

Knowledge-intensive Activities and Regional Inequalities in Poland: A Spatial Centre–periphery Analysis

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Abstract: This paper examines the spatial differentiation of knowledge-intensive activities in Poland within the centre–periphery framework. Contemporary regional development increasingly depends on knowledge-related processes; however, these are unevenly distributed across space. Despite extensive research on the knowledge-based economy, limited attention has been given to the joint spatial patterns of high- and medium-high-technology industries and knowledge-intensive services at lower territorial levels. The aim of the study is to identify the spatial distribution of these sectors and assess their role in shaping regional inequalities. The analysis is conducted at the county (powiat) level using data from the REGON register of the Central Statistical Office. An indirect approach is adopted, treating the sectoral structure of the economy as a proxy for regional knowledge systems. Spatial patterns are examined using descriptive measures and **global Moran's I**. The results reveal a strong concentration of knowledge-intensive activities in metropolitan regions and their functional areas, confirming the persistence of the centre–periphery structure. High- and medium-high-technology industries exhibit stronger spatial clustering, while knowledge-intensive services show greater dispersion but remain concentrated in more developed regions. The findings also indicate increasing spatial autocorrelation over time, pointing cumulative development processes. The study contributes to the literature by integrating sectoral and spatial approaches and demonstrating the usefulness of structural indicators as proxies for knowledge processes at the regional level.

Keywords: Knowledge-based economy, Knowledge processes, Knowledge-intensive services, Spatial differentiation, Centre–periphery, Regional development, Poland

1. Introduction

Contemporary approaches to regional development emphasize the role of knowledge as a key driver of economic growth, innovativeness, and territorial competitiveness. In the knowledge-based economy, regional advantages stem not only from access to traditional production factors but primarily from the ability to create, transfer, and apply knowledge (Lundvall, 1992; Cooke, 2001; Nonaka and Takeuchi, 1995). These processes are systemic and embedded in spatial structures, resulting in their **uneven intensity and effects across regions**.

Numerous studies indicate that knowledge-intensive activities, including high- and medium-high-technology industries and knowledge-intensive services, tend to concentrate in metropolitan regions and more developed areas. This concentration reflects agglomeration advantages such as access to human capital, research and development infrastructure, advanced labour markets, and dense institutional networks (Audretsch and Feldman, 2004; Boschma, 2005; Polèse and Shearmur, 2004). Consequently, the knowledge-based economy contributes to the persistence of the centre–periphery structure.

This issue is particularly relevant for peripheral regions, which are typically characterized by weaker knowledge resources, lower density of economic interactions, and limited access to such activities. These conditions constrain innovativeness, entrepreneurship development, and the formation of more advanced economic structures. **Therefore**, the spatial distribution of knowledge-intensive enterprises reflects differences in regional development potential (Rodríguez-Pose, 2018).

Despite the growing literature on the knowledge-based economy, limited attention has been paid to the spatial differentiation of various segments of these activities at lower territorial levels. Existing research often focuses on R&D, firm-level innovativeness, or general economic structures, while less frequently addressing the joint spatial distribution of high- and medium-high-technology industries and **knowledge-intensive services** within the centre–periphery framework. In particular, there is a lack of studies examining how these two segments reflect the spatial organization of knowledge processes at the local level (Květoň et al., 2022).

The aim of this paper is to identify the spatial differentiation of high- and medium-high-technology enterprises and **knowledge-intensive services** in Poland and to assess their role in **shaping** knowledge processes within the centre–periphery framework. The study adopts an indirect approach, using the sectoral structure of the

economy as a proxy for regional knowledge systems. Specifically, the share of these sectors, defined according to the OECD/Eurostat classification, is used as an indicator of knowledge-intensive activity at the local level.

The analysis is conducted at the county (powiat) level in Poland, enabling the identification of differences between metropolitan and peripheral areas. It is based on statistical data from the REGON register (GUS) and applies spatial analysis methods, including Moran's I, to identify patterns of concentration.

The contribution of this paper lies in integrating sectoral structure analysis with a spatial perspective on knowledge-intensive activities and providing an empirical assessment of their local differentiation. The findings contribute to a better understanding of the concentration mechanisms of knowledge-intensive enterprises and their role in shaping regional inequalities within the centre–periphery framework.

2. Literature Review

2.1 Knowledge-based Economy and the Spatial Dimension of Development

Contemporary concepts of regional development emphasize that knowledge constitutes a key driver of economic growth and territorial competitiveness. In the context of the knowledge-based economy, the importance of traditional resources is **reduced in favour of regions' capacity** to generate, absorb, and utilize knowledge (Noni et al., 2017; Willett, 2020). Within this perspective, a region is understood as a socio-economic system in which development processes result from interactions between firms, public institutions, and the scientific sector (Harmaakorpi and Rinkinen, 2020). This approach is consistent with the concept of regional innovation systems, which highlights the importance of institutional embeddedness of knowledge processes and the quality of linkages among regional actors (Cooke, 2001; Doloreux and Parto, 2005).

An essential element of this perspective is the spatial character of knowledge processes. Knowledge, particularly tacit knowledge, remains strongly embedded in specific territorial contexts, and its diffusion depends on geographical, institutional, and organizational proximity (Wenting, 2008). In this sense, local innovation systems and knowledge spillovers are selective and spatially embedded, with their intensity depending on the density of relationships between actors **as well as** on cognitive and organizational proximity (Breschi and Lissoni, 2001; Boschma, 2005). As a result, the development of the knowledge-based economy is uneven across space, leading to the concentration of innovative activities in selected regions and the emergence of spatial development inequalities (Květoň et al., 2022).

2.2 Knowledge-intensive Enterprises as a component of Regional Economic Structure

Within the analysis of the knowledge-based economy, particular attention is given to enterprises operating in high- and medium-high-technology industries and **knowledge-intensive services**. Both groups constitute important components of the modern economic structure of regions, although they perform different functions in development processes.

High- and medium-high-technology enterprises are associated with advanced production activities and the adaptation and implementation of new technologies. Their operation requires access to specialized labour resources, appropriate infrastructure, and a well-developed institutional environment, which **favours their concentration in more developed regions** (Wachowska, 2014; Murzyn, 2013).

In contrast, knowledge-intensive services encompass activities based on expert competences, information processing, and high levels of qualifications. They play an important role in regional economies by supporting knowledge transfer, enhancing the professionalization of economic activity, and fostering entrepreneurship. Their presence increases the capacity of regions to adapt to technological change and facilitates knowledge diffusion among economic actors, particularly in environments characterized by developed cooperation networks (Alberti and Pizzurno, 2015).

From a regional development perspective, the complementarity of these two segments is of key importance. Industrial enterprises strengthen the technological and production base of a region, while knowledge-intensive services enhance the system's capacity for knowledge diffusion. Their coexistence enables more integrated and knowledge-based development.

2.3 Spatial Concentration of Knowledge-intensive Activities and the Centre–periphery Pattern

The literature indicates that knowledge-intensive activities tend to concentrate in metropolitan regions and growth centres. This results from agglomeration effects such as access to human capital, the presence of

research and development institutions, and well-developed networks of economic linkages (Noni et al., 2017; Willett, 2020).

A consequence of these processes is the spatial polarization of development, manifested in the centre–periphery structure. Core regions attract **such activities** and accumulate development resources, whereas peripheral areas remain less integrated into knowledge-based processes (McCann, 2015). This implies that knowledge flows are selective and depend on the absorptive capacity of regions as well as on the quality of their institutional environment (Cohen and Levinthal, 1990).

It is also important to note that different segments of these activities may exhibit distinct spatial patterns. High- and medium-high-technology industries tend to be more strongly concentrated within specific production and technological systems, whereas knowledge-intensive services may display greater locational flexibility, although they also tend to concentrate in regions with high availability of human capital.

The analysis of these phenomena increasingly relies on spatial statistics tools, such as Moran's I, which enable the identification of clusters of high and low values and the assessment of the degree of spatial concentration of economic activities (Polèse and Shearmur, 2004). This approach allows for a better understanding of the mechanisms underlying the location of knowledge-intensive enterprises and their role in shaping regional inequalities.

3. Methodology

The aim of the empirical part of the study is to identify the spatial differentiation of knowledge-intensive activities in Poland and to determine their distribution within the centre–periphery framework. An indirect approach was adopted, assuming that the sectoral structure of the economy may serve as an empirical proxy for knowledge processes at the regional level.

This study is based on secondary data analysis using aggregated statistical data obtained from the REGON register of the Central Statistical Office (GUS). The use of secondary data allows for a consistent and comparable assessment of the sectoral structure of the economy across all counties in Poland. However, it also implies certain limitations, as the analysis is based on structural indicators rather than direct measures of innovation or knowledge creation processes.

The analysis was conducted at the level of counties (powiats) in Poland, allowing for the identification of spatial differences between metropolitan areas and peripheral regions. This unit of analysis ensures a relatively high level of detail while maintaining the availability of comparable statistical data.

The study applies a sectoral classification based on the OECD and Eurostat methodology (OECD, 2011; Eurostat, 2020), which takes into account the intensity of technology and knowledge. On this basis, two main groups of activities were identified:

- high- and medium-high-technology manufacturing enterprises (HMHT),
- knowledge-intensive services (KIS).

Both groups were treated as indicators of knowledge-intensive activity at the regional level. HMHT enterprises primarily reflect the presence of advanced technological and production activities, while KIS indicate the development of functions related to knowledge transfer, information processing, and support for economic processes.

To operationalize the analysed phenomena, structural indicators were used, defined as the share of enterprises belonging to the identified sectors in the total number of economic entities registered in the REGON system. This approach ensures spatial comparability and allows for the identification of differences in the economic structure at the local level. The empirical analysis was conducted in two stages. In the first stage, changes in the sectoral structure of the economy in Poland between 2010 and 2023 were analysed, allowing for the identification of transformation trends in knowledge-intensive activities. In the second stage, the spatial distribution of HMHT and KIS enterprises was examined using cartographic methods and sectoral share indicators at the county level.

To deepen the analysis, the global spatial autocorrelation statistic Moran's I (Moran, 1950) was applied.

Moran's I was selected because it allows for the identification of global spatial patterns and clustering tendencies in regional economic structures. This measure makes it possible to assess whether similar values of

the analysed variable tend to occur in neighbouring territorial units. It enables the identification of the degree of spatial ordering of the analysed phenomena and the assessment of their concentration.

Formally, Moran's I statistic is expressed as:

$$I = \frac{n}{W} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

where:

n – number of spatial units,

x_i, x_j – values of the variable in units i and j ,

$\bar{x}$ – mean value of the variable,

w_{ij} – elements of the spatial weights matrix,

$W = \sum_{i=1}^n \sum_{j=1}^n w_{ij}$ – sum of all spatial weights.

A key element of the analysis is the spatial weights matrix, which defines the neighbourhood structure between spatial units. In this study, a contiguity-based weights matrix was applied, in which $w_{ij} = 1$ indicates that units i and j are neighbours, while $w_{ij} = 0$ otherwise. Positive values of Moran's I indicate positive spatial autocorrelation, meaning a tendency for similar values to cluster in space. Negative values indicate negative autocorrelation (spatial contrasts), while values close to zero suggest no significant spatial dependence.

4. Results

4.1 Sectoral Structure as a Manifestation of Knowledge-intensive Activities

The analysis of changes in the sectoral structure of the Polish economy indicates a gradual increase in the importance of knowledge-intensive activities in the period 2010–2023. In particular, a significant rise in the share of knowledge-intensive services was observed, accompanied by a decline in the share of less knowledge-intensive services. These changes are presented in Table 1.

Table 1: Changes in the structure of enterprises by knowledge and technology intensity in Poland (2010–2023)

Year/Change	Low-technology industry (LT)	Medium- and high-technology industry (HMHT)	Less knowledge-intensive services (LKIS)	Knowledge-intensive services (KIS)	Agriculture (AGR)
2010	20.8%	0.8%	45.4%	30.6%	2.4%
2023	22.0%	0.7%	38.0%	37.9%	1.4%
Change	+1.2 pp	–0.1 pp	–7.4 pp	+7.3 pp	–1.0 pp

Source: Own elaboration based on GUS data.

The data presented in Table 1 indicate that the share of knowledge-intensive services increased from 30.6% to 37.9%, representing a rise of 7.3 percentage points. At the same time, the share of less knowledge-intensive services declined by 7.4 percentage points. These changes reflect broader economic transformation processes typical of developed economies, where knowledge-intensive sectors are becoming increasingly important.

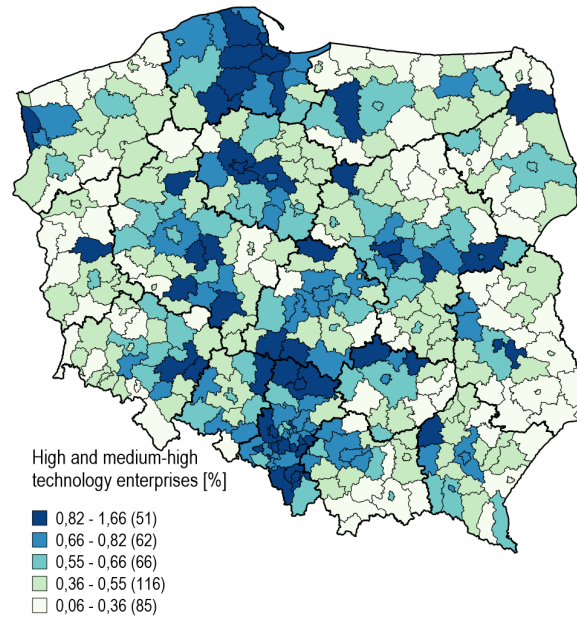
At the same time, the share of medium- and high-technology industry remains relatively low and shows no significant change, suggesting persistent structural limitations in the development of advanced technological and manufacturing activities.

From the perspective of the overall economic structure, this pattern indicates an asymmetric development of knowledge-intensive activities, service sectors are expanding more dynamically than industrial ones. This may point to the growing importance of knowledge diffusion and service-oriented functions in the economy, accompanied by a limited development of an advanced production base.

Consequently, the transition towards a knowledge-based economy appears to be incomplete and uneven, with its development being selective and concentrated primarily in activities requiring the absorption and processing of knowledge.

4.2 Spatial Differentiation and the Centre–periphery Pattern

The spatial analysis reveals clear regional disparities in the concentration of knowledge-intensive activities. Medium- and high-technology sectors are primarily concentrated in large urban centres and their functional areas. The spatial distribution of these enterprises is presented in Figure 1.

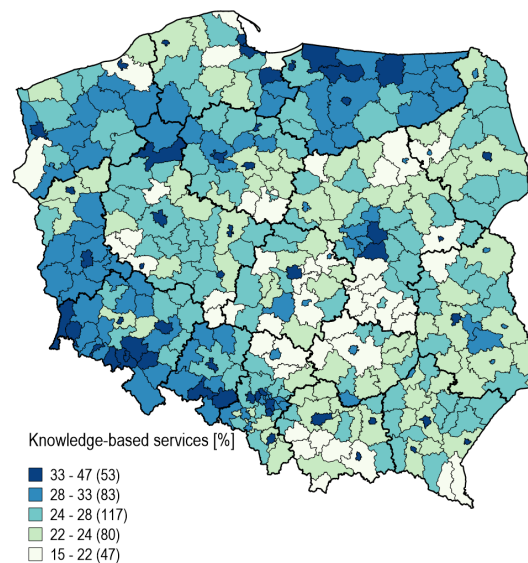


Source: Own elaboration based on GUS data.

Figure 1: Share of high- and medium-high-technology enterprises in total enterprises across Polish counties (2023)

The spatial pattern shown in Figure 1 indicates a clear concentration of technologically advanced activities in metropolitan regions such as Warsaw, Kraków, Wrocław, and Poznań. These areas are characterized by a high level of human capital, well-developed infrastructure, and a favourable institutional environment, all of which support the location of advanced technological activities.

A similar pattern can be observed for knowledge-intensive services (Figure 2), although their spatial distribution is more dispersed. This suggests greater locational flexibility and the ability of these activities to operate beyond major metropolitan centres.



Source: Own elaboration based on GUS data.

Figure 2: Share of knowledge-intensive services in total enterprises across Polish counties (2023)

A comparison of Figures 1 and 2 shows that industrial activities with higher technological intensity exhibit stronger spatial concentration than knowledge-intensive services. These differences result from distinct locational determinants of the two segments of the economy.

The observed pattern corresponds to the classical centre–periphery structure, in which central regions act as the main poles of concentration of knowledge-intensive activities, while peripheral areas are characterized by a lower share of these sectors and a less diversified economic structure.

From a regional development perspective, this indicates that such activities are strongly linked to the availability of resources , infrastructure, and the quality of the institutional environment, leading to the persistence of spatial development disparities.

4.3 Spatial Autocorrelation of Knowledge-intensive Activities

To further explore the spatial patterns, the global Moran’s I statistic was applied to assess the degree of spatial concentration of the analysed phenomena. The results indicate the presence of clear spatial patterns in the distribution of knowledge-intensive activities. The values of the statistic are presented in Table 2.

Table 2: Global Moran’s I statistics for sectors by knowledge and technology intensity in Poland (2010 and 2023)

Year	LT	HMHT	LKIS	KIS	AGR
2010	0.301	0.351	0.361	0.244	0.363
2023	0.298	0.381	0.288	0.310	0.386

Source: Own elaboration using GeoDa.

Note: positive values of Moran’s I indicate positive spatial autocorrelation.

Positive values of Moran’s I indicate a tendency for similar levels of development knowledge-intensive activities to cluster in neighbouring territorial units. This implies the existence of clusters of high values in developed regions and clusters of low values in peripheral areas.

The obtained values indicate a moderate level of spatial autocorrelation, suggesting a significant but not complete level of spatial concentration.

This suggests that the spatial concentration of knowledge-intensive activities is strengthening over time, implying that regions with initially higher levels of such activities tend to reinforce their advantage. This pattern is consistent with cumulative causation mechanisms observed in regional development.

In particular, the increase in Moran’s I for knowledge-intensive services from 0.244 to 0.310 suggests a strengthening of spatial concentration processes in this sector. Similarly, the increase in the index for medium- and high-technology industry (from 0.351 to 0.381) confirms the intensification of agglomeration tendencies in technologically advanced activities.

These results are consistent with the visual patterns presented in Figures 1 and 2, reinforcing the interpretation **their spatial concentration..**

Overall, the findings indicate that the development of these sectors is uneven and selective, with knowledge-intensive activities concentrating in specific areas, thereby reinforcing their competitive advantages. At the same time, lower levels of knowledge-intensive activity persist in peripheral regions, confirming the durability of existing spatial disparities.

5. Discussion

The results indicate that knowledge-intensive activities in Poland exhibit a clearly differentiated spatial pattern and are primarily concentrated in metropolitan regions and their functional areas. This confirms the existence of a centre–periphery structure, in which central regions act as the main poles of concentration of high- and medium-high-technology enterprises and knowledge-intensive services, while peripheral areas remain relatively weakly integrated into knowledge-based processes. These findings are consistent with the literature on regional innovation systems and the knowledge-based economy, which emphasizes the role of institutional conditions, human capital availability, and the density of relational networks in shaping the location of

knowledge-intensive activities (Harmaakorpi & Rinkinen, 2020; Noni et al., 2017). Metropolitan regions offer favourable environments for technologically advanced firms and knowledge-intensive services, leading to the accumulation of these activities and the reinforcement of their competitive advantages.

At the same time, the analysis reveals significant differences between the examined segments of the economy. High- and medium-high-technology enterprises show stronger spatial concentration due to their dependence on specialized infrastructure, technological facilities, and linkages with research and development activities, whereas knowledge-intensive services demonstrate greater locational flexibility, although they also tend to concentrate in more developed regions. These differences highlight the distinct nature and spatial determinants of both segments. An important conclusion is the asymmetric character of structural transformation: the growing importance of knowledge-intensive services, combined with the stagnation of medium- and high-technology industry, indicates the dominance of service-oriented and diffusion functions over technologically advanced production. This suggests that the development of the knowledge-based economy in Poland is driven more by the capacity to absorb and utilize knowledge than by its generation within advanced industrial activities.

The spatial autocorrelation analysis further confirms that knowledge-intensive activities are not randomly distributed but exhibit a clear tendency toward spatial clustering. The presence of high-value clusters in developed regions and low-value clusters in peripheral areas points to cumulative development processes, reinforcing existing regional disparities. This observation is consistent with cumulative causation mechanisms described in regional development theory. The findings also indicate that the spatial distribution of knowledge-intensive activities is strongly influenced by the availability of human capital and institutional resources, as regions with better access to these assets are more capable of attracting and sustaining such activities, while peripheral regions face structural barriers limiting their development potential.

From a regional development perspective, the results suggest that the location of knowledge-intensive enterprises depends on institutional quality, resource availability, and the ability to participate in economic and technological networks. Therefore, policy interventions should not focus solely on strengthening existing growth centres but also on enhancing the development potential of peripheral regions. Key priorities include human capital development, improved infrastructure accessibility, and the strengthening of linkages between firms, research institutions, and public organizations. In conclusion, knowledge-intensive activities represent a key factor differentiating regional development, and their spatial concentration contributes to the persistence of the centre–periphery structure, making an understanding of these mechanisms essential for designing more balanced and inclusive development policies.

6. Conclusions

The analysis confirms that knowledge-intensive activities in Poland exhibit a clearly differentiated spatial pattern and are strongly concentrated in metropolitan areas and their functional hinterlands. The distribution of high- and medium-high-technology enterprises and knowledge-intensive services reflects a persistent centre–periphery structure, with central regions playing a dominant role in the knowledge-based economy. Peripheral regions are characterized by a limited presence of knowledge-intensive activities and a less diversified economic structure, which reduces their capacity to participate in knowledge-based development processes and constrains the emergence of more advanced economic functions.

The findings also demonstrate that different segments of knowledge-intensive activities are shaped by distinct spatial determinants. High- and medium-high-technology enterprises exhibit stronger spatial concentration, while knowledge-intensive services show greater locational flexibility, although they also tend to concentrate in more developed regions. Moreover, the results confirm the existence of significant spatial dependencies, as indicated by positive values of Moran's I , suggesting that these activities follow a cumulative and clustering pattern in which more developed regions attract and reinforce such activities, while peripheral areas remain outside the main zones of concentration.

The study also indicates that the availability of human capital and institutional resources plays a crucial role in shaping the spatial distribution of knowledge-intensive activities. The contribution of this paper lies in demonstrating that the sectoral structure of the economy can serve as a useful proxy for analysing the spatial differentiation of such activities. The integration of structural and spatial approaches provides deeper insight into the mechanisms of concentration of knowledge-intensive enterprises and their role in shaping regional inequalities.

From a policy perspective, the findings highlight the need for targeted interventions aimed at strengthening the development potential of peripheral regions. Key priorities include human capital development, improving infrastructure accessibility, and fostering linkages between enterprises, research institutions, and public organizations. Such measures may enhance the ability of regions to attract knowledge-intensive activities and reduce spatial disparities.

However, the study has several limitations. The applied indicators are indirect and based on the sectoral structure of the economy, which does not allow for a direct assessment of innovativeness. In addition, the use of global Moran's I does not capture local spatial patterns. Future research should therefore incorporate local measures of spatial autocorrelation, spatial regression models, and qualitative approaches to better understand the mechanisms underlying knowledge-intensive activities in regions.

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