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THE RELATIONSHIP ASSESSMENT BETWEEN HUMAN RESOURCES AND INNOVATION PERFORMANCE IN EU COUNTRIES

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ABSTRACT. The scientific study aims to explore the impact of human capital quality on the final score of the Summary Innovation Index (SII) and to identify differences in the values of some indicators within the Human Resources (HR) dimension in EU countries. We use Pearson´s and Spearman´s correlation coefficients to verify the dependence between human capital and innovation performance. We use the comparison method to compare the differences in the values of SII and individual indicators in the HR dimension. When processing the task, we used statistical data within the year 2022, which we drew from the European Commission publication "European Innovation Scoreboard 2022". As a result of our assessment, Sweden, Finland, Denmark, and the Netherlands perform best in the Human Resources dimension as well as in the SII. The worst performers are Romania, Bulgaria, followed by Latvia, Poland and Slovakia. The largest differences among EU countries in the HR dimension are in the "Population involved in lifelong learning" indicator. Hungary shows the most balanced values within the individual indicators of the HR dimension, while the Netherlands shows the most noticeable differences. We confirmed the hypothesis of statistical dependence between the HR dimension and the SII.

JEL Classification: I20, I26, I25, O11, O44

Keywords: innovation, innovation performance, human capital, European Union

Introduction

Economic performance and prosperity are closely linked to human capital quality and its use for new knowledge creation and its implementation into outputs in the form of new technologies, products, production procedures and processes. Knowledge, as a determinant of human capital quality, is transformed into innovation when acting as a driving force of economic efficiency and productivity growth. Therefore, advanced societies put a high value on human capital development, which, in the context of declining returns on physical capital, is becoming a significant source of economic growth based on innovative performance and competitiveness synergy. Nowadays, in the era of the fourth industrial revolution and artificial intelligence, human capital is becoming the most decisive source of economic growth, innovation performance and competitiveness growth. Therefore observing and assessing the impact of factors promoting innovation performance growth is the objective of the economic policy in developed countries. Assessing the strengths and weaknesses of national innovation policies and innovation systems in the context of the European innovation system helps to identify areas for improvement.

According to OECD (2006), "Human capital can be broadly defined as the stock of knowledge, skills and other personal characteristics embodied in people that helps them to be productive. Pursuing not only formal education (early childhood, formal school system, adult training programs) but also informal and on-the-job learning and work experience, all represent an investment in human capital".

Drucker (1993) was one of the first who enriched management with the idea that a new kind of capital was emerging; he called it knowledge capital. He also predicted that while monetary and physical capital receded, knowledge capital would become increasingly highlighted. The theory of human capital was developed significantly by Becker (1994) and others.

Several scientific studies (Teixeira and Queirós, 2016; Neeliah and Seetanah, 2016; Vráblíková, 2017; Bobáková, 2018; Affandi et al., 2019; Sharma, 2019 and others) have shown that human intelligence, education, initiative, creativity and entrepreneurship as the basic characteristics of human capital are the greatest source of wealth for any nation and thus the most important source of economic growth. Our research builds on the results of scholarly studies (Capozza & Divella, 2019; Bilan et al., 2020; Bate et al., 2023; Denkowska et al., 2020; Jašková & Havierniková, 2020) that examine the relationship within the human capital quality, innovation performance and economic growth, when focused on selected European Union countries. The missing aspect in the scholarly studies in this research area is an assessment of the impact of individual innovation performance factors on the Summary Innovation Index tracked by the European Commission. The European Commission publishes an annual European Innovation Scoreboard, which compares the innovation performance of EU countries and selected third countries using the Summary Innovation Index. In our research study, we focused on assessing the dependence of the SII score and the Human Resources dimension and comparing the differences in the values of the individual indicators within the Human Resources dimension in EU countries in 2022.

1. Literature review

Along with the knowledge economy development and the related increasing emphasis on knowledge, human capital and the creation of favourable conditions for its application are becoming increasingly significant in society, as innovation becomes the basis for the dynamic development of a society. Its implementation is preceded by more complex processes, which top experts should back up. A prerequisite for innovation implementation is the accomplishment of research, when human capital is an essential input for doing research (Eriksson et al., 2022). Human capital can support productivity growth by absorbing and applying existing or innovative technologies. It not only reflects the quality of the workforce, but also is an important component of technology absorption and innovation capacity (Cheng et al., 2022). Knowledge is the key factor to promote the development of enterprise innovation ability (Liu et al., 2023). Faggian et al. (2017) consider that creativity, entrepreneurship, and education are all part of a more broadly defined concept of human capital, the most essential production factor in knowledge societies. Koišová et al (2019) stated that a high ratio of employees with a good quality post-graduate education leads to an increase in innovation and work productivity.

Digitization, research and innovation are very closely interlinked areas, and the development all of them together is a fundamental prerequisite for a progress. Digitization is transforming the research and innovation, hence to promote cutting-edge technologies, digital skills of researchers is a must, as well as ensuring the high quality data infrastructures by means of sufficient investment (Filus, 2020). These are challenging processes that can only be efficiently carried out by highly skilled human capital leadership (Benchea & Ilie, 2023).

The relationship between innovation and human capital is thus reciprocal; there is no innovation without human capital, and, on the other hand, innovation affects human capital. Alpaslan & Ali (2017) argue that the development of innovative technological sectors can indirectly improve growth via its positive influence on human capital accumulation as much as human capital can act as an important input into the generation and diffusion of innovative ideas. Similarly, Diebolt & Hippe (2019) argue that human capital is an important factor for innovation and economic development. According to them, an increase in human capital can induce an increase in the number of innovative entrepreneurs and products, thereby indirectly stimulating economic development through the innovation channel.

Innovation is the result of the creativity process, a new idea, new knowledge. The innovation process is associated with a new product development from getting the invention to placing the products on the market. It is actually the preparation and gradual implementation of innovative changes. Machová et al. (2015) emphasize that innovation is a key to the whole organization survival, based on knowledge, creativity, and entrepreneurial feelings. Innovation is a new combination of existing knowledge. The innovation process to be successful, the expertise and skills in the industry area are necessary.

Innovation activities can be defined as a two-step process where at first the creation and diffusion of knowledge occur and then this knowledge is transformed into innovation (Mura et al., 2015).

The role of innovation is to turn the research results into new and better services and products in order to remain competitive on global market and improve the quality of life of European citizens (Kordoš & Krajňáková, 2018).

The result of the innovation process, which brings an economic effect to the entity, which implement it into action, is innovation performance. With the rapid economy development and technology modernization, enterprises face fierce competition. Innovation performance represents the new knowledge and new technology created by enterprises within innovation activities (Liu et al., 2023). Innovation performance is one of the factors that has an impact on development in various areas of social life by its synergistic effect, it affects the economic performance and competitiveness at all levels (Ivanová & Kordoš, 2017). Innovation performance of companies affects the innovation performance of a particular country. There are several views regarding innovation performance assessment, whether by different institutions or individual researchers.

The European Commission evaluates innovation performance on the basis of the European Innovation Scoreboard (EIS), product of which is the Summary Innovation Index. It is the most commonly used indicator to analyse the innovation capacity of European countries. On the basis of the results of this assessment, several authors evaluate the innovation performance of countries or compare the innovation performance of several countries over a certain period. Gajda et al. (2018) assessed the innovation performance of Ukraine and Poland compared to the European Union in 2010-2017. Janošková & Kráľ (2019) assessed the innovation performance of the V4 countries in 2010-2016 based on the indicators contained in the SII. The aim of their research was to identify possible strengths and weaknesses of national innovation systems of these countries and thus to identify the impact of these strengths and weaknesses on innovation position of these countries. Belanová (2021) assessed the innovation performance of Slovakia compared to the European Union average by using the EIS in order to specify its strengths, weaknesses and dynamics. She considers the strengths of innovation performance to be the environmental sustainability, sales impacts, and the use of information technology. Weaknesses are aspects such as reduced performance in digital skills, low number of enterprises offering ICT trainings, as well as application designs and sales of innovative products.

Dworak (2020) focused on the estimation of the innovation gap between Poland and European Union countries based on the SII in 2010-2018. The analysis results confirmed that the level of innovativeness of Polish economy within the observed period remained at a lower level than the EU average, and therefore there is still an innovation gap between the Polish economy and the average of European Union countries.

Other authors focus on a detailed assessment of innovation performance by analysing the individual components of innovation performance and looking for strengths and weaknesses in the innovation performance of selected countries. Svagzdiene & Kuklyte (2016) identified factors influencing the SII in Germany, Estonia and Lithuania. The results of their study showed that the SII in Germany, Estonia and Lithuania was most influenced by the share of GDP allocated to R&D, the number of researchers, the number of issued patents and households with internet access, and therefore, these countries need to ensure that the level of innovation is to be increased and to focus on improving these factors. Ünlü (2017) by means of binary logistic regression analysis and 2016 EIS data assessed which factors influence whether countries are innovative or not. Based on her research, she concludes that R&D investment, human capital, and innovation implemented by SMEs are the factors that mainly affect the innovation performance of countries.

Kleszcza (2021) analyses the main components of innovation determined by the EIS dimensions in order to identify the main components of the Innovation index that differentiate particular countries, by analysing the correlation structure among its components. All calculations were based on the indicators included in the EIS 2020 database, which contains data from the years 2012-2019. The objective of the innovation performance comparative analysis of observed countries based on the principal component analysis (PCA) method was to find the uncorrelated main components of innovation that distinguish the observed countries.

Bielińska-Dusza & Hamerska (2021) in their research identified the determinants influencing the SII and consequently countries' positions in the EIS. They first used a stepwise regression method to assess the impact of 27 indicators on the ranking of countries in the EIS, when identifying 22 determinants that affect countries' positions in the EIS. In the second stage, they used a linear ordering method and made a new ranking, which they then compared with the particular ranking in 2020. Finally, they divided the observed countries into four groups according to the degree of innovation.

Other authors have attempted to assess the innovation performance on the basis of several indexes. Among them, we can mention Roszko-Wójtowicz & Białek (2018), who conducted research on similarities and differences in innovation intensity within the EU member states. Based on the ranking of countries in the following indexes: the Global Innovation Index, the Summary Innovation Index, and the Innovation Output Indicator, they determined the innovation performance of countries by means of a cluster analysis and proposed a different perspective on international innovation rankings to show the mutual relationships among the different synthetic indexes.

However, many authors do not consider the innovation performance assessment based on SII data to be sufficient. In their paper, Edquist et al. (2018) critically argue that the Summary

Innovation Index is not a suitable indicator to assess the innovation performance of countries. They suggest putting more emphasis on the identification and relationship between input and output innovation indicators. Jovanović et al. (2022) used a two-stage data envelopment analysis based on the neo-revolutionary Triple Helix model to assess the effectiveness of innovation systems. They create a new index that includes 19 indicators, and they assess 34 countries. Their results also provide an assessment of the weaknesses and strengths of each observed innovation system.

Corrente et al. (2023) highlight the heterogeneity within the indicators construction to assess the innovation performance of countries. In their paper, they assess the innovation performance of EU countries through their proposed composite indicator, which also takes into account the interaction among criteria, by using the views of universities, government and industry. They propose the application of the Choquet integral to take into consideration possible positive and negative interactions that could be observed among the indicators. That procedure allows stakeholders to select the indicators that are most relevant within the construction of a composite innovation indicator.

The impact of human capital on economic growth and innovation performance is the issue of further studies. Suseno et al. (2020) examined the impact of human and social capital on national innovation performance by means of secondary data from OECD countries. Their findings suggest that both human capital and social capital have a significant impact on national innovation performance. They also find significant differences among groups of countries in terms of human capital, social capital and national innovation performance.

Carvache-Franco et al. (2022b) analysed human capital variables and their relationship with innovation in manufacturing firms in Colombia. They found out that the variable "R&D workers" is an important predictor of product and processes innovation because it represents the skills, abilities and experience of the worker and allows finding new uses of knowledge or combining knowledge to achieve innovation. Moreover, in these companies, human capital acquired by training develops the skills and capabilities that enable product innovation to be achieved, while low investment in training means that the skills achieved in this way are not relevant for innovation.

Chiganze & Sağsan (2022) assessed the effect of human capital on innovation capability and employees´ job performance in academic libraries by means of structured questionnaires in Namibia, South Africa, and Zimbabwe. The results indicated that human capital had a significant and positive effect on innovation capability and employees´ job performance in academic libraries. Innovation capability also had a significant and positive effect on employees´ job performance.

The relationship between human capital and innovation performance in service sector firms in Ecuador has been assessed by Carvache-Franco et al. (2022a) and they find out that increasing education in innovation activities can enhance the potential for innovation in services, and increasing the number of workers with higher education increases the innovation potential in the processes in these firms.

Wardhani et al. (2016) conducted a systematic literature review to identify the relationship among human capital, social capital, and innovation outcome within the period of 1985-2016.

As stated by Ding (2022), innovation is crucial to fostering economic growth and combating social problems. Based on national innovation systems, he assessed how combinations of multiple factors (R&D investment, human capital, social freedom, democracy, globalization, and country wealth) lead to high national innovation performance.

Eriksson et al. (2022) assessed the interaction between human capital and innovation in the process of economic growth. By means of an endogenous growth model, they focused on how taxes and other policy instruments affect incentives to invest in human capital.

2. Methodological approach

The goal of this study is to assess the influence of human resources on national innovation performance of EU countries, by using secondary data of the Summary Innovation Index in 2022.

The European Commission evaluates the innovation performance of EU countries and neighbouring countries in the annual report on the European Innovation Scoreboard, product of which is the Summary Innovation Index.

The innovation performance assessment helps countries evaluate the relative strengths and weaknesses of their national innovation systems and identify challenges that they need to undertake (European Commission, 2023a).

The 2022 EIS was developed based on the assessment of 32 indicators classified into 12 dimensions under four activities: Framework conditions, Innovation activities, Investments, and Impacts.

Framework conditions capture the main drivers of innovation performance being external to the firm and differentiate among three innovation dimensions: human resources, attractive research systems and digitization.

The values of the individual indicators are normalised by means of the min-max method to a score between 0 and 1. The resulting SII indicator is calculated as the unweighted average of the values of the individual indicators.

The innovation performance values of the countries are next converted to the EU average. Based on their scores, EU countries fall into four performance groups: Innovation leaders, Strong innovators, Moderate innovators, and Emerging innovators (European Commission, 2023b).

In our paper we focus on the Human resources dimension (1.1), which measures the availability of a high-skilled and educated workforce. It includes three indicators:

- 1.1.1 New PhD graduates in science, technology, engineering, and mathematics (STEM) per 1000 population aged 25-34,
- 1.1.2 Percentage population aged 25-34 having completed university education,
- 1.1.3 Percentage population aged 25-64 participating in lifelong learning.

In our paper, we assess the dependency of the final SII score and the Human resources dimension and the differences in the values of individual indicators in terms of the Human resources dimension within the EU countries.

We set the following hypotheses:

H0: There is no correlation between the individual human resource indicators and the Summary Innovation Index.

H1: There is a positive correlation between individual human resource indicators and the Summary Innovation Index.

We use the Pearson's correlation coefficient to test the stated hypotheses. We use the Shapiro-Wilk test to verify the normality. The significance of the correlation coefficient is verified by the t-test. We use also Spearman´s rank correlation coefficient.

Next, we compare the achievement scores at level of SII and 1.1 within the EU countries and assess the differences in achieved results of SII, 1.1 and individual HR indicators within the 27 EU countries.

We use the data of the European Commission listed in the European Innovation Scoreboard. We use MS Excel for analysis processing.

3. Results

We first focus on a comparison of EU countries' scores within the SII and dimension 1.1 Human resources in 2022 (*Figure 1*).

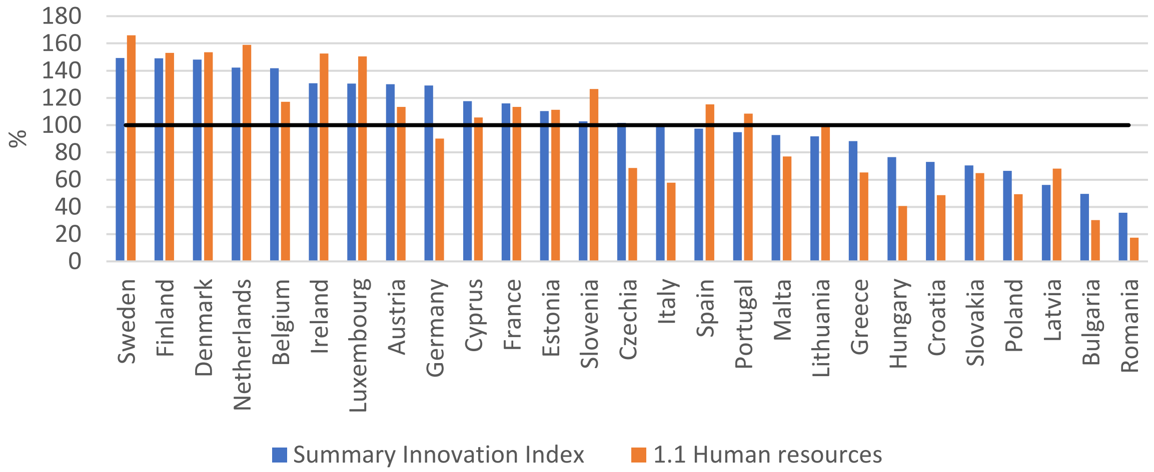

Figure 1. Summary Innovation Index and dimension 1.1 Human resources in 2022
Source: *European Commission (2023a)*

Based on a comparison of the SII and 1.1 Human resources values in 2022, we can conclude that among the 7 top ranked countries, only Belgium has a value of dimension 1.1 lower than the SII value. This shows that a good score on dimension 1.1 has a positive effect on the overall assessment of a country's innovation performance. On the contrary, among the 7 worst performing countries, only Latvia has a 1.1 value higher than the SII value.

Of the countries that fall below the EU average in the SII, only Spain and Portugal score higher than the EU average in dimension 1.1.

Next, we compare the achieved values of the individual indicators within the dimension 1.1 Human resources in the EU countries in 2022 (*Figure 2*).

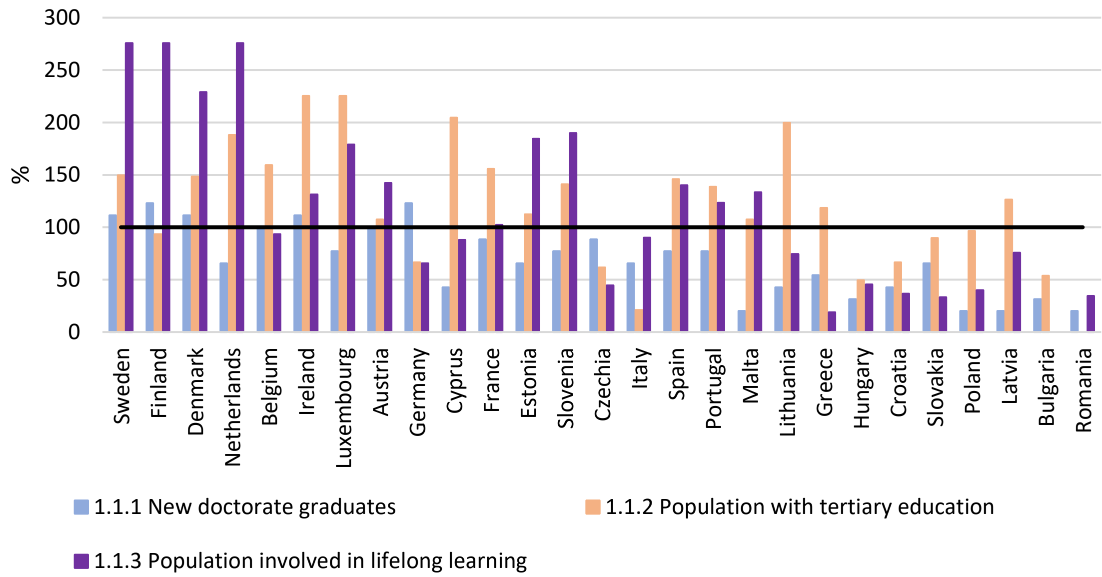

Figure 2. Individual Human Resources Indicators in 2022 in the EU countries
Source: *European Commission (2023a)*

We excluded the last two countries Bulgaria and Romania from further analysis, as data for all indicators were not available for them.

An assessment of the individual dimensions of Human Resources in 2022 reveals that the top 4 countries - Sweden, Finland, Denmark, the Netherlands - have the highest values within the 1.1.3, while the next three countries - Belgium, Ireland and Luxembourg - have the highest values within the 1.1.2 value. We observe markedly different results in the individual dimensions of 1.1 within the EU countries. The most balanced values for each dimension are in Hungary, while the largest differences are in the Netherlands, where the value within the 1.1.1 is only 65.678%, but within the 1.1.3 up to 275.556% of the EU average.

We assessed the differences within the SII, 1.1 and individual indicators of the Human resources dimension within the EU countries (except Bulgaria and Romania). The results are presented in *Table 1*.

Table 1. Differences within the SII values and indicators of Human Resources dimension

	SII	1.1	1.1.1	1.1.2	1.1.3
maximum	149.318 Sweden	166.075 Sweden	122.881 Finland	225.388 Ireland	275.556 Sweden Finland Netherlands
minimum	56.13 Latvia	40.705 Hungary	19.915 Poland Latvia	21.098 Italy	18.889 Greece
variation range	93.188	125.37	102.966	204.29	256.667

Source: *European Commission (2023a), own calculations*

We find out that the largest differences among the EU countries are within the dimension 1.1.3, where the difference between the best and the worst country is up to 256.667 p.p.

Next, we assessed the relationship between the SII and 1.1 Human resources. The results are summarizes in *Table 2*.

Table 2. Dependency analysis between SII and 1.1 Human resources

	Average	Median	Standard deviation	Shapiro-Wilk normality test	Pearson correlation coefficient – r	significance test of the Pearson coefficient – t
Summary Innovation Index	108,309	102,801	27,952	0,290	0,850	0,000
1.1 Human resources	103,092	108,572	38,724	0,124		

Source: *European Commission (2023a), own calculations*

The Pearson correlation coefficient can be used to detect the degree of statistical dependence only if the samples have an approximately normal distribution. We used the Shapiro-Wilk normality test to test the normality. Since its p-values are bigger than the chosen significance level α = 0.05, we conclude that the samples have a normal distribution. The following rankit plots (*Figure 3, Figure 4*) prove this statement.

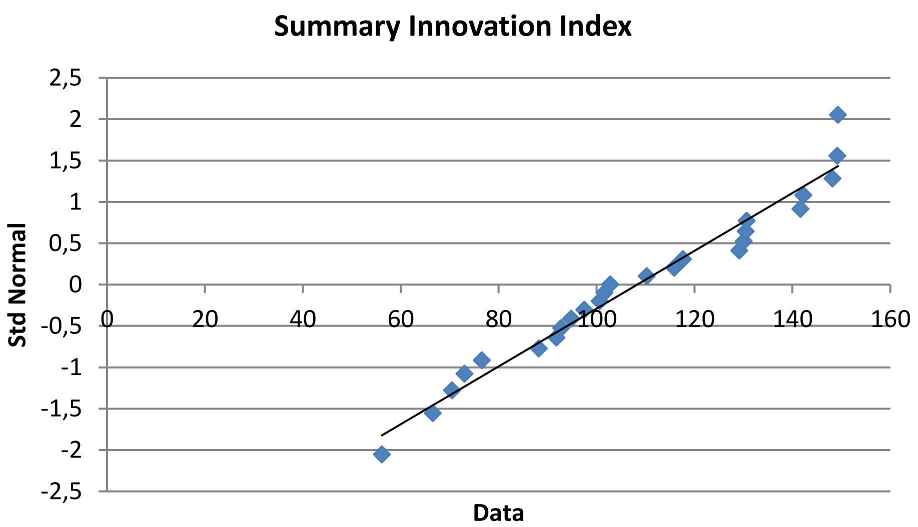

Figure 3. Rankit Plot – Summary Innovation Index
Source: *own elaboration*

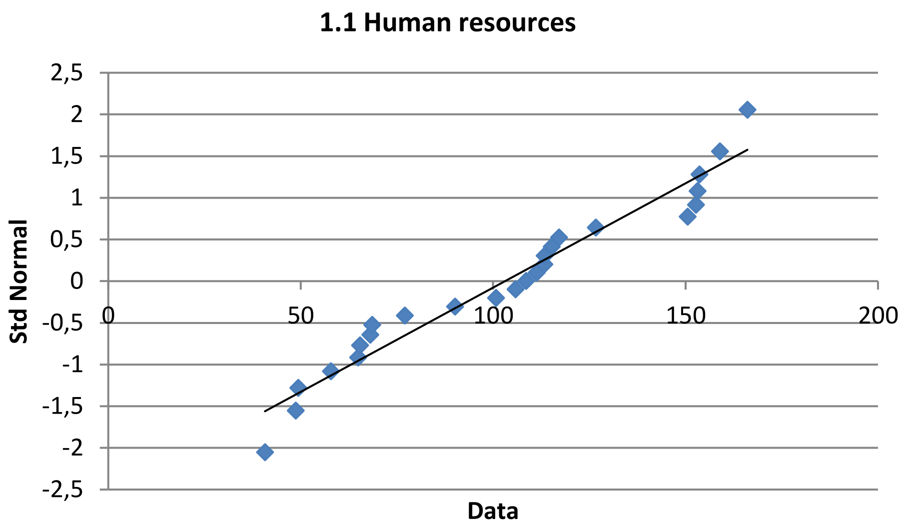

Figure 4. Rankit Plot – 1.1 Human resources
Source: *own elaboration*

From the rankit plots, it can be seen that the individual values perfectly follow the line of the normal distribution and therefore the usage of the Pearson's correlation coefficient was correct. Since the Pearson correlation coefficient reached a value of r = 0.85, we conclude that there is a high degree of dependency between the variables being compared. Since the coefficient is positive, there is a positive linear dependence, which can also be seen in the graph.

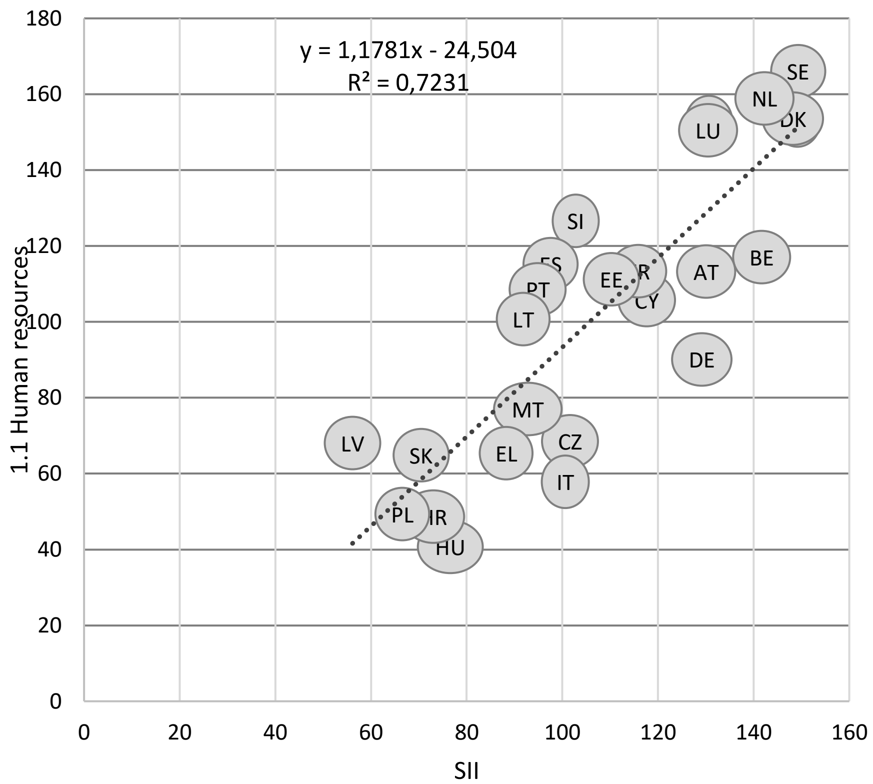

Figure 5. Dependency of SII and 1.1 Human resources
Source: *own elaboration*

The graph shows that there is a positive correlation, even if it is less distinctive.

In the **last** step, we verified whether the correlation coefficient is statistically significant. We used the correlation coefficient significance test and statistics as the test criterion:

$$t = r.\sqrt{\frac{n-2}{1-r^2}}$$

where: r - the Pearson correlation coefficient value
n – the number

Since we are examining a small sample of countries, we also recalculated Spearman's rank correlation coefficient to confirm our findings. We also verified whether the Spearman´s rank correlation coefficient is statistically significant. We used the correlation coefficient significance test and statistics as the test criterion:

$$t = |R|.\sqrt{\frac{n-2}{1-R^2}}$$

where: R – Spearman correlation coefficient of rank correlation
n – count

The results are the content of the *Table 3.*

Table 3. Dependency analysis between SII and 1.1 Human resources

	Spearman´s rank correlation coefficient – R	significance test of the Spearman´s rank correlation coefficient – t
Summary Innovation Index / 1.1 Human resources	0,870	0,000

Source: *European Commission (2023a), own calculations*

Spearman's rank correlation coefficient reached values very similar to Pearson's correlation coefficient. Since the *p-value* of the significance test - t is less than the significance level $t_{(0,000)} < \alpha_{(0,0,5)}$ we reject the tested hypothesis H_0 in favor of the alternative hypothesis H_1. By testing we have proved that there is a statistically significant dependency between the human resources in particular countries and the SII. Our findings confirm the opinions of experts that the quality of human resources significantly affects the innovative performance of companies and the country.

In a society, but especially in the economy, individual phenomena are always in certain links, and since economic laws are valid, everything is conditional on something. In this paper, we were curious about the circumstances that are conditioned by the differences within the Summary Innovation Index among countries. The impact on the SII is certainly diverse and multidisciplinary and is definitely conditioned by other indicators, however we have been focused on human resources. Although statistical analysis is very important to draw right conclusions and recommendations, it must be preceded by the economic context analysis based on the study and analysis of available professional sources. The graphical representation of different indicators (Figure 1 and Figure 2) is also an excellent working tool, which helped us to correctly focus on the human resources variable. Therefore, we have made decision to demonstrate the statistical dependence between the random variables SII and Human Resources in terms of their linkage tightness and consequently the statistical significance.

Our assumption proved to be correct, and we showed a high linkage degree when human resources show up to 72% of the variability in SII and 28% of the variability belong to other causes such as the number of new PhD students, the number of people with a university degree or the amount of investment in innovation.... In the next step, we answered the question whether the calculated correlation coefficient can be generalized to the whole basic set and, therefore, whether there is a statistically significant dependency between the observed features X, Y - Summary Innovation Index and Human Resources. By testing the correlation coefficient significance, we confirmed this dependence thus proving that the SII index is statistically significantly dependent on Human Resources. Based on these partial results, we recommend massive investment into human capital and continue to search for causal links among other indicators that have an impact on the SII.

Discussion and conclusion

The conducted analysis of Human Resources dimension and individual indicators in this particular dimension in EU countries has shown that there are significant differences among the countries being analysed.

Based on the comparison of the values of SII and 1.1 Human resources in 2022, we can conclude that among the 7 top ranked countries, only Belgium has a value of dimension 1.1 lower than the value of SII. This proves that a good score on dimension 1.1 has a positive effect on the overall assessment of a country's innovation performance. On the contrary, among the 7 worst performing countries, only Latvia has a 1.1 value higher than the SII value.

Of the countries that fall below the EU average within the SII, only Spain and Portugal scored higher than the EU average within the dimension 1.1.

An exploration of the individual indicators within the Human Resources dimension in 2022 shows that the top 4 countries - Sweden, Finland, Denmark, the Netherlands - have the highest values in 1.1.3, the other three states - Belgium, Ireland and Luxembourg - in 1.1.2. There are the most balanced values for each dimension in Hungary, while the largest differences are in the Netherlands, where the value for 1.1.1 is only 65.678%, but for 1.1.3 up to 275.556% of the EU average.

The differences between EU countries in the individual indicators of dimension 1.1 are more distinctive, with the largest differences in dimension 1.1.3, where the difference between the best and the worst country is as high as 256.667 p.p.

Comparable results in research regarding the impact of individual indicators on SII are also reported by Janošková and Kráľ (2019), who focused their research on the V4 countries and compared the values of individual indicators in V4 countries in terms of their impact on innovation performance.

A limitation of our research is the fact that the Aggregate Innovation Index methodology changes relatively often and it is not possible to track the development and impact of individual indicators over a longer time series. This issue has been addressed by the authors Roszko-Wójtowicz and Białek (2019) who attempted to propose a procedure for measuring the innovation growth over a time, taking into account the Summary Innovation Index methodology as a starting point. The main result of their work is the proposal of an Average Innovation growth index in EU countries.

The methodology imperfection is also highlighted in article by Bielinska-Dusza and Hamerska (2021). „The primary purpose of this article is to identify determinants affecting the Summary Innovation Index and, consequently, the positions of countries on the European Innovation Scoreboard. Then, based on the identified determinants, these countries are ranked by using the linear ordering method “.

The research results of this scientific study will serve us as a starting point for investigating the impact of other indicators on the development of the dimensions evaluated within the SII.

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References

Affandi, Y., Anugrah, D.F., Bary, P. (2019). Human capital and economic growth across regions: a case study in Indonesia. *Eurasian Economic Review*, 9, 331-347. https://doi.org/10.1007/s40822-018-0114-4

Alpaslan, B., & Ali, A. (2017). The spillover effects of innovative ideas on human capital. *Review of Development Economics*, *22*(1), 333-360. https://doi.org/10.1111/rode.12344

Bate, A.F., Wachira, E.W., & Danka, S. (2023). The determinants of innovation performance: an income-based cross-country comparative analysis using the Global Innovation Index. *Journal of Innovation and Entrepreneurship*, *12*(20), 1-27 https://doi.org/p.10.1186/s13731-023-00283-2

Becker, G.S. (1994). *Human capital: a theoretical and empirical analysis with special reference to education*. 3. ed. Chicago: The University of Chicago Press. 390 Available at: https://www.nber.org/books-and-chapters/human-capital-theoretical-and-empirical-analysis-special-reference-education-third-edition

Belanová, K. (2021). Innovation performance of the Slovak Republic. *Balkan and Near Eastern Journal of Social Sciences*, 07 (Special Issue), 24-28. Available at: https://www.ibaness.org/bnejss/2021_07_special_issue/03_Belanova.pdf

Benchea, L., Ilie, A.G. (2023). Preparing for a New World of Work: Leadership Styles Reconfigured in the Digital Age. *European Journal of Interdisciplinary Studies*, 15(1), 135-143. http://doi.org/10.24818/ejis.2023.10

Bielińska-Dusza, E., & Hamerska, M. (2021). Methodology for calculating the European Innovation Scoreboard—proposition for modification. *Sustainability*, 13, 2199. https://doi.org/10.3390/su13042199

Bilan, Y., Mishchuk, H., Roshchyk, I., & Kmecova, I. (2020). An analysis of intellecutal potential and its impact on the social and economic development of European countries. *Journal of Competitiveness*, *12*(1), 22-38. https://doi.org/10.7441/joc.2020.01.02

Bobáková, V. (2018). Význam ľudského kapitálu a vzdelania pre ekonomický rast. *Verejná správa a spoločnosť, XIX(1)*, 60-75.

Capozza, C. & Divella, M. (2019). Human capital and firms' innovation: evidence from emerging economies, *Economics of Innovation and New Technology,* 28(7), 741-757. https://doi.org/10.1080/10438599.2018.1557426

Carvache-Franco, O., Carvache-Franco, M., Carvache-Franco, W., & Bustamante-Ubilla. M. A. (2022a). Incidence of human capital in the innovative performance of service companies: A study in Ecuador. *Social Sciences* 11(222). https://doi.org/10.3390/socsci11050222

Carvache-Franco, O., Carvache-Franco, M., Carvache-Franco,W., & Bustamante-Ubilla, M. A. (2022b). The relationship between human-capital variables and innovative performance: Evidence from Colombia. *Sustainability*, *14*, 3294. https://doi.org/10.3390/su14063294

Cheng, C., Yu, X., Hu, H., Su, Z., & Zhang, S. (2022). Measurement of China's green total factor productivity introducing human capital composition. *International Journal of Environmental Research and Public Health*, 2022, 19, 13563. https://doi.org/10.3390/ijerph192013563

Chiganze, T. & Sağsan, M. (2022). Relationship between human capital, innovation capability and employee job performance in academic libraries in Namibia, South Africa, and Zimbabwe. *Libri*, *72*(3), 317-334. https://doi.org/10.1515/libri-2021-0037

Corrente S., Garcia-Bernabeu, A., Greco, S., & Makkonen, T. (2023). Robust measurement of innovation performances in Europe with a hierarchy of interacting composite indicators. *Economics of Innovation and New Technology, 32*(2), 305-322(18). https://doi.org/10.1080/10438599.2021.1910815

Denkowska, S., Fijorek, K., & Wegrzyn, G. (2020). Formal and non-formal education and training as an instrument fostering innovation and competitiveness in eu member countries. *Journal of Competitiveness*, *12*(3), 82–98. https://doi.org/10.7441/joc.2020.03.05

Diebolt, C., & Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe. *Applied Economics*, *51*(5), 542-563. https://doi.org/10.1080/00036846.2018.1495820

Ding, H. (2022). What kinds of countries have better innovation performance? A country-level fsQCA and NCA study. *Journal of Innovation & Knowledge*, *7*(4), 100215. https://doi.org/10.1016/j.jik.2022.100215

Drucker, F. P. (1993). *Postcapitalist Society*. New York: HerperCollins Publishers. Available at: http://pinguet.free.fr/drucker93.pdf

Dworak, E. (2020). The innovation gap between the Polish economy and the European Union. *Comparative Economic Research. Central and Eastern Europe, 23*(3), 63-73. https://doi.org/10.18778/1508-2008.23.20

Edquist, C., Zabala-Iturriagagoitia, J. M., Barbero, J., & Zofio, J. L. (2018). On the meaning of innovation performance: Is the synthetic indicator of the Innovation Union Scoreboard flawed? *Research Evaluation*, *27*(3), 196-211. https://doi.org/10.1093/reseval/rvy011

Eriksson, C., Linden, J., & Papahristodoulou, C. (2022). Human capital, innovation, and growth. *International journal of economic theory,* 1-27. https://doi.org/10.1111/ijet.12346

European Commission. (2023a). European innovation scoreboard 2022. Available at: https://research-and-innovation.ec.europa.eu/knowledge-publications-tools-and-data/publications/all-publications/european-innovation-scoreboard-2022_en (20.02.2023).

European Commission. (2023b). European Innovation Scoreboard 2022. Methodology Report. Available at: https://research-and-innovation.ec.europa.eu/system/files/2022-09/ec_rtd_eis-2022-methodology-report.pdf (20.02.2023).

Faggian, A., Partridge, M., & Malecki, E.J. (2017). Creating an environment for economic growth: Creativity, entrepreneurship or human capital? *International Journal of Urban and Regional Research*, *41*(6), 997-1009.

Filus, I. (2020). Správa o výsledkoch výskumu a inovácií (SRIP 2020). Európa ako líder ekologickej a digitálnej transformácie. Available at: https://innonews.blog/2020/05/28/sprava-o-vysledkoch-vyskumu-a-inovacii-srip-2020-europa-ako-lider-ekologickej-a-digitalnej-transformacie/ (09.08.2022).

Gajda, W., Kuznetsov, A. A., & Kuznetsova, S. A. (2018). Does innovation is driving force? Analysis and control for EU, Poland and Ukraine. *Financial and Credit Activity Problems of Theory and Practice*, *4*(27), 111-121. https://doi.org/10.18371/fcaptp.v4i27.154075

Ivanová, E., & Kordoš, M. (2017). Competitiveness and innovation performance of regions in Slovak Republic. *Marketing and Management of Innovations*, 1, 145-158. https://doi.org/10.21272/mmi.2017.1-13.

Janošková, K., & Kráľ, P. (2019). An in-depth analysis of the Summary Innovation Index in the V4 Countries. *Journal of Competitiveness, 11*(2), 68-83. doi: 0.7441/joc.2019.02.05.

Jašková, D., & Haviernikova, K. (2020). The human resources as an important factor of regional development. *International Journal of Business and Society*, 21(3), 1464-1478. https://doi.org/10.33736/ijbs.3364.2020

Jovanović, M., Savić, G., Cai, Y., & Levi-Jakšić, M. (2022). Towards a Triple Helix based efficiency index of innovation systems. *Scientometrics*, 127, 2577-2609. https://doi.org/10.1007/s11192-022-04304-x

Kleszcza, A. (2021). Principal components of innovation performance in European Union countries. Wiadomości Statystyczne. *The Polish Statistician*, 66(8), 24-45. https://doi.org/10.5604/01.3001.0015.2305

Koišová, E., Grmanová, E., Škrovánková, K., & Kostrová, J. (2019). Competitiveness of Regions in the Visegrad Group Countries. *Inzinerine Ekonomika-Engineering Economics*, 2019, 30(2), 203-210. https://doi.org/10.5755/j01.ee.30.2.21746

Kordoš, M., & Krajňáková, E. (2018). Significance of innovation in Slovak regions - issues and challenges. *Ad alta-journal of interdisciplinary research*, *8*(1), 137-141.

Liu, Y., Wang, X., & Yang, Y. (2023). The impact of strategic knowledge disclosure on enterprise innovation performance. *Managerial and Decision Economics*, 1-11. https://doi.org/10.1002/mde.3834

Machová, R., Mura, L., Korcsmáros, E., Seres Huszárik, E., Buleca, J., & Haviernikovà, K. (2015). *Inovačné podnikanie a hodnotenie inovačného potenciálu podnikateľských sietí*. Brno: Tribun EU.

Mura, L., Machová, R., & Tóth, Z. (2015). Evaluation of innovation performance of the business networks. *Hradec Economic Days 2015*, Hradec Králové: Gaudeaumus, 41-47.

Neeliah, H., Seetanah, B. (2016). Does human capital contribute to economic growth in Mauritius? *European Journal of Training and Development*. 40(4), 248-261. https://doi.org/10.1108/EJTD-02-2014-0019

OECD. (2006). Productivity, human capital and educational policies. Available at: https://www.oecd.org/economy/human-capital/

Roszko-Wójtowicz, E., & Białek, J. (2019). Measurement of the average innovativeness change over time in the EU member states. *Journal of Business Economics and Management*, 20(2), 268-293. https://doi.org/10.3846/jbem.2019.8337

Roszko-Wójtowicz, E., & Białek, J. (2018). Diverse approaches to the multidimensional assessment of innovation in the European union. *Acta Oeconomica*, *68*(4), 521-547. https://doi.org/10.1556/032.2018.68.4.3

Sharma, P. (2019). Role of human capital in economic growth: a comparative study of India and China. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3319224

Suseno, Y., Standing, C., Mavi, R., & Jackson, P. (2020). National innovation performance: the role of human capital and social capital. Innovation: The European *Journal of Social Science Research, 33*(3), 296-310. https://doi.org/10.1080/13511610.2018.1536536

Svagzdiene, B., & Kuklyte, J. (2016). The analysis of factors which have impact for Summary Innovation Index in Germany, Estonia and Lithuania, *Transformations in Business & Economics*, *15*(2B), (38B), 784-799. Available at: https://hdl.handle.net/20.500.12259/53251

Teixeira, A. A. C., Queirós, A. S. S. (2016). Economic growth, human capital and structural change: A dynamic panel data analysis. *Research Policy*, *45*(8), 1636-1648. https://doi.org/10.1016/j.respol.2016.04.006

Ünlü, F. (2017). Determination of factors affecting innovation performance with binary logistics regression analysis. *Akademik Sosyal Araştırmalar Dergisi*, *5*(57), 393-403. https://doi.org/10.16992/ASOS.13004

Vráblíková, M. (2017). Ľudský kapitál, inovácie a podnikateľské schopnosti ako zdroje ekonomického rastu. *Trendy a inovatívne prístupy v podnikových procesoch „2017“,* 9 p. Available at: https://www.sjf.tuke.sk/umpadi/taipvpp/2017/index.files/prispevky/33_Vrablikova_LudskyKapital.pdf

Wardhani, A. R., Acur, N., & Mendibil, K. (2016). Human capital, social capital and innovation outcome: A systematic review and research agenda. *2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, Bali, Indonesia, 2016, pp. 355-359. https://doi.org/10.1109/IEEM.2016.7797896