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DISPROPORTIONS IN THE LEVEL OF INNOVATION IN EUROPEAN UNION COUNTRIES

Monika ZIOŁO[1*], Lidia LUTY[2]

[1] University of Agriculture in Krakow; monika.ziolo@urk.edu.pl, ORCID: 0000-0003-0884-4083
[2] University of Agriculture in Krakow; lidia.luty@urk.edu.pl, ORCID: 0000-0001-8250-8331
* Correspondence author

Purpose: One of the most important areas of reflection on innovation and innovativeness is regional policy and issues related to the development of the economy. The phenomena of globalisation and pressure to create a knowledge-based economy means that not only enterprises, but also countries are forced to optimise the use of their potential on a macro, meso or micro scale. For this reason, the issue of innovativeness is connected with particular economic entities and sectors of the economy, with the activity of state, regional and local authorities and the European Union. In the conditions of deepening European integration, stimulating innovation of territorial socio-economic systems is an important instrument of economic policy at the international, national and regional levels. The aim of the study is to assess the level of innovativeness of the region in spatial and dynamic terms. Multivariate Statistical Analysis will be used to determine the aggregated indicator based on data taken from Eurostat database.
Design/methodology/approach: The implementation of the objective will be achieved through the evaluation and comparison of the level of innovativeness of EU countries with the use of a synthetic measure, estimated by using one of the model methods of linear ordering of objects in the years 2015, 2018 and 2021. In the proposed method, the synthetic measure is determined using the distance of the examined objects from the model objects. The dynamic approach will allow to determine the directions of changes. The level of innovation of regions (EU countries) determined by a number of indicators that were adopted in four areas: human capital, finance, business activity and intellectual property protection.
Findings: The region's innovativeness is a multidimensional phenomenon, which is directly unmeasurable, hence the need to use statistical methods when measuring it. Obtained results will allow to assess the studied phenomenon, build a ranking and identify countries with a high, medium or low level of innovation. The results of the analyses confirmed that it is advisable to consider innovation by plane, because in this case there is a greater differentiation of countries. Due to the level of innovation, the highest positions in the ranking were taken by Sweden, Germany, Finland and Austria, at the end of the ranking were countries from Central and Eastern Europe, Poland, Latvia, Bulgaria and Romania. In the area of innovative activities, Estonia ranked very high being classified in the group I of the most innovative countries. The country is characterized by high employment in innovative enterprises, significant expenditure on innovation and a large share of Small and Medium Enterprises (SMEs) introducing product innovations. The fact that the countries of Central and Eastern Europe are

reducing the distance to more innovative EU countries should be assessed positively, as evidenced by lower values of the coefficients of variation in 2021 compared to 2015.

Keywords: innovation of regions, dynamics, Multivariate Statistical Analysis.

Category of the paper: research paper.

1. Introduction

Innovation is an economic category which can be examined and defined on three different levels, namely companies, regions and states (economies) (Kowalik, 2015). Innovation in regions and economies on a macroeconomic level signifies that the entities in that economy have the ability and willingness to constantly seek out and implement scientific findings, research and development results, ideas, inventions, organizational methods and techniques, and improvements in all areas of operation and knowledge (Mirkowska, 2010). It creates a competitive advantage for regions and significantly shapes regional variations of socio-economic development (Dominiak, Churski, 2012).

Emphasising the importance of innovation for regional development, at the Lisbon European Council summit in 2000 the European Research Area (ERA) was established. As one of the key elements in EU strategy on innovation and growth, it identifies the need to overcome the differences between EU countries through targeted funding and improving policies that support innovation (Chessa et al., 2013).

Pachura also notes the need to expand the role of regional innovation policy, as he argues that at the regional level it is possible to manage more effectively, adapting tools and system solutions to local needs (Pachura et al., 2014).

Seeking out countries with a high level of innovation is important, as these countries can provide a benchmark for other territories. The aim of this article is to investigate the disparities between individual countries of the European Union in terms of the level of innovation in 2015, 2018 and 2021. Taking into account the fact that there are differences between countries the level of innovation of regions (EU countries) determined by a number of indicators that were adopted in four areas: human capital, finance, business activity and intellectual property protection.

2. Literature review

In the literature on the subject, the concept of a region's innovation is largely identified with the economy's innovation (Skonieczny, Świda, 2008). Piech (2009) writes following Porter (2001) that a region's competitiveness is strictly a result of its ability to absorb innovations and is the primary source of differences in economic development between regions.

Innovatory capacity is a critical factor for the European Union's economic growth, especially if we take into consideration that an important part of productive growth in advanced nations - as measured in terms of Gross Domestic Product - corresponds to innovation (Freeman, 1994), so we may consider it to be one of the key factors determining competitiveness, business survival, growth and employment. Thus, it is especially important to find out which components of an Research & Development (R&D) system are most decisive as engines of innovation and what are the factors determining systems' innovatory capacity. Among authors seeking out the factors which determine innovations, one can point to the research carried out by Buesaa, Hejis and Baumert (2010). In the opinion of these authors, policies aimed at promoting innovation will have to focus mainly on innovations by companies. It is necessary to create an environment conducive to initiatives and investments, as well as to stimulate R&D and design by companies, bearing in mind that these constitute a decisive factor driving the launch of new products and processes on the market. Agrawal notes that the chances for the development of an economically weaker country or region depends partly on its ability to innovate (Agrawal et al., 2011). Szopik-Depczyńska (Szopik-Depczyńska et al., 2018) point out that a region's innovation level is an important factor affecting both economic growth and growth in employment. The work of such authors as Christopher Freeman (1994), Freeman and Soete (2009), and Crescenzi, Rodriguez-Pose, Storper (2007) point to the need to incorporate knowledge and innovation in shaping the diversification of economic development within regions. Lundvall (1994) emphasizes the importance of knowledge in the process of implementing innovation, stating that "knowledge is the greatest strategic resource, and learning (acquiring knowledge) is the most important process". Studies conducted by Sleuwaegen and Boiardi (2014) recognize the unique importance of employees in the process of implementing innovations. The view that innovation is a key driver for sustainability is widely accepted among scholars, industry professionals and government representatives. This is due to the fact that sustainable development is a pressing issue that requires immediate action and changes from governments, industry, and society as whole (Silvestrea, Ţîrcăb, 2019).

3. Materials and methods

In economic research, we generally deal with the analysis of complex phenomena, i.e. phenomena that cannot be expressed with a single feature and cannot be measured directly. An example of such a phenomenon is the level of innovativeness of regions (EU countries) determined by a number of indicators, which are usually considered in four areas (Table 1): human capital, finance, activity of enterprises and protection of intellectual property.

Table 1.
Selected variables for the analysis

Area	Variable	Item
Human capital	Employed ICT specialists [% share]	W_1
	Employment in knowledge-intensive activities [% share]	W_2
	Employment in innovative enterprises [% share]	W_3
Finance	R&D expenditure in the public sector [% GDP]	W_4
	R&D expenditure in the business sector [% GDP]	W_5
	Direct and indirect government support of business R&D [% GDP]	W_6
	Non-R&D innovation expenditure [% turnover]	W_7
	Innovation expenditures per person employed [thousands euro]	W_8
Business activity	SMEs introducing product innovations [% SMEs]	W_9
	SMEs introducing business process innovations [% SMEs]	W_{10}
	Exports of medium and high technology products [% share]	W_{11}
	Knowledge-intensive services exports [% share]	W_{12}
	Sales of new-to-market and new-to-firm innovations [% of turnover]	W_{13}
Intellectual property protection	PCT patent applications [per billion GDP (in PPS)]	W_{14}
	Trademark applications [per billion GDP (in PPS)]	W_{15}
	Design applications [per billion GDP (in PPS)]	W_{16}

Source: Own study based on Eurostat.

The selection of indicators was preceded by a literature review (Greunz, 2004, Fritsch, Slavtchev, 2006) and a statistical analysis (Table 2). All variables in the studied group of objects meet the basic criterion for selecting variables to describe a complex phenomenon, i.e. they are not quasi-constant variables (Kukuła, Luty, 2015). The recent and current literature on the innovation systems approach, has demonstrated that not all the indicators are adequate for measuring innovativeness (Edquist, Zabala-Iturriagagoitia et al., 2015). Great importance was paid to the quality of data due to their usefulness, topicality, accuracy and elimination of information noise (Nermend, 2017).

Table 2.
Numerical characteristics of the indicators in years 2015, 2018, 2021

Item	2015				2018				2021			
	max	***min***	***Me***	***CV***	***max***	***min***	***Me***	***CV***	***max***	***min***	***Me***	***CV***
W_1	6.80	1.60	3.30	0.19	6.80	1.90	3.60	0.18	7.00	2.10	3.90	0.18
W_2	22.90	6.60	13.50	0.16	22.70	7.20	13.70	0.16	25.70	7.60	14.30	0.14
W_3	72.03	23.44	57.05	0.17	72.03	14.44	55.58	0.20	79.87	15.39	56.15	0.19
W_4	1.08	0.25	0.60	0.22	1.07	0.20	0.55	0.23	1.07	0.20	0.57	0.23
W_5	2.26	0.09	0.82	0.31	2.26	0.11	0.68	0.29	2.44	0.17	0.83	0.27
W_6	0.37	0.00	0.08	0.29	0.41	0.00	0.07	0.27	0.40	0.00	0.07	0.25
W_7	1.55	0.14	0.60	0.24	2.01	0.13	0.58	0.21	2.36	0.10	0.56	0.20
W_8	11.46	0.63	3.68	0.23	12.52	0.74	3.76	0.23	11.95	0.83	4.36	0.27
W_9	34.55	2.84	22.81	0.25	34.24	3.20	23.30	0.26	48.87	9.35	30.40	0.21
W_{10}	49.64	16.40	34.73	0.18	49.18	10.11	34.96	0.22	65.62	7.57	39.44	0.22
W_{11}	67.56	19.41	48.72	0.18	68.65	21.18	49.72	0.17	69.52	29.16	51.26	0.15
W_{12}	92.98	17.94	47.90	0.22	94.02	19.97	49.74	0.21	93.46	20.10	51.44	0.21
W_{13}	69.76	3.69	10.98	0.17	19.12	4.12	9.27	0.22	23.81	1.42	11.47	0.18
W_{14}	9.34	0.21	1.61	0.29	9.36	0.29	1.36	0.27	8.92	0.19	1.28	0.27
W_{15}	36.16	1.74	6.07	0.21	35.89	2.22	6.64	0.20	40.44	2.52	7.27	0.19
W_{16}	17.93	0.45	3.52	0.24	12.09	0.82	3.97	0.21	7.77	0.65	2.55	0.24

Me: Median; CV: Coefficient of Variation.

Source: own study.

In the analysed period, changes in most of the selected indicators were slight and the median values for 10 indicators increased compared to 2015. The most active in introducing innovations were the owners of small and medium-sized enterprises, hence noticeable changes can be observed on the business activity level in the case of indicators W_9, W_{10}, W_{11} and W_{12}. Among the selected features, the most favourable changes took place in the case of introducing product innovation in small and medium-sized enterprises (W_9). In the analysed countries, the SMEs sector saw an average increase by 8% in the number of entities introducing a new product to the market. The most active in introducing product innovations (W_9) were Estonia, Cyprus, Germany, Slovenia, Finland, Sweden and Bosnia and Herzegovina, where about 40% of entities from the SMEs sector made decisions about introducing a new product.

In the case of the W_{11} index showing the share of SMEs introducing business process innovations, the median value increased from 48.7% in 2015 to 51.3%.

In 2021, compared to 2015, the differentiation of the countries presented also slightly decreased, which is indicated by the level of the coefficients of variation, which may indicate the levelling of differences between more and less innovative countries.

The statistical data on the basis of which the analysis was carried out in one year form the matrix:

$$\left[w_{ij}\right]=\begin{bmatrix} w_{11} & w_{12} & \ldots & w_{1k} \\ w_{21} & w_{22} & \ldots & w_{2k} \\ \ldots & \ldots & \ldots & \ldots \\ w_{n1} & w_{n2} & \ldots & w_{nk} \end{bmatrix} \tag{1}$$

where w_{ij} - indicator value W_j for *i* country.

A synthetic measure, which is the tool of Multidimensional Statistical Analysis, was used to assess the level of innovativeness of the EU countries in the analysed areas. Its design was based on a model-free method of aggregating variables:

$$Q_i = \frac{1}{j}\sum_j z_{ij}\,, \tag{2}$$

where:

Q_i - level of innovation in the country and in a given area,

z_{ij} - normalized values of the actual realisation of indicators, determined according to the formula (Walesiak, 2014; Kukuła, Luty, 2015):

$$z_{ij} = \frac{w_{ij} - \min\limits_i w_{ij}}{\max\limits_i w_{ij} - \min\limits_i w_{ij}}\,, \tag{3}$$

z_{ij} - standardized values of the actual realisation of indicators, such that: $z_{ij} \in [0,\ 1]$.

The values of the synthetic variable obtained in the above-described manner are a proposal of a measure describing the assessment of the country's innovation level in the area of human capital, finance, business activity and intellectual property protection in spatial and dynamic terms.

Thanks to the application of the discussed method, the analysed regions were ranked according to the values Q_i in four areas and in total. Within the ordered sets, a topological classification of similar objects was carried out, as follows:

- I group (high level): $$Q_i \in \left(\frac{1}{3}\left(\min_i Q_i + 2\max_i Q_i\right),\ \max_i Q_i\right] \tag{4}$$
- II group (medium level): $$Q_i \in \left(\frac{1}{3}\left(\min_i Q_i + \max_i Q_i\right),\ \frac{1}{3}\left(\min_i Q_i + 2\max_i Q_i\right)\right] \tag{5}$$
- III group (low level): $$Q_i \in \left[\min_i Q_i,\ \frac{1}{3}\left(\min_i Q_i + \max_i Q_i\right)\right] \tag{6}$$

4. Results

Taking into account all the analysed indicators collectively, in 2015, compared to 2018 and 2021, the changes are small. On the planes, in turn, the differentiation of countries is visible. Hence the decision to leave the analysis for 2021 and to assess the differentiation of countries in the indicated planes (Figure 1).

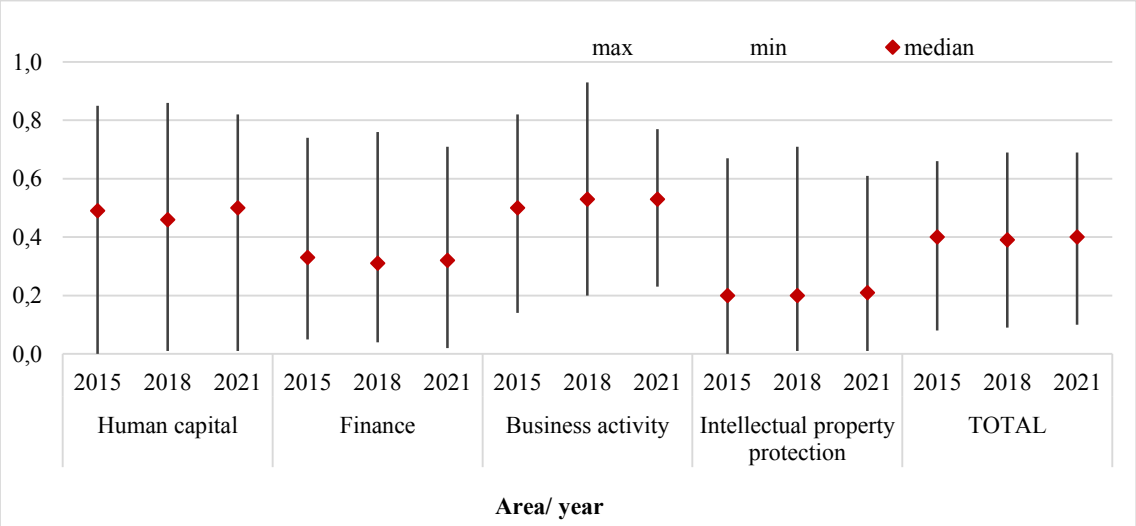

Figure 1. Numerical characteristics of the synthetic variable describing the level of innovativeness in total and in the area of: human capital, finance, business activity and intellectual property protection in the years.

Due to the level of innovation, the highest positions in the ranking were taken by Sweden, Germany, Finland and Austria, at the end of the ranking were countries from Central and Eastern Europe Poland, Latvia, Bulgaria and Romania (Figure 2). In the area of human capital the leaders were Germany, Belgium, Sweden and Austria, the lowest results were observed in Bulgaria, Poland and Romania. In terms of finance, the largest funds for innovation were allocated by Germany, Belgium, Sweden and Austria and the lowest by Latvia, Bulgaria and Romania. The innovativeness of the SMEs sector was the highest in Germany, Sweden and Belgium and the lowest in Latvia, Poland and Bulgaria. Denmark, Sweden and Finland have the highest number of registered innovative patents.

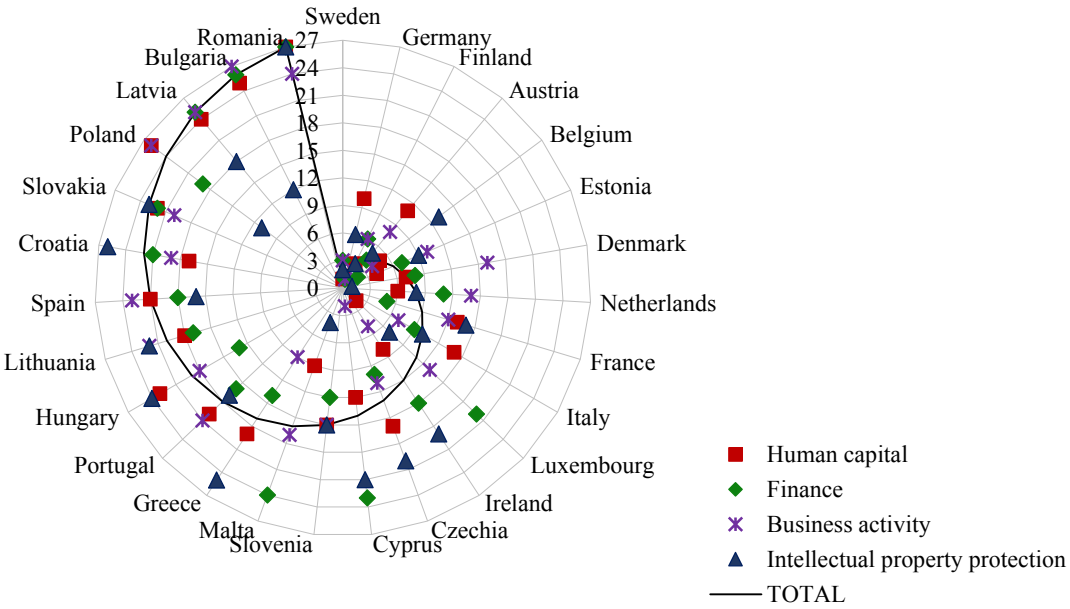

Figure 2. Rankings of EU countries in terms of innovation performance in 2021 overall and in the areas of: human capital, finance, business activity and intellectual property protection.

When assessing the differentiation of indicators between the three groups of countries, the greatest distance can be observed in terms of patent applications (Table 4).

Table 4.
Numerical characteristics of indicators in groups of EU countries similar in terms of innovation performance in 2021

Item	high level				medium level				low level			
	max	*min*	*Me*	*CV*	*max*	*min*	*Me*	*CV*	*max*	*min*	*Me*	*CV*
W_1	7.00	4.00	5.40	0.14	6.10	2.10	3.90	0.17	3.70	2.30	3.10	0.11
W_2	19.00	14.20	15.95	0.08	25.70	11.10	14.60	0.16	12.30	7.60	11.00	0.11
W_3	79.87	56.15	68.93	0.09	71.53	34.58	54.66	0.14	59.77	15.39	38.93	0.22
W_4	1.07	0.70	0.95	0.11	0.74	0.22	0.52	0.24	0.57	0.20	0.48	0.23
W_5	2.44	0.86	1.94	0.19	1.51	0.26	0.74	0.27	0.83	0.17	0.50	0.24
W_6	0.26	0.03	0.10	0.31	0.40	0.00	0.15	0.28	0.12	0.01	0.02	0.32
W_7	2.36	0.16	0.55	0.29	1.01	0.14	0.49	0.31	1.48	0.10	0.62	0.27
W_8	11.95	2.94	7.50	0.26	9.87	2.16	4.36	0.23	4.49	0.83	2.52	0.28
W_8	48.87	26.76	34.10	0.14	48.23	19.54	30.40	0.16	37.77	9.35	15.30	0.24
W_{10}	56.82	39.44	49.87	0.09	65.62	19.00	39.04	0.18	45.33	7.57	21.99	0.27
W_{11}	67.50	41.36	51.33	0.11	69.52	29.16	55.55	0.16	69.03	33.66	43.40	0.16
W_{12}	80.02	45.67	74.38	0.15	93.46	32.80	51.44	0.22	52.81	20.10	41.51	0.22
W_{13}	15.65	1.42	13.98	0.29	23.81	6.35	11.57	0.19	16.11	6.34	9.14	0.18
W_{14}	8.92	1.56	5.31	0.25	3.54	0.53	1.23	0.25	1.28	0.19	0.51	0.24
W_{15}	18.94	6.35	8.80	0.19	40.44	3.07	5.03	0.27	8.01	2.52	5.91	0.26
W_{16}	7.77	2.55	4.60	0.19	5.84	0.76	2.33	0.26	5.16	0.65	1.68	0.30

Me: Median; CV: Coefficient of Variation.

Source: own study.

While the best country in group one, Sweden, reported 8.92 patents per billion GDP (in PPS), the most active country in group III (Spain) reported 1.28 patents per billion GDP (in PPS). A large distance between groups I and III can be observed due to the W5 and W8 indexes. The median R&D expenditure in the business sector (W5) is 1.44pp higher in group I compared to group III. The significance of the differences between the groups of countries can also be observed due to the index (W6), the highest values were obtained in this case by the countries from group II. Due to direct and indirect government support of business R&D (W6), the French government is the most active. The countries from the second group are characterized by the highest value of the W11 index. Exports of medium and high technology products prevailed in Hungary. The countries from group I showed greater differences in terms of 12 variables compared to the countries from group III, which was indicated by higher values of the coefficients of variation.

Table 5.
Innovation levels of EU countries overall and in the areas of: human capital, finance, business activity and intellectual property protection in 2021

Country	Total	Area			
		Human capital	Finance	Business activity	Intellectual property protection
Sweden					
Germany					
Finland					
Austria					
Belgium					
Estonia					
Denmark					
Netherlands					
France					
Italy					
Luxembourg					
Ireland					
Czechia					
Cyprus					
Slovenia					
Malta					
Greece					
Portugal					
Hungary					
Lithuania					
Spain					
Croatia					
Slovakia					
Poland					
Latvia					
Bulgaria					
Romania					

Legend: high level | medium level | low level

Source: own study.

When analysing the innovativeness of countries in terms of 4 planes and in three groups, it is important to emphasize their great diversity. Sweden, Germany, Finland and Austria are among the most innovative countries. Group I countries are characterized by high values of indicators, especially in terms of human capital and business activity. Estonia was ranked high and placed in the 1st group. It stood out in terms of Employment in innovative enterprises (W_3), Non-R&D innovation expenditure (W_7), SMEs introducing product innovations (W_9). In the group with the lowest level of innovation in terms of 4 levels, there are mainly Central and Eastern European countries. The lowest values of 11 out of 16 selected indicators characterize Romania, hence its low position in the third group.

5. Conclusion

The use of a synthetic variable when comparing the innovativeness of countries is fully justified due to the different order of magnitude of the features and different titles in which the indicators are expressed. The inclusion of four planes in the analyses made it possible to present a more detailed differentiation of countries. The division into three groups allowed to distinguish countries with a low, medium and high level of innovation. Sweden, Germany, Finland and Austria can be considered the most innovative. Group I also includes Estonia, which has the highest percentage of people employed in innovative enterprises among the analysed countries, the highest expenditure on innovation, and the highest percentage of enterprises introducing product innovations. The countries of Central and Eastern Europe are the least innovative. Romania was ranked lowest in the rankings. The narrowing of the distance between more and less innovative countries should be assessed positively, although this process is very slow, as indicated by the minimal changes in the coefficients of variation for the selected features in 2021 compared to 2015.

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