20th century and includes a heavy industry center built in

1936-1939 as one of the main Polish projects before World War II. However, the sub-disciplines of the "Quality of Life" RSS often seem to be unrelated, for example, passive houses and oenology.

The presence of a greater number of related industries has proven to have a positive impact on economic growth in Spain, the Netherlands, and Italy, although, at the same time, unrelated diversity in some cases has reduced economic growth (Boschma & Innamarino, 2009). Simonen, Svento, and Juutinen (2014) noted that in order to obtain strong growth, the regions should strive to have a highly diversified structure based on the same technology, i.e. smart specialization. Small regions may have problems with achieving such a structure. Highly diversified or specialized regions that were analyzed in Finland had lower growth rates than regions with 2–3 strong high-tech industries and a few smaller ones. Therefore, whilst smart specialization is important, it does not mean too narrow a specialization or too strong a diversification.

Pylak and Kogler (2019) did not notice the role of unrelated diversity in income growth, especially in less developed regions, although related diversity was important. Unrelated diversity is, however, more characteristic of more developed and wealthier regions, which are denser in terms of varied industrial activity. Less developed regions encounter severe obstacles to diversification beyond related industries due to weaker learning abilities.

Pylak and Wojnicka-Sycz (2014) propose that related diversity may be measured by the average share of industries related to a particular industry in terms of buyers and suppliers present in a particular region from the perspective of their share in employment. The related industries for a particular region are determined by Input-Output tables on a domestic level as industries that have a large share in terms of revenues as buyers or suppliers of a particular industry. If the share of employment of industries related to industries of smart specializations is high in a given region, then it could be posited that it is based on a related diversity, meaning the presence of a common knowledge base and complementary capabilities in geographical space – the region of their location. It means, hence, both cognitive and spatial proximity.

For the analysis of the related diversity of RSS areas, an account was taken of the following statistical industries as reflecting the industries of the RSS of the Subcarpathian region:
1) Aviation RSS – other transport equipment (in the Subcarpathian region, mostly aviation).
2) Automotive – motor vehicles, trailers, and semi-trailers.
3) ICT – computer, electronic and optical products, and Telecommunications and IT, and other information services.
4) "Quality of Life":

- Biodegradable plastics – Rubber and plastic products;
- Tourism – Accommodation and food services; Arts, entertainment, recreation, and other service activities;
- Preventive medicine and care for elderly – Human health and social work;
- Passive construction – Construction;
- Renewable energy – Electricity, gas, water supply, sewerage, waste, and remediation services.

Based on the latest Input-Output tables of the OECD for Poland, the most important suppliers of industries connected with the Subcarpathian RSS, in terms of expenditure in US dollars on inputs from a particular industry, were indicated. The most important suppliers were classed as industries with a share of over 1.5% of the total expenditure on inputs of the particular RSS industry, on average, in the years 2010-2015. Subsequently, the share of the most important suppliers in the average employment in the regional economy was analyzed from the Rzeszow Statistical Office data. A high share of vertically related industries in the regional economy suggests that complementary competences and a common knowledge base are present in the region for the bundle of industries of the Subcarpathian RSS areas. As tables 3 and 4 show, the most important suppliers of the RSS industries (to which circa 85% of expenditures on inputs from these industries go) have, on average, a 45% share in regional employment, which means their significant presence in the region. This ranges from 32.1% in the case of Accommodation and catering and 37.1% in the case of Computer, optical and precision products to 51% in the case of Arts, entertainment, recreation and other service activities, and 45% in the case of Construction and 45.9% in the case of Telecommunication.

The most important suppliers of almost all of the RSS industries are the Wholesale and retail trade and the same industry, which means intra-industrial trade. Other business sector services, Transportation, and storage are important suppliers of all of the analyzed core industries of RSS in the Subcarpathian region. This shows the fact that R&D for particular RSS was correctly included in the bundle of industries constituting the Subcarpathian RSS and Transportation, and storage are crucial to the value chain of each industry. In the case of the "Quality of life" RSS, Electricity and Agriculture are important suppliers for all of the five sub-industries of the RSS. In the case of Automotive, Aviation, and ICT in terms of computer production, the same important suppliers are Rubber and plastics products, Manufacture of basic metals and Fabricated metal products, except machinery and equipment. This reflects a similar complementary competences for these industries. In the case of generally understood industries connected with "Quality of Life" RSS some common complementary competences also exist. However, "Quality of

Life" RSS is not so easily defined by statistical industries and rather consists of varied niche areas that often do not seem to be connected with each other.

Those most connected to other RSS industries are Rubber and plastics products, Computer, electronic and optical products and Electricity, gas, water supply, sewerage, waste, and remediation. These are each important suppliers for six other out of ten industries recognized as related to RSS of the Subcarpathian region. Motor vehicles, trailers and semi-trailers, Telecommunications, IT and other information services, Human health and social work and Arts, entertainment, recreation, and other service activities are important suppliers, each of them, for four other industries of RSS of the Subcarpathian region. The least related to other RSS industries, in terms of serving as their important suppliers, are Other transport equipment and Construction (tables 3 and 4). However, this also shows a similar knowledge base for the Subcarpathian RSS areas and their sometimes complementary character.

**Table 3.** Important suppliers of industries of RSS Aviation, Automotive and ICT and their share in employment in the Subcarpathian region

| Suppliers with a share of over 1.5% in total supplies according to I-O tables | Aviation | Automotive | ICT | | | Share in employment in Subcarpathian region 2017 |
|---|---|---|---|---|---|---|
| | Other transport equipment | Motor vehicles. trailers, and semi-trailers | Computer. electronic, and optical products | Telecommunications | IT and other information services | |
| Chemicals and pharmaceutical products | x | 1.65 | 1.67 | x | x | 1.44 |
| Rubber and plastics products | 2.47 | 5.58 | 4.96 | x | x | 3.76 |
| Manufacture of basic metals | 6.34 | 6.03 | 2.56 | x | x | 1.05 |
| Fabricated metal products, except machinery and equipment | 4.57 | 9.93 | 1.91 | x | x | 4.16 |
| Computer, electronic and optical products | x | x | 40.13 | 4.68 | 2.36 | 0.75 |
| Electrical equipment | 1.85 | 1.84 | 10.14 | x | x | 0.37 |
| Machinery and equipment n.e.c. | 3.35 | 4.28 | 1.92 | x | x | 1.68 |
| Motor vehicles, trailers and semi-trailers | 1.65 | 33.87 | x | x | x | 2.39 |
| Other transport equipment | 38.42 | x | x | x | x | 2.36 |

| Suppliers with a share of over 1.5% in total supplies according to I-O tables | Aviation | Automotive | ICT | | | Share in employment in Subcarpathian region 2017 |
|---|---|---|---|---|---|---|
| | Other transport equipment | Motor vehicles. trailers and semi-trailers | Computer. electronic and optical products | Telecommunications | IT and other information services | |
| Other manufacturing; repair and installation of machinery and equipment | 2.90 | x | x | x | x | 1.07 |
| Electricity, gas. water supply, sewerage. waste and remediation services | x | 1.66 | x | 3.35 | 1.88 | 0.83 |
| Construction | x | x | x | 4.51 | x | 6.15 |
| Wholesale and retail trade; repair of motor vehicles | 12.68 | 15.65 | 15.89 | 10.48 | 10.11 | 15.02 |
| Transportation and storage | 2.26 | 2.40 | 2.94 | 3.00 | 2.22 | 3.66 |
| Publishing, audiovisual and broadcasting activities | x | x | x | 2.54 | 2.88 | 1.36 |
| Telecommunications | x | x | x | 14.53 | 4.29 | |
| IT and other information services | x | x | x | 9.55 | 33.75 | |
| Financial and insurance activities | 2.37 | x | x | 5.00 | 3.25 | 1.14 |
| Real estate activities | x | x | x | 3.50 | 2.76 | 1.18 |
| Other business sector services | 6.19 | 2.88 | 3.62 | 24.76 | 16.13 | 5.24 |
| Human health and social work | x | x | x | 2.20 | 6.94 | 9.28 |
| Arts, entertainment, recreation and other service activities | x | x | x | 1.68 | 1.75 | 1.28 |
| **Share of important suppliers in total expenditures (%)** | 85.05 | 85.76 | 85.74 | 89.79 | 88.32 | 86.93 |
| **Share of employment in industries strongly related to RSS industry (%)** | 41.90 | 39.60 | 37.13 | 45.90 | 39.70 | 64.17 |

**Source**: own calculations on the basis of OECD input-output tables and Rzeszow Statistical Office data.

**Table 4.** Important suppliers of industries of RSS "Quality of Life" and their share in employment in Subcarpathian region

| Suppliers with a share of over 1.5% in total supplies according to I-O tables | Quality of Life RSS | | | | | | Share in employment in Subcarpathian region 2017 |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Rubber and plastic | Electricity. gas. water supply… | Construction | Accomodation and food services | Human health … | Arts. entertainment… | |
| Agriculture, forestry and fishing | 1.68 | 18.53 | 2.33 | 4.06 | 2.92 | 6.53 | 1.22 |
| Food products, beverages and tobacco | x | x | x | 39.84 | x | x | 2.7 |
| Textiles, wearing apparel, leather and related products | 1.98 | x | x | x | x | x | 0.93 |
| Wood and of products of wood and cork | x | x | 2.51 | x | x | x | 1.64 |
| Paper products and printing | 1.82 | x | | x | x | 3.85 | 0.27 |
| Coke and refined petroleum products | 2.58 | 3.00 | 2.93 | x | x | 1.66 | lack of data |
| Chemicals and pharmaceutical products | 20.33 | x | | x | 4.98 | 2.18 | 1.44 |
| Rubber and plastics products | 22.33 | x | 6.66 | x | x | | 3.76 |
| Other non-metallic mineral products | 2.32 | x | 8.33 | x | x | 1.66 | 1.9 |
| Manufacture of basic metals | x | x | 5.36 | x | x | x | 1.05 |
| Fabricated metal products. except machinery and equipment | 2.12 | x | 5.76 | x | x | x | 4.16 |
| Electrical equipment | x | 1.64 | 1.84 | x | x | x | 0.37 |
| Other manufacturing; repair and installation of machinery and equipment | x | 2.21 | x | x | 5.09 | 2.77 | 1.07 |
| Electricity, gas, water supply, sewerage, waste and remediation services | 4.59 | 15.48 | 1.69 | 3.64 | 9.49 | 5.73 | 0.83 |
| Construction | 1.67 | 16.11 | 31.98 | | 3.24 | 4.70 | 6.15 |
| Wholesale and retail trade; repair of motor vehicles | 16.08 | 8.33 | 9.41 | 19.05 | 8.92 | 12.19 | 15.02 |
| Transportation and storage | 3.65 | 5.27 | 2.53 | 1.83 | 2.04 | 3.51 | 3.66 |
| Accomodation and food services | x | x | x | x | 2.53 | x | 1.49 |

| Suppliers with a share of over 1.5% in total supplies according to I-O tables | Quality of Life RSS | | | | | | Share in employment in Subcarpathian region 2017 |
|---|---|---|---|---|---|---|---|
| | Rubber and plastic | Electricity. gas. water supply... | Construction | Accomodation and food services | Human health ... | Arts. entertainment... | |
| Publishing, audiovisual and broadcasting activities | x | x | x | x | | 2.14 | 1.36 |
| Telecommunications | x | x | x | x | 1.85 | 3.00 | |
| IT and other information services | x | x | x | x | x | 2.27 | |
| Financial and insurance activities | x | 2.33 | x | 2.27 | 3.01 | 5.10 | 1.14 |
| Real estate activities | x | x | x | 4.91 | 4.96 | 4.00 | 1.18 |
| Other business sector services | 3.94 | 6.71 | 4.09 | 6.56 | 6.86 | 10.53 | 5.24 |
| Human health and social work | x | 2.51 | x | x | 28.36 | 4.31 | 9.28 |
| Arts, entertainment, recreation and other service activities | x | x | x | 1.67 | 3.45 | 8.69 | 1.28 |
| Share of important suppliers in total expenditures (%) | 85.07 | 82.13 | 85.42 | 83.83 | 87.69 | 84.80 | 84.82 |
| Share of employment in industries strongly related to RSS industry (%) | 44.58 | 43.98 | 45 | 32.27 | 41.06 | 51.04 | 67.14 |

Source: own calculations on the basis of OECD input-output tables and Rzeszow Statistical Office data.

The index of RDSS, calculated according to the formula presented in the Data and methods section, shows that the relative pool of complementary competences required by a particular RSS industry in the Subcarpathian region is the highest for Electricity, Telecommunication and IT as well as Accommodation and food services and Computer, electronic and optical products. It means that suppliers from other industries constitute a much larger share of the average employment in the regional economy than the given RSS industry (figure 3). Hence, cognitive spatial proximity may be most easily achieved in the case of these industries. Nonetheless, all of the analyzed industries are characterized by a much higher share in the regional average employment of the sum of their important suppliers than the share of each of these particular industries in the regional employment.
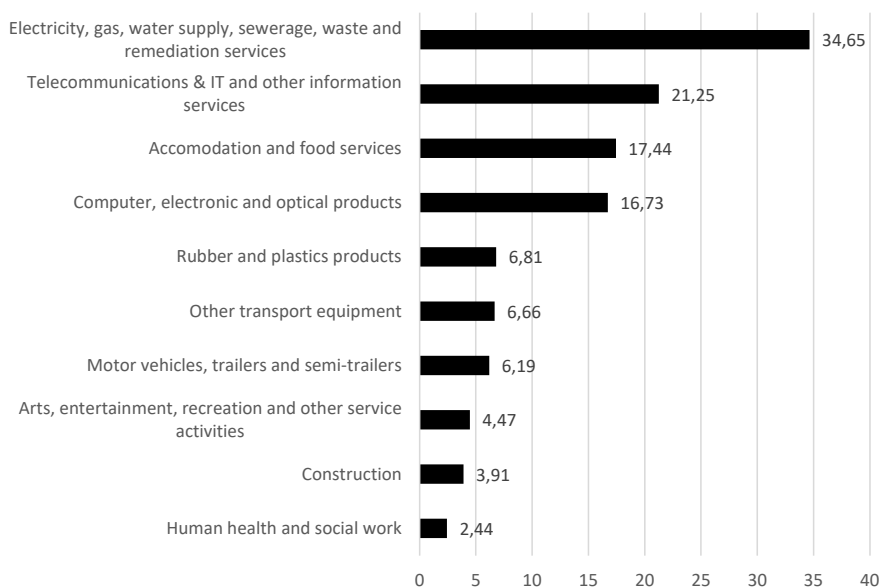
| Industry | Value |
|---|---|
| Electricity, gas, water supply, sewerage, waste and remediation services | 34,65 |
| Telecommunications & IT and other information services | 21,25 |
| Accomodation and food services | 17,44 |
| Computer, electronic and optical products | 16,73 |
| Rubber and plastics products | 6,81 |
| Other transport equipment | 6,66 |
| Motor vehicles, trailers and semi-trailers | 6,19 |
| Arts, entertainment, recreation and other service activities | 4,47 |
| Construction | 3,91 |
| Human health and social work | 2,44 |

**Figure 3.** Index of external related diversity of smart specialization industries – cognitive spatial proximity index

**Source**: own elaboration based on OECD input-output tables and Rzeszow Statistical Office data.

The weakness of this way of calculating related diversity reflecting cognitive proximity is that it is based on general statistical industries and it is impossible to find out about specific sub-disciplines of particular RSS areas, like passive housing, or about the specific competences required for particular niche technologies of smart specializations. For this, direct research might be required, or a detailed analysis of, for example, patent information and data on registered companies on the level of, at least, classes of NACE (statistical classification of economic activities in the EU - Nomenclature statistique des Activités économiques dans la Communauté). Some examples of such analysis in the context of smart specializations or innovative ecosystems are Smoliński, Bondaruk, Pichlak, Trząski, and Uszok (2015) and Corradini and De Propris (2017).

In the CAWI sample, covered by the study of 200 innovative enterprises in the Subcarpathian region, there were 137 entities declaring affiliation to a smart specialization. Most of these entities were identified as active in the field of information technology – 53, automotive industry – 34, electronics – 29, aviation – 28, telecommunications – 25, production of sub-assemblies and materials for automotive industry – 25, passive construction

– 23, production of sub-assemblies and materials for aviation industry – 21, systems for smart homes – 20, energy-saving building materials – 15, renewable energy – 14, within recreational tourism – 13, cognitive tourism – 10, cosmonautics – 8, in the field of biodegradable plastics – 7, production of computers – 6, qualified tourism (e.g. hiking, skiing, cycling, motor, canoeing, sailing) – 6, preventive medicine (preventive: hygiene, dietetics, etc.) – 6. Five respondents indicated the activity in the field of business tourism and organic food. 4 companies described themselves as operating in the field of production of sub-assemblies for computers, ecotourism, agrotourism, and health tourism, and 3 indications concerned culinary tourism and care for the elderly. Two indications were associated with religious and wine tourism, and 1 company operates in the field of natural medicine.

At the same time, 55 out of 137 companies indicated more than one area of specialization, which proves that they are able to operate and function in various areas of smart specializations based on their skills, which means a related diversity of priority areas.

Table 5 shows the number of firms that are active in particular pairs of subdomains of RSS with grey highlighted the statistically significant Chi-square Pearson test calculated on answers of 76 companies covered by the CAWI survey that indicated more than one subarea of RSS as their field of activity. The analysis confirms mainly intra-specialization related diversity as aviation and cosmonautics and aviation-components for aviation, the automotive industry and components for this industry or information technology-electronics-telecommunication-computer production or competences of companies in the field of different types of tourism. However, some inter-specialization, across various RSS areas, related diversity also occurs: as computer components and components for automotive or automotive industry and biodegradable plastics or renewable energy and passive construction and systems for smart homes and electronics and telecommunication. Varied types of tourism are weakly related in terms of competences of RSS companies to passive houses and renewable energy from "Quality of Life" RSS. The latter is rather related to each other and the industrial RSS of the Subcarpathian region. Hence, it may be said that the scope of the "Quality of Life" RSS is too broad and, due to it not being based on related diversity, that it is cognitive proximity. Two distinct subgroups in terms of their knowledge base may be indicated in this RSS area – one based on renewable energy and connected issues as smart and passive houses and energy-saving building materials and, to some extent, biodegradable plastics – and the other subgroup being tourism and health.

**Table 5.** Number of firms active in particular pairs of the Subcarpathian RSS sub-areas (in grey, statistically significant Chi-square Pearson test at p=0.05)

| | Informatics | Electronics | Telecommunication | Computer production | Components for aviation | Automotive industry | Components for automotive industry | Passive construction | Systems for smart homes | Energy-saving building materials | Biodegradable plastics | Cognitive Tourism | Recreational tourism | Ecotourism | Agritourism |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aviation | 7 | 8 | 5 | | 15 | 13 | | | | | | | | | |
| Cosmonautics | 3 | | | | 3 | | | | | | | | | | |
| Informatics | | 19 | 17 | 5 | 4 | 5 | 4 | 3 | 12 | | | | 3 | | |
| Electronics | | | 14 | 3 | 6 | 6 | | | 9 | 3 | | | | | |
| Telecom | | | | 4 | 4 | 4 | | | 7 | | | | | | |
| Computer components | | | | | 3 | | 3 | 2 | | | | | | | |
| Components for aviation | | | | | | 12 | | | 3 | | | | | | |
| Automotive industry | | | | | | | 20 | 5 | | | 3 | | | | |
| Components for automotive | | | | | | | | 5 | 5 | | | | | | |
| Passive construction | | | | | | | | | 11 | | | | | | |
| Systems for smart homes | | | | | | | | | | 9 | | | | | |
| Recreational tourism | | | | | | | | 3 | | | | 6 | | | |
| Ecotourism | | 3 | | | | | | 2 | | | | | 2 | | |
| Agritourism | | 3 | | | | | | | | | | | 2 | 3 | |
| Qualified tourism | | | | | | | | | | | | 4 | 5 | | |
| Health tourism | | | | | | | | | | | | 2 | 3 | | |
| Business tourism | | | | | | | | | | | | 3 | 3 | | |
| Culinary tourism | | | | | | | | | | | | | 2 | | |
| Renewable energy | 5 | 8 | 6 | | | | 6 | 6 | | | | | | 3 | 3 |
| Eco food | | | | | | | | | | | | | 2 | | |

**Source**: own calculations on the basis of the CAWI research in SPSS.

## Geographical proximity in local terms of the Subcarpathian RSS

Table 6 shows location quotients calculated according to the equations presented in the Data and methods section. The largest number of significant concentrations of entities related to smart specializations, four, are located in the Rzeszów poviat and the city of Rzeszów, three in the city

of Krosno and the Mielec poviat. In the Rzeszów poviat, there are significant concentrations of industrial entities of smart specializations, ICT, as well as other fields besides tourism from the RSS "Quality of life." There are concentrations of ICT entities and industrial smart specializations in Krosno. Rzeszów city is characterized by the concentration of ICT entities and other areas of RSS "Quality of Life" (except for tourism). In the Mielec poviat, there are concentrations of entities from industrial smart specializations and firms of manufacturing industries related to industrial smart specializations (plastic and metal products and metal production).

**Table 6.** Significant LQ of RSS companies in Subcarpathian poviats and subregions

| Poviat | LQ Tourism (REGON) | LQ ICT (Web sites queries - WQ) | LQ Industrial RSS IS (WQ) | LQ Quality of Life RSS except Tourism (WQ) | LQ ICT (REGON) | LQ Industrial RSS (REGON) | LQ Industry connected with industrial RSS (REGON) |
|---|---|---|---|---|---|---|---|
| | | | Krosno subregion | | | | |
| bieszczadzki | 2.3 | x | x | x | x | x | x |
| jasielski | x | x | x | x | x | x | 1.35 |
| krośnieński | x | x | x | x | x | x | 1.68 |
| leski | 3.65 | x | x | x | x | x | x |
| Krosno | x | 2.08 | 1.62 | x | x | 1.36 | x |
| | | | Przemysl subregion | | | | |
| lubaczowski | x | x | x | 1.34 | x | x | x |
| przeworski | x | x | x | x | x | x | 1.45 |
| | | | Rzeszow subregion | | | | |
| łańcucki | x | x | x | 1.38 | x | x | x |
| Rzeszów | x | 2.68 | x | 1.67 | 2.06 | 1.11 | x |
| ropczycko-sędziszowski | x | x | 2.04 | x | x | x | x |
| rzeszowski | x | x | 2.18 | 1.51 | 1.28 | 1.59 | x |
| | | | Tarnobrzeg subregion | | | | |
| dębicki | x | x | 1.25 | x | x | x | 1.63 |
| mielecki | x | x | 4.4 | x | x | 4.6 | 2.16 |
| stalowowolski | x | 1.31 | x | x | x | x | x |
| tarnobrzeski | x | x | 1.54 | x | x | x | x |

**Source**: own elaboration based on Klimczak et al. (2017).

The Sanocki poviat is characterized by the concentration of entities of tourism and industrial RSS (Aviation and Automotive), and the Dębicki poviat

by the concentration of industrial RSS and entities from manufacturing industries related to RSS. In other poviats there are individual concentrations of industries related to RSS:

- Bieszczady and Lesko poviats stand out in terms of tourism;
- Stalowa Wola distinguishes itself in terms of ICT;
- industrial RSS firms' concentrations are in Ropczycko-Sędziszowski and Tarnobrzeg poviats;
- in terms of other areas related to RSS "Quality of Life", apart from tourism, Lubaczów and Łańcut poviats stand out;
- concentrations of manufacturing industries related to RSS are in Jasielski and Krosno poviats.

Poviats for which there is no significant concentration of the RSS entities are: Brzozowski, Jarosławski, Kolbuszowski, Leżajski, Przemyśl, Tarnobrzeg, Niżański, Przemyśl, Przeworsk and Strzyżów (Klimczak et al., 2017).
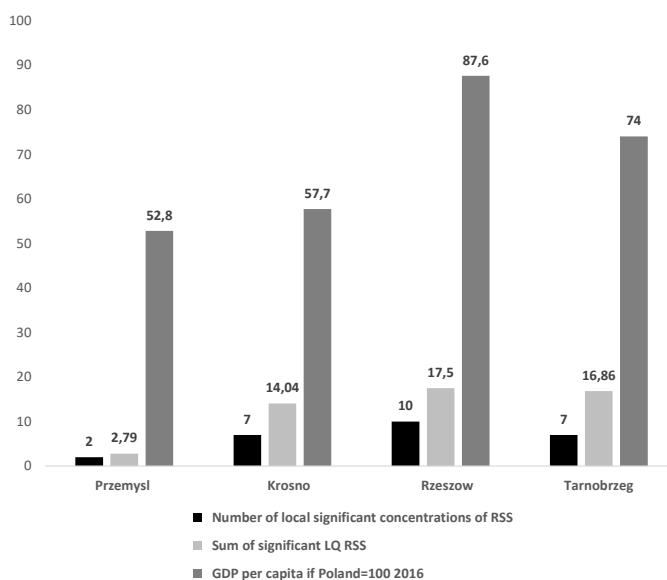


**Figure 4.** Local concentrations of RSS companies and GDP per capita in Subcarpathian subregions

**Source**: own elaboration based on Central Statistical Office data and Klimczak et al. (2017).

It means that RSS companies are, in fact, generally clustered in certain poviats in the region and not evenly spread in the whole region, so they are based on spatial proximity in local terms.

An analysis of the location of poviats in the subregions on a NUTS 3 level in the Subcarpathian region shows that the most developed subregions in terms

of GDP per capita are Rzeszow and Tarnobrzeg. They are also characterized by the highest concentrations of RSS companies in terms of the sum of total significant LQs. The least developed subregion, Przemyśl, is also very poor in local concentrations of RSS companies. It may be assumed that spatial proximity of local concentrations of RSS companies enhances their efficiency, which, however, is also conditioned by better overall local conditions for development of RSS enterprises (figure 4). The study by Klimczak et al. (2017) showed that the presence of entities associated with smart specializations in poviats, in particular the industrial RSS (Aviation and Automotive) and ICT, coincided with a higher income of the population, a greater number of job offers and lower unemployment rates in the poviats.

Ecosystems of smart specializations, therefore, generate a development effect for the areas of their location, and in the case of the labor market, also for the neighboring poviats because they affect the unemployment rate in them as well, which was proved in the analysis with the usage of spatial regressions. These effects are based on a higher than the regional average innovative activity of companies of Automotive, Aviation and ICT RSS, according to the Central Statistical Office data and the analysis of the information placed by firms on their websites (Klimczak et al., 2017).

## CONCLUSIONS

The tool developed for finding out if RSS areas constitute innovative ecosystems based on social, cognitive and geographical proximity consists of a theoretical approach, methods, and sources of data. The theoretical approach shows three characteristics of innovative ecosystems of RSS that are in line with the concept of innovative ecosystem and definitions of 1) social, 2) cognitive and 3) geographical proximities. These are respectively: 1) links in innovative processes between RSS members as well as the entrepreneurial discovery process, 2) new knowledge combination based on related diversity and regional embeddedness and 3) the presence of local concentrations of RSS firms. The efficiency of innovative ecosystems of RSS shall stimulate innovations based on regional development.

The data used for the analysis of innovative ecosystems of RSS are those gathered in direct research into enterprises, OECD data from Input-output tables, statistical data as well as data collected in website queries and desk research. The used methods are varied and depend on the type of proximity. Social proximity may be assessed by a higher propensity of firms of RSS industries/activities than other regional enterprises to cooperate with other partners in an innovation process or to participate in clusters. It may be

measured with the help of micro econometric methods or by the presence of cluster structures in the areas of RSS. Cognitive proximity may be assessed by external and internal-related diversity of RSS areas. The external-related diversity index measures the presence of complementary competences required by RSS industries in the region of their location. Internal-related diversity will mean that firms of RSS may act in varied subdomains of RSS, which means the RSS areas are coherent in terms of a knowledge base. Geographical proximity may be measured by the presence of local, significant concentrations of companies of RSS in the region. Efficiency of RSS, as innovative ecosystems, may be determined by the analysis of the economic results of counties and the presence of RSS entities in them.

The analysis carried out in Poland proved that cooperation in an innovation process, especially with science, stimulates higher innovativeness and research and development (R&D) activity as well as higher competitiveness of enterprises and a better development of the territories of location of innovative companies. Moreover, the studied firms of smart specializations in the Subcarpathian region in Poland turned out to be more prone to cooperate as they more often than other surveyed firms belonged to clusters. Firms belonging to the Subcarpathian industrial smart specializations also were more prone to carry out R&D activity. It means that smart specializations may be perceived as innovative ecosystems based on networks and innovative activity, as R&D constitutes the first phase of most innovative projects. The analysis conducted in the article also proved that the innovative ecosystems of the Subcarpathian RSS, especially those of Aviation, Automotive and ICT, are based on social proximity reflected in the cooperation in an innovation process, especially in clusters. The Subcarpathian RSS are also based on cognitive proximity, reflected in the related diversity of RSS subareas and spatial proximity based on local concentrations of companies. All of the Subcarpathian RSS are characterized by geographical proximity. However, cognitive proximity is not present in the case of the "Quality of Life" RSS. This RSS embraces not innovative tourism, which is not related in cognitive terms to most of the other subareas of this RSS. Moreover, the location of a higher number of touristic companies in poviats in the Subcarpathian region coincided with lower incomes of people in these poviats (Klimczak et al., 2017). It means that Aviation, Automotive and ICT RSS may be perceived as innovative ecosystems based on social, cognitive and geographical proximity and stimulating the innovation-based development of the region. However, it is not the case for the "Quality of Life" RSS.

Further research could embrace a more detailed analysis of the paths of cooperation, the trajectory of those paths within RSS, how cooperation can build different types of proximity. It would help to find efficient ways

of cooperation leading to new value creation while considering the optimal level of proximity and cooperation that would give the highest value added from the perspective of the regional economy, perceived as a set of varied interconnected actors, not individualistic companies.

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## *Abstrakt*

*Artykuł pokazuje, w jaki sposób inteligentne specjalizacje regionalne, które są obecnie najważniejszym narzędziem europejskiej polityki innowacji, mogą być ocenione, czy stanowią innowacyjne ekosystemy oparte na bliskości społecznej, poznawczej i geograficznej. W artykule przedstawiono koncepcje inteligentnych specjalizacji i innowacyjnych ekosystemów, a także koncepcję bliskości i jej aspekty nawiązujące do idei inteligentnych specjalizacji. Koncepcja innowacyjnych ekosystemów jest prezentowana z perspektywy jej powstania i relacji do innych koncepcji i teorii. Współpraca różnych podmiotów w procesie innowacji jest uważana za główną cechę zarówno inteligentnych specjalizacji, jak i innowacyjnych ekosystemów oraz przejaw bliskości społecznej. Powiązana różnorodność obszarów inteligentnej specjalizacji wskazuje na ich bliskość poznawczą, a osadzenie w danym regionie administracyjnym odzwierciedla ich bliskość geograficzną. Wyniki badań przeprowadzonych w województwie podkarpackim pokazują, że firmy w inteligentnych specjalizacjach są bardziej zaangażowane w badania i rozwój oraz innowacje i bardziej podatne na współpracę niż inne firmy oraz że inteligentne specjalizacje mają pozytywny wpływ na rozwój regionalny, co świadczy o ich bliskości społecznej i wskazuje na wydajność ich innowacyjnych ekosystemów. Mierzona jest również powiązana różnorodność podkarpackich regionalnych inteligentnych specjalizacji (RSS), aby pokazać ich bliskość poznawczą. Analiza lokalizacji firm RSS pokazuje, że charakteryzują się one nie tylko regionalną, ale często także lokalną bliskością geograficzną. Zastosowane metody to badanie źródeł wtórnych, kwerenda internetowa, przegląd literatury, analiza danych statystycznych oraz bezpośrednie badania oparte na ankiecie i analiza ekonometryczna wyników ankiety. Artykuł odpowiada na brak badań inteligentnych specjalizacji w kontekście bliskości.*

***Słowa kluczowe**: regionalne inteligentne specjalizacje, innowacyjne ekosystemy, bliskość społeczna, bliskość poznawcza, bliskość geograficzna.*

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## Conflicts of interest

The authors declare no conflict of interest.

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