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Changes in the spatial patterns of industrial innovativeness in Dolnośląskie Voivodeship (Poland) in 2009–2019

Abstract: This article aims to identify changes in the industry's patterns in innovativeness and show its spatial diversity based on the example of the largest urban centres in Dolnośląskie Voivodeship. An assessment of the level of concentration of industrial activity was used as the basis for identifying these processes. The range of issues used for analysis depended on data availability, especially at the local level. The analysis of industrial activities' location was carried out based on entities registered in Section C (Manufacturing) of the Polish Classification of Economic Activities. The spatial patterns of industrial innovativeness were presented using the classification of manufacturing according to R&D levels. The research results indicate significant changes between 2009 and 2019 in the spatial patterns for both the voivodeship and its urban areas regarding the industry's concentration and specialisation. At the same time, this was accompanied by a decrease in industrial production. Dolnośląskie Voivodeship shows a significant spatial diversification in such concentration and specialisation. The patterns identified indicate the growing role of the area surrounding Wrocław as one of intensive infiltration of industrial activities from the main centre. These processes are also found in smaller urban centres of the voivodeship; however, this infiltration is selective.

Keywords: changes in the spatial structure; concentration and specialisation processes; Dolnośląskie Voivodeship; innovativeness; industry; spatial differentiation

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INTRODUCTION

Changes taking place in industrial production affect its spatial organisation. They are taking place under the influence of changes in the social division of labour, external benefits, greater flexibility of the labour market and stronger ties between industry

and local socio-economic conditions. As a result, the modern industry's locational requirements have been transformed, and new industry trends and clusters are found. In the post-industrial era, the increasing costs of functioning in a city, scientific and technical progress, increases in education, and numerous environmental barriers have contributed to the decentralisation of economic activity. One of the consequences of this phenomenon is an increase in the locational attractiveness of areas surrounding cities (Brezdeń, Szmytkie, 2017; Budner, 2006). New industrial areas are multi-centred and less concentrated.

Among the main factors behind these changes is the development of science and technology. For this reason, an important way of describing the economy is through the degree of modernity of manufactured products and applied technologies, and these depend on the level of research and development. Contemporary development of the knowledge-based economy is based on its intensive use, resulting in an increasingly rapid generation of technical and organisational progress. The more important factors determining this progress's pace and high economic development level are innovativeness and knowledge transfer. An increase in innovativeness and the introduction of new or significantly improved products or advanced technological processes contribute to the full use of available resources and an increase in the economy's efficiency (Brezdeń, 2015; Ferreira, Raposo, Fernandes, 2013).

The article shows the spatial differentiation in industrial concentration in Dolnośląskie Voivodeship in 2009–2019. The aim is to identify spatial changes in the industry in innovativeness and show its spatial diversity based on the example of major urban centres in Dolnośląskie Voivodeship. An assessment of the concentration and specialisation of industrial activities was used as the basis for identifying these processes. The article presents analyses concerning manufacturing entities' spatial patterns according to R&D levels and industrial production value. It also shows changes in the variables used for analysis between 2009 and 2019, which became the basis for determining industry trends in innovativeness in the voivodeship.

RESEARCH AREA, METHODS AND DATA SOURCES

Dolnośląskie Voivodeship is a very diverse region in terms of its physical geography and socio-economic development, covering an area of nearly 20 000 km² and inhabited by 2.9 million people (GUS, 2020, 25 November). It has both typically agricultural areas with a low development level (e.g. Górowo and Lwówek poviats) and highly developed urban areas with a high economic activity level (large cities, e.g. Wrocław). Several industrial or mining activity areas exist in the voivodeship (e.g. Legnica-Głogów Copper District – LGOM). The region itself consists of 169 gminas of various sizes and characteristics.

Due to the diversified rates of change, and depending on the specificity of gminas under study, besides looking at the entire voivodeship, a detailed analysis of the indicators was made for four areas:

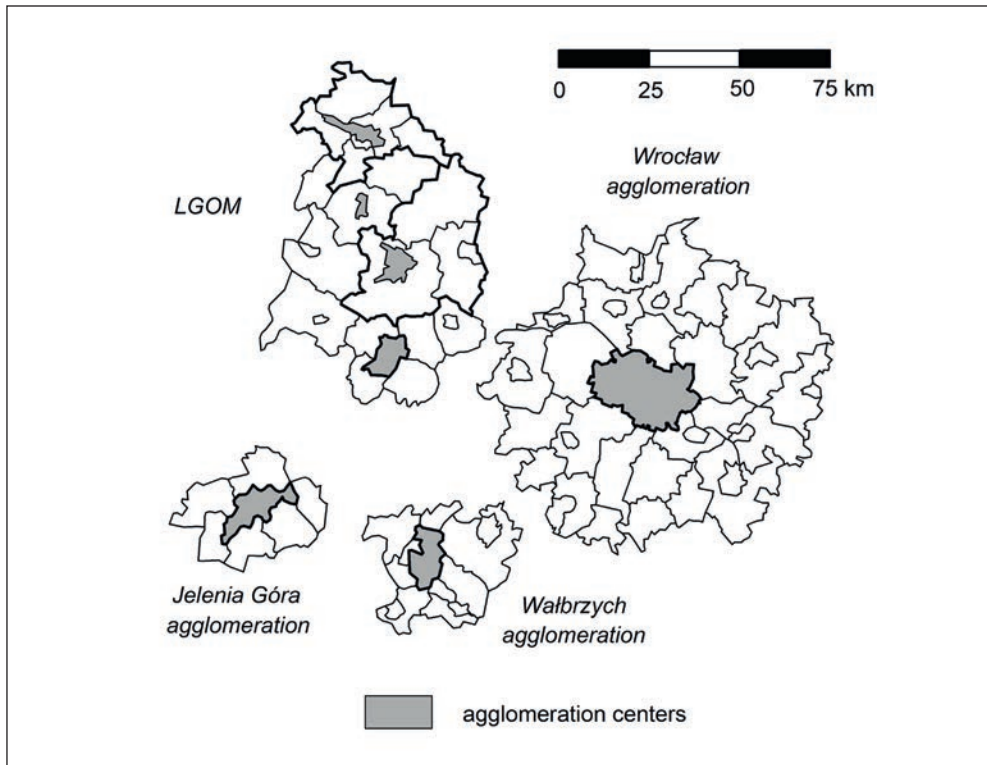
- Wrocław agglomeration: including the city of Wrocław and two 'rings' of gminas adjacent to the city (ring I – the gminas of Czernica, Długołęka, Kąty Wrocławskie, Kobierzyce, Miękinia, Oborniki Śląskie, Siechnice, Wisznia, Żórawina; ring II – the gminas of Bierutów, Borów, Brzeg Dolny, Dobroszyce, Domaniów, Jelcz-Laskowice,

Jordanów Śląski, Kostomłoty, Mietków, Oleśnica, Oława, Prusice, Sobótka, Środa Śląska, Trzebnica, Zawonia),

- Wałbrzych agglomeration: including Wałbrzych and the adjacent gminas of Boguszów-Gorce, Głuszyca, Jedlina-Zdrój, Mieroszów, Stare Bogaczowice, Szczawno-Zdrój, Świdnica, Świebodzice and Walim,
- Jelenia Góra agglomeration: including Jelenia Góra and the adjacent gminas of Janowice Wielkie, Jeźów Sudecki, Mysłakowice, Piechowice, Podgórzyn and Stara Kamienica,
- LGOM agglomeration: covering the four largest towns of Legnica, Lubin, Głogów, Polkowice, together with the adjacent gminas of Chocianów, Chojnów, Głogów, Grębocice, Jerzmanowa, Kotla, Krotoszyce, Kunice, Legnickie Pole, Lubin, Miłkowice, Pęcław, Prochowice, Radwanice, Rudna, Ścinawa and Żukowice (Figure 1).

The individual agglomerations identified for detailed analysis were under the direct influence of large urban areas with significant economic potential (LGOM). Within the areas of these agglomerations, the largest number of industrial entities is concentrated. Also, the most significant changes in terms of innovativeness are found there. As Wrocław is the region's capital, it was assumed that its area of influence extends into the second ring of adjacent gminas, although for other agglomerations, it was limited to those gminas directly bordering. The spatial range refers to Straszewicz (1985: 9), who defined such areas as those "directly surrounding or adjacent to a large city", taking into

Figure 1. The largest agglomerations with surrounding gminas of Dolnośląskie Voivodeship



Source: authors

account, however, the degree of development of urbanisation processes in the vicinity of large cities (Szmytkie, Sikorski, 2020).

Quantitative methods were used to identify spatial changes in the innovativeness of industry in Dolnośląskie Voivodeship. The analysis was based on statistical data in the form of the number of economic entities from Section C (Manufacturing), broken down by sections of the Polish Classification of Economic Activities (*Polska Klasyfikacja Działalności* – PKD). The spatial patterns of industry were presented using the classification of manufacturing according to R&D levels for high technology, medium-high technology, medium-low technology and low technology (GUS, 2018). For both the entire region and particular agglomeration areas, the analysis was based on data from the Local Data Bank.

The location quotient (LQ), Herfindahl-Hirschman index (HHI), discrete index and Ziolo's synthetic index were used to diagnose the development and spatial differentiation in the concentration of industrial activity.

The location quotient (LQ) is a popular tool in economic geography. This indicator is a measure of the concentration of activities in an area in relation to a reference area. The voivodeship and the average value for each analysed feature were adopted as references for this research (Bóasson, 2002).

The Herfindahl-Hirschman concentration index (HHI) is most often used in sector regulation and antitrust proceedings (Kwiatkowska, 2014) and works well in spatial research. It is calculated as the squares of firms' market shares within an industry for all administrative units in a region. Index values range from close to zero for dispersed features to 10 000 for highly concentrated features. In practice, a value lower than 1000 means a low concentration, exceeding 1800 – a high concentration, and above 2500 – a very high concentration of a phenomenon (Rogalski, 2010).

Ziolo's (1985) synthetic measure is a procedure for a linear ordering of spatial units describing the degree of industrial activity concentration. It also makes it possible to answer which output features determine the measure and to what extent. It is expressed by the following formula (Ziolo, 1985):

$$x''_{kj} = \frac{\sum_{j=1}^m x'_{kj}}{m}$$

where:

x'_{kj} – normalised j^{th} empirical measure of the k^{th} form of concentration

$\sum_{j=1}^m x'_{ij}$ – overall value of the j^{th} measure

A discrete indicator that is also often used to assess the degree of concentration of a given phenomenon calculated by summing the N largest units' shares is also used (Kwiatkowska, 2014). The choice of N is arbitrary and depends on the purpose of the study and the number of units in a given area (Curry, George, 1983). In an analysis of concentration, N is usually 2, 3, 5 to a maximum of 10.

An analysis of industrial entities' distribution according to the R&D classification and depending on the distance from an agglomeration centre is also applied. Due to a lack of specific geolocation data for industrial entities from Section C (in the Local Data Bank, data are given by gmina, not by a specific town), it was decided to use the distance from the agglomeration centre to successive rings. The number of entities found in the area of a given distance ring within a given gmina (for example, if there were 100 entities in a gmina and this gmina overlapped two distance rings, then depending on how much of a given ring was covered, a proportionate number of entities was assigned). The method's purpose is not to accurately (quantitatively) estimate industrial entities' distribution according to the R&D classification in individual gminas adjacent to the agglomeration areas of the voivodeship but to present specific trends in the distribution of industrial entities in the period analysed.

PROCESSES OF CONCENTRATION AND SPECIALISATION OF INDUSTRIAL ACTIVITY

Economic models derived from growth theories, trade and economic geography indicate very diverse factors determining concentration and specialisation (Fujita, Thisse, 2004; Krugman, 1991; Porter, 1996). On the one hand, an increase in sectoral specialisation of national economies and regions is expected due to existing comparative advantages and resources (Budner, 2006), while on the other, existing theories of growth indicate a decline in specialisation resulting from the equalisation of labour and capital productivity (Batóg, 2008; Goschin, Roman, Ileanu, 2009).

Specialisation in industrial production is closely dependent on the degree of concentration and scale, so production must be sufficiently large before such specialisation. This specialisation then leads to further concentration, and these processes are strongly intertwined (Batóg, 2008). As a result, the concentration and specialisation of industrial production should bring several benefits to the national economy: an increase in production, an increase in labour productivity, an improvement in production quality, a reduction in production costs and an increase in profitability.

Concentration and specialisation are also elements that lead to spatial divisions on different scales. Factors differentiating the dynamics of industrial development in Polish regional space include, among others, availability of qualified staff, transport accessibility and location concerning sales markets.

The concentration of specialised production has a significant impact on the deepening of production and supply relationships, interdependence between the distribution of individual industries, and the functional division of space (Midelfart-Knarvik, Overman, 2002).

Consequently, the processes of concentration and specialisation are also accompanied by structural changes. In developed countries' economies, this is expressed primarily in the reduction of production and employment in industries with obsolete technology and decreasing demand for their products, and at the same time accelerating the growth rate in industries using modern technologies and for products for which there is growing demand. This tendency occurs in all developed industrial countries, but the pace and scale of change vary considerably (Brezdeń, Szmytkie, 2019; Coenen, Moodysson, Martin, 2014; Kourtit, Gordon, 2019; Winiarski, 2002).

Geographical differences in production costs often affect the relocation of the industry. Industrial production “infiltrates” through the hierarchical system of urban centres, from larger to smaller. The causes of industrial dispersion are increased labour costs and the emergence of development thresholds in large urban agglomerations (Moriarty, 1991). This process is also related to the product life cycle (Vernon, 1960).

In recent years, rising costs of congestion in large urban centres, deteriorating amenities and rising wage levels have led to increasing migration from metropolitan centres to the periphery. Human resources as well as production enterprises and services are subject to this process (Bodenman, 2000). The reasons for shifting production are complex; the main motive is, of course, the desire to reduce production costs and increase operational flexibility. The primary determinants in relocating production include the level of labour costs, the quality and qualifications of labour resources, infrastructure, availability of supply and sales markets, and legal and institutional conditions (Moszyński, 2007). Hence, contemporary location trends for industrial activity indicate connections between growth in areas surrounding urban centres and their attraction for the industry. It causes significant changes in the industrial spatial patterns in the region.

These processes and the economic, often industrial, activity that coincides occur near many urban centres. Each city has its characteristics that influence industrial restructuring depending on historical background, economic base and the quality of the socio-cultural environment (Ernst, Alexeev, Marer, 1996).

The location attractiveness of the zone surrounding a city depends on the quality of the economic resources present. Moreover, these may be a factor stimulating development or a barrier to its development (Poniatowska-Jaksch, 1998). Therefore, sustainable regional growth must be accompanied by improving the quality of a city’s resources and those of its surrounding area, as this determines further development and thus shapes the conditions appropriate for the emergence of innovation.

In strategies for locating industry, maximising land rent is seen as a factor in the zonal development of a city (Alonso 1960; Ford 1996; Park, Burgess, McKenzie, 1925; Śleszyński, 2014). Changes in land rent occur depending on location, i.e. it decreases with distance from the centre. The land’s intended use also influences land rent, as the degree of investment, topographic and groundwater conditions, location in relation to existing power sources, and other utilities do. Another element of industrial activity is labour resources, potential employees and their qualifications. The diversity of these resources results from causes such as place of residence, demographic and social differences (sex, age, social origin, and others), and a person’s predisposition to work. The monetary expression of the labour cost is the wage, which results from a given labour market (Melitz, 2003; Poniatowska-Jaksch, 1998).

Therefore, the reasons for the relocation of the industry are complex, conditioned by many factors inherent in the enterprise and its environment. The primary motive is sometimes just the desire to reduce production costs and increase operational flexibility.

CHARACTERISTICS OF SELECTED ASPECTS OF INDUSTRIAL CONCENTRATION IN DOLNOŚLĄSKIE VOIVODESHIP

Dolnośląskie Voivodeship is one of the most industrialised regions in Poland. It has consistently been fourth nationally in terms of the value of industrial production sold

at over 78.9 billion PLN in 2009 and over 129.6 billion PLN in 2018, following Mazowieckie, Śląskie and Wielkopolskie Voivodeships (GUS, 2020, 11 October). It is also worth emphasising that Dolnośląskie Voivodeship has shown high growth in the value of industrial products sold in relation to most industrialised regions of Poland: with an increase of nearly 170% in 2009–2018, it ranked behind Wielkopolskie (184%) but ahead of Mazowieckie (169%) and Śląskie (155%), with an average growth rate of 170%. The increase in industrial production value in the voivodeship was in this value per capita: from 27 500 PLN in 2009 to 44 700 PLN in 2018.

The increase in industrial production value corresponded to an increase in the number of industrial entities. However, the increase in production value was much more significant, demonstrating the increase in Dolnośląskie typical of more technologically advanced industries.

In 2009–2019, the number of industrial entities from Section C (Manufacturing) in Dolnośląskie Voivodeship increased from 24 459 to 27 038 (an increase of 10.5%). The vast majority were still located in urban areas (71.7% in 2009, 65.5% in 2019). However, there was a noticeable decrease in their proportion and a simultaneous increase in rural areas (28.3% in 2009, 34.5% in 2019), and the gminas adjacent to large urban areas (24.0% in 2009, 27.5% in 2019) (Table 1).

Table 1. The number and location of industrial entities from Section C (Manufacturing) in Dolnośląskie Voivodeship: 2009–2019

Area/year	Year		Percentage share in the total		Percentage change (2009–2019)
	2009	2019	2009	2019	
Urban areas	17 542	17 722	71,7	65,5	-6,2
Rural areas	6 917	9 316	28,3	34,5	6,2
Agglomerations*	9 980	10 022	40,8	37,1	-3,7
Agglomeration surroundings	5 873	7 442	24,0	27,5	3,5
Agglomeration total	15 853	17 464	64,8	64,6	-0,2
Dolnośląskie Voivodeship	24 459	27 038	100,0	100,0	-

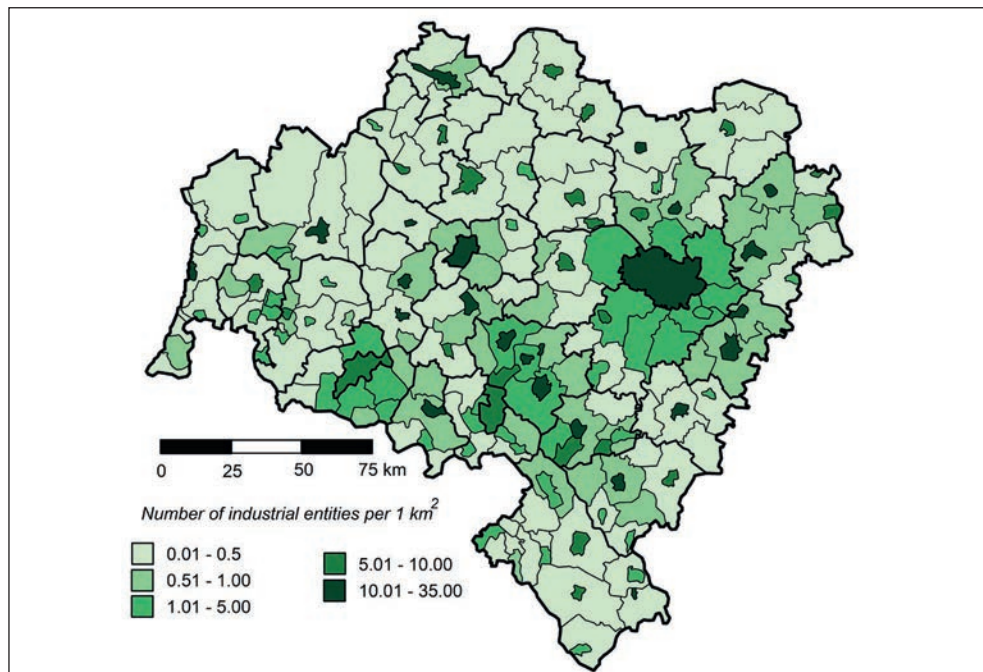
* Wrocław, Wałbrzych, Jelenia Góra, Legnica, Lubin, Głogów, Polkowice

Source: authors based on the GUS (2020, 11 October)

The highest concentration of industrial activity in 2019 was recorded in large and medium-sized settlements of the voivodeship, especially in Wrocław and in the gminas in its immediate vicinity, as well as in Legnica, Świdnica, Dzierżonów, Jelenia Góra and its neighbouring gminas, and Chojnów. These are all areas with a traditionally developed industrial function (Figure 2).

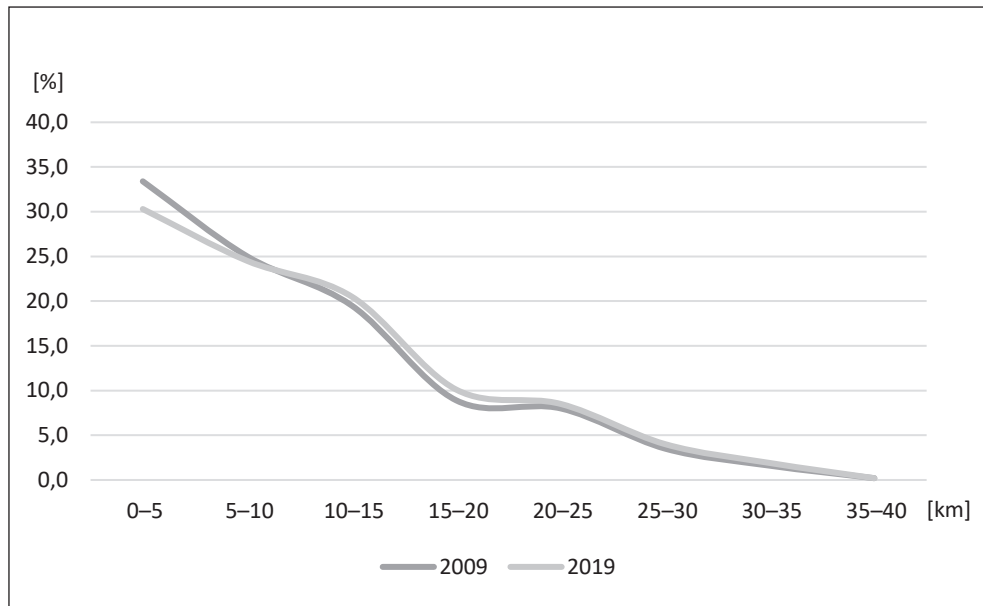
As already mentioned, in the period analysed, a gradual change in industrial activity concentration was noticeable, favouring an increase in importance in rural areas and gminas surrounding the voivodeship's largest agglomerations (see Table 1). The greatest concentration is still found in the agglomerations nevertheless. Compared to 2009, a trend of increasing importance in concentration in areas 10 km or more from the agglomeration centres has been found (Figure 3). The observed changes are influenced by various factors, including the processes of deglomeration of industrial activity from large cities' centres and relocation to surrounding areas (Sikorski, 2020).

Figure 2. Density of industrial entities from Section C (Manufacturing) per km² in the gminas of Dolnośląskie Voivodeship in 2019



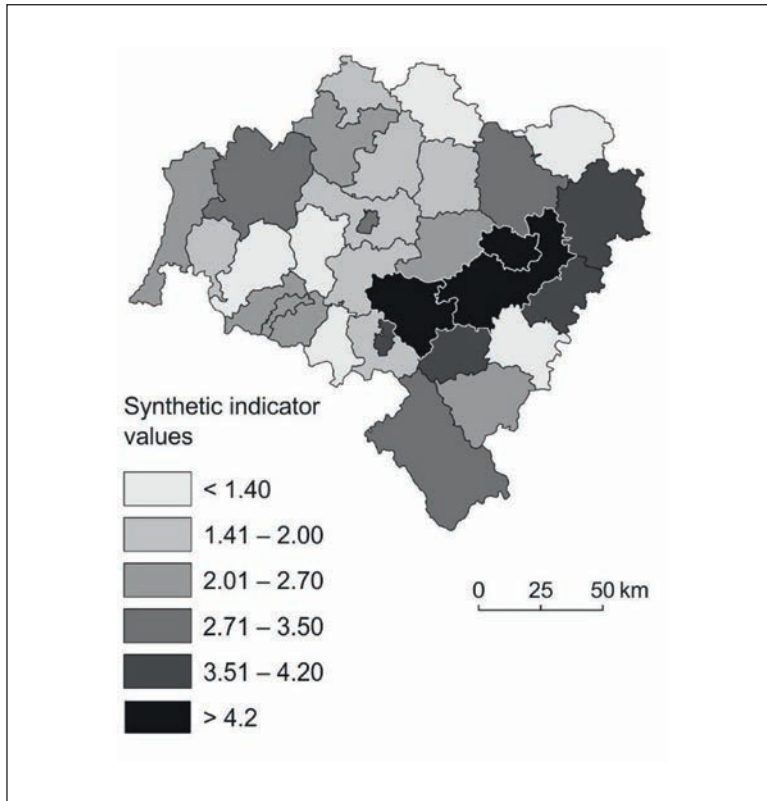
Source: authors based on the GUS (2020, 11 October)

Figure 3. Distribution of industrial entities from Section C (Manufacturing) in the largest urban areas of the region, depending on the distance from the centre of the agglomeration: 2009–2019



Source: authors based on the GUS (2020, 11 October)

Figure 4. Synthetic indicator for industrial activity in Dolnośląskie Voivodeship in 2018



Source: authors based on the GUS (2020, 11 October)

Synthetic indicators confirm spatial differentiation in industrial activity concentration into areas surrounding the main urban settlements by powiat (Figure 4). The following diagnostic features were used for its calculation: the proportion of industrial entities out of the total number – as a percentage, the proportion of industrial production in the voivodeship as a whole – as a percentage, the proportion of employees in the industry out of the total number – as a percentage, the proportion of newly registered entities in 2009–2018 in manufacturing out of those in the voivodeship as a whole – as a percentage, and the proportion of entities in manufacturing deregistered in 2009–2018 out of the total number for the voivodeship as a whole – as a percentage. The value of the synthetic index in the voivodeship shows that the contemporary dominant industrial concentration area is metropolitan Wrocław, albeit with spatial diversification. Simultaneously, the importance of industry in the traditionally industrialised areas of the south-western part of the voivodeship, which used to be an essential part of the Sudeten industrial district, is significantly diminishing and is an expression of the de-industrialisation of some areas of the voivodeship.

In the period analysed, attention is drawn to industrial concentration processes, although lower, in the surroundings of Legnica and Jelenia Góra, i.e. in the Legnica and Jelenia Góra powiats. There is also a much more significant change in industrial production growth in powiats (threefold in Legnica and doubled in Jelenia Góra) than in the

urban settlements themselves (Legnica – a twofold increase, stable in Jelenia Góra). These patterns indicate the infiltration character of contemporary industrial concentration processes, and this process occurs in smaller urban areas.

Contemporary location trends for industrial activity indicate a connection between moving to cities' surroundings, especially from large cities, and suburbanisation. This process leads to significant changes in industrial spatial patterns in the voivodeship. Its general consequence is that the level of concentration of industrial production per capita in the entire Dolnośląskie Voivodeship has continued to decrease significantly (Brezdeń, 2018). The decreasing HHI value evidences it for the voivodeship over many years, and between 2009 and 2018, it decreased from 956 (itself a low concentration level) to 766 in 2018. The value also confirms the decreasing concentration of industrial production for the CR5 concentration indicator, i.e. the sum of the five poviats with the highest share of total industrial production for the voivodeship, which decreased from 63.8% in 2009 to 56.3% in 2018. A similar situation was found for the CR10 concentration ratio, which decreased from 78.7% in 2009 to 76.1% in 2018. The growing importance of surrounding areas for industrial production is mainly seen in those poviats making up the CR10 index, i.e. the sum of the ten poviats with the highest share of total industrial production value in the voivodeship. The top five poviats show some significant shifts in production; in 2009 this consisted of Wrocław (a city with poviat rights), Lubin, Polkowice, Zgorzelec and Wałbrzych, by 2019 these were Wrocław (a city with poviat rights), Lubin, Polkowice, the city of Wrocław itself, and Wałbrzych. In 2009, the following five poviats were Świdnik, Legnica (a city with poviat rights), Zgorzelec, Oława and Oleśnica, while by 2019, the proportion in the area surrounding Wrocław had clearly increased, i.e. Wrocław Poviats (threefold to 10.2%), Oława (twofold to 6%) and Oleśnica (to 3.5%). At the same time, there was a marked reduction in the share of LGOM, i.e. Polkowice (14.5% to 9.5%) and Lubin (14.1% to 10%), and cities with poviat rights, namely Wrocław (20.3% to 17.4%) and Wałbrzych (8.7% to 7.5%), along with Zgorzelec Poviats (5.5% to 4%). Interestingly, among the poviats with the most significant shares of industrial production sold, both in 2009 and 2019, Jelenia Góra (a city with poviat rights – the fourth-largest settlement in the voivodeship and once an important industrial centre), was not found. In 2019, Legnica's share was lower than that of the poviats surrounding Wrocław (Oława and Oleśnica), not to mention Wrocław Poviats itself, whose share was nearly three times higher.

CHARACTERISTICS OF SELECTED ASPECTS OF INDUSTRIAL INNOVATIVENESS IN DOLNOŚLĄSKIE VOIVODESHIP AND ITS AGGLOMERATIONS

Despite the systematic decline in the concentration of industry in the voivodeship, as indicated in the earlier part of the work, the location of industry shows more complex patterns. It is possible to observe two different location processes in action, depending on the level of technology. The high-tech industry, in particular, is increasing in concentration, while production involving medium-low and low technologies is undergoing a progressive dispersion in the voivodeship. It is confirmed by an analysis of the HHI concentration index for industrial entities according to R&D levels, where the changes identified show a growing concentration of high technology entities. The value of the indicator for this category among voivodeship gminas was 2974 in 2009. This level testified to a very high concentration, and which by 2019 had become even greater

(Table 2). The HHI value of 3369, demonstrates the existence of an oligopoly in this respect in the voivodeship, where Wrocław takes 57%, followed by Legnica (3%), Koberzyce Gmina (2.7%), Świdnica (2.6%), Jelenia Góra (2.2%) and the gmina of Długołęka (2.1%). Growth will also occur in the future, confirmed by high technology entities' survival rate (the HHI value for newly registered entities being much higher than for those de-registered (Table 2).

Table 2. The HHI value for industrial entities according to R&D levels in Dolnośląskie Voivodeship: 2009–2019

HHI values		
Industrial entities		
Technology level according to R&D	2009	2019
High technology	2974	3369
Medium-high technology	1479	1409
Medium-low technology	879	671
Low technology	669	623
Newly registered 2009–2019		
High technology		3918
Medium-high technology		1548
Medium-low technology		558
Low technology		646
De-registered 2009–2019		
High technology		2929
Medium-high technology		1323
Medium-low technology		677
Low technology		653

Source: authors based on the GUS (2020, 11 October)

In 2009–2019, among the new industrial entities in Dolnośląskie Voivodeship, most belonged to high (increased by 17.6%), medium-high (19.7%) or medium-low (17.1%) technologies. This increase in the number of high and medium-high entities in the voivodeship demonstrates favourable conditions for innovativeness. The most significant growth was recorded in the largest agglomerations' direct surroundings (an average increase of over 35%). Interestingly, in cities and agglomeration centres, there was a decrease in the number of low-tech industrial entities (Table 3). The results indicate that in Dolnośląskie Voivodeship, there is an increase in low-tech industrial entities, mainly due to their dynamic growth in the zones of the city's immediate hinterland and urban agglomerations.

An important aspect of changes in the industry's spatial patterns in the voivodeship is the apparent shift of industrial activity towards more peripheral areas, mainly applying to medium-low and low technology industries (Figure 5 C, D). This process is evident in the case of Wrocław agglomeration. An analysis of the location quotient (LQ) concentration index for industrial entities, according to R&D levels, indicates the particular importance of an urban environment in creating favourable conditions for high technology activity (Figure 5 A). The highest values were primarily characteristic of Wrocław, where the LQ index's value was twice as high as the average for the entire region. The high technology industry is characterised by high expenditure and a requirement for highly specialised technology and highly qualified staff. Such an environment

is found in the central part of an urban-industrial agglomeration (Moriarty, 1991; Reniski, 2008). A lower level for industrial entities is found in the centres, but with a corresponding increase in the first and second rings for lower technological levels. It should also be emphasised that the level of concentration of high and medium-high technology entities is in the first ring of gminas around Wrocław, higher than the average for the whole region. It confirms the growing importance of a large city's immediate surroundings as an environment conducive to innovative activities after the urban area itself.

The similarity of the industry's spatial pattern in the first ring compared to urban areas indicates some differences in filtering industrial activity in the surroundings of Wrocław concerning many cities in Western Europe or North America (Boiteux-Orain, Guillain, 2003; Coffey, Shearmur, 2002).

Table 3. The number and location of industrial entities from Section C (Manufacturing) in Dolnośląskie Voivodeship by level of technology: 2009–2019

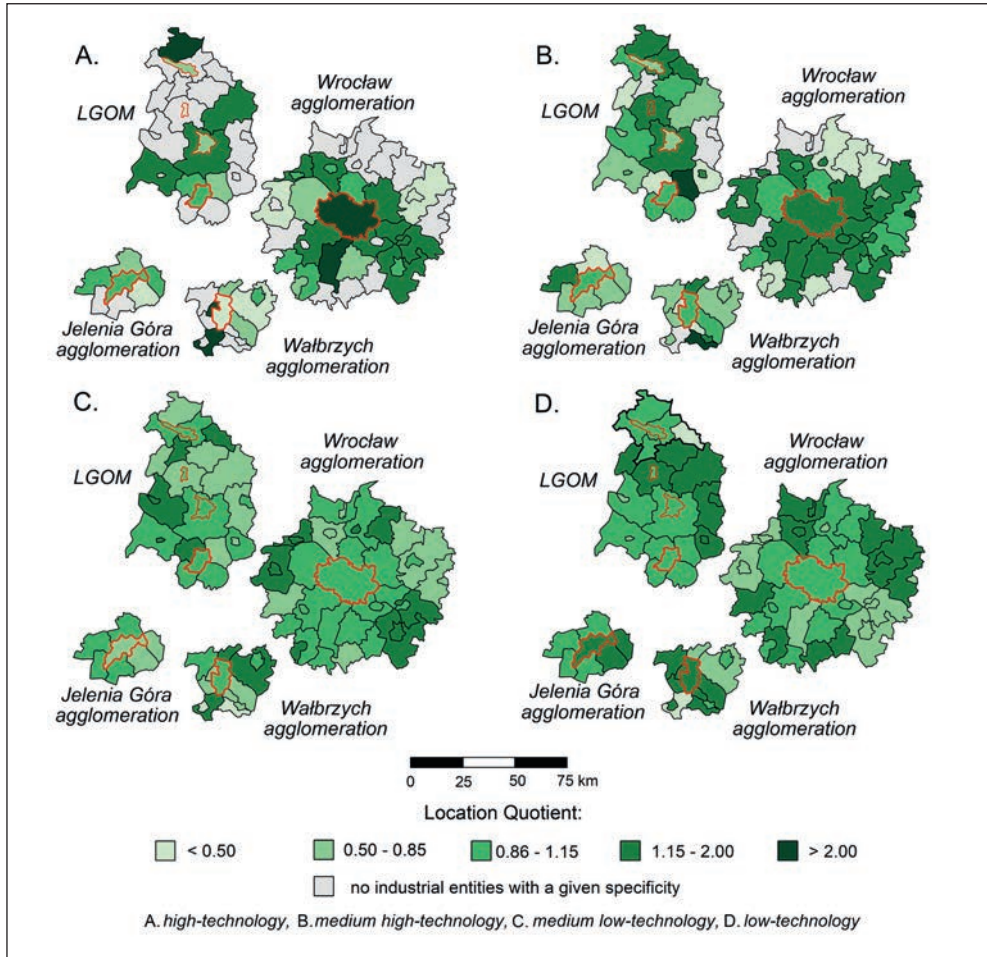
Area	Year	Technology level				Total
		High	Medium-high	Medium-low	Low	
Urban areas	2009	445	1 180	8 102	7 815	17 542
	2019	504	1 278	8 521	7 419	17 722
	(2009–2019)	13.3%	8.3%	5.2%	-5.1%	1.0%
Rural areas	2009	88	335	3 214	3 280	6 917
	2019	123	536	4 726	3 931	9 316
	(2009–2019)	39.8%	60.0%	47.0%	19.8%	34.7%
Agglomerations*	2009	335	762	4 647	4 236	9 980
	2019	415	861	4 620	4 126	10 022
	(2009–2019)	23.9%	13.0%	-0.6%	-2.6%	0.4%
Agglomeration surroundings	2009	103	379	2 728	2 645	5 855
	2019	140	525	3 745	3 020	7 430
	(2009–2019)	35.9%	38.5%	37.3%	14.2%	26.9%
Agglomeration total	2009	438	1 141	7 375	6 881	15 835
	2019	555	1 386	8 365	7 146	17 452
	(2009–2019)	26.7%	21.5%	13.4%	3.9%	10.2%
Dolnośląskie Voivodeship	2009	533	1 515	11 316	11 095	24 459
	2019	627	1 814	13 247	11 350	27 038
	(2009–2019)	17.6%	19.7%	17.1%	2.3%	10.5%

* Wrocław, Wałbrzych, Jelenia Góra, Legnica, Lubin, Głogów, Polkowice

Source: authors based on the GUS (2020, 11 October)

Simultaneously, the indicated patterns show the growing role of the entire surrounding zone as an area intensively infiltrated by industrial activity from urban areas, which also results in a growth of industrial areas (Rudewicz, 2016). In the case of Wrocław agglomeration, a vital role is additionally played by the high level of the available warehouse, production, logistic and service space in Bielany Wrocławskie (Kobierzyce Gmina in the first ring of the agglomeration) where two motorways intersect: A4 in the east-west axis (Berlin–Kyiv) and A8 along the north-south axis (Wrocław–Poznań–Gdańsk and Wrocław–Łódź–Warsaw). There are multi-functional centres in the form of technology parks, often in the subzones of special economic areas, offering an opportunity for 'built-to-suit' investment projects (assuming the design

Figure 5. Concentration of industrial entities in the largest agglomerations of Dolnośląskie Voivodeship in 2019



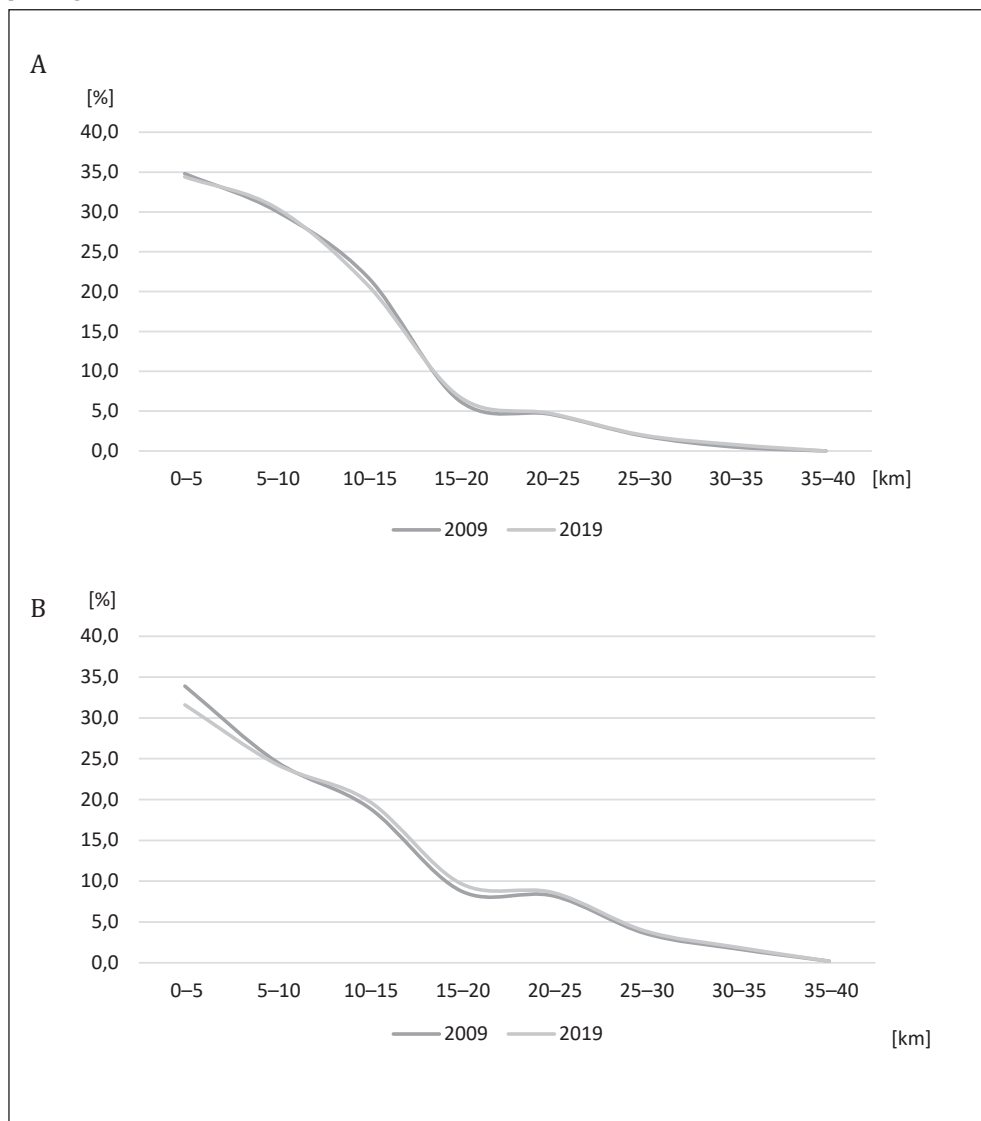
Source: authors based on the GUS (2020, 11 October)

and construction of a building according to the needs of a specific tenant), warehouse, production, logistics and service space, and thus creating favourable conditions for high and medium-high technology industrial entities.

However, areas surrounding an agglomeration are, in principle, a much more favourable environment for medium-low and low technologies, as evidenced by higher LQ values for low technology entities (Renski, 2008).

Empirical data show a traditionally high concentration of high technology in the centre of a metropolitan area where there is a set of favourable conditions (the presence of many qualified young people, numerous high-tech companies enabling favourable 'coopetition'). Therefore, high-tech entities are created more often in the centre than outside, although these new companies' exit rate is also high (Arauzo, 2005; Coll-Martínez, Moreno-Monroy, Arauzo-Carod, 2016).

Figure 6. Distribution of high-tech (A) and low-tech (B) industrial entities in the largest agglomerations depending on the distance from the centre: 2009–2019



Source: authors based on the GUS (2020, 11 October)

Specific factors in the location of economic activity play a unique role in the concentration of industrial activity (e.g. the main communication routes, the economic functions of satellite settlements (especially in the Wrocław agglomeration), the spatial distribution of subzones of special economic areas or institutional forms of innovation support, e.g. in the form of technology parks. The industrialisation of the surrounding areas occurs only in such places and, in effect, leads to increasing specialisation (Filion, 2001).

Therefore, these analyses show that the relocation and spatial infiltration of industry around individual agglomerations occurs selectively. The processes of concentration and relocation in the Wrocław agglomeration are more complex and internally diversified than the other areas due to the size of Wrocław and its function in the entire economic system of the voivodeship. The city is the primary labour market in the region; hence it has an extensive influence, including the two rings of gminas surrounding it. In the case of other agglomerations in the voivodeship, these processes are not very transparent. However, industrial infiltration diffusion is visible in the surroundings of smaller urban centres as well, especially LGOM and the Jelenia Góra agglomerations (Figure 5 C, D). However, this applies primarily to medium-low and low technology industries, although some symptoms of the growing importance of high technology are found in LGOM. Overall, this is because a central agglomeration can attract more innovative entrepreneurs and has long been considered a centre of innovation (Brouwer, Budil-Nadvornikova, Kleinknecht, 1999; Campi, Blasco, Marsal 2004; Vernon, 1960). Due to the risks associated with product development, new firms in agglomeration centres may have a greater propensity to fail, but at the same time, have a more significant potential for growth (Renski, 2008). Due to greater diversity, central areas offer the most inspiring environment for new projects. After successful development, companies gain an increased advantage in such an environment, making it easier for them to relocate to places with a lower level of competition that offer lower production costs. Industrial entities where high importance is placed on knowledge have a greater chance of being located in large cities and are found less often as the size of an urban area decreases. It is also seen in smaller agglomerations in the voivodeship and suggests that we should expect higher rates in creating new innovative firms in critical urban areas and lower values in smaller agglomeration clusters and peripheral rural areas.

In the period analysed, slight changes in the spatial distribution of high and low technology industrial entities in the largest voivodeship agglomerations, depending on the agglomeration centre's distance, were noticeable (Figure 6). Gradually, there has been visible deconcentration of the high technology industry's activity towards the surrounding areas of the largest agglomerations in the region, which confirms earlier findings that there are apparent symptoms of the deconcentration of industrial activities from the centres of agglomerations to more peripheral locations in the voivodeship.

These deconcentration symptoms mainly concern low technology (Figure 6 B) with much smaller shifts for the high technology industry (Figure 6 A).

SUMMARY

Dolnośląskie Voivodeship shows significant spatial diversification of industrial concentration. In the analysed period, there was a decrease in the concentration of industrial production in the voivodeship. The most significant increase was recorded in poviats directly located beside the region's main urban centres (Wrocław, Legnica, Jelenia Góra), and these areas are the modern "drivers" of the voivodeship industry. This process is accompanied by a decline in the importance of the southern part of the region and LGOM (deindustrialisation). The rapid growth of industrial entities often occurs in the surrounding zones of the largest agglomerations, especially Wrocław. However, the voivodeship is internally significantly diversified, and the scale is related to the urban area's size.

The significant increase in the number of high and medium-high technology entities in the voivodeship proves its favourable conditions for innovativeness.

There is a relocation of industrial entities into the ring of gminas surrounding an agglomeration, especially for Wrocław, including those in high technology, as evidenced by the scale of the dynamics of the growth of entities with the still dominant position of the urban center. It confirms the growing importance of a large city's immediate surroundings as an environment conducive to innovative activities after the central urban areas themselves. On the other hand, industries with a lower technology level are located in the more peripheral area of the second ring in Wrocław.

An essential change in the industry's patterns in the voivodeship is a clear shift of industrial activity towards peripheral areas. It applies mainly to medium-low and low technology industries and is particularly visible for the Wrocław agglomeration. An analysis of the LQ concentration index of industrial entities according to R&D levels indicates the urban environment's particular importance in creating favourable conditions for high-tech activity.

Therefore, these analyses show that the relocation and spatial infiltration of innovative industry (especially high technology) into individual voivodeship agglomerations occur selectively. The processes of concentration and relocation of industrial entities in the Wrocław agglomeration are more complex and internally diversified in relation to other agglomerations. It is due to its size and its function in the economic system of the entire voivodeship.

Specific factors in the location of economic activity which play a unique role in industrial concentration include the main communication routes, economic functions of surrounding urban areas (especially in the Wrocław agglomeration), and the spatial distribution of special economic area subzones and technology parks. Their effect may, in the future, increase the functional specialisation of areas in terms of industrial innovativeness.

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