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The concept of technological proximity in the development of European Union national innovative systems

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Abstract. The development of national innovative systems is intended to solve a number of issues: from decreasing socio-economic inequality in countries and regions to creating environments favourable to new high-tech production and diversification of industrial composition. Determination of the possibilities for expanding the set of innovative types of economic activity must be scientifically substantiated, since significant financial, material and human resources may be consumed in creating and supporting new economic sectors within the framework of state policy. This article contains an attempt to create a mechanism for revealing promising trends in the development of an innovative economic sphere, taking into account comparative advantages in the commodity composition of exports by determining technological proximity indicators. The article aims to substantiate the possibility of using the concept of technological proximity in developing national innovative systems. The study employs technological proximity indicators based on the revealed comparative advantages (RCA) of countries by commodity groups of export. A matrix of technological proximity in the industrial fields (at a six-unit level) for 28 countries of the European Union in 2007–18 was made. The results revealed comparative advantages by groups of high-tech products in EU countries in real time. The analysis of technological proximity in the industrial sector has shown the types of economic activity connected with the innovative sector, which was used to determine the countries' degree of participation in the manufacture of high-tech products. The proposed mechanism can be used in the development and implementation of national and regional policy in the sphere of innovative systems, since it allows promising areas for creation and support of new high-tech productions to be determined.

Key words:
national innovative systems,
technological proximity,
technological proximity index,
revealed comparative advantages

Contents:

1. Introduction

In recent years, the inequality problem has touched many countries and regions of the world. Nor has it passed by the European Union, where there is an apparent divergence in the level of social and economic development (Iammarino et al., 2019). Globalisation and technological changes have led to more efficient dislocation of economic activities, which has resulted in labour outflow from rural areas, a decrease in demand for highly qualified workers in small and medium industrial cities, and stagnation of incomes for populations in non-central regions. This problem is increasingly a subject of scientific discussions (Kovalev, 2017).

Interregional economic inequality can be explained by the action of two force groups, both of which are connected with innovative development. The first force group is a change in stages of long-term cycles of scientific and technical progress. In the 1970s there was a new wave of technological changes in European countries due to a number of factors: innovative production, the implementation of new services and improvement of financial operations, and the occurrence and active application of agglomeration effects in large cities. The employment level in many traditional spheres of industry has significantly decreased due to automation; the efficiency of supply chains has increased due to improvements in transportation and the optimal territorial allocation of production (Levy and Murnane, 2005). Such transformations were accompanied by changes in the employment structure – highly qualified and more sought-after specialists aimed to concentrate in large industrial and creative centres, to the disadvantage of peripheral and intermediate ones (Iammarino et al., 2019).

The second force group explaining the economic inequality through innovative development is long waves, which are peculiar to certain regions. They depend on qualitative and quantitative features of population (both workers and consumers), official and unofficial institutions, the environment created for developing innovations and entrepreneurship, and the specifics of the companies and economic or industrial sectors present in a region.

These two cycles develop unevenly; this means that there are periods of convergence and divergence among regions. So, at the present time, the prevalent wave facilitates the geographical concentration of economic activity in the most attractive places and stimulates more innovative types of activity.

Because regions can have significant socio-economic disproportions and irregular distribution of innovative resources, the prerequisites for creating innovative systems very much differ spatially (Zeschky et al., 2011). One of the most popular models of a regional innovative system is one created based on the experience of Germany and the UK (Cooke, 1992; Cooke and Morgan, 1998). It includes two subsystems: knowledge producers (investigators) and knowledge consumers (organisations), which interact in favourable organisational and institutional conditions (March, 1991; Heindl, 2020).

Regional innovative systems are part of the national innovative systems and reflect the character of various territories. The model of regional innovative systems was developed based on the understanding that the character of innovative activities may differ not only between countries but also at the regional level within the same country. Such activity tends to concentrate geographically in those places where there is a certain development of innovative subjects, and organisations and institutions have certain knowledge and are available to interact (Breschi and Malerba, 2001). When the conditions for development of high-tech productions are available in a region, a more stable regional innovative system can be created (Rastvortseva, 2020). Industrially developed and developing regions have unequal chances for path breaking. The first group of regions, with a high concentration of industrial production, has more capabilities for transition to new related branches, unlike the second group, which retains its marginality (Zhu et al., 2015).

The conditions for a national or regional innovative system to develop can only be evaluated through a determination of the relatedness of economic sectors. Technological innovations will contribute to economical growth in the existing branches and stimulate the occurrence of new economy. The innovative development path is based on the concept of “creative destruction”, which can be defined as the occurrence of new industrial branches as a result of change in and addition to existing ones. Regions in which a technologically proximate pool of industries has been created have more possibilities to develop a diversified production.

According to the diversification concept, regions should specialise in production and export of “associated” and “proximate” goods (Saviotty, 1996). “Associated” goods are those whose manufacture requires the same production factors, process complexity level and institutional background (Hausmann et al., 2011). The empiric investigations carried out in this sphere show that, as time goes by, countries tend to change their specialty, moving predominantly towards the production of “associated” goods (Neffke et al., 2011). The investigators also pay attention to the analysis of future opportunities of regions from the point of view of diversifying the production structure and revealing the path dependency. They believe that regions with a set of technologically associated branches are characterised by higher economic growth (Saviotty, 1996).

Such statements conform to the modern investigations in the sphere of new economic geography (NEG). NEG followers consider changes in the development of regional structures based on endogenous factors (Kogler et al., 2017). They believe that technological proximity is a key force in the economical growth in regions and a driver of regional diversification (Boschma and Frenken, 2011; Neffke et al., 2011).

The purpose of the investigation the results of which are represented in this article is to substantiate the possibility of using the concept of technological proximity for the development of national innovative systems. The object of investigation comprises countries of the European Union; the investigation period is 2007–18. We shall analyse the assumption that if production sectors are technologically connected between each other (i.e. the same institutions, infrastructure, technologies or some combination thereof are required for their development) then they will have a tendency towards production in tandem. We will show those types of economic activity whose availability will facilitate the efficient development of national innovative systems.

The article consists of five parts. The following (second) section will contain the theoretical background for investigation and a review of the bibliography. The third section will disclose the investigation methodology, initial data and analysis algorithm. The investigation results will be given in the Section 4; the conclusions will be represented in Section 5.

2. Theoretical background and bibliography

Economic development is a key purpose of regions’ functioning. Systematic qualitative changes in the industrial branches existing in a region stimulate an increase in economic, political and social welfare (Saha, Nibedita, 2019). In recent decades there has been a growing applicability of studies showing that economic development does not always take place in the most rational way, but depends on some events in the past. So, Acemoglu et al. explain the key factors of economic growth in the peculiarities of institutions that were established several centuries ago. Engerman and Sokoloff, and La Porta et al. have shown that the mainstay of such institutions is events in the colonial history of countries.

The idea of economic development is continuously connected with innovations, technological improvement and the production of high-tech goods, which have long been considered to be the key driver of economic growth (Aghion and Howitt, 1990). Therefore, the impacts of innovation on the socio-economic development of regions have been widely discussed in previous studies, but with divergent areal coverage, methods and datasets (Makkonen, 2011). It is thus important to understand that the production of high-tech goods is one of the most localised types of economic activity, and its development makes it possible for regions to avoid path-dependence.

The geographical distribution of high-tech production facilities is investigated at the intersection of such scientific doctrines as evolutionary economics, allocation theory and new economical geography (NEG). The provisions of *evolutionary economics* explain how the proximity and availability of knowledge influence the future trajectory of a region's development and its opportunities for diversification, and what consistent patterns are formed in the region at the "production" and "consumption" of knowledge. *Allocation theories* show the combination of factors influencing companies at the selection of a location for executing innovative activities. The NEG ideas make it possible to understand how regions and cluster groups develop under the influence of endogenous factors, first among which is local knowledge (Kogler et al., 2017).

The new economic geography underlines the importance of diversification in the process of countries' and regions' development – in particular, for industry-specific trade (Krugman, Helpman, 1985). More diversified structures of production and export stimulate economic growth, since this contributes to the occurrence of new ideas and technologies and their distribution, as well as determining the type of resources and unified infrastructure required for the development of new types of economic activity, including innovative activity.

Investigation of diversification within the theories of evolutionary economics plays a special part. Here, two main approaches are distinguished. The first – path dependence (Boschma, Frenken, 2007) – underlines the endogenous process of regional development and confirms that regions are more inclined to develop in branches technologically connected to existing ones (Boschma, Frenken, 2011). The main reasons for dependence are the increasing returns to scale, self-supporting growth, positive feedback, network effects and "path dependence". Positive feedback and self-supporting growth especially complicate the transition of regions to an innovative path of development. Entrepreneurship, transfer of companies, knowledge and infrastructural peculiarities become the forces supporting development on the basis of technological proximity. While considering the results of processes taking place in the region, history becomes an important factor; and in this case preceding conditions have a significant influence on present dynamics. The dependence of a regional path on preceding development was proven empirically through the example of such countries as Great Britain (Boschma, Wenting 2007), Spain (Boschma et al., 2012) and the USA (Essletzbichler, 2015).

The second approach to the study of regional development underlines the exogenous character of the creation of a new trajectory and confirms that the occurrence of new branches sometimes does not depend on the regional basis, but is connected with external actions – for example, as a result of a technological revolution (Bathelt, Boggs, 2003), a crisis (Meyer-Stamer, 1998) or a state policy (He, Zhu, 2019). Events that are not significant in a certain time period can ultimately wield a major influence on the process by giving rise to or modifying institutions or sequences of events. Such a state of affairs shall bring into question scientific political theories that explain that pivotal changes can only occur under the influence of significant causes. Such an approach underlines the importance of critical stages in the formation of a "dependence path", which create strong institutions and depress opportunities for alternative development. There is a separate block of studies in this sphere dedicated to investigating the influence that certain regional innovative policies have on establishing and developing regional innovative systems (Meyer-Stamer, 1998; Boggs, 2013; He, Zhu, 2019).

In order to create a successful innovative system, knowledge exchange between branches is necessary. Efficient distribution of information and innovations is possible with high diversification of technologically associated industrial sectors. Just such conditions provide more opportunities for distribution of secondary knowledge and training.

The concept of technological proximity between industry sectors is one of the most popular in the investigation of diversification and previous development theory. The availability of technologically proximate sectors in the region can be considered as an additional stimulus to economic development. The industrial diversification creates conditions for the occurrence of new ideas, the distribution of modern technologies, the concentration of creative populations and employees, which will contribute to accelerated, intensive development. The high-tech types of economic activity will more likely find their place in cities with a diversified economy (Jacobs externalities), and mature industry sectors – in non-diversified inhabited localities (the application of external localisation effects).

"Technological proximity" is the interrelation between industry sectors based on existing production peculiarities and makes it possible to qualitatively determine which new branches should optimally be developed in view of a region's existing technological portfolio. Researchers are increasingly investigating the technological proximity between industry sectors (goods) and its influence on regional development and the occurrence of new sectors. Based on analysis of the country export basket, Hidalgo et al. have shown how the existing composition of industry types can influence regional diversification, since the types of economic activity that are more proximate to those existing in a region will more likely gain traction in that region (Hidalgo et al., 2007).

Since the 1980s, researchers in the sphere of economic geography have been explaining the possibility of long-term economic growth in regions through the life-cycle stages of the industry sector. They have shown that regions developing new sectors and creating a regional innovative system have a higher rate of economic growth than those remaining in maturer sectors. Old-industry regions often become hostages to their prior success due to higher salaries, effective trade unions, concentration of population and traffic load.

Investigation of "new" regions takes place as if they have no economic history, which is wrong initially. There are not many studies aimed at the possibility of old-industry regions changing through the creation of a regional innovative system. The way new development paths occur is described in the studies of Scott (1988), Stoper and Walker (1989), Martin and Sunley (2005), and Simmie and Carpenter (2006). It was noted that in conditions of technological proximity of industry sectors in regions, competitiveness improves and opportunities for successful development of new industry branches are created. It is necessary to take this fact into consideration when developing a regional innovative system.

The development of innovations makes it possible for regions to depart from existing industry-specific tendencies in the economy through technological proximity. Interrelation between the industry branches in the region determines what new types of economic activity can occur. The development rate of branches depends on the regional composition of industry types formed in the past.

During the development of national and regional innovative systems, the stimulation of development of new branches must be economically substantiated. In regions with a high density of branches the transition to innovative development will be easier due to the existing proximity. Because the set of industrial branches and their levels of development differ in regions, the process of transition to new branches will be unique. Thus, it is necessary first to determine those innovative types of activity that are the most proximate to the existing industry-specific structure of the region.

Before we proceed to the methodology of technological proximity determination let us explain why regions often strive to support a pool of unconnected branches. The "portfolio effect" allows a region to avoid potential industry-specific shocks. By decreasing risks in such a way, the regional policy hinders the transition to innovative development (Makkonen, 2011).

3. Investigation methodology and data

In determining technological proximity, the methodological approaches have several major problems. Firstly, it is traditionally considered that the technological proximity can be determined on the basis of the standard industrial classifications of economic activity types in use in countries. This is not always the case: since the development of inter-industry relations has a dynamic character, the indices of technological proximity between different industrial sectors can be high. Secondly, several methodological approaches to determining technological proximity can be distinguished, each with its own advantages and disadvantages. The most pressing is a method of technological proximity index calculation based on the probability that the country develops comparative advantages in producing associated products (Hidalgo et al., 2007). Also of interest is a method of revealing industrial clusters based on the Porter algorithm for revealing clusters (Porter, 2003). It consists of five sequential stages and makes it possible to analyse the activity of branches within the created cluster groups.

In order to reveal the competitive advantages of groups of high-tech goods producers in EC countries we use the index of revealed comparative advantages (RCA). The index was proposed (B. Balassa, 1965) to determine trade advantages of countries in relation to products, and to correspond to the fullest extent possible to the existing comparative advantages. The coefficient is in essence based on the assumption that the export basket of a country serves as an indicator of the economics complexity level and its production potential, due to which conclusions can be made as to the tendency of its development. Such a coefficient is calculated as a ratio of the products export specific weight by certain type in the general scope of the country's export to the specific weight of the same type products in the world scope of export:

$$RCAij = \frac{xij\,/Xij}{xwj/Xwt} \tag{1}$$

where: x_{ij} – share of country products export i of commodity group j; X_{ij} – general volume of country's export i; x_{wj} – world volume of export of commodity group j; X_{wt} – world volume of goods export.

Thus, the key property of the coefficient is its neutrality to factors determining comparative advantages (Hausmann et al., 2011). Interpretation of the indicator consists in the following: if the indicator value lies within $1<RCA<\infty$, then it is assumed that the country's economy has the revealed comparative advantages in the production of goods. Otherwise (RCA<1), no revealed comparative advantages are observed.

The following stage of our analysis consists in calculating the distance weighed by technological proximity between high-tech products and the rest of the goods the country does not yet produce/export at a level of revealed comparative advantages. According to Hidalgo, the country's economy grows due to modernisation of type of products manufactured and exported (Hidalgo et al., 2007). It is supposed that the technologies, capital and knowledge necessary for the creation of such new products shall be reproduced more easily from technologically proximate products. In this connection we study the system of interrelations between products and analyse the location of high-tech products relative to others. As a rule, they are located in a tightly connected core, whereas products with a lower income remain on the periphery. The index of technological proximity is calculated by the following formula:

$$f\ pp' = \frac{\sum_c MM^T}{\max(k_{0,p^1}k_{0,p^2})} \tag{2}$$

where: MM^T – a matrix of data on the goods being exported, based on the RCA indicator; k_{0,p^1} – adoption of product 1; k_{0,p^2} – adoption of product 2.

Interpretation of the indicator consists in the following: the simpler the export of some country or region, the more the distance to the comparatively complex goods.

So, we can distinguish those types of economic activity that are technologically proximate to the innovative ones, and determine the reasonable direction for national or regional systems' development.

In order to determine the high-tech branches, use was made of the OECD classification and the following groups were selected: aerospace, computers and office equipment, electronic-communication technologies, pharmaceutics and scientific tools. According to the standard international codification system SITC Rev.4, these include 2, 3, 5–9. Industrial sector data concerning 28 EC countries were collected with a breakdown at the six-figure level, and a base of 4,765 products was created among which 87 products are high-tech.

4. Results

The obtained results of the comparative advantage index made it possible to determine what groups of high-tech products have production advantages in EC countries: medicaments containing penicillin and its derivatives (13 countries); optical tools (13), electric panels and combinations of devices (12), smart-cards with integral circuits (12), measuring devices and instruments (10). It was revealed that the most high-tech countries are Great Britain, France, Germany and Denmark (Fig. 1).

At the following stage of the analysis the matrix of technological proximity indices 735×735 was created, which made it possible to determine branches proximate to the high-tech production in EC countries. The results of the analysis performed have shown that the majority of 98 high-tech branches are in close relation with each other, since the resulting coefficient of proximity between branches is 0.5 (*f pp'>0.5)*. It should be noted that the branches are considered as related if the proximity coefficient exceeds 0.25. However, to maintain the analysis integrity we have chosen a threshold value of 0.5. For example, the proximity coefficient between such branches as optical tools, production of electronic devices and measuring devices is 0.6, and between production of diagnostics equipment and measuring devices is 0.56.

It can also be noted that the high-tech branches demonstrate the availability of technologically proximate branches that are not high-tech – for example, pharmaceutical and chemical branches, the proximity coefficient of which is 0.54. The revealed interrelations between the branches are indicators reflecting the development potential of new branches. Since new types of economic activity have more chances of efficient inclusion into production structures when they are proximate to existing ones.

Figure 2 shows a process diagram of the degree of the countries' involvement in the manufacture of high-tech products:

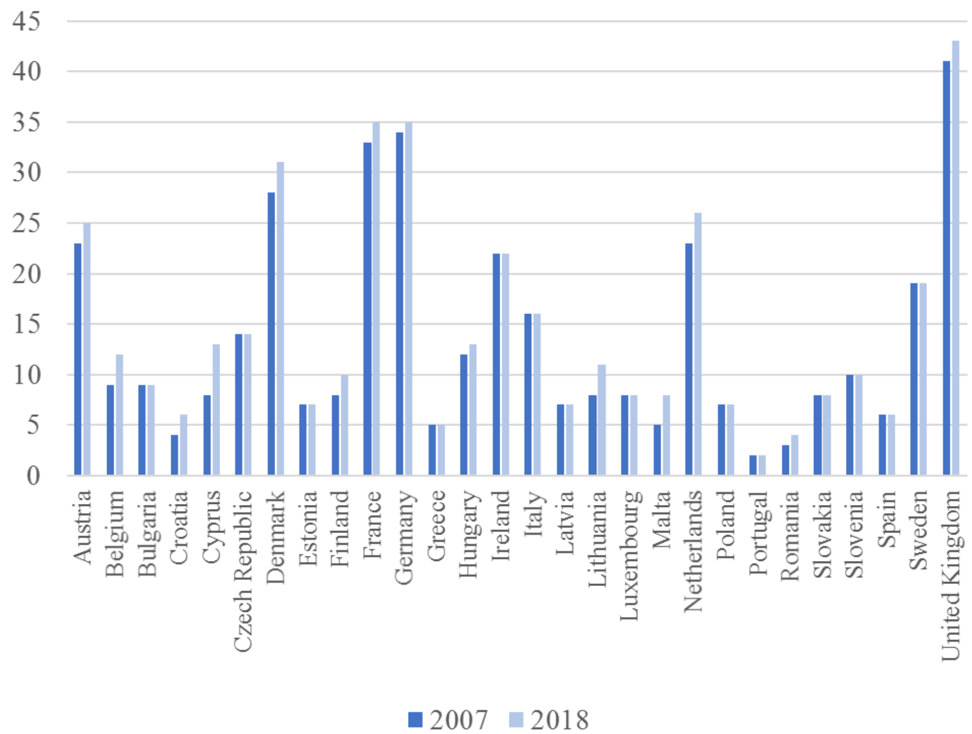

Fig. 1. Histogram of comparative advantages by high-tech branches in the European Union countries, units

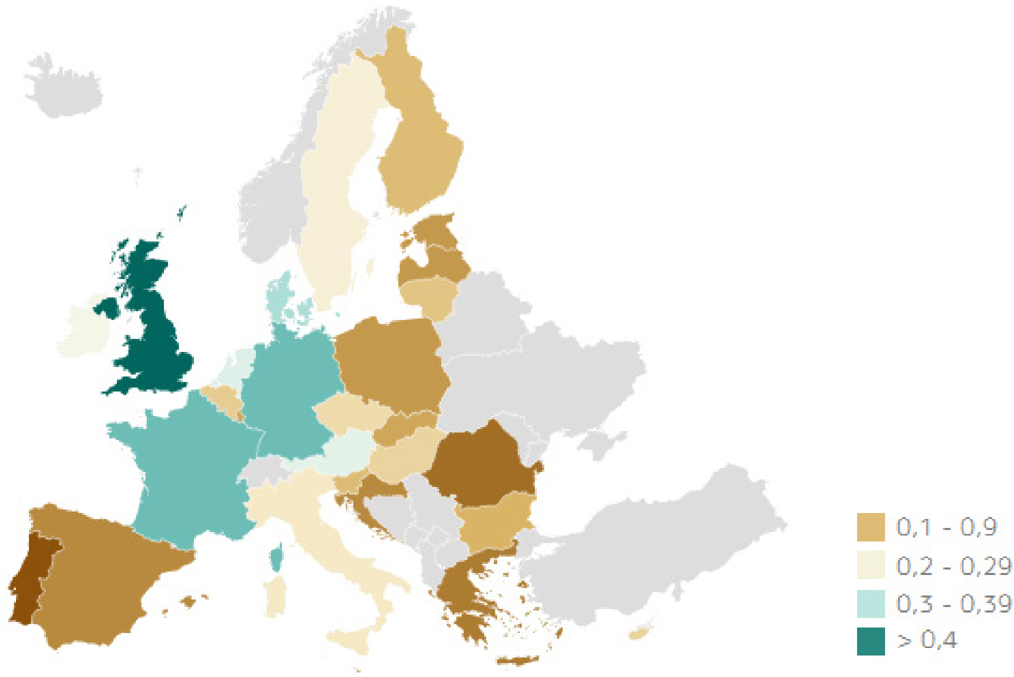

Fig. 2. Degree of the countries' involvement in the manufacture of high-tech products in EC countries

Four countries — Great Britain, Germany, France, and Denmark — together account for around 50% of the high-tech products in the EU. According to Eurostat, Great Britain has the most enterprises in the high-tech knowledge-intensive services sector, followed by France and Germany. If we look at turnover and value-added in high-tech manufacturing, then Germany has the highest turnover in countries with comparable numbers of high-tech manufacturers. Germany's high-tech manufacturing turnover stood at EUR 120 billion, followed by France (70 billion) and Italy (45 billion). Turnover was higher in the high-tech knowledge-intensive services sector than in high-tech manufacturing, in all countries for which data are available. Knowledge-intensive services generated a production value at least three times higher than high-tech manufacturing in the UK, Lithuania and Spain.

5. Conclusion

Development of innovations through the creation and support of new high-tech branches will help resolve many social and economic issues in countries and regions, including inequality issues. Creating favourable conditions for the efficient functioning of a national or regional innovative system is possible by determining the proximity of economic branches to reveal the types of economic activity technologically proximate to new innovative sectors of industry, and by specifying prospective development directions.

We have shown that the concept of technological proximity was considered in the scientific literature upon the provisions of evolutionary economics, allocation theories and new economic geography. Technological proximity is the interrelation between branches based on existing production peculiarities. It allows for a quantitative determination of which new branches should optimally be developed, based on the existing branch portfolio of a region.

The most popular approaches to evaluating technological proximity involve calculating an index based on the comparative advantages of manufactured and exported goods and a method for distinguishing industrial clusters. Determining types of economic activities technologically proximate to innovative ones can reveal the most promising directions for creating a new composition of branches of economy within the frames of a national or regional innovative system.

On the basis of 28 European Union countries, 98 branches technologically proximate to the high-tech production sector were revealed, including: medicaments containing penicillin and its derivatives; optical tools; electric panels and combinations of devices; smart-cards with integral circuits; and measuring devices and instruments. It was determined that the majority of types of economic activity are in close relation with each other or are accompanied by branches not directly high-tech.

The territorial location of branches is characterised by the prevalence of such high-tech branches as scientific tools, electronic and telecommunication technologies and pharmaceuticals. On the whole, countries and regions more fully develop and support those types of activity that are most connected with the existing composition of branches.

In further research, the analysis of high-tech industries at the level of EU regions is especially relevant to identify the features of regional innovation systems and to determine the impact of related industries on the development of innovation systems.

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Spatial differentiation of public administration employees due to professional burnout

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Abstract. The paper presents the results of classifying public administration employees in terms of level of occupational burnout, taking into account their place of residence, gender and age. One of the methods of multidimensional statistical analysis – classification trees – was used as a research tool. Two dependent variables are defined. The first has only two variants, defined as "no occupational burnout" and "occupational burnout", which characterise all respondents. The second dependent variable was limited to those respondents diagnosed with occupational burnout and has four variants corresponding to intensity of burnout. The obtained results indicate the differentiation of voivodeships (first-order administrative regions) in terms of the level of the studied phenomenon.

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