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Innovation of the Visegrad Group State Regions

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Abstract:

Purpose: *The purpose of the article is to assess the spatial differentiation of innovation across the regions of the Visegrad Group countries. The article also proposes a research hypothesis H1: the level of innovation of the Visegrad Group regions varies.*
Design/Methodology/Approach: *The theoretical section is a thorough review of the leading specialist literature. In the empirical part, Hellwig's method was used to assess the level of the regions' innovation. The values of Hellwig's taxonomic innovation measures, i.e. synthetic measures, for each of the six variables were calculated.*
Findings: *The article contains the results of research in the field of regional innovation. On the basis of statistical data from Eurostat, the taxonomic measures of innovation were calculated for individual regions of the Visegrad Group. It was shown that there is a large variation in the innovativeness of the regions in the V4 countries.*
Practical Implications: *The results of the research can be used in the formation of innovation policy by the European Union, which will make it possible to equalise disparities in the uneven development of individual V4 regions.*
Originality/Value: *The article presents the results of own research on the evaluation of the V4 regions' innovation level.*

Keywords: *Innovation, region, Visegrad Group.*

JEL codes: *R11,R12, O31.*

Paper type: *Research article.*

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1. Introduction

Regional innovation is a concept that refers to a region's ability to create and implement new solutions, technologies, products and methods of operation that contribute to economic and social development. This concept is a key element of modern regional policy and development strategies, as innovative regions have greater potential to attract investment, create new jobs and improve the quality of life of their residents.

The innovativeness of the regions of the Visegrad Group (V4), comprising Poland, the Czech Republic, Slovakia and Hungary, is a key factor influencing the competitiveness of these countries' economies on the international stage. The V4 region, due to its shared historical experience and a similar level of economic development, is an interesting area of research into the ability to implement innovation. Innovation in the regional context refers not only to technological advancement, but also to the ability to adapt to changing market conditions, cooperation between the public, private and scientific sectors, and the creation of an environment conducive to new ideas and technologies.

The purpose of the article is to assess the spatial differentiation of innovation in the regions of the Visegrad countries.

The diversity of regions, of their resources and capabilities mean that there is no one-size-fits-all model for innovation development. Therefore, in order to raise the level of a region’s innovativeness , it is necessary to use a comprehensive approach that takes the specifics of a region and its resources into account.

In order to assess the level of the 35 V4 regions’ innovativeness, statistical data obtained from Eurostat on the amount spent on R&D activities and the level and structure of employment in the R&D sector were used. The study employed Hellwig's method, which made it possible to calculate the value of a synthetic measure determining the level of innovation of individual regions.

2. Literature Review

Powerful regionalist tendencies in Europe over the centuries have led to disintegration and differentiation of spatial arrangements. Cultural, natural and economic conditions as well as historical and political factors have played important parts in the process of region formation. A definition or delimitation of the region that would be generally accepted has not evolved so far, however.

A region is defined as an area with more or less firmly defined boundaries, which often serves as an administrative unit below the state level. Regions have an identity created by distinctive factors such as landscape, climate, language, ethnicity, history, etc. (...) A region is an attempt to divide populations or places with certain

similarities into units that serve administrative purposes (European regional...,2005). According to Lodejska and Szymanski (2018), a region is not only an area bounded by a geographic horizon, but also an abstract concept, connecting people not only through a common location on the map, but also a unique history, tradition and culture.

A region is also a territory that brings together a specific group of people who stand out from the general population, having a more or less original way of life. the concept of region appears in a triple role, an object of study, an object of cognition and a tool of action. In this regard, it is possible to define an economic region as a spatially compact area that is part of a larger region, coherent within and forming a complex with a particular economic profile.

Economic regions are divided in line with a variety of criteria, e.g. level of development, structural distinctiveness or types of operations in place. As far as the criterion of structural distinctiveness is concerned, there are two kinds of regions: functional (node) and homogeneous (superficial, zonal) regions. Homogeneous regions are relatively uniform in respect of certain characteristics, whereas node regions are under the influence of a centre (node) that focuses the remaining fragments of the region. Nodes are commonly formed by municipal and transportation centres. Intensity of characteristics constituting such a region diminishes as one moves away from the centre towards peripheries.

Treating the region as an object of a highly complex and active structure allows for looking at the term from the viewpoint of the systems theory. Beginning with this approach, an economic region can be defined as a spatial and economic arrangement encompassing a part of economic space that is relatively delineated from its environment. It is permanently inhabited, used and developed by a specific community and full of diverse, bilaterally linked economic operators that are elements (units) of the system. Recognition and qualification of these units, as well as relations among them, are of paramount importance to analysis and assessment of a regional economic system.

This system is a result of a region's development, on the one hand, and a major driver (or limitation) of the process, on the other hand. For each region, external links with other systems of the same rank or of higher orders, e.g. a national economy, international market or the global economy, are essential as well. The degree of a region's openness or closure largely determines such links. External links between regions currently strengthen in effect of globalisation and international integration processes. This is fostered by technical and technological progress that reduces costs of transferring production factors.

Modern states differ in terms of systemic solutions. This is a result of, among other things, diverse historical, ethnic, cultural or geographic conditions (Willa, 2010).

Therefore, the economic regions that make up the member states differ in nature, legal status, the way they operate or their level of competitiveness.

Regional competitiveness is one of the levels of economic competitiveness, which is defined, for example, as 'the ability of the economy to provide residents with a high and growing standard of living and a high level of employment, based on sustainable foundations' (European Commission, 2010). Mesocompetitiveness means using the resources existing in a territorial unit in such a way as to achieve and maintain a high standard of living for the current and future inhabitants of a region and enable its continuous development (Meyer-Stamer, 2008).

A multi-criteria RCI index is used to assess the level of competitiveness of a region, which includes various aspects of competitiveness divided into three groups: basic (including institutions, macroeconomic stability, infrastructure), efficiency (including higher education, labor market efficiency), and innovation (including technological readiness, the state of development of enterprises, and innovation) (Annoni and Dijkstra, 2019; Chrobocińska, 2021; Kiseľáková *et al.*, 2019).

It follows that a region's innovativeness is a key factor affecting its competitiveness (Korres and Drakopoulos, 2009). It can be defined as the ability and motivation of the economy (enterprises) to continuously seek and put into practice scientific research, new concepts, ideas and inventions (Kot, 2018).

The modern perception of innovation is moving away from a single event to a complex of processes, phenomena and events that create new designs, goods, technologies in the sphere of production and services. Factors that influence the innovativeness of a region include not only economic conditions, but also the social and political dimensions of learning and innovation creation (Nowakowska, 2013).

On the basis of the presented literature, it is possible to make the research hypothesis H: the level of innovation of the regions of the Visegrad Group state varies.

3. Methods

Special administrative divisions have been introduced to the Community area for the purposes of regional policies. These divisions were necessary as statistical systems of the particular member states did not provide for comparability of collected data. For this reason, a standard Nomenclature of Units for Territorial Statistics has been instituted by force of Regulation of the Parliament and Council of Europe dated 26 May 2003 (EC Off. J. 2003, L 154 of 21.06.2003).

The first letters of the name make up the abbreviation NUTS, which defines European Union regions. The NUTS establishes a hierarchic classification including three basic 'levels' of the NUTS. Each of the European Union member states is

divided into a specific number of first-level regions (NUTS 1), in turn split into second-level units (NUTS 2) and finally NUTS 3.

The research used the NUTS 2 division of regions. The evaluation of the level of innovation of the regions of the Visegrad countries was made using the method of Z. Hellwig's method. The results obtained from 35 regions (17 from Poland, 4 from Slovakia, 8 from the Czech Republic and 8 from Hungary) were analyzed.

The study consisted of the following stages:

- Creating a set of diagnostic characteristics,
- Normalisation of the diagnostic characteristics,
- Calculation of taxonomical metrics.

The list of diagnostic characteristics used indicators available with the European Union public statistics (Eurostat) concerning various aspects of regional competitiveness (Table 2). This source assured comparability and relatively high reliability of the statistics. Each factor and each diagnostic variable were assigned a unique symbol (identifier) to distinguish them from other variables and attribute specific numerical values to them Only variables characterised by a relatively high changeability were taken into consideration – 20% was adopted as the boundary value of the variation coefficient.

Table 1. *The diagnostic variable set of the region innovation*

Determinants of regional innovation		
Category	Measures (Effects - innovation results)	Type of variable
Science and technology	x_1 - Researchers - percentage of total employment in 2021. [full-time count].	Stimulant
	x_2 - Staff employed in R&D in 2021. [Full-time equivalent]	Stimulant
	x_3 - Gross domestic expenditure on R&D in 2021. [Euro per capita].	Stimulant
	x_4 - Employment in technology and knowledge-intensive sectors in 2023. [percent of total employment].	Stimulant
	x_5 - Scientists and engineers (HRST) in 2023. [percentage of population in the labor force].	Stimulant
	x_6 - Growth rate of employment in research and development in 2020. [percent].	Stimulant

Source: *Authors' own research.*

In assessing the innovation of the regions, the characteristics were normalized by conducting a standardization of the *j-th* variable in the *i-th*region. Calculations were carried out using formulas for stimulants:

$$t_{ij} = \frac{x_{ij} - \bar{x}j}{S_j} \tag{1}$$

where:

t_{ij} – standardized values of the j-th variable in the i-th region,
i - the number of the region,
j - the number of the variable,
x_{ij} – the value of the j-th variable in the i-th region,,
$\bar{x_j}$ – arithmetic mean of the j-th variable,
S_j – standard deviation of the j-th variable.

Using the final set of diagnostic indices on standardisation, Hellwig's taxonomical metrics of competitiveness, i.e. synthetic metrics for each of the variables distinguished and partial metrics for aspects distinguished in the particular areas, were calculated for each region.
A model object of the following coordinates was determined based on a matrix of standardised variables:

$$O = \lfloor x_{0j} \rfloor \tag{2}$$

where:
$x_{0j} = max_i \{t_{ij}\}$
t_{ij}– standardised value of j^{th} metric in i^{th} territorial unit.

Euclidean distances from the model object were then determined:

$$d_{i0} = \sqrt{\sum_{j=1}^{m} (t_{ij} - x_{0j})^2} \tag{3}$$

where:
d_{i0} – euclidean distance between i^{th} object and the model object,
m, n –number of variables, number of objects/regions, respectively
t_{ij} – standardised value of j^{th} metric in i^{th} territorial unit,i = 1, 2, …, n,
j = 1, 2, …, m,[5]
x_{oj} – standardized value of the model unit / normalized value of the model for the j-th variable.

Taking these assumptions into account, a synthetic metric can be computed according to:

[5] *In our own study: i = 1, ..., 37; j = 1, ..., 6.*

$$S_i = 1 - \frac{d_{i0}}{d_0} \tag{4}$$

where:
d_{i0} – euclidean distance between i^{th} object and the model object,
d_0 – critical distance of a given unit from the model:

$$d_0 = \bar{d}_{i0} + 2 \cdot S_0 \tag{5}$$

$\bar{d}_{i0}$ – arithmetic mean of taxonomical distances between i^{th} object and the model object:

$$\bar{d}_0 = \frac{1}{n} \cdot \sum_{i=1}^{n} d_{i0} \tag{6}$$

S_0 – standard deviation of taxonomical distances between i^{th} object and the model object:

$$S_0 = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(d_{i0} - \bar{d}_0\right)^2} \tag{7}$$

In light of the method adopted, the higher the synthetic metric, the greater a region's innovation. Differences between the metrics point to development imbalances between particular regions.

4. Results

Based on the identified diagnostic variables, a synthetic measure of innovation was calculated for each V4 region (Table 2).

Table 2 presents detailed data describing the NUTS 2 regions of the Visegrad Group, covering various aspects of research and development (R&D) activity and employment in technological sectors. Based on an analysis of the collected statistics, it can be indicated that the highest percentage of scientists among total employment in 2021 was achieved by the Hungarian Budapest region (3.07%), as well as the Czech city of Praha (2.59%) and the Polish capital Warsaw region (with the same percentage). Regions with a low share of researchers included Severozápad in the Czech Republic (0.11%) and the Mazovian regional in Poland (0.13%). Among Polish NUTS 2 regions, the Kujawsko-Pomorskie and Warmińsko-Mazurskie regions were by far the weakest in this regard (0%).

The largest employment in R&D in 2021 was recorded in the Polish region - the capital Warsaw (57,774 full-time equivalents), followed by Hungary's Budapest (36,088), while the Czech Republic's Prague (30,244.9) should be indicated in third

place. The lowest values were recorded in smaller regions, such as Poland's Lubuskie (1,120.3), Świętokrzyskie (1,601.1) and Opolskie (1,677.7), or the Czech Republic: Severozápad (1,429.9).

The highest gross domestic R&D expenditures per capita in 2021 were achieved by regions such as Praha (1,467.76 euros per capita), Budapest (903.55 euros/person), Warsaw Capital (878.11 euros/person) and Bratislavský kraj (627.84 euros/person), suggesting high research activity in these regions. The situation was diametrically opposed, for example, in the Czech region of Severozápad (57.38 euros per capita) or the Polish Lubuskie region (41.16 euros per capita).

The highest percentage of employment in technology and knowledge-intensive sectors in 2023 was recorded in regions such as Praha (12.7% of total employment), Budapest (12.1%), Bratislavský kraj (10.9%) and the capital Warsaw (10.1%). In regions such as Lubuskie, Opolskie and Świętokrzyskie, the rate was 0%. Analyzing the other V4 countries, in this regard, the Czech Republic's Severozápad region was the weakest (2.2%), Hungary's Dél-Alföld (2.4%), and Slovakia's Západné Slovensko (3.6%).

Considering another measure of the percentage of scientists and engineers in 2023 (the percentage of the population in the labor force), Praha (16.4%) was the most favorable in this regard, followed by Budapest (14.6%), and the Warsaw Capital Region (14.5%) came next. At the opposite pole was the Dél-Dunántúl region, as the percentage there was only 3.8%. The penultimate place also belonged to the Hungarian region, in this case Észak-Alföld (3.9%).

Some regions, such as the Warmian-Masurian region (69.1%), the Mazovian regional region (56.3%), as well as Podlaskie (39.4%) or even Lubuskie (31.6%) saw high growth in R&D employment in 2020. While there was a downward trend in others, such as Észak-Magyarország (-40.5%), Stredné Slovensko (-24.9%), Észak-Alföld (-24.2%), Dél-Alföld (-21.7%), Západné Slovensko (-21.5%), or Közép-Dunántúl (-17.6%). It is worth noting that in the Czech Republic, only one region, i.e. Moravskoslezsko, showed a negative trend (-2.3%). On the other hand, the opposite situation occurred in Slovakia, as only one Slovak region recorded a positive percentage, the Bratislavský kraj region in question, with a percentage of 30.1%.

Assessing the level of innovation of the Visegrad Group regions, as measured by the synthetic $_{M1}$ measure, one can see a significant differentiation of the V4 regions, which can be divided into four groups, i.e., with a high, moderate, low and very low level of innovation.

The analysis shows that the average for the EU-27 was ~0.526, which confirms the high level of innovation of all countries belonging to the European Union.

Table 1. *Calculation of the taxonomic index of innovation of the Visegrad Group regions*

Region NUTS 2		X_1	X_2	X_3	X_4	X_5	X_6	Standardization						Euclidean Distance	Synthetic meter M
Czech Republic	Praha	2.59	30 244.9	1 467.762	12.7	16.4	2.2	2.42	-0.12	4.00	2.72	2.83	-0.11	6.85	0.4276
	StředníČechy	0.58	8 385.1	446.103	5.5	7.2	3.6	-0.24	-0.16	0.60	0.34	-0.16	-0.04	9.15	0.2356
	Jihozápad	0.6	6 667.4	298.394	3.8	6.6	8.2	-0.21	-0.17	0.11	-0.22	-0.36	0.16	9.49	0.2066
	Severozápad	0.11	1 429.9	57.378	2.2	4.7	5.3	-0.86	-0.18	-0.69	-0.75	-0.97	0.03	10.50	0.1226
	Severovýchod	0.51	7 483.7	256.111	4.2	6.2	3.8	-0.33	-0.17	-0.03	-0.09	-0.49	-0.03	9.66	0.1931
	Jihovýchod	1.34	18 679.5	528.482	5.8	9.4	20.0	0.77	-0.14	0.88	0.44	0.55	0.70	8.25	0.3109
	StředníMorava	0.67	6 908.8	292.708	3.4	6.5	8.3	-0.12	-0.17	0.09	-0.36	-0.39	0.17	9.52	0.2043
	Moravskoslezsko	0.49	4 871.1	207.672	4.1	7.1	-2.3	-0.35	-0.17	-0.19	-0.12	-0.19	-0.31	9.74	0.1862
Hungary	Budapest	3.07	36 088	903.555	12.1	14.6	4.5	3.06	-0.11	2.12	2.52	2.24	0.00	7.05	0.4110
	Pest	0.34	3 246	81.003	8.6	7.7	-11.0	-0.55	-0.17	-0.61	1.36	0.00	-0.70	9.76	0.1844
	Közép-Dunántúl	0.53	4 331	185.573	5.4	6.0	-17.6	-0.30	-0.17	-0.26	0.31	-0.55	-1.00	10.00	0.1643
	Nyugat-Dunántúl	0.4	3 155	162.893	4.0	4.9	-12.3	-0.47	-0.17	-0.34	-0.16	-0.91	-0.76	10.25	0.1434
	Dél-Dunántúl	0.51	2 962	93.013	2.7	3.8	13.1	-0.33	-0.18	-0.57	-0.59	-1.27	0.39	10.22	0.1456
	Észak-Magyarország	0.34	2 280	71.025	4.7	4.1	-40.5	-0.55	-0.18	-0.65	0.07	-1.17	-2.03	10.96	0.0845
	Észak-Alföld	0.41	4 146	98.807	4.4	3.9	-24.2	-0.46	-0.17	-0.55	-0.02	-1.23	-1.29	10.62	0.1123
	Dél-Alföld	0.56	4 941	157.165	2.4	4.8	-21.7	-0.26	-0.17	-0.36	-0.69	-0.94	-1.18	10.52	0.1212
Poland	Malopolskie	1.45	25 860.6	351.451	6.3	12.0	30.2	0.92	-0.13	0.29	0.60	1.40	1.15	8.10	0.3235
	Śląskie	0.65	16 161.1	147.058	3.8	9.5	5.1	-0.14	-0.15	-0.39	-0.22	0.59	0.03	9.45	0.2102
	Wielkopolskie	0.43	10 577.3	146.609	2.5	7.1	-4.1	-0.43	-0.16	-0.39	-0.65	-0.19	-0.39	10.04	0.1610
	Zachodniopomorskie	0.38	3 43.,3	82.203	3.1	8.1	11.2	-0.50	-0.17	-0.61	-0.45	0.13	0.30	9.81	0.1806
	Lubuskie	0.18	1 120.3	41.159	0	6.7	31.6	-0.76	-0.18	-0.75	-1.48	-0.32	1.22	10.28	0.1408
	Dolnośląskie	1.01	17 806.1	235.378	5.5	11.3	-0.8	0.33	-0.15	-0.10	0.34	1.17	-0.24	8.96	0.2512
	Opolskie	0.3	1 677.7	72.304	0	6.4	14.1	-0.61	-0.18	-0.64	-1.48	-0.42	0.43	10.37	0.1338
	Kujawsko-pomorskie	0	6 243.1	124.688	3.6	7.1	-4.2	-1.00	-0.17	-0.47	-0.29	-0.19	-0.39	10.18	0.1496
	Warmińsko-mazurskie	0	3 147.3	128.201	1.8	6.5	69.1	-1.00	-0.17	-0.46	-0.88	-0.39	2.90	9.89	0.1735
	Pomorskie	1.04	12 955.5	273.111	6.4	12.0	1.0	0.37	-0.16	0.03	0.64	1.40	-0.16	8.76	0.2683
	Łódzkie	0.56	8 824.7	162.549	4.2	7.6	-14.9	-0.26	-0.16	-0.34	-0.09	-0.03	-0.87	9.91	0.1719
	Świętokrzyskie	0.23	1 601.1	51.67	0	6.8	-1.2	-0.70	-0.18	-0.71	-1.48	-0.29	-0.26	10.58	0.1163
	Lubelskie	0.56	7 029.4	117.173	2.3	7.3	3.3	-0.26	-0.17	-0.49	-0.72	-0.13	-0.06	9.93	0.1704
	Podkarpackie	0.53	6 144.5	137.182	2.6	7.7	3.0	-0.30	-0.17	-0.43	-0.62	0.00	-0.07	9.85	0.1773
	Podlaskie	0.43	2 948.4	96.528	2.3	7.7	39.4	-0.43	-0.18	-0.56	-0.72	0.00	1.57	9.63	0.1953
	Warszawski stoleczny	2.59	57 774	878.113	10.1	14.5	17.8	2.42	-0.07	2.04	1.86	2.21	0.60	6.89	0.4241

	Mazowiecki regionalny	0.13	2 008	45.82	1.8	5.7	56.3	-0.83	-0.18	-0.73	-0.88	-0.65	2.33	10.05	0.1599
Slovakia	**Bratislavský kraj**	2.43	10 545.7	627.837	10.9	11.4	30.1	2.21	-0.16	1.21	2.13	1.20	1.15	7.25	0.3943
	Západné Slovensko	0.39	4 879.6	127.83	3.6	4.3	-21.5	-0.49	-0.17	-0.46	-0.29	-1.10	-1.17	10.57	0.1171
	Stredné Slovensko	0.4	3 153.5	105.915	3.7	4.9	-24.9	-0.47	-0.17	-0.53	-0.26	-0.91	-1.32	10.57	0.1164
	Východné Slovensko	0.44	3 778.7	73.289	4.5	5.4	-12.1	-0.42	-0.17	-0.64	0.01	-0.75	-0.75	10.26	0.1430
	EU-27	1.61	3103026 .00	740.42	5.00	8.6		1.13	6.00	1.58	0.17	0.29	-0.20	5.67	0.5263
	Arithmetic mean	**0.76**	**90960.9 6**	**265.11**	**4.47**	**7.70**	**4.54**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**9.46**	**0.2094**
	Standard deviation	**0.76**	**501956. 61**	**300.56**	**3.02**	**3.08**	**22.24**	**1**	**1**	**1**	**1**	**1**	**1**	**1.25**	**0.1047**
	Coefficient of variation	**100%**	**552%**	**113%**	**68%**	**40%**	**490 %**	-	-	-	-	-	-	**13%**	**50%**

Source: *Author's calculations.*

However, among the regions of the Visegrad Group, Prague (~0.428), the Warsaw Capital Region (~0.424) and Budapest (~0.411) were ranked highest. In these areas, the level of innovation should be seen as high. Bratislavský kraj in Slovakia received a score of ~0.394, bringing the region close to the top and thus ranking among the most innovative regions of the V4.

Six regions were ranked in the moderate innovation category, i.e., Malopolska (~0.323), Jihovýchod (~0.311), Pomorskie (~0.268), as well as Lower Silesia (~0.251), Střední Čechy (~0.236) and Silesia (~0.210).

Next are the regions with a low level of innovation. As many as fourteen V4 regions were classified in this group. Among them was the Jihozápad region (~0.207), which opened this group, while the region that ranked at the end of this pile was the Mazovian regional (~0.16).

The lowest scores described areas classified as regions with very low levels of innovation. This group included thirteen regions. This list was opened by the Kujawsko-Pomorskie region (~0.150), followed by Dél-Dunántúl (~0.146) and then Nyugat-Dunántúl (~0.143). The entire list was closed by the Észak-Magyarország region (~0.084), indicating the weakest innovation activity and relatively the greatest distance to catch up with the EU average

5. Discussion

The literature most often presents research results on the competitiveness of regions (Chrobocińska, 2023; Grassia *et al.,* 2022), while the impact of innovativeness of companies/sectors/institutions on the development of the region is studied by few authors.

As a result of our own research, synthetic measures of innovativeness of individual regions of the Visegrad Group countries were calculated, which indicated a wide

variation in the level of innovativeness of V4 regions. The results of this research confirmed the findings of the literature analysis.

R. Halásková and co-authors. (2022) studied the key areas of research potential in the regional conditions of 14 Czech self-governing regions in 2015 and 2020. 11 indicators (R&D) were used for analysis using multivariate methods. The results showed internal similarities of Czech regions according to the three R&D factors created in 2020. The relationship in Czech regions between the created factors of research potential (in the public sector, the business enterprise sector, potential human resources) on one side and economic level of regions and total R&D expenditures as percentage of regional GDP on the other side was examined.

Burdiuzha (2021) conducted a study on the growth of innovation in the agricultural sector in the Visegrad countries in 1995-2019. Her results show that the increase in GERD investment in this sector positively affected the growth of value added to GDP and the number of patents granted, which contributed to the growth of innovation in agriculture

Similarly, research results were obtained by Jablonska (2024), who showed that the entrepreneurship rate in V4 countries is strongly related to innovation in small and medium-sized enterprises (SMEs), whether product, process, marketing or organizational. Investment in venture capital and workforce training, especially in ICT, also play an important role, further supporting new business development and entrepreneurship in V4 countries. This differentiates these countries from moderate innovators, where these factors are less important.

According to Golejewska (2012), capital regions lead the way in innovation. In her research, she showed large differences in the levels of innovation in the Visegrad countries, especially in the capital regions, with the exception of the Mazowieckie Voivodeship, which fared worse compared to other capitals. In the 2004-2009 study, the number of regions with balanced levels of inputs (INPUT) and outputs (OUTPUT) of innovation decreased. Eastern Poland's regions recorded the lowest scores, which contrasted with Czech and Hungarian regions that had lower inputs but high innovation effects.

According to E. Ivanova and J. Masarova (2019) innovation plays a significant role in the social and economic development of countries and regions Their research has shown that the highest innovation performance is performed by the regions of Praha and the Bratislava region.

The largest relative differences in innovation performance between Visegrad Group regions are in indicators Public private co publications, International scientific co publications, SMEs with marketing or organizational innovations and Innovative SMEs collaborating with others (more than 54%). The smallest differences are in

indicators: Exports of medium-high/high-technology intensive manufacturing, Most cited scientific publications, Trademark applications, and Non R&D innovation expenditures

6. Conclusion

The Visegrad countries show similarities in terms of economic and social development, but there are significant differences between them in the level of innovation of individual regions. This is influenced by a number of factors, such as the availability of research and development infrastructure, the education level of the population, support from the public administration and the culture of entrepreneurship.

Therefore, the study of innovation in the V4 regions becomes important not only from the perspective of the development of the individual countries' development, but also in the context of striving for sustainable development of the entire region and its competitiveness in the European Union.

Taking into account the diagnostic variables underlying the evaluation of the region's innovation level, the synthetic measures of innovation of all V4 regions were calculated. Based on our own research, we found that the synthetic measure M1 was the highest in the EU-27.

Among the Visegrad Group regions, Praha (0.427), the Warsaw Capital Region (0.424) and Budapest (0.411) were in this set, which also achieved a high level of innovation. Bratislavský kraj in Slovakia received a score of 0.394. Similar survey results were obtained by E. Ivanova and J. Masarova. Their study, comparing the innovativeness of NUTS II regions in the Visegrad Group (V4) countries, showed that the performance of the Visegrad Group regions in terms of innovativeness is well below the EU average, with the exception of Prague and Bratislava, which achieved the best results. Prague recorded the highest innovation performance in 2011 and 2017. The lowest results were attained by some regions in Poland. The indicators for employment in high-tech manufacturing and services were the highest, while EPO patent applications were the lowest.

The results of the study on innovation of the Visegrad Group's regions countries show large discrepancies in both the level of inputs and effects, with the capital regions leading the way. This confirms the correctness of the research hypothesis H1: the level of innovation of the Visegrad Group state regions varies.

The Visegrad Group countries share many goals and challenges, but differ in their approaches to innovation policy, regional development strategies and in the effectiveness of implementing innovative solutions. Therefore, an analysis of innovation in the V4 regions can provide valuable insights into the effectiveness of different strategies and the identification of the best practices that can contribute to

improving the innovation potential of these countries. This is also crucial in the context of the European Union's cohesion policy, which aims to close development gaps between regions and support those that are less advanced in terms of innovation.

In the face of global challenges such as climate change, digitisation and globalisation, the ability of the regions to generate innovation is becoming increasingly crucial to their future.
Given the challenges faced by the Visegrad Group (V4) regions and the varied levels of innovation across them, future research into regional innovation should focus on expanding the analysis to include the indicators of entrepreneurship, digitalisation, and support for startups.

Another crucial area for future research should also involve examining the collaboration between the public sector, private enterprises, and research organisations. It is particularly important to investigate cooperation models that most effectively support knowledge and technology transfer, thereby contributing to regional innovation growth.

Additionally, it would be valuable to analyse the impact of innovation policies on the development of regions with lower innovation indicators, which could provide practical recommendations for strategies aimed at levelling development opportunities within the European Union.

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