

Study of the Level of Innovation in the European Union: Poland Compared to the Leading Countries

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Abstract: Knowledge and innovation are key resources of modern economies. The ability to transform knowledge into new products, technologies, marketing methods and organizational solutions (and thus into broadly understood innovations) is not only the basis of entrepreneurship, but also the foundation for building competitive advantage. Thus, supporting innovation remains the main challenge for managers and staff in power, and the very concept of innovation in enterprises, regions and countries is rightly considered an important area of research. Innovation is therefore an economic category that is measurable. The theory and practice of economic life have allowed the development of a number of metrics for measuring innovation, enabling the assessment of not only its level, but also the source of the innovative potential of individual entities. Taking into account the above, the article presents the results obtained by the EU and its individual countries, based on short theoretical considerations regarding the essence of innovation and the methodological basis for its measurement by the European Commission (in the annual European Innovation Scoreboards EIS using the Summary Innovation Index - SII). The basis for the study is the data contained in the EIS from 2016-2023. The article uses the method of analysis, synthesis and graphical presentation of data. The research focused on Poland and Denmark, which was the leader in innovation in the last study, overtaking the long-term front-runner Sweden.

Keywords: Innovation, Summary Innovation Index

1. Introduction

Innovations are currently treated as one of the most progressive factors of competitiveness, growth and development. Supporting innovation therefore remains the main challenge for managers and staff in power, and the very concept of innovation in enterprises, regions and countries is rightly considered an important area of research (Szklarz et al, 2021; Bielińska-Dusza and Hamerska, 2021; Stojanović, Puška and Selaković, 2022). Innovation is therefore an economic category that is measurable. The theory and practice of economic life have allowed the development of a number of metrics for measuring innovation, enabling the assessment not only of its level, but also the indication and assessment of the sources of innovation potential of individual entities (Krawczyk-Sokołowska, Piersceniak and Caputa, 2021). Without a doubt, a special area of interest in this matter is human capital: knowledge, entrepreneurial attitudes and appropriate resource management. The above may be confirmed by the fact that the above-mentioned categories were included in the structure of the Summary Innovation Index, a measure used by the EU to monitor the innovation of its countries.

The aim of the article was to conduct an analysis of the level of innovation in Poland compared to EU countries, with reference to nations that have been innovation leaders for years. The study was based on the latest European Innovation Scoreboard (EIS 2023) data. The countries, to which the results obtained by Poland were referred, are Sweden (the leader in previous years) and Denmark, with the best results among all EU countries in 2023. Indirectly (due to the interdependence of knowledge and innovation) this will allow us to determine how Poland uses knowledge and the potential of its resources compared to other countries. In the era of globalization and the race of economies, innovation and knowledge - as their sources - have become particularly important. Therefore, conducting dedicated research and showing the results, as presented in the article, is important due to the need to monitor this phenomenon. This allows us to determine the level of innovation in individual countries and the factors determining it (developing and inhibiting it). They can thus become a contribution to identifying the directions of necessary changes and optimizing decision-making processes in this area.

To achieve the indicated goal, first of all, short theoretical considerations were presented in the field of the essence of innovation and knowledge as its basis. Then, the methodological assumptions for measuring innovation in the EU using the Summary Innovation Index and the data taken into account when determining the level of innovation in individual countries and the entire EU are presented. The essential part of the presented considerations is a descriptive and graphical presentation of the level of innovation in the EU and member states, with particular emphasis on the comparison of the results obtained by Poland with the results of countries placed on the innovation map in the Innovation Leaders group. The presented data will allow for the identification and preliminary comparisons to other EU countries of Poland's innovative potential, based, in

the authors' opinion, mainly on knowledge and financial resources. At the same time, it is an introduction to further work, in which Poland's innovation profile will be determined based on the decomposition of the SII index. The results of this work will be presented in the publication: "Analysis of Poland's innovation profile based on the decomposition of the Summary Innovation Index (SII)".

2. Knowledge as the Basis for Innovation - Outline of the Issues

Innovation and knowledge are basic components of the development of enterprises, countries, economies and various organizations. Innovation-oriented entities are modern knowledge enterprises. These entities recognize its power and see it as a key factor in shaping competitive advantage, resulting from the ability to transform knowledge into new products, services, technologies, marketing techniques and organizational solutions, i.e. into innovations. When analysing the issues of knowledge and innovation, it is impossible not to notice a certain interdependence. Without appropriate knowledge potential, it is difficult to plan and implement any changes and innovations. On the other hand, innovations create demand for new areas of knowledge (Kokot-Stępień and Krawczyk, 2023; Chomać-Pierzecka, 2018). Going further, the greater the knowledge in the field of innovation processes, the more productive are human resources, which translates directly into an increase in knowledge capital and innovation capital (Myjak, 2022).

It is obvious that the scale of innovative activity is determined by the innovative potential of organizations, the use of which in an effective manner means having innovative capacity (including the creative creation process). Managerial and employee competencies are assumed to be the key determinants of building and developing innovative capacity - in particular "inside" knowledge (creativity and knowledge of employees, databases held by the enterprise/organization) and knowledge obtained from outside. Other elements include: modern infrastructure, work organization, cooperation in knowledge management (i.e. building knowledge alliances with clients and other entities and using open sources of knowledge, purchasing technology (Karaś, 2021; Haberla and Kuźmińska Haberla, 2013). The process of converting external knowledge into internal knowledge and back into external knowledge - materialized in innovations - is also considered particularly important in the innovation process (Baruk, 2016; Castaneda, and Cuellar, 2020).

Innovation and innovativeness are identified with novelty, or more precisely, with beneficial novelty that will not exist without scientific and technical knowledge. Innovation is a category with a large semantic capacity. This results in numerous definitions and taxonomies (Ostraszewska and Tylec, 2017; Kogabayev and Maziliauskas, 2017; Taylor 2017), with particular importance given to the interpretation contained in the Oslo Manual (2018), which allows for distinguishing individual types of innovation, as well as its important feature indicating that the innovation must find practical application. Thus, the term "innovation" means "a new or improved product or process (or combination thereof) that differs significantly from the entity's previous products or processes and which has been made available to potential users (product) or put into use by the entity (process)". According to this definition, there are two main types of innovations, i.e. product innovations (new or improved product/service) and business process innovations. In the previous edition of the Manual (2005), four of them were distinguished, i.e. product, process, marketing and organizational innovations (OECD, 2018). Quoting the above definition here is important because the Oslo methodology is used by Eurostat (including the EIS) and is the basis for developing the Summary Innovation Index (SII), which is a set of sub-indicators grouped into dimensions and categories (Onea, 2020; Janoskova and Kral, 2019).

3. The Essence of Measuring Innovation with the Summary Innovation Index (SII)

The analysis of the literature on the subject allows us to conclude that various and extensive tool sets and measures have been developed that can be used to assess the level of innovation of countries or enterprises. At the same time, methodological problems are identified in the construction of the measures themselves, which makes it difficult and sometimes impossible to conduct analyses and make comparisons (Podstawka, 2021; Szuper, 2021). Therefore, there is no ideal model of the innovation research system. The SII Summary Innovation Index used by the EU - despite its limitations - allows for a synthetic assessment of the innovativeness of EU countries and for making appropriate comparisons (Mikołajczyk, 2016). The SII index is a composite index calculated (since 2001) on the basis of sub-indexes, grouped within categories and dimensions. Tables 1-3 present the categories and dimensions of the indicator, divided into the last 3 periods in which its significant modifications were made. The last major revision took place in 2021. As a result, the SII indicator from 2021 is a set of 32 sub-indexes grouped into 4 main categories and 12 dimensions of innovation (European Commission, 2022; European Commission, 2023).

Table 1: Categories and dimensions of SII sub-indexes in 2010-2016

Categories and dimensions of SII sub-indexes (2010-2016)			
Innovation dimensions	Catalysts	Firm activities	Outputs
	Human resources	Firm investments	Innovators
	Open, perfect and attractive research systems	Relationships and entrepreneurship	Economic effects
	Finance and support	Intellectual assets	
25 indicators			

Source: own elaboration on European Commission, 2016.

Table 2: Categories and dimensions of SII sub-indexes in 2017-2020

Categories and dimensions of SII sub-indexes (EIS 2017-2020)				
Innovation dimension	Framework conditions	Investments	Innovative activities	Impacts
	Human resources	Firm investments	Innovators	On employment level
	Attractive research systems	Finance and support	Linkages	On sales level
	Innovation-friendly environment		Intellectual assets	
27 indicators				

Source: own elaboration on European Commission, 2018; European Commission, 2020.

Table 3: Categories and dimensions of SII sub-indexes in 2021-2023

Categories and dimensions of SII sub-indexes (EIS 2021-2023)				
Innovation dimension	Framework conditions	Investments	Innovative activities	Impacts
	Human resources	Firm investments	Innovators	On employment level
	Attractive research systems	Finance and support	Linkages	On sales level
	Digitalisation	Use of information technologies	Intellectual assets	Environmental sustainability
32 indicators				

Source: own elaboration on European Commission, 2022; European Commission, 2023.

In previous years, the SII index included (European Commission, 2016, European Commission, 2018, European Commission, 2020):

- 25 indicators, 3 categories, 8 dimensions (2010-2016),
- 27 indicators, 4 categories, 10 dimensions (2017-2020).

The SII index ranges from 0 to 1. The closer to 1, the higher the level of innovation of a given country. Currently, this indicator is calculated based on 32 sub-indicators (Crisan and Stanica, 2022; Šofranková et al, 2022). Based on the value of the indicator and its level in relation to the EU average, belonging of a given country to one of the four groups of innovation efficiency for EU Member States is determined. The following classification scheme was adopted in EIS 2023:

1. Innovation Leaders - countries for which the SII value was above 125% of the EU average,
2. Strong Innovators - countries for which the SII value was between 100% and 125% of the EU average,
3. Moderate Innovators - countries for which the SII value was from 70% to 100% of the EU average,
4. Emerging Innovators - countries for which the SII value was below 70% of the EU average.

These thresholds and the names of individual groups have also been modified compared to previous editions (Preda et al, 2019). Even a superficial analysis of the data allows us to conclude that Poland is classified in the fourth category, i.e. countries with the lowest level of innovation.

4. Innovation of the European Union According to the SII index value

The 2023 Innovation Scoreboard (EIS 2023; European Commission, 2023a), based on eight years of data, provides a comparative assessment of the research and innovation performance of EU Member States and selected third countries and the relative strengths and weaknesses of their research and innovation systems. It helps countries assess where they need to focus their efforts to improve their innovation performance. The EIS 2023 report is the third edition published using the new measurement framework introduced in 2021 and, as this report shows, in 2016-2023 the European Union improved its innovation performance (expressed by the SII index) by approximately 8.5 percentage points. Over this period, the innovation performance of most EU Member States has improved, confirming that the Union is a favourable environment for innovation. However, the innovation gap between countries persists because countries with weaker innovation systems are developing at a slower pace than the European Union.

2022				2023	Ranking change	Performance change 2016-2023 (pp)	
INNOVATION LEADERS	Sweden	SE	1	2	📉	-1	10,4
	Finland	FI	2	3	📉	-1	18,3
	Denmark	DK	3	1	📈	2	16,0
	Netherlands	NL	4	4	🔀	0	8,6
	Belgium	BE	5	5	🔀	0	14,1
STRONG INNOVATORS	Ireland	IE	6	9	📉	-3	2,3
	Luxembourg	LU	7	8	📉	-1	-1,5
	Austria	AT	8	6	📈	2	6,4
	Germany	DE	9	7	📈	2	7,6
	Cyprus	CY	10	10	🔀	0	35,6
	France	FR	11	11	🔀	0	-1,6
EU27			12	12	🔀	0	8,5
MODERATE INNOVATORS	Estonia	EE	13	13	🔀	0	29,3
	Slovenia	SI	14	14	🔀	0	2,9
	Czechia	CZ	15	15	🔀	0	21,0
	Italy	IT	16	16	🔀	0	15,6
	Spain	ES	17	17	🔀	0	9,7
	Portugal	PT	18	19	📉	-1	7,7
	Malta	MT	19	18	📈	1	10,9
	Lithuania	LT	20	20	🔀	0	16,7
	Greece	EL	21	21	🔀	0	22,2
EMERGING INNOVATORS	Hungary*	HU	22	22	🔀	0	7,7
	Croatia	HR	23	23	🔀	0	14,8
	Slovakia	SK	24	24	🔀	0	6,4
	Poland	PL	25	25	🔀	0	13,3
	Latvia	LV	26	26	🔀	0	3,5
	Bulgaria	BG	27	27	🔀	0	4,4
	Romania	RO	28	28	🔀	0	1,4

*since 2023 Hungary's performance group is Moderate Innovators

where:

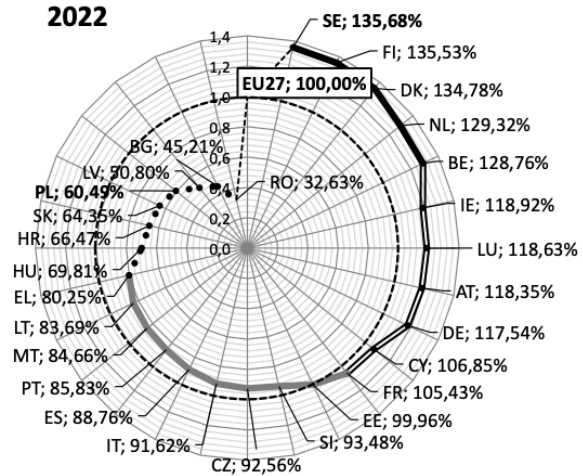
— Innovation leaders;

== Strong innovators;

— Moderate Innovators;

.... Emerging innovators

2022



2023

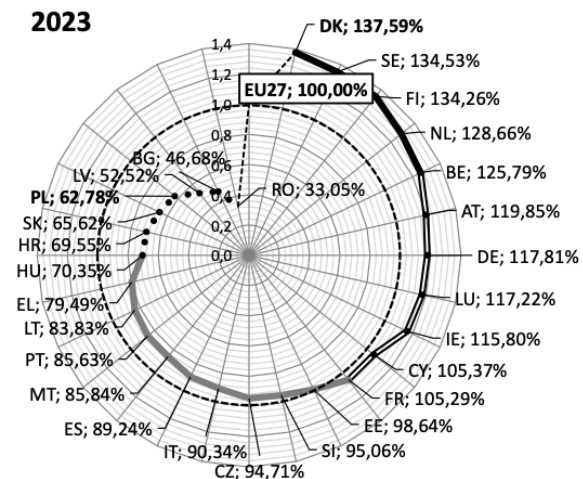


Figure 1: Development of innovation performance in EU member states according to the value of the Summary Innovation Index (SII) in 2022 and 2023 (as a percentage of the EU average)

Source: own elaboration on Eurostat data.

The analysis of research results contained in subsequent European Commission reports on innovation proves that over the years both the level of innovation in individual countries and the share of countries within the four groups characterizing the categories of innovators change. The modification of the methodology for 2021-2022 and the percentage range of classification of innovators also had a significant impact on these changes. Figure 1 shows the division of European Union countries into groups of innovators, corresponding to the results included in EIS 2022. This data is compared with the latest results from EIS 2023. The purpose of this graphical presentation was to show changes in the ranking on the innovation map of EU Member States over the course of the last two years of analysis and to present the evolution of innovation by comparing the results from 2016 with the latest results.

Between 2016 and 2023, differences in performance between Member States decreased, most significantly in the groups of strong and moderate innovators. However, the distribution of innovation performance groups still shows a geographical concentration - innovation leaders and most strong innovators are located in Northern and Western Europe, and most moderate and emerging innovators are located in Southern and Eastern Europe. As mentioned earlier, the EU's innovation performance has increased by 8.5 percentage points since 2016, driven by an increase in innovation in 25 EU Member States (except Luxembourg and France). The Member States that increased innovation the most are: Cyprus, Estonia, Greece, Czech Republic (by 20 percentage points or more; grey in the last column of the table). Generally speaking, the greatest improvement was recorded in the case of indicators included in the Innovative activities and Investments dimensions, i.e.: business process innovators (SMEs), venture capital expenditures, international scientific co-publications, job-to-job mobility.

In the latest edition of the European Innovation Scoreboard (EIS 2023), the distribution of Member States by performance groups remains largely unchanged compared to the previous year (Figure 1). It is worth emphasizing that Denmark is a new innovation leader with the best results in the EU, outdistancing Sweden after several years of its leadership position. According to the results of the latest Commission report, taking into account that the average SII innovation index for the European Union for 2023 was 0.54761, the group of other innovation leader countries included Sweden, Finland, the Netherlands and Belgium with innovation results significantly above-mentioned average. The SII index for this group of countries ranged from 0.6888 to 0.7535. Figure 1 presents the percentage of each country's SII index to the EU average, which was treated as a base value (100%). Its analysis shows that the percentage results of the strongest innovators significantly exceed the EU average - by a minimum of 25.79pp (Belgium) and a maximum of 37.59pp (leader - Denmark). Countries with decreasing SII index values, approaching the EU average (0.5766-0.6563; 105.29% and 119.85%, respectively), are included in the group of strong innovators and include, in descending order: Austria, Germany, Luxembourg, Ireland, Cyprus and France. By far the largest decline in the ranking of EU countries (and strong innovators) was recorded by Ireland, which dropped from 6th position in the ranking in 2022 to 9th in 2023. In turn, in France and Luxembourg, as the only European countries, there was a slight decline in results compared to the results in 2016. This highlights the need for continued efforts to increase innovation capacity, regardless of past performance.

The largest group, consisting of 10 members, comprise moderate innovators, i.e.: Estonia, Slovenia, the Czech Republic, Italy, Spain, Malta, Portugal, Lithuania, Greece, as well as a new member of this group - Hungary. In this group of innovators, Estonia showed the level of innovation closest to the EU average, differing only slightly from the EU average with a score of 98.64%. Hungary made significant progress and moved up to the better performing group, moving up the rankings from Emerging innovators. However, they still remained in 21st place among European countries (22nd including the average for the entire EU), so qualifying for the Moderate innovator category was due to the increase in the percentage of Hungary's SII in the EU average from 69.81% in 2022 to 70.35% in 2023. The results achieved by Croatia, Slovakia, Poland, Lithuania, Bulgaria and Romania with SII index values in the range of 0.1810-0.3809 place the above-mentioned countries well below the EU average, which resulted in their classification in the last group - Emerging innovators. In this group, the greatest progress in increasing innovation compared to 2022 was made by Bulgaria (increase in the share of the SII index in the EU average by 6.0pp) and Poland (increase in the share of the SII index in the EU average by 5.2pp), and taking into account the eight-year period - Croatia (increase in the SII share by 14.8pp) and again Poland (increase in the SII share by 13.3pp).

5. Poland's Innovativeness Compared to the European Union Leader Countries - Analysis of SII and Dimensions of Innovation

Poland, with an innovation index of 62.8% of the EU average, ranks in the last group of innovators - emerging. With the change in the methodology for calculating the SII index, starting from 2021, its innovation standing on the European Union results map deteriorated - from the position of a moderate innovator to the level of an emerging innovator. Figure 2 presents the evolution of Poland's results in the field of innovation, measured by the level of the SII index in 2016-2023, taking 2016 as the base year and presenting the annual pace of change. Poland's innovativeness has improved significantly over time, with this improvement occurring cyclically every second year of analysis. The largest declines in innovation were recorded in two years: in 2018 compared to the previous year (by 0.20%) and in 2020 compared to 2019 (0.89%). In the comparison of data from 2021/2020 and 2023/2022, the growth dynamics of the SII index was the highest, which ultimately translated into an overall improvement in Poland's innovativeness by 24.28% compared to 2016. The fastest pace of change was recorded in 2023 - the level of innovation measured by the SII index increased by 8.31% compared to the previous year.

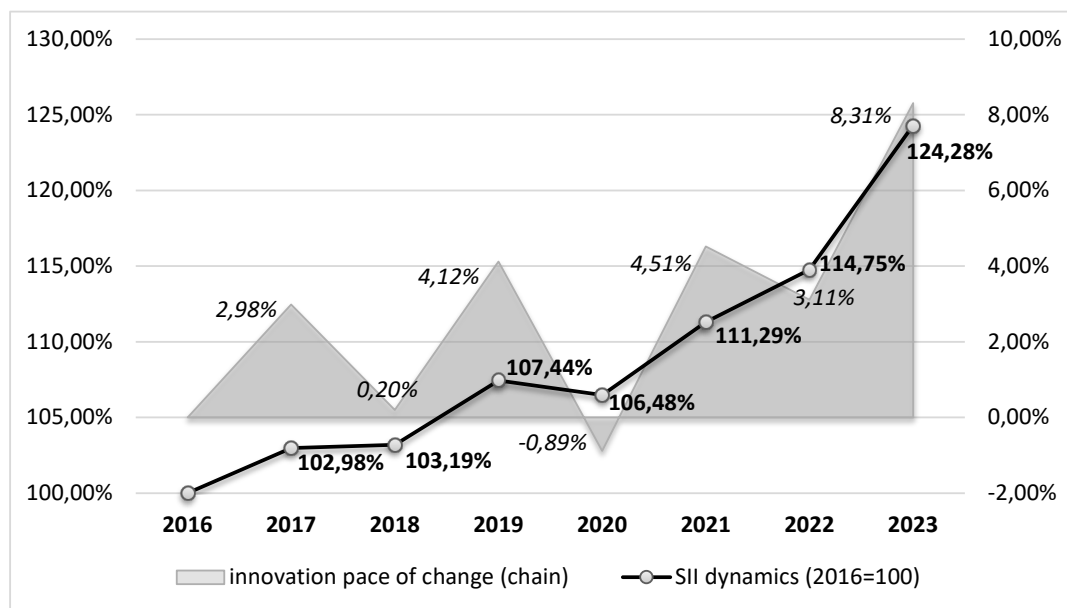


Figure 2: Evolution of Poland's level of innovation in 2016-2023

Source: own elaboration on Eurostat data.

In the further course of the analysis, the results of Poland, the innovation leader from 2022 - Sweden, and the innovation leader from 2023 - Denmark, were assessed in terms of the dimensions of innovation, which are presented in Figure 3. Similarly to Figure 1, reference was made to the EU average, and the aim was to show the strengths and weaknesses of both the 24th country in the innovation ranking of European countries - Poland, as well as to illustrate the results achieved in the field of innovation by countries considered the best in this matter over the last two years.

Despite a significant increase in innovation over the last year, Poland performs worse than the EU average in all 12 dimensions of the EU Summary Innovation Scoreboard (marked alphabetically), as presented in Figure 3. The distribution of Poland's innovation dimensions (light grey) also allows stating that progress is gradual and the results for 2023 do not differ significantly from the results from the previous year. In 2022, the average values for Poland in the twelve components of the indicator ranged from 41.4% of the EU average of the Innovators (G) dimension to 84.3% for Digitization (C), and in the case of the contemporary innovation leader - Sweden - in the range of 86.9% determined by the Environmental Sustainability (L) and 202.2% for the Use of Information Technology (F). In 2022, Sweden exceeded the EU average in 11 out of 12 dimensions of innovation, including in six cases by a minimum of 40.0pp (a maximum of 102.2pp).

In 2023, the Innovators (G) dimension was again the one in which Poland achieved the weakest results (41.4% of the EU average), while innovation measured in dimension F - Use of information technologies - came closest to the EU average. It was this dimension that developed the fastest in Poland, which resulted in an increase in the indicator, calculated as a percentage of the EU average compared to 2022, by 18.6pp - the highest for all

dimensions. The next result concerned Attractive research systems (B), but here the increase in the indicator was not so significant - only by 4 percentage points. Decreases were recorded for these dimensions: Digitization (-3.2pp), Environmental sustainability (-0.7pp) and Linkages (-0.1pp).

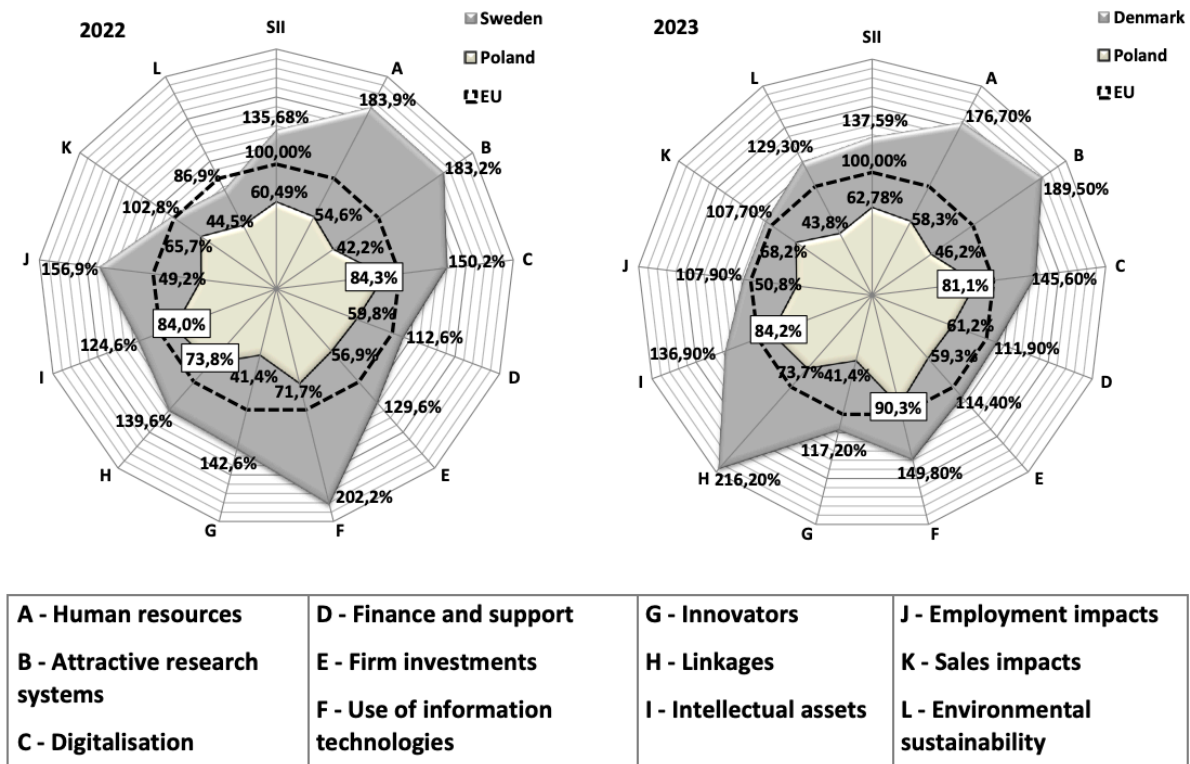


Figure 3: Dimensions of innovation and the level of the Summary Innovation Index (SII) for Sweden, Denmark and Poland in 2022 and 2023 (as a percentage of the EU average)

Source: own elaboration on Eurostat data.

It is worth paying attention to the results achieved by the new (2023) European innovation leader, i.e. Denmark. This country, overtaking Sweden and Finland in 2023, became the innovation leader thanks to the SII index value of 137.6% of the EU average. This was partly due to significantly improved indicators for non-R&D innovation spending and sales of innovative products, and partly due to a decline in Sweden's innovation performance in 2022-2023. Denmark's innovation performance has been growing at a rate of 16pp since 2016, which is higher than the EU average (8.5pp; last column in Figure 1). In 2023, Denmark exceeded EU values in all 12 dimensions of innovation, although this result was not uniform. In 5 cases, the dimension values exceeded the EU average by 25.50pp, in three - by more than 50.0pp (including a maximum of 116.2pp). Both Denmark and Sweden were undisputed leaders in terms of Human resources (A), achieving 176.70% and 183.50% of the average EU indicator value in 2023, respectively (second and first place in the EU). Denmark's progress is particularly visible here, as it moved up from third place in the ranking to second, outclassing Finland. These countries are therefore distinguished by a high share of labour resources with appropriate skills and qualifications that are necessary to build a knowledge-based economy.

6. Conclusions

Innovation is the engine of development. The driving force of innovation is people and their knowledge. Man, thanks to his knowledge, skills and actions, is responsible for most of the processes taking place in modern organizations, including countries and their associations, such as the European Union. The ability to create and implement innovative solutions, and thus the ability to develop himself and the above-mentioned organizations, depends on a person's knowledge, ingenuity and creative involvement. In the literature on the subject one can find statements about the philosophy of development through innovation as a combination of knowledge and experience (Chomać Pierzecka, E 2018).

Innovation, knowledge and creativity are also familiar to Polish enterprises, but despite human resources (often indicated as a strong point of the Polish economy), it cannot be said to be innovative, especially when compared to other EU countries. Research on Poland's innovative performance based on 32 sub-indicators conducted in 2023 shows that the innovativeness of the Polish economy measured by the dynamics of the SII index, despite an almost 8.31% increase compared to 2022 and a 24.28% increase from 2016, is still very weak. Poland is most lagging behind in the area of innovative activities (in the Innovators dimension), expressed in the scope of introducing innovations to the market or within its organizations (41.4% of the EU average), Environmental sustainability (43.8% of the average) and Attractive research systems (46.2% of the EU average). Only three of the 12 dimensions come close to the EU average, i.e. the Use of information technologies (90.3% of the EU average), Intellectual assets (84.2% of the average) and Digitalization (81.1% of the average) and the rest of the analysis is devoted to these areas in the next publication, titled "Analysis of Poland's innovation profile based on the decomposition of the Summary Innovation Index (SII)". The elements undoubtedly influencing the results of innovation should include those regarding geopolitical variants, which have a decisive impact from at least February 2022 on the Polish economy. On the one hand, turmoil in supply chains that occurred much earlier (2020) in connection with the COVID-19 pandemic led to reduced profitability or even bankruptcy of many economic entities in Poland. On the other hand, the war started by Russia in Ukraine determined the need to quickly adjust the policy of energy supply and commodity exchange, which still has a significant impact on the country's economy. Despite these factors unfavourable for the competitiveness of the Polish economy, the Polish industrial system, in which small and medium-sized enterprises operate, forces them to be innovative as one of the conditions for staying on the market and to make strategic changes within enterprises, requiring the application of knowledge and the employment of qualified employees.

The presented data also confirm that the European Union is an organization bringing together countries with different economic profiles and - as can be seen from the presented data - a strongly differentiated level of innovation. The process of building and increasing the innovativeness of such different countries is a difficult and multi-stage task, therefore there is a need to constantly monitor progress in this area. The results of this monitoring and comparison allow for the optimization of decision-making processes, both at the EU level and in individual Member States. This article, through the analysis and systematics of data, contributes to the assessment of this process and can constitute a basis for further research.

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