
Regional Capital Dynamics and Cluster Development: Insights from Poland's National Key Clusters

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Abstract:

Purpose: The main objective of the article is to assess changes in the structure of National Key Clusters (NKC). The article answers three key research questions: (1) what changes occurred in the structure and number of clusters in the analyzed years and how they reflect the dynamic needs of the Polish economy, (2) what factors determine the maintenance of the status of the NKCs, and (3) how the clusters that have lost this status differ from those that have maintained it.

Design/Methodology/Approach: The answer to the research questions is to be the basis for the verification of the research hypothesis, which has been formulated as follows: The dynamic development of cluster structures in Poland is a response to changing market needs and economic trends, and key clusters play an important role in the development of various sectors. The fact that some clusters maintain their status and the emergence of new players on the market, especially in the areas of innovative technologies, reflects their importance for the economy and their ability to adapt to new challenges.

Findings: International experience shows that the creation of cluster structures brings significant benefits both for the entire economy and for individual enterprises. In the context of Poland, the development of clusters is of key importance for improving innovation and competitiveness of the economy. Despite existing challenges, such as low expenditure on research and development and the need for better coordination between the public and private sectors, clustering can effectively support the use of a country's innovation potential.

Practical Implications: Cooperation between businesses, research institutions and public administrations is an important part of the process of transforming the economy in a knowledge-based and collaborative direction.

Originality/Value: The article brings an innovative approach to cluster analysis, combining the analysis of long-term economic phenomena with an empirical assessment of the dynamics of NKCs.

Keywords: Cluster, clusters policy, national key clusters, regional capital factors, regional development management.

JEL classification: L26, L53, L84.

Paper Type: Research article.

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1. Introduction

In Poland, the development of clusters is a key element of the development of the economy, including the knowledge-based economy. Clusters, i.e., groups of related companies and institutions cooperating with each other in a given region, enable more effective use of resources and knowledge sharing. Poland, due to its strategic location in Europe, has the potential to develop clusters that can attract international investment and support regional economies.

One of the key aspects of the development of clusters in Poland is their cooperation with the public sector, which can provide not only financing, but also a legal framework conducive to the functioning of cluster structures. In recent years, various support programs have been introduced to promote and develop the activities of cluster structures. However, despite the existing initiatives, Poland still ranks low in international innovation rankings, which proves the need for further work on improving the effectiveness of these programs (Bronżewska and Majdowski, 2015).

In the context of the Europe 2020 Strategy, Poland has committed to increasing expenditure on research and development (R+D) to the level of 1.7% of GDP, of which more than half of this expenditure should come from the private sector (Bronżewska and Majdowski, 2015). Achieving this goal requires intensifying activities, especially in the business sector, which are key to innovation. Clusters can provide a platform for cooperation between enterprises and research units, which can lead to better use of innovation potential.

The experience of other countries shows that the creation of cluster structures can bring measurable benefits both in macro terms, i.e., for the country's economy, and micro-ones, i.e., for enterprises. In conclusion, the development of clusters in Poland is of great importance for improving innovation and competitiveness of the economy. While there are some challenges, such as low R+D spending and the need for better coordination between the public and private sectors, clustering can help to better exploit the innovation potential.

Cooperation between enterprises, research institutions and public administration will be the key to the successful transformation of the Polish economy towards a knowledge-based and collaborative economy (Choińska-Jackiewicz, Lubos, Łata, Mackiewicz, and Wancio, 2020).

In the aspect of the research problem constructed in this way, the main objective of the article was to assess changes in the structure and number of National Key Clusters in the years 2018-2024. To achieve this goal, the following research questions were asked:

- What changes in the structure and number of clusters have occurred in the years, and how do these changes reflect the dynamic needs of the Polish

economy?

- What factors determine the maintenance of the status of the National Key Cluster by Polish clusters over the years?
- How do clusters that have lost the status of a National Key Cluster differ from clusters that have maintained it?

The answer to the research questions is to be the basis for the verification of the research hypothesis, which has been formulated as follows: The dynamic development of cluster structures in Poland is a response to changing market needs and economic trends, and key clusters play an important role in the development of various sectors. The fact that some clusters maintain their status and the emergence of new players on the market, especially in the areas of innovative technologies, reflects their importance for the economy and their ability to adapt to new challenges.

2. Literature Review

2.1 Definitional SWOT Analysis of Cluster Structures

The cluster is there. It is a geographically concentrated set of enterprises, research and development institutions, educational units and public institutions that cooperate in a specific sector of the economy, creating a network of cooperative and competitive connections. A cluster is not only a collection of independent entities, but is an integrated ecosystem that fosters the development of innovation, exchange of knowledge and technology between its participants.

A characteristic element of clusters is the concentration of efforts in a given sectoral area, which allows to achieve a competitive advantage through specialization (Păuna, 2015; Bevilacqua, Anversa, Cantafio, and Pizzimenti, 2019; Azmaiparashvili and Davituliani, 2023; Liapis *et al.*, 2013).

Economic development is not evenly distributed but creates growth poles – areas where concentrated economic activity develops faster. In the context of clusters, these growth poles can arise in places where local resources and regional specificities are conducive to the emergence and development of such structures (Hospers and Beugelsdijk, 2002; Baranowska and Sroka, 2009; Szymańska, 2009).

Thanks to the spatial proximity, companies within the cluster have easier access to knowledge and technology, which is conducive to the rapid implementation of innovations. Companies can benefit from joint research, infrastructure and support each other in the production process, which increases their operational efficiency. In this way, clusters become innovation centers that significantly increase the competitiveness of their members on the domestic and international market (Skawińska and Zalewski, 2009; Pigola, Costa, Mazieri, and Scafuto, 2022; Rahmadita, 2023).

Operating in geographical proximity allows companies in the cluster to benefit from economies of scale. Logistics and transportation costs are reduced, which can lead to lower overall production costs. Companies in clusters can also jointly procure raw materials or services, which gives them more negotiating power with suppliers (Havierníková, Okręglicka, and Lemańska-Majdzik, 2016; Zhernov, Nekhoda, and Petrova, 2020).

The cluster attracts qualified employees and gives companies the opportunity to invest in the development of their skills. Specialized employees can move between companies in the cluster, which fosters the exchange of knowledge and experience. In addition, the proximity of research centers within clusters enables cooperation with universities and research and development centers, which leads to a dynamic development of human resources (Hospers and Beugelsdijk, 2002; Tong, Zainudin, Yan Jing-dong, and Abd Rahman, 2023; Wu, Yin, and Liu, 2023).

Thus, the geographical aggregation of interconnected companies, specialised suppliers, service providers, companies operating in related sectors and related institutions (for example, universities, standardisation bodies and industry associations) in their respective fields both compete and cooperate.

Clusters that reach critical mass (the necessary number of enterprises and other institutions creating the agglomeration effect) and are successful in competition in specific areas of activity are a feature of almost every national, regional, state and even metropolitan economy, mainly in economically developed countries (Porter, 1990; 1998; 2001).

It is also worth mentioning the term "cluster initiative" used in the literature on the subject, which is often used interchangeably with the term "cluster". However, it is crucial to distinguish between these two terms. Thus, Ölvell, Sölvell, Lindqvist, and Ketels (2008) indicate that these are "organized efforts aimed at the development of the cluster and increasing its importance and competitiveness in the region, undertaken by the companies that are part of the cluster, regional authorities, the research and scientific community, as well as public-private organizations. In addition, the initiative often clearly indicates the existence of a cluster organization coordinating activities within it. (...). They can be stand-alone and focus on just one cluster, or they can be part of a wider regional or national competitiveness strategy with multiple cluster initiatives running simultaneously."

In the PARP report (Hołub-Iwan J. (ed.), 2012) we also find a definition indicating the diversity of entities focused on the development of cluster members, i.e., key players (i.e., enterprises and institutions related to a given industrial or geographical sector) who cooperate and create a certain structure supporting the development of the cluster.

To sum up, a "cluster" means a geographical concentration of enterprises that are

related to each other in both commercial and non-commercial relations. On the other hand, "cluster initiative" refers to organized activities supporting the development of a given cluster.

2.2 Classification Diversity of Cluster Structures

To fully interpret the convergence of selected cluster features, it is necessary to discuss the classification diversity of clusters, which results from the fact that there is no single, universal cluster model that would be ideally suited to all types of economies. Each country or region has created its own types of clusters resulting from specific historical or cultural conditions, and the relationships occurring in cluster structures have determined their systematics.

Five basic classifications are most often cited. In addition, the first two classifications are characterized by the same types. Within the division of clusters due to the structure of participating enterprises, the nature of connections and the type of internal cooperation, we distinguish (Markusen, 1996):

1. A network cluster (in the form of an industrial district) that consists of a network of small enterprises with the same or similar type of production. They are characterized by the ability to quickly adapt to the changing market and diverse requirements, through cooperation and the use of new technologies. In addition, they lack one central point around which enterprises are concentrated.
2. A concentric cluster (the so-called "axis and spokes"), which is characterized by the existence of large enterprises around which a network of suppliers is anchored. Small businesses are often linked to the parent company through the supply chain. Unlike network clusters, large enterprises dominate the relationships between them. Interactions are more about supply links than sharing innovation. Financial and business services are tailored to the needs of dominant enterprises, and the labour market is less flexible than in a network cluster. The advantage and profit of the region depend on the dominant company or industry.
3. A satellite cluster is the clusters that are the spokes for the axis. In such a region, there is a minimum of exchange and cooperation, and most of the links are external production links and other relationships with a large company. Labour markets tend to be business-dependent and have a high degree of migration to and from the cluster. A satellite cluster differs from a coaxial cluster in that enterprises (satellites) located around a large enterprise can start working together independently of the large enterprise.

4. An institutional cluster (anchored around an institution) is dominated by public institutions or non-profit entities (m.in.: research and development laboratories, universities, public administration). These entities attract a group of suppliers focused on meeting their needs and, compared to other types of clusters, play a strongly dominant role. The institutional cluster is primarily oriented inwards, responding to the needs of the parent company.

The second classification concerns the cluster development model. There are four types here, but the Italian model has the features of the network type, and the American model has the features of the concentric type (Gorynia and Jankowska, 2008):

1. The Italian model is characterized by the dominance of specialized small and medium-sized enterprises, the lack of a formalized structure and capital links between the cluster members, and the lack of a separate management structure. It is modeled on the tradition of craft networks and close family relationships based on trust.
2. The Danish model is based on the key role of network brokers, not only identifying potential members, but also undertaking new initiatives aimed at building and expanding an efficient partnership in the cluster structure.
3. The Dutch model is a modified version of the Danish model, exposing the role of cooperation with scientific and R&D institutions in coordinating the work of the network broker and the active policy of the government.
4. The American model is characterized by close cooperation of large enterprises, hierarchically linked to many small and medium-sized enterprises.

The last three classifications refer to the phase of the life cycle, the leaders forming the cluster, and the production and/or service chain (Van Dijk and Sverisson, 2003):

Division of clusters according to the phase of the life cycle:

1. Phase I, also known as embryonic or hatchery, is the initial period in the functioning of the cluster, in which several or a dozen entities begin cooperation in the basic industry, around which cooperative relations are organized, thus achieving common goals. In this phase, more enterprises join the cluster, including entities from the so-called related and supporting sectors.
2. Phase II, called the growth or maturity phase. This is a period when a large number of entities belong to the cluster and its links with the environment are strong. Within the cluster, new entities are created, and the entities

operating in it merge and transform.

3. Phase III, called the decline or transformation phase. This is a period in which the interest of entities in the functioning of the cluster decreases, there is a decrease in connections between cluster participants and a decrease in competitiveness resulting from the aging of the industry around which the cluster has been organized.

In the case of the direction of the forces forming the cluster, we distinguish:

1. Bottom-up approach, i.e., the so-called bottom-up approach, creating cluster structures by groups of enterprises.
2. Top-down approach, i.e. the so-called top-down approach, the creation of cluster structures by regional authorities. Clusters are defined in the form of regional innovation strategies and play the role of a factor causing an increase in the competitiveness of the region.

The last important classification is the division of clusters according to the number of stages of the production and/or service chain, within which we define:

1. Deep clusters, typically covering all stages of the production and/or service chain.
2. Shallow clusters, covering only one or a few stages of the production and/or service chain.

2.3 Analysis of Cluster Policy at the National and Regional Level and Its Perspectives in the Context of Supporting National Key Clusters

Cluster policy in Poland at the national level is based on the integration of various development policies, including industrial, innovative, as well as labour market and education policies. As part of the national cluster policy, special emphasis is placed on supporting National Key Clusters, which are strategically important for the economy. The Ministry of Development identifies these clusters as key growth poles that can contribute to increasing Polish's international competitiveness.

At the national level, cluster policy focuses on supporting innovation and international expansion of clusters. Between 2004 and 2020, cluster policy has evolved, going through different stages. In the initial period (2004-2006) it focused mainly on promoting the idea of clustering and training cluster animators. This was followed (2007-2013) by focusing on supporting the formation and development of clusters through a variety of operational programmes.

The next stage (2014-2020) is the professionalization of cluster management and the

internationalization of National Key Clusters. (European Commission: Executive Agency for Small and Medium-sized Enterprises, Notten, Delponte, Wintjes, Carneiro, Meyborg, Schnabl, Zenker, Amichetti, Stahlecker, and Dosil Mayán, 2019).

At the regional level, cluster policy is closely linked to regional smart specialisation strategies to support innovative sectors specific to a given region. An example is the support for clusters from the biotechnology sector in the Małopolskie Voivodeship or the ICT cluster in Pomerania. At the regional level, it is crucial to adapt support instruments to the specifics and needs of local enterprises, which allows for the construction of more sustainable and effective structures.

In the perspective of the development of cluster policy in Poland after 2020, the documents indicate several key directions (Choiowska-Jackiewicz, Lubos, Łata, Mackiewicz, and Wancio, 2020):

1. Professionalisation of cluster management: Increasing the competences of cluster coordinators and further investing in their development is crucial. The aim is to create highly professional structures that are capable of collaborating both nationally and internationally
2. Support for internationalisation and cross-border cooperation: In the coming years, it is planned to intensify activities related to the internationalisation of clusters to help Polish companies integrate into global value chains. The cluster policy will promote cooperation with clusters in other EU countries and with clusters with a global reach.
3. Integration into regional innovation strategies: Clusters will be a key tool in the implementation of smart specialisation strategies at regional level, which is expected to lead to the development of new industries and technologies in the regions

Thus, cluster policy in Poland is a complex mechanism that combines activities at the national and regional level to support the development of clusters with high economic and innovative potential. Soon, it will be crucial to strengthen international cooperation and further integrate cluster policy with other public policies, such as innovation and industrial policy.

4. Research Methodology

The research methodology and the aim of the article are closely related to the analysis of the dynamics and structure of clusters in Poland, which directly responds to the conclusions from international experience in the field of economic clustering. The article adopts an approach based on two stages of research, which is in line with the practices used in other countries, which use clustering as a tool to increase competitiveness both at the macroeconomic (national) and microeconomic (for individual companies) levels.

The first stage of the study was to verify the relationship between various factors of regional capital, through the analysis of measures of assessing the quality of individual factors and the differentiation of regional capital in different time periods. To assess the stability or variability of spatial differentiation of regional capital in Polish voivodships, the results obtained in three editions of the survey conducted in 2007, 2011 and 2019 were compared.

To determine the degree of similarity or variability in the spatial distribution of regional capital, correlation coefficients between the values of measures obtained for individual voivodships in different years were calculated. A high, positive correlation between the results from the two editions of the study indicates the durability of the spatial differentiation of the analysed regional capital factor in the compared periods. On the other hand, a low correlation, its absence or negative correlation would indicate a significant spatial variability of the structure of regional capital over time.

In the second stage of the research, a comparative analysis was carried out to assess the dynamics of changes in the status of National Key Clusters in different periods. The following structures were compared:

1. Clusters that have maintained their status in subsequent rounds, enabling the identification of stable clusters with high innovation potential.
2. Clusters that have lost status or have not renewed it in subsequent rounds, allowing you to analyze the reasons for churn.
3. New clusters that have obtained the status of National Key Clusters enabling the assessment of new players on the market and their potential impact on the economy.

Verification of the relationship between various factors of regional capital and analysis of measures of assessing the quality of individual factors allows for the assessment of stability and variability of spatial differentiation of regional capital in Poland in different periods. The comparative analysis of the results from three editions of the research (2007, 2011, 2019) allows us to understand to what extent regional resources change and evolve, which is the foundation for the development of clusters.

Thus, the study makes it possible to assess to what extent current cluster structures are rooted in stable regional resources, and to what extent they must adapt to changing economic and innovation conditions.

Comparative analysis of the structures of Key National Clusters in different periods allows to assess the dynamics of change and stability of these structures. The survey makes it possible to assess which clusters have maintained their status and which have not, which is important for understanding which sectors have the greatest potential for innovation and economy.

This analysis allows for the identification of stable clusters and those that have appeared on the market as new players, which responds to the needs of the economy in the context of adaptation to changing market conditions and modern technologies. This answers the main research question concerning the factors determining the maintenance of the status of National Key Clusters.

4.1 Description of the Statistical Methods Used

The obtained values of the synthetic measure and partial measures for individual factors of regional capital, as well as statistical features used as measures of the results of the location of enterprises, are quantitative features expressed on a quotient scale. Therefore, the Pearson correlation coefficient was used to assess the strength of the relationship between them, and the significance test for this coefficient was used to statistically verify the occurrence of the relationship.

The Pearson correlation coefficient, which is a measure of the strength of the correlation relationship between features X and Y, is calculated according to the formula:

$$r_{xy} = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

where i denotes observations; x_i , y_i , and \bar{x} , \bar{y} the values of features X and Y respectively for observations i ; means of features X and Y.

In the test of significance for the correlation coefficient, the null hypothesis assumes the lack of correlation between features X and Y ($H_0: \rho_{XY} = 0$, ρ – the true value of the correlation coefficient in the population) and is verified against the alternative hypothesis about the occurrence of correlation ($H_1: \rho_{XY} \neq 0$). Character test stats:

$$t = \frac{r_{xy}}{\sqrt{1 - r_{xy}^2}} \sqrt{n - 2},$$

where n is the number of observations, has a student's t-distribution with $n - 1$ degrees of freedom (Sobczyk, 2001).

During the presentation of the results of the empirical analysis, the values of the correlation coefficient and the results of the test in the form of threshold levels of significance (p-values) were presented. The null hypothesis of no correlation between traits is rejected for those pairs of traits for which $p\text{-value} < \alpha$. Significance codes (asterisks) are used to present the results of verification (significance assessment) of the relationship at the level of significance 5% (*), 1% (**), and 0.1% (***), marking with the appropriate code those pairs of traits for which the null

hypothesis of no correlation between the traits constituting the pair has been rejected. The dependencies marked with codes are statistically significant at the level of, respectively, 5%, 1% and 1%. When verifying at the 5% materiality level adopted as the baseline, all dependencies marked with any of the codes should be considered material.

5. Research Results and Discussion

To assess the persistence (or variability) over time of the spatial differentiation of regional capital by Polish voivodships, the images of differentiation obtained in three editions of the study were compared: 2007, 2011 and 2019. The high positive correlation between the values of the measure obtained for the community of voivodships in the two compared editions of the survey indicates the similarities of spatial differentiation of the analysed element of regional capital in the compared years. A low correlation, its absence, and even more so a negative correlation would indicate the variability of spatial differentiation of regional capital over time.

The assessment of correlation over time concerns partial measures, representing individual factors of capital, and a synthetic measure, representing a comprehensive measurement of location attractiveness. Comparisons were made for all three possible combinations of measurement points in time (2007 vs 2011 and 2011 vs 2019, representing subsequent editions, and 2007 vs 2019, i.e. a comparison of the outermost editions). The results of the evaluation are presented in Table 1.

The results of the analysis indicate a very high inertia, stability of regional capital over time and a very slow pace of changes in the factors shaping this capital. Correlations between the assessments for different periods are very high and, with one exception, all statistically significant. As for the synthetic measure expressing comprehensive location attractiveness, the correlation coefficient between the different editions turned out to be no lower than 0.94.

Although the dependence is very strong for almost all partial factors, there is some variation between them in terms of the strength of the dependence. Where there is a tendency for some slow, evolutionary changes, it is observed primarily in the comparison of the most distant editions, i.e. 2007 vs 2019. It can be said that factors slightly more susceptible than others to slow changes over time are V6 (labor market) and V8 (costs of doing business), to a lesser extent V3, V5, V9 and V15.

On the other hand, the only factor that is subject to really significant changes over time, significantly changing the regional diversity of its condition in the time horizon corresponding to the period of implementation of the three editions of the survey, turned out to be the V10 factor – the academic base and vocational education. It can be presumed that the state of this factor is most affected by the tools of conscious regional policy and management of innovative development.

Table 1. Assessment of the correlation between the results of the assessment of the state of regional capital at different points in time (2007 vs 2011 and 2011 vs 2019)

Regional capital factor	Comparison of years (of the survey editions)		
	2007 vs 2011	2011 vs 2019	2007 vs 2019
V1 - Sales markets	0,99 (0,000) ***	0,98 (0,000) ***	0,98 (0,000) ***
V2 - Sourcing Markets	0,94 (0,000) ***	0,96 (0,000) ***	0,95 (0,000) ***
V3 - Real Estate Market	0,82 (0,000) ***	0,77 (0,000) ***	0,81 (0,000) ***
V4 - Transport infrastructure	0,99 (0,000) ***	0,96 (0,000) ***	0,95 (0,000) ***
V5 - Information and telecommunication s infrastructure	0,88 (0,000) ***	0,76 (0,001) ***	0,80 (0,000) ***
V6 - Labour market	0,86 (0,000) ***	0,70 (0,002) **	0,65 (0,007) **
V7 - Capital Market	0,97 (0,000) ***	0,98 (0,000) ***	0,93 (0,000) ***
V8 - Costs of doing business	0,84 (0,000) ***	0,82 (0,000) ***	0,72 (0,002) **
V9 - Business Support Institutions Database	0,91 (0,000) ***	0,98 (0,000) ***	0,82 (0,000) ***
V10 - Academic Base and vocational education	0,64 (0,008) **	0,72 (0,002) **	0,44 (0,090)
V11 - Database of research and development institutions	0,99 (0,000) ***	0,96 (0,000) ***	0,97 (0,000) ***
V12 - Quality of Life	0,75 (0,001) ***	0,90 (0,000) ***	0,82 (0,000) ***
Synthetic Meter	0,96	0,94	0,96

	(0,000) ***	(0,000) ***	(0,000) ***
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Source: Author's calculations

The results of the analysis confirm that the spatial differentiation of the quality of regional capital factors is largely shaped by long-term phenomena and is characterized by significant inertia. Despite its high inertia, it is subject to certain changes over time and can be shaped by innovative development management tools, which means that in order to ensure up-to-date knowledge, the image of regional capital diversity should be periodically updated and subject to ongoing monitoring. Identifying certain factors with a slightly higher susceptibility to change, and above all observing changes, allows you to identify key areas in which cluster development can play an important role.

The development of clusters as a tool supporting innovation and competitiveness can contribute to faster adaptation of regions to changing economic conditions. By concentrating resources and knowledge in specific sectors, clusters can effectively exploit more vulnerable factors such as information technology, infrastructure development and human capital to drive economic growth. Regular analysis and updating of data on the state of regional capital allows for better planning of cluster development, considering changing market needs and innovation opportunities.

Observation of changes in the V10 factor, which may be related to the level of innovation or technological potential of the region, indicates the need for continuous monitoring and adaptation of regional development policy to the specific conditions of each voivodeship. In this way, clusters can be more effectively integrated into regional development strategies, maximising their impact on economic growth and increasing their ability to adapt to the challenges of long-term changes in regional capital.

The analysis of changes in key clusters in Poland over six rounds, from 2018 to the current one valid until 2025, shows the evolution and changes in the structure of clusters depending on their specificity and areas of activity. The key findings of the analysis relate to the following areas:

1. Stability of some clusters

Some clusters have maintained their status as National Key Clusters (NKC) for several rounds. Examples: (i) Aviation Valley Cluster: present in each round from I (until 2018) to V (until 2024), which shows its stable position in the Polish aviation industry; (ii) Mazovian ICT Cluster and Polish Construction Cluster: also maintained their status for several rounds, demonstrating the importance of these sectors for the economy.

2. Name and Specialization Changes

Some clusters have undergone changes in nomenclature, which may suggest their

development or a change in terms of specialization. For example: Evoluma Industrial Cluster (formerly Metalworking Cluster) continued its activities with a new name, which may have been due to the expansion of the scope of activities beyond metalworking.

3. Increase in the number of new clusters

In subsequent rounds, new clusters appeared, which proves the development of various sectors. Examples of new clusters include: (i) Silesia Automotive & Advanced Manufacturing, which joined in the fourth round (2022) and then maintained its status in the sixth round; (ii) the Polish Cluster of Composite Technologies and the Cluster of Photonics and Optical Fibres, which received the status in the fifth round (until 2024).

4. Clusters with shorter status

Some clusters have only been granted NKC status for a shorter period, not renewed in subsequent rounds. Examples: (i) the Polish Aluminium Cluster, which had the status only in the first round; (ii) NUTRIBIOMED Cluster, present in the second and fifth rounds, but not continued in the others.

5. Specialization of new clusters

In the sixth round, new specializations appear, which reflect the development of innovative technologies: (i) the Silesian NANO Cluster and the Cluster of Innovative Technologies in Manufacturing show the growing importance of nanotechnology and innovative manufacturing technologies.

6. Continuation of clusters in different sectors

Some clusters from earlier rounds continued their activities in later rounds, which proves their stable development and adaptation to changing conditions. An example may be: (i) LifeScience Kraków Cluster, present since the second round and continuing its activities until the sixth round.

7. Sectoral differentiation

The clusters represent a variety of sectors, from information technology, through aviation, chemicals, automotive, to recycling and new manufacturing technologies. This distribution shows broad support for various sectors of the economy, which is important for the creation of innovative and competitive sectors in Poland.

8. Changes in waste management clusters

The Waste Management and Recycling Cluster has changed its name to the Circular Economy and Recycling Cluster, which indicates adaptation to new trends in the circular economy.

The analysis of cluster changes in Poland over six rounds shows the dynamic development of cluster structures in response to market needs and changing economic trends. Key clusters play an important role in the development of various

sectors, which is reflected in the maintenance of their status and in the emergence of new players on the market, especially in the areas of innovative technologies.

6. Conclusions and Recommendations

The results of the analysis confirm that the spatial differentiation of the quality of regional capital factors in Poland is shaped mainly by long-term phenomena characterized by significant inertia. Despite this inertia, some factors are more susceptible to change, highlighting the importance of tools for managing innovative development, such as cluster policy.

Particular attention was paid to the V10 factor (academic base and vocational education), which shows greater dynamics of change, suggesting that it may be the most susceptible to regional policy actions. The analysis of the status of National Key Clusters (NKC) in 2018-2024 showed the stability of some clusters and the emergence of new players, especially in innovative technologies.

Recommendations:

- Ongoing monitoring and updating of cluster policy – Due to the inertia of most regional capital factors but considering the dynamics of some of them, it is recommended to regularly update cluster policy to adapt it to changing economic conditions and market needs.
- Supporting innovative sectors – In the context of new players in the cluster market, especially in technology, those sectors with the greatest potential for development, especially in research and development (R+D) and cooperation with academia, should be intensively supported.
- Increasing cross-sectoral cooperation – It is recommended to further promote cooperation between enterprises, scientific institutions and public administration, which will contribute to faster adaptation of regions to changing economic and technological conditions.
- Continue to monitor susceptible factors – A key action will be to monitor factors such as the V10 that can most affect cluster growth. In this way, cluster policy can be more flexible and more effective in supporting innovative development.

Thanks to these activities, it will be possible to use the potential of clusters as a tool supporting innovation and regional competitiveness to a fuller extent.

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