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Article

Assessing the Level of Innovation of Poland from the Perspective of Regions between 2010 and 2020

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Abstract: The growing and expanding zone of the free-market economy results in increasing competition in the global market, which leads companies to seek and implement solutions that will give them a competitive advantage. The authorities of countries and regions are also increasingly involved in this process, seeing it as an opportunity to develop and build a knowledge-based economy. One of the main factors improving competitiveness and providing opportunities for development is innovation, particularly developed at the local level. For this reason, activities that support research and development of innovation at the regional level are increasingly appreciated and gain greater importance. This article refers to regional innovation in Poland by analyzing its level between 2010 and 2020. The basis of the analysis was 15 selected indicators characterizing three dimensions related to the innovative development of regions, namely innovative capacity, innovative position, and economic development. This assessment was regarded as a multi-criteria problem, for which the CODAS method was used. Its application made it possible to achieve the main objective of this paper, which was to determine the level of innovation of studied regions and, on this basis, to create their ranking. In addition, the evaluation of the level of innovation of the regions for each of the analyzed dimensions was also carried out, and the relationship between the level of economic development and the capacity and innovative position of the regions was specified. The measure for evaluating the level of innovation, for each case studied, was the value of the H_i index, taken as a synthetic measure of regional innovation. The results show that the level of innovation for the regions in Poland varies widely as a function of time as well as the location of these regions. Differences in the dynamics of change and different levels of development of the analyzed dimensions characterizing innovation are evident. The results provide new knowledge in the field of regional development and should be used when creating a regional development strategy for individual regions, Poland, and the EU.

Keywords: innovation; regional development; economic growth; open innovation; CODAS method

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1. Introduction

The main factors determining the economic growth of individual countries and regions in recent decades are Science, Technology and Innovation (STI) [1–3]. In the free-market global economy, these factors have a key impact on the competitiveness of companies from these countries and regions. Of particular importance in this case is regional innovation, defined as the ability and motivation of the economy to continuously seek and put into practice scientific research, new concepts, ideas, and inventions [4,5]. Additionally, the linking element between the factors indicated is knowledge, which is the basis for the development of an innovative economy. This is particularly important for the development of regions where economic activity is carried out in practice, and its innovativeness determines the development of these regions. The level of innovativeness of the region is determined by the innovation system, consisting of the scientific, technical and production subsystems, institutional arrangements and the relationship between them [6,7]. Due to

the number of participating entities, the degree of complexity, as well as the multiplicity of economic, social and economic phenomena accompanying the process of building an innovative economy, this system is very complex. Therefore, it can be said that the development of a regional and innovative economy involves processes of social and economic transformation that take place in the regional space on many levels. They include economic, social, environmental and cultural issues, which are interrelated by numerous interdependencies [8].

The importance of regional development in the modern economy is evidenced by its extensive inclusion in the EU policy [9–12]. According to the assumptions of this policy, member states should strive to eliminate regional differences in economic development, which should be primarily based on the development of innovation. Here, innovation is treated as a fundamental factor in the growth and economic development of regions. The main tasks of this policy are to promote job creation, build competitiveness and economic growth, improve the quality of life, and implement the idea of sustainable development. These processes are implemented through a number of programs and initiatives, the priorities and activities of which are co-financed by structural funds. The European Union (EU) has a very broad regional policy, the purpose of which is to level the development opportunities of all regions and create favorable conditions for this development.

Despite the efforts made and the costs incurred by central and local authorities, the development levels of individual regions in the EU and in Poland show very large economic and innovation differences [13,14].

These differences are caused by a combination of very many technological, economic, organizational and social factors [15]. This state of affairs applies to virtually all EU countries, including Poland, where, in accordance with the EU policy, activities are being carried out to build an innovative knowledge-based economy. Accession to the EU and the creation of a competitive free market economy have resulted in the increasing importance of regional innovation development in Poland. It is increasingly accepted that innovation, in addition to entrepreneurship, is the basis for building a competitive advantage and provides an opportunity for economic growth and development [16].

When considering the role of regions in generating innovation and economic growth, it seems reasonable to study the level of innovative development, search for instruments for quantitative measurement of innovation performance and develop methodology for objective assessment of innovative development of regions.

To date, the issues of studying the innovativeness in the regions of countries have concerned China [17–20], Japan [21,22], Spain [23], Russia [24], Australia [25] and Germany [26,27], among other places. In the case of Poland, on the other hand, the re-search to date has only covered issues related to the impact of human capital associated with the innovation of regions [28], as well as assessing the innovativeness of Peripheral Regions of Eastern Poland [29] or its impact on Growth and Stagnation Regions in Poland [30]. In turn, one study [31] assessed the partial innovativeness of the regions of Poland for specific dimensions (innovation activities, impact, framework conditions, investment). However, it did not cover the overall level of innovation, taking into ac-count these dimensions. Thus, there is a noticeable research gap in the study of the overall level of innovation of Polish regions. Admittedly, there are national reports on the innovativeness of regions [32], which can be treated as supporting literature for a deeper study of the issue in question.

Therefore, conducting such studies, in the context of the need to adapt to EU requirements related to energy and climate transition and sustainable development becomes fully justified. Especially since it is in the regions, i.e., the local environment, that the main part of the country's economic activity is carried out by micro, small and medium-sized enterprises. Thus, the development of regional entrepreneurship and innovation to build a competitive economy is an important factor in the economic development of the country and the EU.

With regard to this extremely important and topical problem, a comprehensive study was performed, the main objective of which was to assess the level of innovation of regions

(voivodeships) in Poland between 2010 and 2020. This assessment was carried out on the basis of indicators characterizing three dimensions of regional innovation: innovative capacity, innovative position and economic development.

The MCDM approach was applied to the research, using the CODAS method. The evaluation of the innovative development of regions in Poland was made on the basis of 15 selected indicators, characterizing this development in three basic dimensions: innovative capacity, innovative position and economic development. By adopting a 10-year time horizon for the study, it was also possible to trace changes taking place in the studied regions and its dynamics.

Relative to the existing studies, the research carried out makes an important scientific and utilitarian contribution. First of all, it refers to the regions of one of the largest EU countries and innovation, a key economic area that determines the future of the entire EU. Despite the relevance and timeliness of this topic, such a comprehensive study has not yet been undertaken. Thus, it becomes legitimate to fill the resulting research gap and complete the state of knowledge in this area.

An important factor testifying to the novelty of the presented research is the inclusion of a set of 15 indicators, characterizing the innovative development of Polish regions in three dimensions: innovative capacity, innovative position, and economic development. Such a broad approach to the research provides the possibility of obtaining reliable findings. The approach to assessing the regional level of innovative development, using the CODAS method, as one of the latest methods belonging to the MCDM group, should also be treated as novel. The use of this method made it possible to determine the value of a synthetic, universal index (H_i) of innovative development of regions based on the adopted sub-indices. The analysis of the value of this index allows a transparent and clear assessment of the innovativeness of the studied regions, and the determination of changes in this innovativeness during the analyzed period. Thus, the value of this index facilitates the interpretation of the results obtained and the determination of change trends.

Another significant factor testifying to the originality of the research conducted is the adoption of a 10-year time horizon, which makes it possible to trace changes in terms of the level of regional development in Poland. Such a long period of research also makes it possible to trace changes in individual dimensions characterizing innovation, which can be used, for example, to build strategies for the economic development of these regions, leveling up and identifying the reasons for such a state.

In addition to an overall, general assessment of innovative development, the analysis is supplemented by an assessment of individual regions of Poland in the three studied dimensions that make up this development: innovative capacity, innovative position and economic development. In addition, this analysis was supplemented by the determined statistical correlations between these dimensions, which should also be considered a new approach to the issue in question.

Therefore, it can be concluded that both in terms of the subject and object of research, the methodology developed and applied, and the results obtained, this study represents a new approach to the assessment of regional innovation.

2. Background and Literature Review

2.1. Background

In the EU, supporting regional innovation is a strategic objective formulated in, among others, the Lisbon Strategy, the Europe 2020 Strategy, the Competitiveness and Innovation Framework Program and the EU regional policy, which define the criteria and procedures for supporting the pro-innovative development of regions [33,34].

These strategies and the entire EU policy assume that economic development should be based on three pillars: the development of an economy based on knowledge and innovation (smart development), an economy that uses resources efficiently (sustainable development) and employment and social cohesion (inclusive development). An important element of building an innovative economy, within the framework of smart development, is the

identification, selection and building of smart specializations both at the level of regions, countries and the entire European economy.

Therefore, the framework for innovation policy pursued and implemented in Europe in recent years is based on the concept of smart specialization developed by Foray and Goenag [35] and Foray et al. [36,37]. The smart specialization approach [38] states that innovation policy should be embedded in the local context. It must therefore be based on local specificities in R&D and production activities that are important for the development of individual regions over the long term. Achieving economic growth and wealth (prosperity) is possible by focusing and building on regions' strengths and local knowledge resources.

Thus, there has been an evolution in the EU policy in the concept of supporting the development of innovation. It has moved from the development and activity of the R&D sector and increased internationalization, and the use of public governance mechanisms toward building smart specialties based on market mechanisms for the creation, dissemination, and adaptation of technological change [39].

These changes are crucial for the current and past economic development of the EU, including Poland. This is because they decisively shift the emphasis toward smart specialties adequate to the potential, resources and opportunities and traditions of a given region. This approach confirms the validity of this research undertaken. After all, the assessment of regional innovation should provide new knowledge in this area, enable the evaluation of regions and support pro-development activities in this area. That is why the construction of regional development strategies based on regional smart specialties should consider the findings of the research presented in this paper.

2.2. Literature Review

The link between innovation and regions is widely documented in the literature, especially in terms of the regional dimension of innovation processes and their multidimensionality.

This is because the region has ceased to be perceived only as a location of economic activity and is treated as an incubator of innovation and an essential element for the occurrence of innovation absorption and diffusion processes. It has become a very important area of the organization of the economy, a place for the creation of knowledge and innovation and technological capabilities of entities. This is because innovation makes it possible to build the competitive advantage of regions, ensuring the development and prosperity of entire countries. Innovation, on the other hand, makes it possible to transform existing capabilities and resources into new ideas that can be successfully implemented.

Regions, wishing to improve (develop) their innovativeness, invest in knowledge, science, higher education and the entire research and development sector. The effects of such activities are, of course, spread over time, but with good organization and management, they can guarantee their long-term and effective development [40].

Therefore, regional innovation should be understood as a region that creates a climate of innovative behavior of entities of the production and service spheres, as well as local government units, and at the same time encourages local communities to become actively involved in this process. It must also have R&D potential ready to conduct scientific research, cooperate with various entities and implement the results of scientific research into the economy [41].

The role and importance of the regional dimension in the context of innovative development is widely known and appreciated [42–44]. This is because the innovativeness of a region affects its economic growth, which determines the economic growth of the country as a whole [45].

Innovation is also considered a geographically limited phenomenon that occurs (arises) within the regional innovation system [46]. Therefore, in the innovative development of regions, an extremely important role is played by the stakeholders (participants) in this process and the connections taking place between them [27,47]. On the other hand, the geographical proximity between innovations affects their easier implementation and the occurrence of synergistic effects [48]. Regional capacity for innovation creation is primarily

related to research and development activities and access to knowledge resources. On the other hand, the generation of new knowledge and innovation creation depend on individuals and the interactions between them [49–51].

It is also very important to state that regional characteristics and the openness of institutions to the introduction of new ideas play a key role in the success of innovation activities [52,53].

Many works also point out that many social, economic, organizational and technological factors influence differences in regional innovation. These are related to, among other things, the degree of industrialization of regions [54–56], the distribution of human capital [28], and knowledge transfer and financial support [57]. Additionally, other important factors are access to new technologies, operational resources, and attitudes of human resources toward innovation and entrepreneurship, as well as access to institutions supporting innovation [58].

The multifacetedness, interdisciplinarity and complexity of innovation processes are therefore very widely reflected in the publications presented. That is why it is reasonable to take into account this multidimensionality also in the research presented in this paper.

Many works also deal with the measurement of the level of innovation. Most frequently, for this purpose, various synthetic measures are used, which are the result of combining, according to a specific algorithm, various values of selected parameters (indicators).

This approach, involving the determination of a composite innovation index, was first introduced at the micro level by Hollenstein [59], who developed a composite measure of a company's innovation using factor analysis and a set of selected variables. In recent years, at the macro level, composite indicators, taking into account various factors, are used to measure and compare the innovativeness of countries/regions [60]. The most comprehensive indicator for measuring countries' innovation is the Global Innovation Index (GII), developed jointly by INSEAD, World Intellectual Property Organization (WIPO) and Cornell University [61]. In the EU, the European Innovation Scoreboard (EIS) is used to measure innovation at the country level, and the Regional Innovation Scoreboard (RIS) [62] is used to measure regional innovation. The RIS indicator focuses on measuring the innovation of a particular region in the context of all regions in the EU countries. These indicators are calculated as the unweighted average of the rescaled scores for all indicators where all indicators receive the same weight. It is difficult to assess the level of innovation of regions in a country on its basis.

In recent years, a different approach has also been used to measure innovation, based on new metrics that take into account various factors and data, as well as modern analytical tools. This approach is due to the availability of data and the complexity of the problem of measuring innovation. Thus, Szopik-Depczyńska et al. [14] used a measure based on the multi-criteria taxonomy to measure the innovativeness of regions in the EU countries. In turn, Zemstov and Kotsemir [63], Firsova and Chernyshova [64], Chen and Guan [65] used an approach based on DEA methods to measure the level of innovativeness. Additionally, Garcia-Bernabeu et al. [23] used the Multiple Reference Point-based Weak and Strong Composite Indicators approach.

The cited selected works show how complex and interesting the problem of determining the innovativeness of a region or a country is. With regard to the results of the presented works and the lack of a comprehensive analysis of regional innovativeness in Poland, it was assumed that in this paper the CODAS method (belonging to the group of MCDM methods) will be used to evaluate regional innovativeness. This is a relatively new method designed for multi-criteria analysis and has not yet been used to study innovation. This new approach, additionally based on 15 selected indicators characterizing the most relevant areas related to the innovativeness of regions, should provide new knowledge regarding the evaluation of these regions.

3. Materials and Methods

The section discusses the data used for the study and describes its source, as well as the CODAS method used for the analysis. The developed method of classifying the studied regions in terms of their innovativeness is also presented.

3.1. Data

The analysis presented here uses data (indicators) that are contained in the Local Data Bank [66]. A set of 15 indicators that characterize the regions of Poland in terms of innovation capacity, innovation position and economic development was used for the study (Table 1). The set of indicators was the author's choice, resulting from the analysis of the literature and the availability of data. Thus, in order to analyze the differences in regions in Poland in terms of the level of innovative development, a set of indicators was adopted relating to human capital, financing of R&D activities, activity of enterprises in the sphere of innovation, protection of intellectual property, regional wealth and labor activity, as well as economic efficiency of enterprises. The selection of indicators was also intended to make it possible to assess the diversity of the level of innovation of the regions and determine which of them have problems with the development of innovation, and which of them achieve very good results in this process.

Table 1. Characteristics of indicators (diagnostic variables) adopted for the study.

Area	Indicator	Marking	Direction of Impact
Innovation capacity of the region	R&D expenditures, in relation to % of GDP	X1	+
	Business sector R&D expenditures, in relation to % of GDP, %	X2	+
	Employed in R&D per 1000 economically active people	X3	+
	University graduates per 10,000 population	X4	+
Innovation position in the region	Average share of innovative enterprises in the total number of enterprises	X5	+
	Service enterprises that introduced an innovative solution	X6	+
	Industrial enterprises that have introduced an innovative solution	X7	+
	Share of net revenues from sales of innovative products in total net revenues from sales, %	X8	+
	Patent applications	X9	+
	Patents granted	X10	+
Economic development of the region	GDP per capita, PLN	X11	+
	Average gross monthly wages and salaries, PLN	X12	+
	Unemployment rate, %	X13	-
	Number of registered business entities per 10 thousand residents	X14	+
	Entities with foreign capital per 10 thousand residents	X15	+

The indicators adopted for analysis, covering data from 2010 to 2020, are also diagnostic variables. The study uses a dynamic approach, which allows comparisons to be made between the values of variables for different periods, not only relative to the other objects of the study (i.e., regions-voivodships), but also relative to time.

The set of 15 indicators presented in Table 1 formed the basis for further analysis, on the basis of which the differences in innovative development of individual regions were assessed and their ranking was created.

Units of administrative division of Poland (16 in total) called voivodeships were adopted as regions. Since 1990, they have been units of basic territorial division of government administration, and since 1999 they have also been units of local self-government. Their location and names are shown in Figure 1.

Figure 1. Administrative division of Poland with names of voivodships (studied regions) (own elaboration).

3.2. Methods—COmbinative Distance-Based Assessment Method

The combinative distance-based assessment method (CODAS), developed by Keshavarz Ghorabaee et al. in 2016 [67], belongs to the MCDM method group and uses a combinational form of measuring two distances: Euclidean and Taxicab distances, which are used to evaluate alternatives. The algorithm of the research procedure in this method consists of eight basic steps:

1. To construct an assessment matrix:

$$X = \left[x_{ij}\right]_{n\times m} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

where x_{ij} $\left(x_{ij} \geq 0\right)$ denotes the performance value of the i-th alternative in the j-th evaluation criterion $(i \in \{1, 2, \ldots, n\}\ and\ j \in \{1, 2, \ldots, m\})$.

2. To calculate a normalized decision matrix:

$$n_{ij} = \begin{cases} \frac{x_{ij}}{\max\limits_{i} x_{ij}}\ if\ j \in N_b \\ \frac{\min\limits_{i} x_{ij}}{x_{ij}}\ if\ j \in N_c \end{cases} \quad (2)$$

where: N_b and N_c represent the criteria for evaluating benefits and costs.

3. To calculate a weighted normalized decision matrix:

$$r_{ij} = w_j n_{ij} \quad (3)$$

where w_j $\left(0 < w_j < 1\right)$ denotes the weight of the j-th criterion for evaluating alternatives, and $\sum_{j=1}^{m} w_j = 1$.

4. To determine a negative-ideal solution:

$$ns = \left[ns_j\right]_{1\times m} \quad (4)$$

$$ns_j = \min_{i} r_{ij} \quad (5)$$

5. To determine the Euclidean and Taxicab distances, as alternatives from the negative-ideal solution:

$$E_i = \sqrt{\sum_{j=1}^{m} \left(r_{ij} - ns_j\right)^2} \tag{6}$$

$$T_i = \sum_{j=1}^{m} \left|r_{ij} - ns_j\right| \tag{7}$$

6. To determine a relative evaluation matrix

$$Ra = [h_{ik}]_{n \times m} \tag{8}$$

$$h_{ik} = (E_i - E_k) + (\psi(E_i - E_k) \times (T_i - T_k)) \tag{9}$$

where: $k \in \{1, 2, \ldots, n\}$, and ψ denotes the threshold function for recognizing the equality of Euclidean distances of two alternatives. The threshold function ψ is determined from the following relation (10):

$$\psi(x) = \begin{cases} 1 \; if \; |x| \geq \tau \\ 0 \; if \; |x| < \tau \end{cases} \tag{10}$$

In this Equation (10), τ is a threshold parameter, the value of which is set by the decision maker. Suggested values of this parameter range from 0.01 to 0.05. If the difference between the Euclidean distances of two alternatives is less than τ, the two alternatives are also compared by the Taxicab distance. In the presented research, the value of τ = 0.02 was used for calculations.

7. To calculate the result of the evaluation of each alternative:

$$H_i = \sum_{k=1}^{n} h_{ik} \tag{11}$$

The H_i index value determined for each region will be taken as a measure of that region's degree of innovation.

8. To rank alternatives according to decreasing evaluation values—ranking of alternatives.

In the CODAS method, as in any of the MCDM methods, there is no detailed classification of objects. Therefore, to carry out such a classification, two basic parameters of the taxonomic measure were used, which are the arithmetic mean and standard deviation. To evaluate the studied regions (voivodeships) in Poland in terms of their innovativeness, the following class ranges were distinguished:

(1) Class I—low level—leading innovation:

$$H_i \geq \overline{H_i} + s_{H_i} \tag{12}$$

(2) Class II—medium-high level—strong innovation:

$$\overline{H_i} + s_{H_i} > H_i \geq \overline{H_i} \tag{13}$$

(3) Class III—medium-low level—moderate innovation:

$$\overline{H_i} > H_i \geq \overline{H_i} - s_{H_i} \tag{14}$$

(4) Class IV low level—emerging innovation:

$$H_i < \overline{H_i} - s_{H_i} \tag{15}$$

where $\overline{H_i}$ is the mean value of the H_i, s_{H_i} is the standard deviation of H_i.

Based on the criteria adopted, a process of prioritization of the regions under study was carried out.

4. Results

4.1. The Preliminary Analysis

The first stage of the study determined the dynamics of change in the value of indicators of innovation and economic development in individual regions (voivodeships) in Poland between 2010 and 2020. The indices of the dynamics of change show the size and direction for each indicator. The indices are determined as the ratio of the indicator's value in the final year to its value in the base year. Table 2 shows the indices of change in indicators for the period between 2010 and 2020, as well as for intermediate periods, i.e., for the years 2020–2015 and 2015–2010, for all 16 studied regions.

The results show that the values of the indicators of innovation and economic development in the studied regions between 2010 and 2020 changed to a different extent. Between 2010 and 2020, the highest average dynamics of change for all regions was achieved by the indicator "Service companies that introduced an innovative solution" (indicator X6), and the lowest—"business sector R&D expenditures in relation to GDP" (indicator X2). In the analyzed period for all regions, the indicators of the dynamics of change took positive values, which means that there was an increase, not a decrease, which should be considered a very positive result.

At the same time, when analyzing the periods 2015–2010 and 2020–2015, it can be noted that in the first period, higher growth rates were reported for indicators: X1–X5, X9–X10, X12, and in the second period for indicators: X6–X8, X11, X13–X14.

4.2. The Fundamental Research

4.2.1. Measurement and Evaluation of Different Levels of Innovative Capacity for Regions in Poland

One of the basic areas of shaping the economy's innovativeness is the ability to create innovative solutions. Factors that are of key importance for this area include human capital and knowledge, as well as the level of expenditures allocated to research and development activities. Determining reliable measures of these factors is not an easy process. The most commonly used variables characterizing human capital and knowledge relate to the level of education of the population. In this study, this is expressed by the number of employees in R&D per 1000 economically active people (indicator X3) and by the number of university graduates per 10,000 population (indicator X4). The creation of new innovative solutions must be preceded by the conduct, oftentimes very expensive research, by competent people. For these reasons, it is crucial for the development of innovation to provide financing for this activity. In this area, the indicators adopted characterize the involvement of the economy in supporting the science sector, that is, R&D expenditures, in relation to % of GDP (indicator X1), as well as the financing of R&D expenditures by companies (indicator X2), which allows linking R&D activities to the market and the commercialization of results.

When considering the diagnostic variables discussed (Table 1), which characterize the innovative capacity of the regions in Poland, calculations were carried out using the CODAS method. As a result, the values of the Hi index (synthetic measure) and Euclidean and Taxicab distances from the anti-pattern were determined for the dimension characterizing the innovative capacity of the regions in 2010, 2015 and 2020 (Table 3).

The calculations made and the designated ranking of the innovative capacity of the regions of Poland showed that seven regions (voivodeships) in all analyzed years occupied the same position in the ranking. The highest positions 1–5 were occupied by the Masovia, Lesser Poland, Opole Province, Pomerania and Lower Silesia Voivodeships, respectively. Position 11 was invariably occupied by the Kuyavia-Pomerania Voivodeship, and position 16 (last)-by the Lubuskie Voivodeship.

A decrease in the ranking position between 2010 and 2020 was recorded by the West Pomerania, Greater Poland and Lodzkie Voivodeships, and an increase by the Warmia-Masuria, Opole Province and Lublin Voivodeships. The remaining regions were characterized by stability in terms of their ranking positions between 2010 and 2020. Slight changes in the ranking occurred only in 2015.

Table 2. Dynamics of change in indicators of innovative development for regions in Poland between 2010 and 2020.

Regions (Voivodeships)	2010–2020														
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
	%														
Lower Silesia(Dolnośląskie)	255	23	174	72	189	193	185	138	99	136	155	167	43	121	95
Kuyavia-Pomerania (Kujawsko-Pomerania)	281	13	126	58	190	291	136	42	138	194	153	166	53	115	81
Lublin (Lubelskie)	184	21	132	60	212	196	223	130	210	309	158	159	63	122	150
Lubusz (Lubuskie)	307	16	88	42	146	132	155	338	236	243	153	165	41	116	61
Lodzkie (Łódzkie)	179	18	142	48	245	279	221	126	134	182	162	168	51	118	97
Lesser Poland (Małopolskie)	241	13	178	74	241	263	223	118	119	176	166	175	51	126	132
Masovia (Mazowieckie)	163	22	110	67	231	280	187	140	105	119	86	154	54	127	112
Opole Province (Opolskie)	458	6	108	49	148	155	143	269	117	154	153	162	51	111	76
Subcarpathia (Podkarpackie)	141	51	105	64	163	149	171	124	304	347	162	164	59	124	175
Podlasie Province (Podlaskie)	256	17	110	54	229	280	206	115	170	336	158	163	57	122	167
Pomerania (Pomorskie)	292	25	150	83	217	254	185	25	111	136	162	162	48	119	89
Silesia (Śląskie)	191	24	135	59	180	215	158	88	124	133	152	154	49	113	102
Holy Cross (Świętokrzyskie)	113	55	112	45	184	241	146	105	176	188	147	162	56	116	100
Warmia-Masuria (Warmińsko-Mazurskie)	173	25	122	54	228	379	156	52	113	139	150	164	51	118	52
Greater Poland (Wielkopolskie)	150	26	82	59	208	205	209	80	106	178	164	159	40	121	95
West Pomerania (Zachodnio Pomorskie)	171	33	94	42	214	238	195	107	114	306	154	163	47	108	79
Average	222	24	123	58	202	234	181	125	149	205	152	163	51	119	104
	2015–2010														
Lower Silesia	167	64	177	86	95	85	103	251	138	185	124	123	65	108	100
Kuyavia-Pomerania	148	57	119	81	92	95	90	72	131	229	123	122	78	105	100
Lublin	167	60	110	78	92	72	107	161	170	336	124	119	89	107	131
Lubuskie	157	38	118	64	87	71	97	104	218	329	123	122	68	105	86
Lodzkie	106	49	127	67	105	94	115	115	115	162	126	124	84	107	114
Lesser Poland	149	43	166	103	105	79	125	89	171	153	128	123	80	109	118
Masovia	128	48	107	86	88	76	99	59	140	151	67	119	86	111	115
Opole Province	267	41	117	79	91	63	111	99	111	175	123	121	74	103	96
Subcarpathia	140	97	140	91	83	81	83	97	235	216	127	123	86	108	156
Podlasie Province	238	79	121	73	120	121	121	86	105	309	122	121	86	109	133
Pomerania	187	58	128	101	88	72	102	42	126	137	125	122	72	107	107
Silesia	133	61	135	81	80	54	96	85	138	128	121	120	82	105	118
Holy Cross	136	93	129	78	82	81	83	75	151	128	117	120	82	104	100
Warmia-Masuria	73	25	126	72	83	72	88	34	180	172	122	121	81	105	90
Greater Poland	129	64	127	81	91	70	107	131	148	208	129	119	66	108	110
West Pomerania	106	72	119	67	119	118	119	207	182	366	124	122	74	101	117
Average	152	59	129	81	94	82	103	107	154	212	120	121	78	106	112
	2020–2015														
Lower Silesia	153	37	99	83	199	227	180	55	72	73	125	135	66	111	153
Kuyavia-Pomerania	189	23	105	71	206	307	151	59	105	85	124	136	68	110	189
Lublin	110	35	121	77	229	274	208	81	123	92	127	133	70	114	110
Lubuskie	195	43	75	66	168	186	160	325	108	74	124	135	60	110	195
Lodzkie	169	37	112	72	234	297	192	110	117	113	128	136	60	111	169
Lesser Poland	162	30	108	72	230	334	178	132	70	115	130	142	64	116	162
Masovia	127	47	103	79	261	368	188	238	75	79	129	129	63	114	127
Opole Province	172	14	93	62	163	248	128	271	105	88	125	134	68	107	172
Subcarpathia	101	52	75	71	197	184	205	127	129	161	127	133	69	114	101
Podlasie Province	108	22	91	74	190	232	169	133	161	109	130	135	66	112	108
Pomerania	156	43	117	82	247	351	181	59	88	99	129	133	66	111	156
Silesia	144	39	100	73	225	402	164	104	90	104	126	129	60	108	144
Holy Cross	84	59	86	58	224	298	176	139	116	147	126	134	68	111	84
Warmia-Masuria	238	100	97	75	274	530	177	153	63	81	123	135	63	112	238
Greater Poland	116	41	64	73	228	291	196	61	71	85	127	134	61	112	116
West Pomerania	161	46	78	62	180	202	164	52	63	84	125	134	64	108	161
Average	149	42	95	72	216	296	176	131	97	99	127	134	65	111	149

Table 3. Values of the synthetic measure of innovative capacity (H_i), Euclidean (E_i) and Taxicab (T_i) distances and rankings of the regions studied.

Regions (Voivodeships)	2010				2015				2020			
	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking
Lower Silesia	0.171	0.334	0.365	5	0.224	0.446	1.001	5	0.237	0.456	1.270	5
Kuyavia-Pomerania	0.089	0.174	−0.944	11	0.101	0.196	−0.965	11	0.099	0.188	−0.936	11
Lublin	0.150	0.271	0.018	8	0.168	0.303	0.103	6	0.156	0.285	−0.030	6
Lubuskie	0.031	0.034	−1.876	16	0.021	0.021	−2.244	16	0.020	0.020	−2.187	16
Lodzkie	0.151	0.285	0.033	7	0.119	0.236	−0.686	10	0.130	0.254	−0.440	8
Lesser Poland	0.315	0.606	2.685	2	0.348	0.695	3.006	2	0.354	0.682	3.169	2
Masovia	0.403	0.790	4.113	1	0.378	0.746	3.483	1	0.370	0.735	3.430	1
Opole Province	0.065	0.099	−1.335	15	0.071	0.116	−1.453	13	0.057	0.086	−1.595	14
Subcarpathia	0.209	0.378	0.974	3	0.302	0.545	2.246	3	0.274	0.467	1.875	3
Podlasie Province	0.097	0.166	−0.824	10	0.120	0.228	−0.664	9	0.100	0.175	−0.910	10
Pomerania	0.205	0.377	0.907	4	0.248	0.485	1.385	4	0.264	0.528	1.712	4
Silesia	0.110	0.219	−0.614	9	0.128	0.255	−0.545	8	0.126	0.247	−0.510	9
Holy Cross	0.077	0.122	−1.139	13	0.094	0.167	−1.082	12	0.078	0.119	−1.266	12
Warmia-Masuria	0.075	0.125	−1.180	14	0.047	0.074	−1.831	15	0.070	0.132	−1.393	13
Greater Poland	0.151	0.287	0.040	6	0.161	0.314	−0.011	7	0.138	0.248	−0.318	7
West Pomerania	0.084	0.136	−1.036	12	0.067	0.121	−1.516	14	0.054	0.099	−1.648	15

Based on the calculated values of the H_i index, four classes of the level of development of Poland's regions in terms of innovative capacity were determined for 2010, 2015 and 2020 (Table 4). In addition, the average level of this development for the entire analyzed period was also specified (Figure 2). The levels were determined based on Equations (12)–(15).

Table 4. Levels of Polish regions in terms of their innovative capacity.

Years	Levels of Innovative Capacity			
	High—Leader in Innovative Capacity	Medium-High—Strong Innovative Capacity	Medium-Low—Moderate Innovative Capacity	Low—Emerging Innovative Capacity
2010	Lesser Poland Masovia	Lower Silesia Lublin Lodzkie Subcarpathia Pomerania Greater Poland	Kuyavia-Pomerania Opole Province Podlasie Province Silesia Holy Cross Warmia-Masuria West Pomerania	Lubuskie
2015	Lesser Poland Masovia Subcarpathia	Lower Silesia Lublin Pomerania	Kuyavia-Pomerania Lodzkie Opole Province Podlasie Province Silesia Holy Cross Greater Poland West Pomerania	Warmia-Masuria Lubuskie
2020	Lesser Poland Masovia Subcarpathia	Lower Silesia Pomerania	Kuyavia-Pomerania Lublin Lodzkie Opole Province Podlasie Province Silesia Holy Cross Warmia-Masuria Greater Poland West Pomerania	Lubuskie

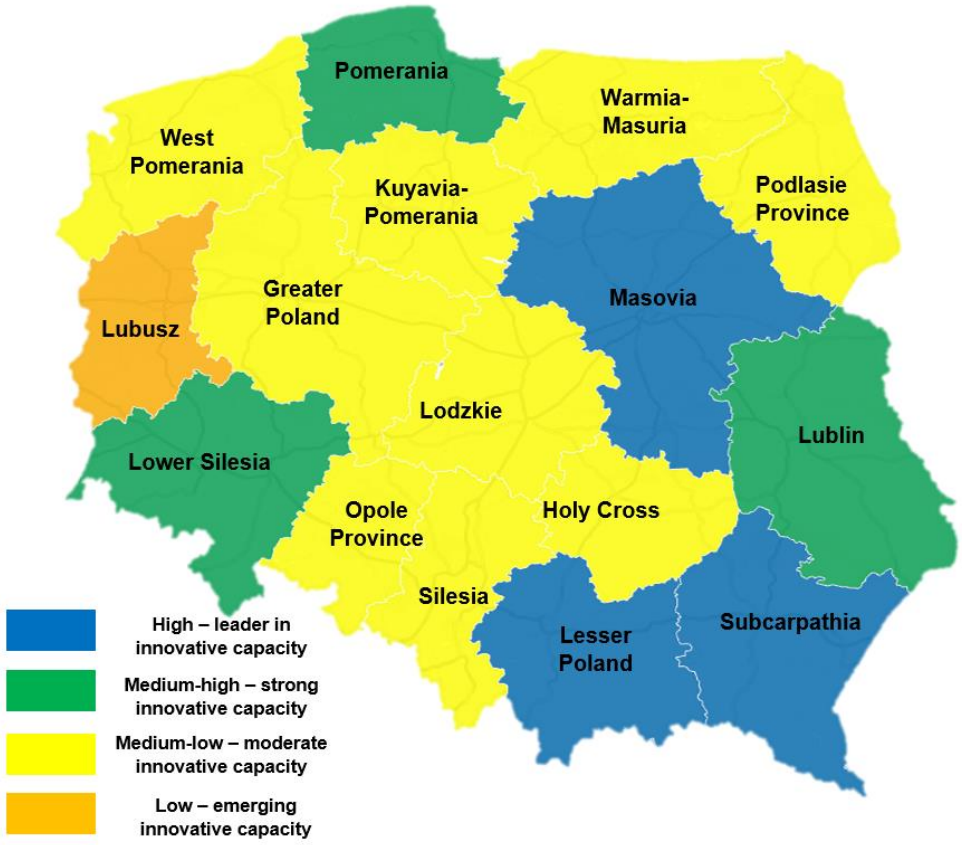

Figure 2. Summary of the average level of innovative capacity of the regions in Poland between 2010 and 2020.

The results show that in terms of the innovative capacity of the regions in Poland, which was characterized by four indicators (X1, X2, X3 and X4) relating to human capital and knowledge, as well as the level of expenditures allocated to research and development activities, the best averaged results throughout the analyzed period were achieved by the Lesser Poland, Masovia and Subcarpathia Voivodeships (blue color in Figure 1). For years, the highest R&D expenditures were incurred by the Masovia and Lesser Poland Voivodeships, which translates into their high innovative capacity. These regions, especially their provincial cities, are leading scientific centers with the largest number of universities, which also translates into the number of graduates and those employed in the R&D section.

The appearance of the Subcarpathia region in this group can be regarded as a surprise. However, Rzeszów (the provincial city of the region) has been promoted as the "capital of innovation" since 2009. For more than a decade, very large funds have been invested in higher education and research and development activities building an innovative region. The region has some of the highest business sector R&D expenditures as a percentage of GDP in the country, which averaged more than 0.7% in the analyzed period (2010–2020) (only Masovia and Lesser Poland voivodeships have similar values). All these activities make the region, in terms of innovative capacity, one of the leading in Poland.

By analyzing the results obtained, it is also possible to trace the changes that took place in innovative capacity for individual regions. Consistency in terms of strong innovative capacity was characterized by the Lower Silesia and Pomerania Voivodeships. In 2010, the second group also included the Lodzkie, Subcarpathia and Greater Poland Voivodeships, which in 2015 and 2020 fell into group 3, i.e., regions with moderate innovative capacity. Additionally, the Lublin Voivodeship in 2020 counted a drop to group 3. The low dynamics of change between 2010 and 2020 was characterized by group 4 with emerging innovation. In 2010, 2015, and 2020, the Lubuskie Voivodeship was reported in this group, and in 2015 also the Warmia-Masuria Voivodeship.

4.2.2. Measurement and Evaluation of Different Innovation Positions in the Studied Regions

The second area analyzed was the position of innovation in the region, which was characterized by six indicators (X5, X6, X7, X8, X9 and X10). The first four of these relate to innovative activities and testify to the level of awareness of enterprises of the importance of innovation in their functioning and competitiveness in the market. In addition, two indicators (X9 and X10) are also included, covering patent applications and patents granted, which can be considered a measure of implementing cooperation between science and industry, and generally determining the level of inventiveness.

As can be seen, this area mainly characterizes the innovativeness of enterprises, which is extremely important for regions. Enterprises wishing to grow and make profits must adapt to a dynamically changing environment, including responding to the actions of competitors. Innovation is one of the key factors that can provide them with this. Therefore, innovative enterprises are the driving force of regional as well as central economies and the EU as a whole.

When taking into account the diagnostic variables (Table 1), characterizing the position of innovation in the studied regions, calculations were made using the CODAS method and the values of the H_i index (synthetic measure), and the Euclidean and Taxicab distances were determined from the anti-pattern for this dimension for 2010, 2015 and 2020. The results of the calculations are summarized in Table 5.

Table 5. Values of the synthetic measure of innovation position (H_i), Euclidean (E_i) and Taxicab (T_i) distances and ranking of the regions studied.

Regions (Voivodeships)	2010				2015				2020			
	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking
Lower Silesia	0.067	0.259	−0.023	6	0.128	0.373	0.771	2	0.086	0.301	−0.305	12
Kuyavia-Pomerania	0.061	0.146	−0.110	9	0.075	0.165	−0.081	11	0.066	0.158	−0.618	15
Lublin	0.056	0.145	−0.196	10	0.055	0.188	−0.394	13	0.088	0.272	−0.265	11
Lubuskie	0.037	0.068	−0.489	13	0.025	0.045	−0.873	15	0.132	0.135	0.444	3
Lodzkie	0.026	0.125	−0.669	16	0.061	0.182	−0.311	12	0.095	0.297	−0.156	9
Lesser Poland	0.066	0.273	−0.036	7	0.098	0.352	0.288	5	0.154	0.484	0.792	2
Masovia	0.100	0.497	0.515	2	0.088	0.460	0.122	6	0.174	0.636	1.117	1
Opole Province	0.087	0.179	0.306	5	0.079	0.156	−0.012	10	0.129	0.201	0.390	4
Subcarpathia	0.100	0.216	0.506	3	0.086	0.202	0.100	7	0.106	0.275	0.021	7
Podlasie Province	0.031	0.053	−0.596	15	0.084	0.154	0.059	8	0.077	0.167	−0.435	13
Pomerania	0.167	0.327	1.586	1	0.142	0.269	0.996	1	0.125	0.304	0.332	5
Silesia	0.092	0.394	0.388	4	0.084	0.322	0.055	9	0.118	0.451	0.218	6
Holy Cross	0.047	0.103	−0.332	12	0.039	0.052	−0.661	14	0.066	0.127	−0.622	16
Warmia-Masuria	0.054	0.105	−0.229	11	0.020	0.031	−0.954	16	0.094	0.174	−0.170	10
Greater Poland	0.063	0.234	−0.086	8	0.110	0.305	0.481	3	0.099	0.320	−0.096	8
West Pomerania	0.037	0.095	−0.503	14	0.108	0.255	0.446	4	0.066	0.166	−0.614	14

The results show that the ranking positions of individual regions varied widely during the period under study. In 2010 and 2015, the Pomerania Voivodeship was the leader with a large advantage over Masovia Voivodeship (in 2010) and Lower Silesia Voivodeship (in 2015). On the other hand, in 2020, the leading position was occupied by the Masovia Voivodeship, with the Lesser Poland Voivodeship coming in second. The positions of other regions also show large changes in the ranking in the various years studied. It can also be seen that there were considerable changes in the designated values of indicators in those years. This shows that, in these years, there were significant changes in the structure and activities of enterprises in the various regions. It is also evident that there is a lack of stability in the development of business innovation, which is characteristic of developing economies, which Poland undoubtedly is.

With regard to the value of the synesthetic measure H_i and using Equations (12)–(15), the level of innovation position in the studied regions in 2010, 2015 and 2020 was evaluated (Table 6) and the average values of this level in the 10-year perspective were determined (Figure 3).

Table 6. Summary of the levels of innovation positions in the studied regions.

Years	Levels of Innovation in Regions			
	High—Leader in Innovative Capacity	**Medium-High—Strong Innovative Capacity**	**Medium-Low—Moderate Innovative Capacity**	**Low—Emerging Innovation Capacity**
2010	Pomerania	Masovia Opole Province Subcarpathia Silesia	Lower Silesia Kuyavia-Pomerania Lublin Lubuskie Lesser Poland Holy Cross Warmia-Masuria Greater Poland West Pomerania	Lodzkie Podlasie Province
2015	Pomerania Lower Silesia	Kuyavia-Pomerania Lublin Lesser Poland Masovia Silesia Greater Poland West Pomerania	Lubuskie Opole Province Subcarpathia Podlasie Province	Lodzkie Holy Cross Warmia-Masuria
2020	Lesser Poland Masovia	Lubuskie Opole Province Subcarpathia Pomerania Silesia	Lower Silesia Lublin Lodzkie Podlasie Province Warmia-Masuria Greater Poland	Kuyavia-Pomerania Holy Cross West Pomerania

Figure 3. Average level of innovation position in the studied regions between 2010 and 2020.

The results indicate that Masovia and Pomerania Voivodeships (blue color in Figure 2) were characterized by a high level of innovation and were leaders in this area in Poland.

The position of the Masovia Voivodeship is mainly due to the scientific and industrial development of its capital, Warsaw. By contrast, the Pomerania Voivodeship is characterized by a highly industrialized local economy and very vibrant academic centers. The result of cooperation between industry and universities, in both regions, are high rates of patents granted and patent applications. For example, during the analyzed period, on average—in Masovia Voivodeship—about 400 patents were granted each year and nearly 800 patent applications were filed. Voivodeships such as Masovia, Pomerania, Lesser Poland, and Silesia have a significant advantage over, for example, eastern regions of Poland. This results from the intensive development of business environment institutions, including primarily science and technology parks. These institutions, through support from, for example, EU funds, are becoming local centers of entrepreneurship and innovation development. These activities also translate into broader commercialization of technology and knowledge [68].

The worst situation, for this area, is in the regions (voivodeships) of Holy Cross and Warmia-Masuria (orange color in Figure 2), which are among the smallest economic regions in Poland, and are characterized by a low degree of industrialization and fewer academic centers. These are the regions characterized by the smallest GDP per capita values, the highest unemployment rates and relatively low values of average wages in the economy [69].

4.2.3. Measurement and Evaluation of Different Levels of Economic Development of the Regions in Poland

To measure the level of economic development of the regions in Poland, a set of five indicators (X11, X12, X13, X14, and X15) was used to characterize the overall condition of individual regions (GDP per capita, number of registered business entities per 10,000 residents, entities with foreign capital per 10,000 residents) and the standard of living of citizens (unemployment rate, average wage). The results of the analysis, for individual years, for the area are shown in Table 7.

Table 7. Values of the synthetic measure of economic development (H_i), Euclidean (E_i) and Taxicab (T_i) distances and rankings of the regions studied.

Regions (Voivodeships)	2010				2015				2020			
	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking
Lower Silesia	0.129	0.274	0.610	3	0.142	0.305	0.900	3	0.136	0.293	0.894	3
Kuyavia-Pomerania	0.040	0.080	−0.820	13	0.038	0.077	−0.750	11	0.031	0.062	−0.788	11
Lublin	0.050	0.069	−0.658	11	0.031	0.049	−0.865	12	0.024	0.042	−0.893	13
Lubuskie	0.099	0.176	0.116	8	0.085	0.169	−0.001	8	0.074	0.149	−0.089	9
Lodzkie	0.079	0.158	−0.198	9	0.075	0.156	−0.169	9	0.077	0.157	−0.053	8
Lesser Poland	0.106	0.204	0.241	7	0.102	0.209	0.258	7	0.108	0.231	0.443	5
Masovia	0.263	0.551	2.760	1	0.229	0.441	2.316	1	0.230	0.439	2.413	1
Opole Province	0.075	0.153	−0.262	10	0.069	0.143	−0.264	10	0.055	0.116	−0.404	10
Subcarpathia	0.028	0.033	−1.012	15	0.021	0.034	−1.026	15	0.021	0.032	−0.938	14
Podlasie Province	0.043	0.060	−0.775	12	0.030	0.049	−0.881	13	0.027	0.052	−0.846	12
Pomerania	0.110	0.234	0.303	6	0.114	0.246	0.460	5	0.106	0.229	0.418	6
Silesia	0.122	0.251	0.493	4	0.115	0.241	0.466	4	0.113	0.228	0.528	4
Holy Cross	0.037	0.067	−0.864	14	0.028	0.047	−0.923	14	0.020	0.037	−0.961	15
Warmia-Masuria	0.020	0.031	−1.142	16	0.014	0.021	−1.147	16	0.009	0.010	−1.128	16
Greater Poland	0.144	0.282	0.839	2	0.164	0.317	1.265	2	0.164	0.313	1.357	2
West Pomerania	0.119	0.208	0.447	5	0.112	0.209	0.431	6	0.087	0.168	0.117	7

The results indicate a large spatial differentiation of Poland's economic development, while the designated rankings show great stability. The recorded changes amounted to a maximum of two positions. However, as many as five voivodeships maintained their positions throughout the analyzed period (Masovia, Greater Poland, Lower Silesia, Pomerania—the upper part of the ranking, and Opole Province, Warmia-Masuria—the lower part of the ranking).

The results obtained, taking into account the division of the regions into four groups of the level of economic development are shown in Table 8, while the average level of this development for a 10-year perspective is shown in Figure 4.

Table 8. Summary of the levels of innovation positions in the studied regions.

Years	Levels of Economic Development of the Regions			
	High—Leader in Innovative Capacity	**Medium-High—Strong Innovative Capacity**	**Medium-Low—Moderate Innovative Capacity**	**Low—Emerging Innovation Capacity**
2010	Masovia	Lower Silesia Lubuskie Lesser Poland Pomerania Silesia Greater Poland West Pomerania	Kuyavia-Pomerania Lublin Lodzkie Opole Province Podlasie Province Holy Cross	Subcarpathia Warmia-Masuria
2015	Masovia Greater Poland	Lower Silesia Lesser Poland Pomerania Silesia West Pomerania	Kuyavia-Pomerania Lublin Lubuskie Lodzkie Opole Province Podlasie Province Holy Cross	Subcarpathia Warmia-Masuria
2020	Masovia Greater Poland	Lower Silesia Lesser Poland Pomerania Silesia West Pomerania	Kuyavia-Pomerania Lublin Lubuskie Lodzkie Opole Province Subcarpathia Podlasie Province Holy Cross	Warmia-Masuria

The results show stable positions of individual regions. In 2015 and 2020, the group of the most developed regions included the Masovia and Greater Poland Voivodeships (promoted from the second group), and in 2010 only the Masovia one.

The group of voivodeships with a "medium-high" level of economic development was also characterized by little change during the period under review. In all the years under study, it included the Lower Silesia, Lesser Poland, Pomerania, Silesia and West Pomerania Voivodeships, and only in 2010, additionally the previously mentioned Greater Poland and Lubuskie Voivodeships.

The economic situation was found to be weaker in the remaining regions of Poland. These included mainly the eastern part of the country and regions from central Poland (Lodzkie, Kuyavia-Pomerania) and southern Poland (Opole Province) (Figure 3). The stability of the results obtained, especially in the third and fourth groups (Table 8), indicate that it is not easy to catch up with development. The results also confirm the existence of significant disparities in development between the eastern and western parts of Poland. Better developing voivodeships were found in western (Silesia, Lesser Poland, Lower Silesia, Lubusz), northwestern (Pomerania) and central Poland (e.g., Masovia, Greater Poland). Such an economic division, however, is not surprising, but the result of significant differences in the development of these areas and their potential.

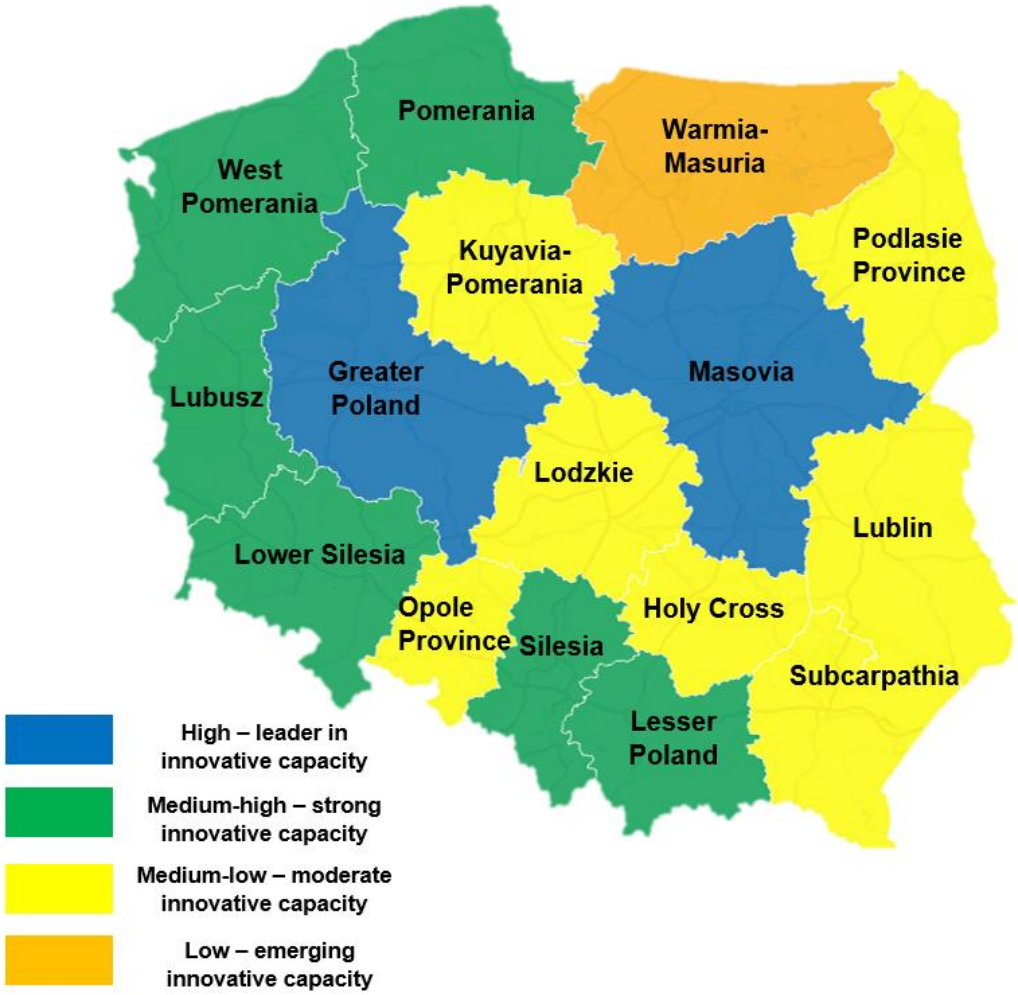

Figure 4. Average level of economic development of regions (voivodeships) in Poland.

4.2.4. Measuring the Relationship between the Level of Innovative Capacity, the Position of Innovation and the Economic Development of the Regions between 2015 and 2020

The next stage of the study also checked the Pearson correlation values that exist between the average level of innovative capacity, innovation position and economic development of the regions between 2015 and 2020. The basis for determining the correlation values were the average values of the synthetic measure obtained for all these three dimensions (areas of analysis). The results obtained are shown in Table 9 and Figure 5.

Table 9. Correlations between the dimensions characterizing the level of innovation of the regions.

	Innovation Capacity	Innovation Position	Economic Development
Innovation capacity	1.00	**0.77**	**0.55**
Innovation position	**0.77**	1.00	**0.77**
Economic development	**0.55**	**0.77**	1.00

Notes: Values in bold indicate statistically significant results.

The results obtained clearly indicate that there are significant positive relationships between the level of economic development of a given region and the level of innovation capacity and the level of innovation position in these regions. Such a link between these three most important, from the point of view of innovation development, is most reasonable and proves the validity of their adoption in the analysis.

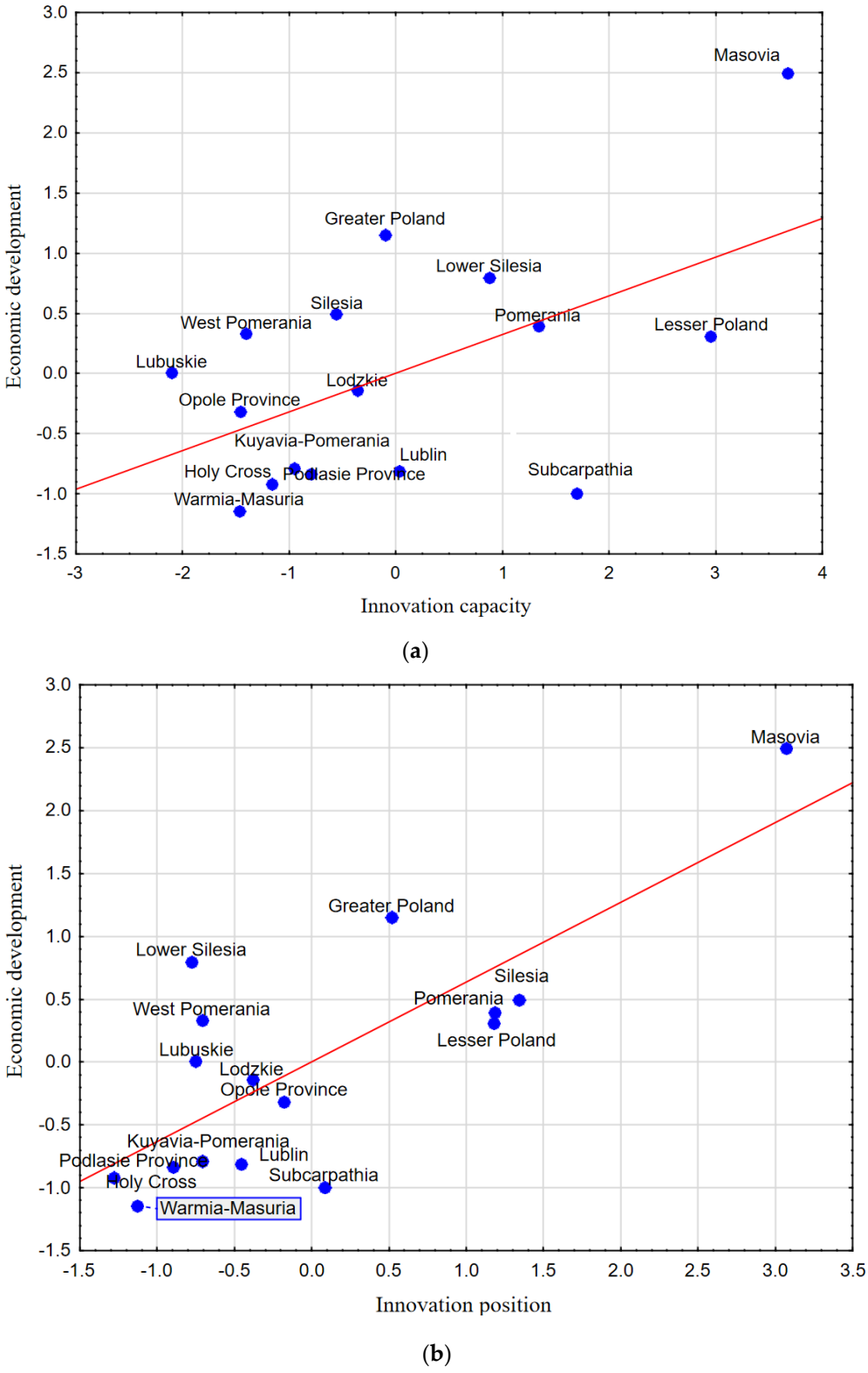

Figure 5. Relationships between the level of economic development of the regions and their innovation capacity (**a**) and innovation position (**b**).

4.2.5. Measurement and Evaluation of Differences in the Overall Level of Innovative Development of the Regions in Poland

The last part of the study measured and assessed the differences in the overall level of innovative development of the regions in Poland between 2010 and 2020 (in 5-year intervals).

This assessment is important because of the differences that exist in the scope of the studied areas of individual regions in Poland.

The results of calculating the value of the synthetic measure of innovative development of regions H_i and Euclidean and Taxicab distances from the anti-pattern for this development are presented in Table 10.

Table 10. Values of the synthetic measure of overall innovative development (H_i), Euclidean (E_i) and Taxicab (T_i) distances and ranking positions of the regions studied.

Regions (Voivodeships)	2010				2015				2020			
	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking	E_i	T_i	H_i	Position in the Ranking
Lower Silesia	0.079	0.284	0.215	5	0.101	0.369	0.507	3	0.093	0.34	0.288	5
Kuyavia-Pomerania	0.038	0.131	−0.437	12	0.044	0.144	−0.413	12	0.041	0.134	−0.55	15
Lublin	0.05	0.153	−0.241	9	0.057	0.172	−0.207	9	0.063	0.199	−0.188	9
Lubusz	0.037	0.095	−0.455	13	0.031	0.08	−0.619	15	0.059	0.109	−0.263	10
Lodzkie	0.055	0.178	−0.167	8	0.052	0.188	−0.284	10	0.066	0.239	−0.144	8
Lesser Poland	0.104	0.339	0.613	2	0.115	0.396	0.734	2	0.13	0.452	0.882	2
Masovia	0.17	0.593	1.691	1	0.158	0.53	1.431	1	0.168	0.597	1.489	1
Opole Province	0.047	0.149	−0.302	11	0.044	0.141	−0.413	13	0.057	0.142	−0.29	11
Subcarpathia	0.07	0.198	0.065	7	0.089	0.238	0.304	6	0.088	0.245	0.204	6
Podlasie Province	0.032	0.085	−0.534	14	0.048	0.139	−0.352	11	0.042	0.131	−0.528	14
Pomerania	0.096	0.309	0.495	3	0.097	0.319	0.438	4	0.096	0.339	0.33	3
Silesia	0.087	0.299	0.338	4	0.08	0.277	0.175	7	0.096	0.322	0.325	4
Holy Cross	0.031	0.096	−0.554	15	0.031	0.081	−0.616	14	0.035	0.095	−0.648	16
Warmia-Masuria	0.03	0.086	−0.564	16	0.016	0.039	−0.854	16	0.042	0.108	−0.528	13
Greater Poland	0.075	0.264	0.15	6	0.09	0.312	0.329	5	0.085	0.298	0.152	7
West Pomerania	0.049	0.144	−0.266	10	0.062	0.204	−0.114	8	0.045	0.149	−0.482	12

The results obtained indicate that in terms of the overall innovative development of the regions in Poland, the best results between 2010 and 2020 were achieved by the Masovia Voivodeship, which occupied the invariably leading position in the ranking, and the Lesser Poland Voivodeship, occupying the second position. The Masovia Voivodeship obtained the highest value of the synthetic measure H_i in each year of the analysis and is definitely the outlier region in terms of overall innovative development. The second position (Lesser Poland Voivodeship) is also stable. The Pomorksie and Silesia Voivodeships also did very well (in 2010 and 2020, while slightly weaker in 2015). The weakest in terms of overall innovative development were Warmia-Masuria Voivodeship (last position in 2010 and 2015) and Holy Cross Voivodeship (last position in 2020).

It can also be said that in the regions (voivodeships) of Masovia, Lesser Poland and Lublin there were no changes in the rankings in terms of dynamic development. The remaining voivodeships for each year of analysis experienced changes, including both improvement and deterioration in ranking positions.

With regard to the values of the H_i index for overall innovative development, the levels of this development were determined for the regions studied (Table 11). Figure 6 presents a graphical depiction of these results, showing the spatial differentiation of Poland in terms of the average innovative development of the regions (voivodeships).

Table 11. Levels of overall innovative development of the regions in Poland.

Years	Levels of Overall Innovative Development			
	High—Leader in Innovative Capacity	**Medium-High—Strong Innovative Capacity**	**Medium-Low—Moderate Innovative Capacity**	**Low—Emerging Innovation Capacity**
2010	Lesser Poland Masovia	Lower Silesia Subcarpathia Pomerania Silesia Greater Poland	Kuyavia-Pomerania Lublin Lubusz Lodzkie Opole Province Podlasie Province Holy Cross Warmia-Masuria West Pomerania	
2015	Lesser Poland Masovia	Lower Silesia Subcarpathia Pomerania Silesia Greater Poland	Kuyavia-Pomerania Lublin Lubusz Lodzkie Opole Province Podlasie Province West Pomerania	Holy Cross Warmia-Masuria
2020	Lesser Poland Masovia	Lower Silesia Subcarpathia Pomerania Silesia Greater Poland	Kuyavia-Pomerania Lublin Lubusz Lodzkie Opole Province Podlasie Province West Pomerania	Holy Cross Warmia-Masuria

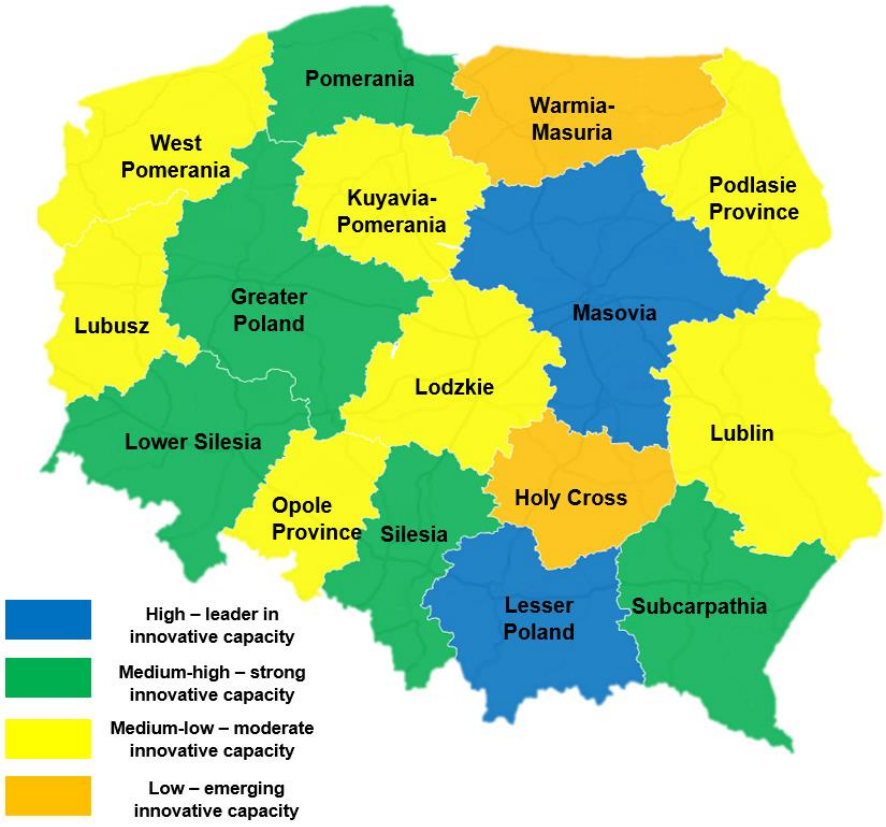

Figure 6. The average level of overall innovative development of the regions (voivodeships) in Poland.

The analyses carried out made it possible to assign individual regions of Poland to one of four classes in terms of the level of overall innovative development based on the indicators adopted. The results indicate that Lesser Poland and Masovia Voivodeships are the best developed regions throughout the analysis period and quite significantly different from the others. Their level of development is high, and these regions are undoubtedly leaders in Poland. By contrast, five regions are characterized by a "medium-high" level of development with a strong overall level of their innovation (Lower Silesia, Subcarpathia, Pomerania, Silesia, and Greater Poland).

In 2010, none of Poland's regions was characterized by a low level of overall innovative development and was classified as an emerging region in terms of innovation. However, in 2015 and 2020, Swietokrzyskie and Warmia-Masuria regions (voivodeships) received such a rating.

These results indicate that the simplified division into Poland A and Poland B, which has been operating in Poland so far, in which the eastern voivodeships were characterized by a significant lag in relation to the western voivodeships, does not fully correspond to reality. The study showed that, although two regions from the so-called Poland B, i.e., the Holy Cross and Warmia-Masuria Voivodeships, are characterized by the lowest level of overall innovative development, the Subcarpathia Voivodeship is already characterized by a "medium-high" level of (strong) innovativeness, and the Lubusz and Podlasie Province Voivodeships by a level with moderate innovativeness. At the same time, moderate innovativeness is also found in many regions of so-called Poland A, i.e., Opole Province, Lodzkie, Kuyavia-Pomerania and Lubusz and West Pomerania Voivodeships. This means that the disparities in the level of innovation that exist in Poland are to a small extent due to differences related to the geographic location of the region (related, among other things, to access to raw materials, proximity to highly developed countries, access to the sea, etc.) and different historical conditions (resulting from the influence of neighboring countries). Instead, the results indicate that the factors determining the level of innovation in the region are the level of economic development, human resources, and social creativity.

5. Discussion

In a knowledge-based economy, innovation is one of the key factors affecting economic growth and the competitiveness of businesses, regions and individual countries. In the European Union, Poland currently ranks among the countries with greater absorption of innovation than creation of innovation. This is due to the fact that Poland started developing a free and competitive economy much later than the countries of the so-called "old EU". According to the latest European Commission report [58], Poland is among the countries counted among the so-called emerging innovators. At the same time, the same report indicates that Poland has an above-average share of non-innovators with no inclination to create innovations. These not-so-favorable data make it necessary to take measures to improve this situation, i.e., to stimulate innovative entrepreneurs, scientists and those in government.

For the innovative economic development of a country, of utmost importance are its regions (in Poland identified with voivodeships), where research and economic activities are carried out [14]. This close connection between regions and innovative activity, in the EU was already noted in the 1980s, creating the idea of building plans for technological development at the regional level. Since 1994, Regional Innovation Strategies (RIS) have been created in the EU and refined in subsequent years. In 1994, the European Commission's Directorate General for Entrepreneurship created the so-called Innovation Programs, and within their framework Regional Innovation and Technology Transfer Strategies (RITTS) were created. Today, the EU has the European Regional Development Fund (ERDF) program, which provides funding to public and private entities in all EU regions. Its goal is to reduce economic, social and territorial disparities. These measures clearly indicate the huge role and importance of regions in building an innovative knowledge-based economy. This course of action covers all EU countries, including Poland.

Poland's accession to the EU only in 2004 results in a noticeable lag, compared to most of the so-called "old EU", in regional development, including in the area of innovation [58]. However, the process of developing the regional economy began somewhat earlier, because already between 2001 and 2002, when, as an EU candidate country, five Polish regions began to create Regional Innovation Strategies (RSI). These were the Warmia-Masuria, West Pomerania, Greater Poland, Silesia and Opole Province Voivodeships. In 2003, the process of creating RSI also included the remaining regions (voivodeships). The regional innovation policy in Poland is therefore a relatively new area of activity, which has recently begun to develop more and more dynamically, as evidenced by the results obtained, which indicate great progress in this area.

They also show that the innovativeness of individual regions varies strongly. In general, however, four groups of regions can be identified, ranging from voivodeships with emerging innovation to those that are innovation leaders. It should also be mentioned that the leading regions from Poland already rank in the middle of European regions, which confirms the progress in the process of improving the innovativeness of the economy [28].

When taking into account the capacity and position of innovation in the regions and their economic development in the country, the dominant regions (voivodeships) are Masovia and Lesser Poland, which significantly exceed the average level of innovative development of the other voivodeships. This state of affairs is mainly due to the fact that the capitals of these regions are Warsaw and Krakow, which are very large and strong economic, business and educational centers. Particularly important in this case are the high level of higher education and foreign investment in new technologies. There is also a synergy effect in these cities due to cooperation between the scientific community and modern business. Therefore, it can be assumed that also in the future these two regions will develop dynamically in terms of innovation.

The second group, regions that are characterized by strong innovativeness, includes the Lower Silesia, Subcarpathia, Pomerania, Silesia i Greater Poland (Table 11). These are regions with very high development potential. This is due to their location (e.g., along major transportation routes), significant degree of industrialization and high scientific and research activity. The large resources of these regions provide the basis for activating mechanisms for both the creation and absorption of innovations.

The largest number of regions (voivodeships) in Poland, as many as 7, are classified as having a moderate level of innovation (Table 11). These include the Kuyavia-Pomerania, Lublin, Lubusz, Lodzkie, Opole Province, Podlasie Province and West Pomerania Voivodeships. These are regions that require economic and organizational changes and developmental impulses to increase innovation potential. It is also reasonable, despite a certain element of inter-regional rivalry, to benefit from the good practices and experiences of other more developed regions. In these regions, despite a noticeable increase in R&D expenditures, increasing the number of patent applications and patents granted, there are considerable reserves for improving innovation.

On the other hand, two voivodeships, Holy Cross and Warmia-Masuria, are included in the regions of emerging innovation (Figure 5). Their low level of innovation is associated with a relatively weak level of industrialization, low scientific and research activity (e.g., low R&D expenditures, low number of patents, etc.), which consequently leads to low labor productivity, a high unemployment rate compared to other voivodeships, and poor performance in terms of revenue from sales of innovative products. These regions, as well as those in the third group (Table 11), should be given special programs to encourage the creation and implementation of innovative solutions in the economy. More emphasis should also be placed on the development of National Smart Specializations (NIS), which are part of the European Commission's concept relating to the implementation of the policy of creating innovative regions and countries of the Union [70]. This support for projects included in the KIS should motivate entrepreneurs and the scientific community to be more creative and innovative. Inter-industry cooperation, e.g., within the framework of Open Innovation [71–74], supported by the government, should lead to an increase in activity

in this area, including the creation and implementation of new strategies and business models [75–78].

An important element with a significant impact on the development of a regional innovation economy is also close cooperation between relevant EU agencies and regional authorities. At this level, goals and tasks should be defined for groups of regions with common or similar characteristics in terms of innovation. This should also take into account the potential and capabilities of regions to support or limit innovative development.

A number of studies [79–87] also report that the innovative development of regions should be based on close cooperation between academia and industry, a well-developed network of clusters in specific sectors or industries, an adapted organizational and institutional support structure, and stakeholders with a strong entrepreneurial mindset in the regional innovation system.

When discussing the results, it is also worth referring to the Regional Innovation Scoreboard. In Poland, the most innovative, compared to the regions of European countries, are the Warsaw Capital Region (moderate innovator) and the Małopolska Voivodeship (moderate innovator) [62]. This voivodeship achieved the second of the four levels of innovation (compared to more than 200 other regions) in the EU. Much worse results were obtained by the other voivodeships, which are included in the group of regions classified as emerging innovator. On the other hand, the results of the research presented in the paper, [31] based on the indicators and methodology of the Regional Innovation Scoreboard, do not indicate which regions have the highest overall level of innovation and which have the lowest. They only evaluate regions in four dimensions, and in these dimensions indicate leaders, vice-leaders and the weakest regions. For individual assessed dimensions, the Warsaw Capital Region and the Pomeranian Voivodeship fare best among Polish regions, which is in line with the results of this study. The differences are a result of the research methodologies used and the different indicators taken into account in the study, as well as the period for which the study was conducted.

It is also worth mentioning that the results of research conducted more than two decades ago [30] showed that the most innovative regions in Poland were the voivodeships of Lesser Poland, Pomerania, Silesia and Lower Silesia. Thus, despite the passage of time, the leaders of the innovation process remained the same. In relation to the other regions, as evidenced by the result of this study, continuous improvement in this regard is evident, but catching up with the best is not an easy process.

The results obtained in the paper broaden knowledge in the field of evaluation and analysis of regional innovation in Poland over a period of one decade, i.e., 2010–2020. This is because they indicate that large academic centers, a good geographical location and a high degree of industrialization of the region, as well as developed service activities, have a very positive impact on the overall level of innovation of the region. Of key importance, however, are personnel resources, openness to new solutions and cooperation between all stakeholders.

At the same time, the presented research results indicate the direction of further work in the field of innovation of Polish regions. It seems reasonable to perform detailed analyses of the relationship between regional innovation and digitalization, poverty levels, development of RES and other key issues related to the country's sustainable development. The results of such studies should show the effects of regional innovation development and which economic areas benefit most from these new developments. It is also worth analyzing the impact of smart specialties on the development of regional innovation.

6. Conclusions

The level of innovation of regions changes as a result of many processes taking place in the economy of a country, which include economic, environmental and social issues. Measurement of this level is an extremely important and complex issue, for which it is necessary to use a number of diagnostic variables characterizing this level, and appropri-

ate analytical tools. In this context, multivariate analysis becomes the most appropriate approach to this issue.

This article presents the results of the assessment of the level of innovation of Polish regions (voivodeships) between 2010 and 2020. The CODAS method belonging to the group of MCDM methods and a set of 15 indicators (diagnostic variables), characterizing the most significant areas of regional innovation, were used for the assessment. This method made it possible to determine a synthetic measure (H_i index), on the basis of which the evaluation of the level of innovation of regions was carried out and their ranking was created. The determination of the overall level of innovation was also supplemented by an analysis of the sublevels characterizing the areas of innovation included in the analysis (innovation capacity, innovation position and economic development).

The results show that Poland is a country with significant differences in the level of innovative development in different regions. The reason for this is the geographical location of these regions, the different level of industrialization and, consequently, the economic level, the number of universities and other factors. In the analyzed period (2010–2020), the best results related to the position and level of innovative development were obtained by the Masovia and Lesser Poland Voivodeships, and the weakest results were obtained by the Holy Cross and Warmia-Masuria Voivodeships, i.e., slightly less economically developed. The best result obtained for the Masovia Voivodeship is mainly due to the huge economic and scientific potential of Warsaw, which is located on its territory. This Voivodeship is also home to many domestic and foreign companies, government institutions and universities, cultural centers and scientific institutes, as well as foreign representative offices, which facilitates access to the latest technologies and innovative solutions. The high position of the Lesser Poland Voivodeship is due to the fact that it is home to Krakow, a city with a tremendous history (the former capital of Poland), with notable academic (including Jagiellonian University—one of the oldest universities in Europe) and cultural centers, and many domestic and foreign institutions and companies. Multiculturalism and access to new technologies, as well as a large pool of young and educated people, guarantee the dynamic development of an innovative economy, from which both regions benefit.

The results also indicate that the factors that have a tremendous impact on the position (rise/fall) of a region in the designated rankings and determine the level of innovative development are expenditures incurred on R&D activities, innovations introduced by companies, patent applications, patents granted, GDP per capita and average wages in the region. Academic potential is also an important factor. After all, without educated young people, it is difficult to develop innovation.

The research and the results show that the analysis of regional innovation development is of great importance for the development strategies of these regions and the country as a whole, as well as the EU. This is because it is obvious that all ideas and concepts developed at the national or European level must be implemented in the local market. Without knowledge of its specifics, the current state and the changes taking place, it is difficult to effectively introduce reforms in such a demanding area as innovation. The research also proves that any programs supporting pro-innovation activities should be tailored to regional specificities. Convincing the local community and relying on traditions and experiences and the diverse potential of local environments can yield far more favorable results than a uniform and therefore unsuited to local specifics approach. Indeed, it is important to note that the implementation of new solutions always raises concerns and uncertainty about their validity and effects. The regional approach, which, by the way, has been favored by the European Union for years, is undoubtedly a very appropriate course of action in this regard. This is because it is based on making the best possible use of the potential of the regions to improve the lives of their inhabitants and reduce the possibility of marginalization of any areas of the EU.

The presented findings provide new knowledge in the field of regional innovation development in Poland, and the developed and applied research methodology can also be successfully used to study regions in other countries.

It would be reasonable and extremely interesting to conduct such a study with the same indicators for several EU countries and compare the results. The analysis of the dynamics of change could be used to monitor and evaluate these regions and identify leaders whose experience could be used. Solidarity among the EU countries should be the foundation of regional development in this extremely important area for Europe, which is the innovation of the economy.

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