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ANALYSIS OF REGIONAL DISPARITIES IN HUMAN CAPITAL IN EUROPEAN UNION COUNTRIES*

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Abstract. Human capital is one of the key factors for sustainable economic growth and social development. In the European Union, which is characterized by relatively significant differences between individual member states, the analysis of human capital and the determinants that influence it plays an important role in understanding regional disparities in quality of life and economic performance. The aim of this article is to analyse the level of human capital in EU countries using the Human Development Index, identify its regional disparities, and assess the extent to which spending on key areas contributes to HDI variability between countries. At the same time, we also focused on assessing the importance of non-expenditure factors that may influence the level of human capital in order to provide a more comprehensive view of the issue. The analysis is based on Eurostat and United Nations Development Programme databases for the period 2014–2023. A one-factor analysis of variance supplemented by Tukey's HSD test was used to determine the existence of regional differences in HDI. We used the Mann-Whitney U test to determine whether the identified differences were the result of unequal spending in three key areas affecting human capital (health, education, and research and development). Finally, we used multiple regression and correlation analysis to identify other (non-expenditure) factors that could be significant determinants of human capital. We found that HDI values are higher in northern and western European countries than in southern and eastern European countries. There is a statistically significant difference in HDI between countries with higher and lower spending on health care and research and development, respectively, but there is no statistically significant difference in HDI between countries with lower and higher spending on education. Among non-expenditure factors, average life expectancy at birth and the proportion of the population with tertiary education appear to be significant determinants of HDI. Other variables analysed, despite a positive correlation with HDI, did not show a statistically significant impact.

Keywords: European Union; human capital; human development; Human Development Index; regional disparities

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1. Introduction

Extensive research in the field of human capital and human development stems from the importance of the human factor in achieving economic growth and development of society (Gruzina et al., 2021, Ziberi et al., 2022, Sultana et al., 2022, Ramallari & Velaj, 2023, Carillo, 2024, Uddin et al., 2025 and others). Human capital, as one of the most important sources of economic growth, includes the knowledge, skills, health and abilities of individuals, which directly affect productivity and, consequently, the quality of life (Evanoff, 2021, Zahra Al-Hujaimi & Al-Hashemi, 2021, Cappelli et al., 2023, Chereyeva et al., 2025 and others). Within the European

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Union, which is characterized by differences in the historical, economic and social development of individual countries, the analysis of human capital is key to understanding differences in economic levels and quality of life. A wide range of indicators is used to assess the level of human capital and human development, including the Human Development Index. This index includes indicators of education, life expectancy and living standards, thus providing a comprehensive view of the development and quality of life of the population.

This article focuses on assessing the level of human capital in the EU Member States using the Human Development Index, identifying regional disparities, with particular attention paid to the key factors that shape human capital and assessing how they contribute to these differences. The aim of the article is to provide a deeper and more comprehensive view of the issue of human capital in the four basic geographical areas (regions) of Europe: Northern, Western, Southern and Eastern Europe.

To determine the existence of regional differences in HDI, a one-way analysis of variance was used, which was supplemented by Turkey's HSD test to refine the results. To verify whether the differences in HDI between the studied groups of countries can be at least partially influenced by unequal spending in three important areas (health, education, research and development), the Mann-Whitney U test was used in the next part of the analysis. In addition, we also tried to identify non-expenditure factors that could have an impact on the level of human capital through multiple regression analysis and correlation analysis. Despite the importance of HDI as an indicator of human capital development, there are only a limited number of studies that systematically examine regional differences in HDI within the EU and at the same time analyse the impact of expenditure factors on these differences (Laskowska & Dańska-Borsiak, 2016; Hippe, 2020; Ederer et al., 2020). This research therefore responds to the need for a more comprehensive approach to understanding, in particular, the expenditure determinants of human capital in the European context but also complements them with non-expenditure determinants at the pan-European level. The research uses a combination of several statistical methods, which allows for a deeper assessment of the relationships between the HDI and its individual determinants. In addition, its results can provide an incentive for the creation of public policies, especially in the areas of investment in health, research and development, as well as education, especially given their different levels of impact on the HDI. The finding that education expenditure does not show a statistically significant impact on the HDI also opens space for a discussion on the effectiveness of public resources in this area and suggests the need to re-examine existing theoretical models that assume the existence of a linear relationship between the amount of expenditure affecting human capital and its level.

The structure of the article is as follows: in the first part we will focus on a summary of the theoretical foundations of the research issue, in the next part we will explain the research methodology. In the third part we will present the research results, in the fourth part we will evaluate the achieved results in the context of the findings of other authors dealing with the given issue as part of the discussion. The conclusion contains a summary of the most important results and findings of the article.

2. Theoretical background

Human capital is considered a key driver of the knowledge economy, playing a fundamental role in its development. For this reason, to ensure the progress of the economy and society, it is essential to pay attention to the development of human capital by increasing investments in human capital (Xu & Li, 2020). According to Kucharčíková et al. (2024), people as representatives of human capital are carriers of knowledge, ideas and experiences that contribute to increasing the performance and competitiveness of society. According to Harper (2025), human capital is perceived as a set of characteristics and abilities that include knowledge, talent, skills, intelligence and education. These aspects are individually and collectively controlled and owned by individuals in the population and are of importance for the economy. Angrist et al. (2021) understand human capital as resources associated with the knowledge and skills of individuals. Similarly, Cappelli et al. (2023) define human capital as the set of knowledge and skills that individuals accumulate over time, which results in an impact on labour productivity and innovative capacity, thus considering human capital as one of the most important determinants of economic growth. A detailed description of human capital is offered in his study by Evanoff (2021), who characterizes human capital as a set of habits, knowledge, and social and personal characteristics, including creativity, that include the ability to perform work and create economic value. It consists of the

knowledge, skills, and health that people invest in and accumulate throughout their lives to fulfil their potential as productive members of society. Similarly, Zahra Al-Hujaimi & Al-Hashemi (2021) have elaborated on the nature of human capital, referring to it as a general concept of knowledge and skills contained in people that play an important role in determining labour productivity and their ability to absorb new knowledge and master new technologies. Furthermore, human capital is defined as an intangible asset or quality that is not included in the balance sheet of a company, and which can be categorized as the economic value of a worker's experience and skills, and includes assets such as education, training, intelligence, skills, health, and other things that employers value, such as loyalty and punctuality. Turgel & Fazylzhan (2023) understand human capital as a set of skills, abilities, and knowledge acquired through investments in education, health, and continuing education, which are used to generate profit for both individuals and society.

While the theoretical framework of human capital emphasizes its universal importance, empirical studies point to significant regional differences in its level. Hippe (2020) draws attention to the fact that there are regional inequalities around human capital in European countries, which are influenced by historical development, geographical location, but also the orientation of government policy. Following this, in line with the aim of the article, in the empirical part we focus on testing hypothesis H1, which assumes that there is a statistically significant difference in the average HDI value between individual EU regions.

According to Matei and Ceche (2018), human capital consists of those abilities of individuals that are characteristic of them and remain the same in any social environment and can be used in the labour market in exchange for economic resources of any kind. In practice, human capital, according to the authors, consists of educational capital (skills acquired by individuals in the process of education, but also outside it) and biological capital (physical abilities of individuals, synthesized most often through health status). Given the above, investments in human capital can take various forms, with investments in school education, vocational training in the workplace and healthcare among the basic ones (Kipyego, 2023). The investments are characterized by their constant and long-term nature of investment and are inextricably linked to the individual who acquires them in the form of knowledge and skills, which contributes to increasing professional and professional skills, and subsequently to increasing production and productivity growth. Kipyego (2023) refers to this phenomenon as an internal effect resulting from investments in human capital. In addition, he also mentions an external effect, since increasing the productivity of one employee also positively affects the efficiency of other workers in the company.

Education and health are therefore considered the most important investments in human capital, according to Shafud (2020). Higher education and better health enable growth in labour productivity, production growth, and economic growth. As Chereyeva et al. (2025) state, investments in human capital help increase labour productivity, improve the level of education and health of the population, as well as support innovative development and improve the quality of life. Based on this, Turgel & Fazylzhan (2023) consider healthcare facilities, educational and scientific institutions, and continuing education centres as sources of human capital assets. Also, according to Erasmus (2021), the key elements of human capital development are based on investments in the education and health sectors. On the one hand, investment in education is a tool that creates new skills, knowledge and incentives that drive economic expansion by increasing the skill of individuals and creating a productive economy. Thus, education spending creates new technologies, inventions and innovations that lead to wealth creation and human capital development. On the other hand, health in old age reflects a state of complete well-being that leads to a competent workforce and improves human capital development through the acquisition of skills and knowledge. Similarly, Bassey et al. (2023) based on human capital research in Nigeria states that investment in education and health enhances human capital development in developing countries. The fact that sustainable economic growth cannot be achieved without human capital development is stated by Olawumi (2020), recommending increased spending on education and health to improve the quality of life, material well-being of workers and life expectancy for the sake of higher productivity. As Gruzina et al. (2021) point out, the efficiency of human capital investments is usually determined by the ratio of costs to economic results, or rather, actual results with expectations. A quantitative assessment of the social efficiency of human capital investments is measured by the contribution to economic growth, which should be reflected in GDP growth.

Healthcare plays an important role in the quality of human capital. Higher spending on healthcare increases the productivity of human capital, as healthier individuals can work more efficiently, including in physical and mental stress (Raghupathi & Raghupathi, 2020). As Zarulli et al. (2021) argue, increasing healthcare spending is essential to achieving life expectancy growth, but more efficient use of resources can help countries improve their life expectancy even without increasing spending. Currently inefficient countries could benefit the most from spending reorganization, as the example of similar countries shows that higher levels of life expectancy at birth are achievable. Similarly, Ataklı Yavuz & Yilmaztürk (2023) state that societies that allocate sufficient resources to health tend to have higher quality of life and better health status. However, they point out the importance of efficient management of health spending and allocation of resources to the right areas. They suggest developing balanced and effective policies to ensure the sustainability of health systems and provide equitable health services to all segments of society. Since several authors point to the key role of health in the formation and development of human capital, in the empirical part we will focus on testing the hypothesis H2 that there is a statistically significant difference in the HDI value between groups of countries differentiated by the level of health spending.

Within the framework of human capital research and its development, most authors focus on clarifying the importance of education and its impact on the level of human capital. Garanin (2022) considers education to be the basis of human capital, because human capital is embodied in the knowledge, skills and abilities that are the result of education. Naros & Simionescu (2019) recall that education plays an important role in adapting human resources to the dynamic demands of the labour market and provides more options for choosing a better job.

Education is essential for economic growth and profitability because, according to Ramallari & Velaj (2023), it increases efficiency and helps the economy advance in the development process, which is a prerequisite for long-term development. As Coman et al. (2022) recall, education is the main engine of economic growth, and the education system must be organized in such a way that it prepares individuals to perform professions that may not even exist at the time of study. In addition, they state that public policies should improve the quality of general education and support lifelong learning programs for the adult population to ensure an adaptable and competitive workforce. In the above context, investing in education, according to Ziberi et al. (2022), means first and foremost investing in human resources, i.e. creating a skilled workforce that will influence the creation of innovations, increase productivity and wages, reduce the requirements for the state to finance various social programs, and increase the state budget through the accumulation of taxes, which will subsequently have a positive impact on the country's economic growth. In a similar vein, Okerekeoti (2022) expressed himself, stating that spending on education contributes to the development of human capital, which can lead to a trained workforce that can increase the productivity of both physical and human resources and subsequently lead to higher economic growth. Of course, higher education also has a positive impact on the standard of living of the individual, because, as Guijarro-Garvi et al. (2022), educated individuals earn greater monetary returns, obtain better-paid jobs, which reduces their risk of material deprivation and contributes to a higher level of subjective well-being. Given the essential importance of education for improving the quality of human resources and stimulating economic development, Oktaviany (2024) emphasizes the need for public financing of education as a fundamental element of long-term economic progress and improving personal well-being. Government spending on education can be, according to Tabar et al. (2017), an effective factor in promoting and acquiring knowledge, improving education and strengthening the spirit of innovation and originality in the community, and increasing the level of education of people in society represents an increase in the human capital of a given country, which leads to improved efficiency, enhanced production capacity and economic growth. Zogjani et al. (2024) based on research in Kosovo recommends an efficient allocation of education spending and aligning it with broader economic objectives to maximize growth potential and support economic development. Coronel and Díaz-Roldán (2024) examining the impact of public spending on education, productivity, wages and growth in the EU found that productivity growth is mainly contributed by spending on research and development in education and employment in sectors with high technological content, where a high level of skills is needed. They point out the need to use resources efficiently, which requires a distinction between the quantitative and qualitative dimensions of education provision. Education financing can be considered efficient if it leads to an increase in productivity. Based on the importance attributed to investment in education for human capital development, the empirical part focuses on testing hypothesis H3, that there is a statistically significant difference in the HDI value between countries differentiated by the amount of education spending.

Several authors link the importance of education for the growth of human capital not only with healthcare, but also with the development of the digital economy, with innovation and research. As Patel and Annapoorna (2019) state, the growing dependence of industry on sophisticated capacities has significantly increased the importance of education for increasing the availability of human capital. The product of an educated mind is societal and global progress, which increasingly depends on research, invention, innovation and adaptation. Simmons (2024) states that education plays a key role in strengthening human capital and creating innovation, which in turn contributes to the economic prosperity of the country. For this reason, policymakers should prioritize investments in education to develop human capital and innovation, which would subsequently facilitate economic development.

Based on the results of their research, Kousar et al. (2023) recommend that the Pakistani government allocate more funds from its budget to health, education and social protection programs in order to increase its human capital, as these are the areas that have a positive and significant relationship with human capital in terms of primary, secondary and tertiary education attainment and life expectancy at birth.

Yu et al. (2023) found that there is a strong relationship between education expenditure, human capital development and innovation in science and technology, as education expenditure contributes not only to socio-economic development but also to the accumulation of human capital and progress in scientific and technological innovation. They conclude that the accumulation of human capital can accelerate the growth of scientific and technological innovation and stimulate economic growth, if education expenditure is increased and the quality of education is improved. According to them, increasing education spending can not only increase the innovative capacity of the educated, but also strengthen their ability to adopt and apply new technologies, leading to the transformation and transfer of knowledge, making education spending an effective means of supporting innovation in science and technology.

Science and progress are also highlighted as key factors influencing the formation of human capital by Gruzina et al. (2021). They state that economic growth in modern society is driven by ubiquitous innovations at all stages of its reproductive process. The generator and consumer of all new ideas is represented by a person (citizen and customer), who is also a highly qualified employee with up-to-date knowledge that needs to be constantly updated and supplemented throughout his or her life, as well as real-life experience. In their study, Diakodimitriou et al. (2025) found that education spending significantly affects economic growth, identifying R&D spending as the main channel through which this occurs. According to them, strategic allocation of funds in education, especially in conjunction with R&D, should strengthen economic growth and resilience, therefore, policymakers should support innovation in supporting tertiary education, funding research programs or other areas of education that are related to R&D. They explain this by saying that to sustain economic growth and support innovation, an education policy that ensures a skilled workforce that can fully exploit advances in R&D is essential. According to Paula & Silva (2021), it is important to invest in R&D, as there is a positive impact of R&D investment on national development, which is mediated by the total number of patent applications in a country. Patent applications are often considered one of the key factors in the development of technological innovation, but also in the overall economic development of countries (Leogrande et al., 2022). As Diebolt & Hippe (2019) show, human capital is the most important historical factor related to current patent applications per capita and current GDP per capita. Newer EU regions generally have lower patents per capita than the “old” Member States, and the same is true for GDP per capita.

The relationship between human capital and science and research is two-way. On the one hand, an increase in the inflow of human capital causes firms to produce more patents and improve the quality of innovations (Yang et al., 2022). On the other hand, higher spending on science and research contributes to the development of human capital, which in turn contributes to the innovation of the enterprise. Based on the above, it can be concluded that the increase in the density of human capital in research is associated with a significant increase in publications and patents, which indicates that countries that invest relatively more in personnel working in research and development produce more research outputs in the form of patents and publications (Ayan et al., 2023). Since, in addition to education and health, many authors claim that investment in research and development also significantly affects the level of human capital, in the empirical part of the research we will

also test hypothesis H4, that there is a statistically significant difference in HDI between groups of countries differentiated by the level of research and development expenditure.

Education, health, science and research are fundamental factors influencing the level of human capital in the sense of the above. However, the measurement of the level of human capital itself is debatable, because there are several approaches that focus on different areas and characteristics of human capital. Turgel & Fazylzhan (2023) identified four main categories of approaches in human capital research in their research: investment approach, human capital as a fund (reserve), human capital as a factor of production and human capital as an asset. The investment approach allows us to assess the concept of “human capital” through investments in education, health and further education, which after a certain time can bring dividends to a person in the form of wages. The second approach, the approach to human capital as a “fund”, examines it as a “reserve” of skills, abilities and human capabilities that a person acquires during his life. The approach to human capital as a factor of production pays special attention to human competencies, which are the main driving force of production and the economy. The latter approach considers the physical and non-physical assets that constitute human capital itself.

As Matei & Ceche (2018) state, the process of assessing human capital is generally very complex. It should consider and include the characteristics of the impact and classification of human capital at a general or specific societal level. The diversity of measurement methods suggests the need to introduce a unified approach, since comparing the results of different indices within and between countries is not possible (Armstrong & Taylor, 2020).

In connection with the investment approach to measuring human capital, the Human Development Index indicator is often used in research. Patel & Annapoorna, (2019) examined the impact of education expenditure on human resource development in India, assessing the relationship between education expenditure and India's ranking in the Human Development Index. Okafor et al. (2017) used HDI to examine the impact of government expenditure on human capital development in Nigeria. Edeme & Nkalu (2019) also conducted research on the relationship between public expenditure and human capital using HDI in the context of Nigeria. Maharda & Aulia (2020) conducted their research on the relationship between government expenditure on education and health and HDI in the context of Indonesia. The relationship between human development (measured by HDI) and health expenditure in 25 OECD countries between 2003-2019 was investigated by Ataklı Yavuz & Yilmaztürk (2023). They found that increased investment in health (whether by the public sector or households themselves) contributes to human development in these countries. Although most of the studies mentioned have shown a positive relationship between human capital expenditure and the Human Development Index, the relationship was not confirmed in the study by Okafor et al. (2017).

3. Research objective and methodology

The aim of the article is to analyse the level of human capital in the European Union countries through the Human Development Index, identify its regional disparities and assess the extent to which the level of expenditure on key areas contributes to the variability of the HDI between countries. At the same time, the article focuses on assessing the importance of non-expenditure factors that may affect the level of human capital, to provide a more comprehensive view of the issue. The analysis was carried out for the period 2014-2023 and was based on statistical data from Eurostat and the United Nations Development Programme. We used the Human Development Index (HDI) to express the level of human capital, as it represents a relatively comprehensive and internationally recognized indicator that captures the most important dimensions affecting human capital.

Using one-way analysis of variance (ANOVA), we investigated whether there are regional differences in HDI in EU countries. We chose this method because it is a frequently used method for comparing means across groups (Montgomery, 2017). Countries were divided into four groups for this analysis, in accordance with geographical location and historical and socio-economic conditions, as well as their division in some other studies (Hudzelyak, 2024; Stojanovic, Zakic, 2024; Malinauskaite et al., 2024; Pagiotti et al., 2024):

- Western European countries (Belgium, France, Netherlands, Luxembourg, Germany, Austria, Ireland)
- Northern European countries (Sweden, Finland, Denmark)
- Southern European countries (Portugal, Spain, Italy, Greece, Malta, Cyprus)
- Eastern European countries (Slovakia, Czech Republic, Hungary, Poland, Estonia, Lithuania, Latvia, Bulgaria, Romania, Slovenia, Croatia).

To determine which regions, have statistically significant differences, Tukey's HSD test was used, which is suitable for comparing all pairs of groups and is often used as a complement to ANOVA in calculations (Montgomery, 2017). We used the formula:

$$HSD = q_{crit} * \sqrt{\frac{MS_{within}}{n_{ef}}}$$

where:

q_{crit} – table value

MS_{within} – ANOVA output

n_{ef} – effective group size $\frac{2}{\frac{1}{n_1} + \frac{1}{n_2}}$

If $HSD <$ the difference between the respective groups, the result is statistically significant. Conversely, if $HSD >$ the difference between the respective groups, the result is not statistically significant.

To examine whether the differences in HDI between these groups of countries are at least partially determined by inequalities in the volume of expenditures in three key areas (health, education, research and development), the non-parametric Mann-Whitney U test was used in the next section. According to Nachar (2008), this test is one of the most powerful non-parametric tests and there is a good probability that it will provide statistically significant results. The amount of expenditure was assessed based on the share of the respective expenditure group in GDP. Countries were divided into two groups for each expenditure category – countries with below-average and above-average expenditure, and the average HDI level for the years 2014-2023 in these groups was analysed. We used the formulas (1,2):

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \quad (1)$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \quad (2)$$

where:

n_1 n_2 – sizes of two groups

R_1 R_2 – sum of the order of values of the first and second groups.

Given that the amount of expenditure itself may not automatically correlate with the quality and efficiency of its use, and therefore with the real development of human capital, we also conducted a multiple regression analysis, in which, in addition to the expenditure variables, we also included three outcome indicators (average life expectancy at birth, share of the population with tertiary education, number of patent applications per million inhabitants), which we assumed could be significant determinants of HDI. We used the formula (3):

$$y_j = b_0 + b_1 x_j + \dots b_n x_n + \varepsilon \quad (3)$$

To supplement and deepen the interpretation of the results of the regression analysis, we also conducted a correlation analysis, the aim of which was to identify the basic relationships between individual variables, assess their strength and identify the existence of possible relationships between variables that were considered independent in the regression analysis. We based our analysis on the formula (4):

$$r_{xy} = \frac{n \sum_{i=1}^n x_i y_i - \sum_{i=1}^n x_i \sum_{i=1}^n y_i}{\sqrt{[n \sum_{i=1}^n x_i^2 - (\sum_{i=1}^n x_i)^2][n \sum_{i=1}^n y_i^2 - (\sum_{i=1}^n y_i)^2]}} \quad (4)$$

4. Results

As part of the assessment of the level of human capital in EU countries, we decided to identify whether there are differences in HDI between geographical regions (areas) of the EU. The aim of this part of the analysis was to determine whether there are statistically significant differences in the average HDI value between individual parts of Europe, which are characterized by different historical, economic and socio-political conditions. The countries were divided into four basic groups - Northern, Western, Southern and Eastern Europe. To verify whether there are statistically significant differences in HDI between these groups, a one-way analysis of variance (ANOVA) was used (Table 1). We tested the following hypothesis:

H1: There is a statistically significant difference in the average HDI value between individual EU regions.

Table 1. One-way analysis of variance of HDI in EU regions

Groups	Count	Sum	Average	Variance		
West	7	6.5338	0.9334	0.00026		
North	3	2.8474	0.94913	0.000021		
South	6	5.3702	0.89503	0.00018		
East	11	9.6111	0.87374	0.00079		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.02264	3	0.00755	16.652	5.71×10^{-6}	3.028
Within Groups	0.01042	23	0.00045			
Total	0.03307	26				

Source: UNDP, own calculations

The analysis was performed at a significance level of $\alpha = 0.05$. The calculated value of the test statistic $F=16.652$ significantly exceeds the critical value $F \text{ crit} = 3.028$. The p-value found of 0.0000057 was very low. Based on these results, we accept H1, which states that there is a statistically significant difference in the average HDI value between the individual regions of the EU. Thus, through a one-way analysis of variance, we found that the level of human development is not evenly distributed in the European Union. The average HDI values for the period 2014–2023 in the individual regions of the EU are shown in Figure 1.

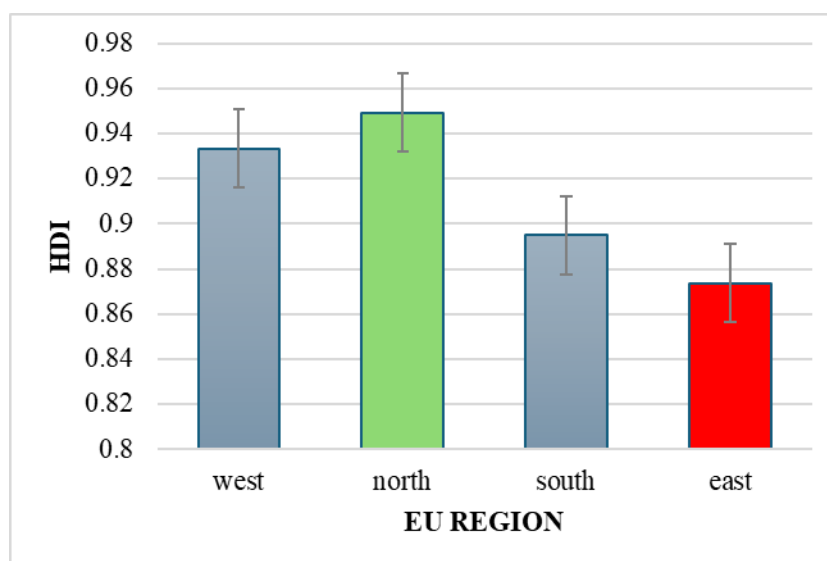


Figure 1. Average HDI values in the regions of the EU

Source: UNDP, own processing

Western Europe was represented in the analysis by 7 countries (Belgium, France, Netherlands, Luxembourg, Germany, Austria, Ireland) with an average HDI of 0.9334, Northern Europe by 3 countries (Sweden, Finland, Denmark) with an average HDI of 0.9491, Southern Europe by 6 countries (Portugal, Spain, Italy, Greece, Malta, Cyprus) with an average HDI of 0.8950 and Central and Eastern Europe by 11 countries (Slovakia, Czech Republic, Hungary, Poland, Estonia, Lithuania, Latvia, Bulgaria, Romania, Slovenia, Croatia) with an average HDI of 0.8737. The highest average HDI values were thus recorded in the countries of Northern Europe, followed only very slightly by the countries of Western Europe, while lower values were found in the countries of Southern and especially Eastern Europe. This may reflect long-term differences in the economic and social levels of individual regions. Since we found that there are differences between individual EU regions, we decided to identify between which regions these differences are statistically significant (Table 2).

Table 2. Tukey's HSD test

Groups	Difference	n ₁	n ₂	Effective sample size	Honestly significant difference	Statistical significance
West - North	0.0157	7	3	4.20	0.0406	no
West - South	0.0384	7	6	6.46	0.0327	yes
West - East	0.0597	7	11	8.56	0.0285	yes
North - South	0.0541	3	6	4.00	0.0416	yes
North - East	0.0754	3	11	4.71	0.0383	yes
East - South	0.0213	11	6	7.76	0.0299	no

Source: UNDP, own processing

Using the Tukey HSD test performed at a significance level of $\alpha = 0.05$, we identified which EU regions have statistically significant differences. The results show that the largest difference in average HDI (0.0754) was recorded between the countries of Northern and Eastern Europe. This value exceeded the statistical significance threshold of $HSD = 0.0383$, indicating the existence of a significant difference in the level of human development between the countries of the Northern and Eastern EU. Lower, but still statistically significant differences were also recorded between the countries of Western and Eastern Europe ($0.0597 > 0.0285$), Northern and Southern Europe ($0.0541 > 0.0416$), as well as between the countries of Western and Southern Europe ($0.0384 > 0.0327$). On the contrary, the difference between the western and northern regions of the EU was not statistically significant ($0.0157 < 0.0406$), which suggests that these two regions have a similar level of human development typical of advanced economies with long-term investments in education, healthcare and research. Interestingly, the difference between the eastern and southern EU countries was not statistically significant either ($0.0213 < 0.0299$), which indicates a relatively comparable level of HDI in these two groups of countries, despite differences in geographical location and historical development. The results of the Tukey HSD test thus confirmed that the best conditions for human capital development are in the countries of northern and western Europe, while the countries of eastern and southern EU achieve lower, but comparable HDI values. This suggests that despite the EU's efforts for gradual convergence, regional disparities in human capital still exist, which may result from several aspects.

Since the analysis showed that there are statistically significant differences in HDI between the EU regions, and that countries in the west and north of the EU perform better in terms of human development than countries in the south and east, we decided to investigate whether these differences can be explained, at least in part, by the different levels of expenditure on key areas (health, education, research and development) that affect human capital. To this end, we performed a series of Mann-Whitney U tests, which are suitable for comparing two independent groups when the groups have different numbers of data. We compared countries with higher spending (above the EU average) and lower spending (below the EU average) in terms of their HDI. We tested the following hypothesis:

H2: There is a statistically significant difference in HDI between countries with higher and lower expenditure on health.

Table 3. Public expenditure on health – Mann-Whitney U test

Group 1	Group 2	U value	Critical value U (p <0,05)	Z-score	p-value	Statistical significance
EU countries with above-average healthcare expenditure	EU countries with below-average healthcare expenditure	32.5	50	2.81452	0.00496	yes

Source: Eurostat, own calculations

We investigated whether there is a statistically significant difference in the level of the Human Development Index between EU countries that spend above-average and below-average health care (Table 3). The analysis was carried out for the years 2014-2023, while the average value of health care expenditure for the entire period was calculated for each EU country. From these average values, an overall average value was then calculated, which made it possible to divide EU countries into two groups – countries with above-average and below-average public health care expenditure. These two groups of countries were then assigned HDI values. To test this hypothesis, we used the Mann–Whitney U test. The analysis was carried out at a significance level of $\alpha = 0.05$. The U value in this case was 32.5. The critical value of U at $p < 0.05$ is 50. $32.5 < 50$, indicating a statistically significant difference in HDI between countries with above-average and below-average spending. The result was also supported by the z-score = 2.81452, which means that the difference is approximately 2.8 standard deviations away from the expected U value. The result is also confirmed by the low p-value of $0.00496 < 0.05$. Based on these results, we confirm H2, which assumed that there is a statistically significant difference in HDI between countries with higher and lower public spending on health. This finding may signal that investment in health can play an important role in human capital development. Higher investments in health can mean better access to health care, which can be reflected in increasing life expectancy, reduced morbidity, which is subsequently reflected in the HDI value. However, this statement is only generally valid, since even among countries with above-average health expenditure values, we find countries that also show below-average HDI values (Spain, Croatia or Italy), and conversely, among countries with below-average health expenditure values, we find countries that also show above-average human development values (Ireland, Luxembourg or Malta). These exceptions point to the fact that the amount of health expenditure is only one of several factors that can influence the HDI, or that it is not only the amount of expenditure that is important, but also its effective use. We tested the following hypothesis:

H3: There is a statistically significant difference in HDI between countries with higher and lower education expenditure.

Table 4. Public expenditure on education – Mann-Whitney U test

Group 1	Group 2	U value	Critical value U (p <0,05)	Z-score	p-value	Statistical significance
EU countries with above-average expenditure on education	EU countries with below-average expenditure on education	69.5	50	1.01905	0.30772	no

Source: Eurostat, own calculations

We proceeded similarly to public expenditure on health in the case of public expenditure on education (Table 4). We investigated whether there was a statistically significant difference in the HDI level between EU countries with above-average and below-average public expenditure on education. The subject of the analysis was data for the period 2014-2023 and the average value of expenditure for the given period was calculated for each EU country. The average values for individual member states were then used to calculate the overall

average value, based on which we divided EU countries into countries with below-average public expenditure on education and countries with above-average public expenditure on education. The Mann–Whitney U test was used to test the hypothesis that there was a statistically significant difference in HDI between countries with higher and lower expenditure on education. The analysis was performed at a significance level of $\alpha = 0.05$. In this case, the calculated test statistic value $U = 69.5$ was higher than the critical value $U = 50$, indicating that there is no statistically significant difference between the groups. This finding is also confirmed by the low z-score = -1.01905, which is within the non-significance interval, and the statistical non-significance was also confirmed by the p-value $0.30772 > 0.05$. Based on these results, we reject H3, which assumed that there is a statistically significant difference in HDI between countries with higher and lower public spending on education. Since it has been shown that higher public spending on education may not automatically lead to better human capital development, but education is generally considered one of the most important prerequisites for its development, it would be necessary to pay attention to other related aspects such as the quality of the education system in individual countries, the availability of education for different social groups, the connection of education with the labour market, etc. These factors can significantly influence the extent to which investments in education translate into improvements in human development in individual countries. We tested the following hypothesis:

H4: There is a statistically significant difference in HDI between countries with higher and lower R&D expenditures.

Table 5. R&D expenditures – Mann-Whitney U test

Group 1	Group 2	U value	Critical value U ($p < 0.05$)	Z-score	p-value	Statistical significance
EU countries with above-average expenditure on R&D	EU countries with below-average expenditure on R&D	14.5	47	3.60229	0.00032	yes

Source: Eurostat, own calculations

As part of the analysis, we investigated whether countries with higher R&D expenditure as a share of GDP achieve significantly higher HDI compared to countries with lower expenditure (Table 5). As in previous cases, we examined data for the period 2014 to 2023, calculating the average amount of expenditure for each EU member state over the entire period. Based on the individual averages, we then determined an overall average for all EU countries. Accordingly, we divided the countries into two groups – those with below-average R&D expenditure and those with above-average expenditure. To test the hypothesis that there is a statistically significant difference in the human development index between these two groups of countries, we used the Mann–Whitney U test. The analysis was performed at a significance level of $\alpha = 0.05$. The calculated U value was 14.5, which is significantly lower than the critical value $U = 47$, indicating the existence of a statistically significant difference in HDI between countries with above-average and below-average R&D expenditures. The statistical significance of the result is also confirmed by the low p-value of $0.00032 < 0.05$ and the z-score = -3.60229, which significantly exceeds the threshold of non-significance. Based on these results, we therefore confirm H1 that there is a statistically significant difference in HDI between the two groups of countries studied. The above finding suggests that R&D expenditures can significantly contribute to the development of human capital. R&D usually supports innovation, technological progress and productivity, which has the potential to positively affect the quality of life and the overall level of human development. However, we consider it necessary to emphasize again that this is a general trend that does not apply in some cases. Even some countries with lower spending in this area, such as Ireland or Luxembourg, achieve above-average levels of human development. On the other hand, Estonia spends above average on research and development but lags behind in human capital development. A quantitative increase in spending on research and development creates a favourable precondition for improving the HDI, but it does not guarantee its improvement. Human capital is determined by many other factors, and therefore attention should also be focused on other areas.

Since we found out based on the previous analysis that education spending alone may not automatically lead to better human capital development, we decided to identify other factors through multiple regression analysis that could influence the level of human capital in EU countries. In addition to the expenditure indicators already used (government expenditure on health, government expenditure on education and expenditure on research and development), we also included in the analysis outcome variables that we believed could have an impact on human capital development (life expectancy at birth, share of the population with tertiary education and number of patent applications per million inhabitants). We chose these variables because of their ability to capture at least partially the qualitative aspects of human capital and the potential for innovation, which is often a more accurate indicator of the efficiency of expenditure than the volume of investment itself (Table 6). The main reference indicator remained the HDI in this extended analysis applied to the EU.

Table 6. Multiple regression analysis

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Statistical significance</i>
Intercept	0.4940	0.1036	4.7682	0.0001	yes
Public administration expenditure on healthcare	-0.0005	0.0044	-0.1060	0.9167	no
Public administration expenditure on education	-0.0021	0.0041	-0.5003	0.6223	no
Expenditure on research and development	0.0202	0.0076	2.6468	0.0155	yes
Life expectancy at birth	0.0043	0.0014	3.1019	0.0056	yes
Share of the population with tertiary education	0.0013	0.0006	2.1952	0.0401	yes
Number of patent applications per million inhabitants	0.0000	0.0000	1.0829	0.2917	no

Source: UNDP and Eurostat, own calculations

Based on the results of multiple regression analysis, it can be concluded that the regression model achieved a high degree of explained variability. The value of the coefficient of determination $R^2 = 0.8617$. This means that approximately 86% of the changes in HDI can be explained by the included variables (public expenditure on health, public expenditure on education, expenditure on research and development, average life expectancy at birth, proportion of the population with tertiary education, and number of patent applications per million inhabitants). Even after considering the number of predictors, the model explains a high degree of variability, as confirmed by Adjusted $R^2 = 0.8202$. Although some variables were not statistically significant, the model is statistically significant, as confirmed by the low Significance F value of 0.0000001.

The coefficient for variable healthcare expenditure is -0.00046, but it is not statistically significant (p-value = 0.9167). Therefore, within the selected model, it can be concluded that healthcare expenditure does not have a significant impact on HDI in the EU, although the Mann-Whitney U test confirmed that there is a statistically significant difference in HDI between countries with higher and lower healthcare expenditure. This discrepancy may indicate that the relationship between health expenditure and HDI is not linear, or that it is influenced by other factors that are not captured in the regression model but were detected by the non-parametric test. In the case of education and research and development expenditure, we find consistency between the Mann-Whitney U test and regression analysis. Based on $p = 0.6223$, education expenditure does not have a significant impact on HDI in EU countries, as has been previously demonstrated. On the contrary, for research and development expenditure, the coefficient = 0.02024 is positive and statistically significant ($p = 0.0155$), indicating that higher investment in research and development contributes to an increase in HDI. If we look at the outcome indicators, average life expectancy at birth, as one of the important indicators of the health status of the population, based on the results of the regression model, shows a positive and statistically significant impact on the HDI (coefficient = 0.00432; $p = 0.0056$). This means that an increase in average life expectancy is associated with an increase in HDI. Although education expenditure was not statistically significant, the outcome indicator for education – the proportion of the population with tertiary education – has a positive and statistically significant impact (coefficient = 0.00131; $p = 0.0401$) on the HDI. A higher proportion of the population with higher education increases the quality of the workforce, the innovative potential, and the country's ability to adapt to

change, which contributes to increasing the level of human capital. However, the number of patent applications per million inhabitants is not statistically significant ($p = 0.2917$), meaning that patents cannot explain changes in HDI. However, this indicator shows considerable differences between countries and its importance could increase in connection with the development of an innovative knowledge economy.

The results of multiple regression analysis showed that several factors influence human capital development, but not all expenditures have a direct demonstrable impact on HDI. There may be several reasons for this. The cause may be their ineffective spending, mediated effects through other factors, possible multicollinearity between independent variables, but also the fact that the impact of some expenditures may not be immediately apparent, but only after a certain time lag. We supplemented these findings with a correlation analysis (Table 7).

Table 7. Correlation matrix

	HDI	Health expenditure	Education expenditure	R&D expenditure	Life expectancy at birth	Share of population with tertiary education	Number of patent applications
HDI	1.000						
Health expenditure	0.572	1.000					
Education expenditure	0.436	0.342	1.000				
R&D expenditure	0.768	0.811	0.568	1.000			
Life expectancy at birth	0.746	0.459	0.161	0.467	1.000		
Share of population with tertiary education	0.595	-0.021	0.424	0.286	0.409	1.000	
Number of patent applications	0.704	0.351	0.343	0.557	0.526	0.516	1.000

Source: UNDP and Eurostat, own calculations

The correlation matrix shows that there is a strong linear relationship between HDI and R&D expenditure, with a correlation coefficient of $r = 0.768$, indicating that countries with higher investment in R&D generally have a higher HDI. Another significant dependence was observed between HDI and average life expectancy ($r = 0.746$), which is not surprising, as this variable is directly included in the calculation of HDI itself. Given the results of the multiple regression analysis, according to which patent applications are not a significant predictor of HDI, the existence of a strong correlation between HDI and the number of patent applications ($r = 0.704$) is surprising. However, such a discrepancy between the results of correlation and regression analysis is a common phenomenon. The number of patent applications shows a relatively strong correlation with other independent variables included in the regression model, with research and development expenditure ($r = 0.557$) and the proportion of the population with tertiary education ($r = 0.516$). In the regression model, a significant part of the variability was explained by these variables, and as a result, the number of patent applications did not explain the additional variability of the HDI beyond what was already captured by other factors. Thus, the effect of these variable overlaps with other related variables in the model. We observed the weakest, albeit still positive, correlation with HDI in education spending ($r = 0.436$), which confirmed previous findings. However, it can be assumed that these expenditures contribute to a certain extent to the development of human capital, but rather indirectly, or with a time lag. Some correlations between independent variables were also noteworthy. For example, the correlation coefficient between research and development expenditure and health expenditure reached a value of $r = 0.811$. Such a close link between the two areas may reflect the fact that a large part of investment in research and development is related to healthcare. At the same time, such multicollinearity between independent variables could have affected the statistical significance of individual predictors in the regression model, as it is more difficult to interpret the individual contribution of each independent variable to

the dependent variable when their effects overlap. As regards independent variables, research and development expenditure and education expenditure ($r = 0.568$) correlated more strongly, as well as research and development expenditure and the number of patent applications ($r = 0.557$), which points to the complex interdependence of these factors within countries' development policies.

5. Discussion

To express the level of human capital, we used the human development index, as it is internationally widespread and used in many studies (Patel & Annapoorna, 2019; Okafor et al., 2017; Edeme & Nkalu, 2019; Maharda & Aulia 2020; Bassey et al. 2023, and others). Nevertheless, it is sometimes subject to criticism, and some authors, such as Herre & Arriagada (2023), recommend considering the use of other indices, such as The Inequality-adjusted Human Development Index (IHDI), The Gender Development Index (GDI), or The Augmented Human Development Index (AHDI). First, we compared the differences in average HDI between EU countries. We found that countries in northern and western Europe have higher HDI values than countries in southern and eastern Europe, which is consistent with Hippe (2020), who argues that there are regional inequalities in human capital in European countries, influenced by historical developments, geographical location, and government policy orientation. Similarly, Laskowska & Dańska-Borsiak (2016) state that the highest level of human capital is typical of the richest regions of Western Europe, while the lowest level is found in the poorest countries that have only recently become members of the EU and in the countries of Southern Europe, including Greece.

In line with the literature (Railaite & Čiutienė, 2020; Nezhnikova 2020; Zarulli et al. 2021; Ataklı Yavuz & Yilmaztürk, 2023), it has been confirmed that public spending on health care and research and development has a positive impact on HDI. Mann-Whitney U tests revealed statistically significant differences in HDI between countries with higher and lower spending in these areas. According to Ederer et al. (2020), the level of investment in technological development and knowledge creation is too low, especially in Central and Eastern European countries, which is also reflected in low spending on areas such as healthcare, culture, and research and development in these countries compared to the rest of Europe. A remarkable but literature-supported (Linhartová, 2020; Okafor et al., 2017) finding was that spending on education did not show a statistically significant relationship with HDI. This may be because it is not always the volume of investment that is decisive, but rather its effectiveness (Zarulli et al., 2021), or that its impact is only felt after a certain time lag. This is also pointed out by Al Mamun et al. (2025), according to whom spending on education has a significant impact on HDI in the long term, which points to a time lag between investments and their real impact on development. In addition, the statistically insignificant relationship between education spending and HDI may also be related to the level of development of countries, because although in our case the impact of public spending on education on HDI appeared to be statistically insignificant, Bassey et al. (2023) found that government spending on education in Nigeria had a significant impact on human capital development as measured by HDI in both the short and long term.

Looking at the results of the regression and correlation analysis, it turned out that education spending did not show a statistically significant relationship with HDI and only achieved a lower correlation coefficient. On the contrary, the share of the population with tertiary education was a statistically significant predictor of HDI and had a higher correlation coefficient. This result contradicts the claim by Julistia et al. (2025) that spending on education affects the human development index, but that the final level of education has no impact on it. Another interesting variable was patent applications per capita, which, according to Diebolt & Hippe (2019) and Yang et al. (2022), are closely related to the historical accumulation of human capital as well as GDP per capita. This finding is consistent with our observation that countries with a higher human development index tend to have a higher number of patent applications, as evidenced by the relatively high correlation coefficient. However, when we included other relevant variables in the multiple regression analysis, patent applications did not prove to be a statistically significant predictor of HDI levels, probably due to multicollinearity and overlapping effects of independent variables. Given the economic situation in individual countries, this does not change the fact that the uneven distribution of human capital and innovation across regions leads to differences in development between regions (Jagodka & Snarska, 2023). This spatial inequality remains a challenge for the European Union, which has long sought convergence among member states in many areas, including education, innovation, and healthcare.

Theoretical and practical implications: Our findings therefore show that the level of human capital does not depend solely on the volume of investment in key areas, but is also influenced by non-expenditure determinants, confirming the need for a more comprehensive approach to human capital issues. The research also confirms the existence of regional inequalities in human capital, supporting existing theories about the persistence of historical, economic, and socio-political differences between the countries of northern, southern, western, and eastern Europe. Since we have found that increasing expenditure in individual areas affecting the level of human capital may not ensure a higher level of human capital, policies aimed at its development should not only consider the amount of investment but also evaluate its effectiveness and redistribution to different sub-areas. Our findings may also provide impetus for regional policies within the EU, as despite the EU's efforts to achieve convergence in many areas, there are still more or less significant differences between member states. For this reason, it would be necessary, especially in areas with lower HDI, to re-evaluate the strategies for human capital development that have been applied so far.

6. Conclusions

The aim of this article was to analyse the level of human capital in European Union countries using the Human Development Index, identify regional disparities, and assess the extent to which spending on key areas contributes to HDI variability between countries. At the same time, we also focused on assessing the importance of selected non-expenditure determinants of human capital. The set objective was achieved. Through a one-factor analysis of variance, we found that there are statistically significant differences in HDI levels between individual EU regions. In northern and western European countries, the HDI is higher than in southern and eastern European countries. This was also confirmed by Tukey's HSD test, according to which there are statistically significant differences in the average HDI between the north and south, north and east, west and east, and west and south of the EU. These differences result from long-term historical, economic, and socio-political differences between individual regions. A series of Mann-Whitney U tests showed that there is a statistically significant difference in HDI between countries with higher and lower spending on healthcare and research and development, respectively. However, this finding is not absolute, as there were exceptions among countries, i.e., some countries with above-average expenditure had below-average HDI values, and conversely, other countries with below-average expenditure had above-average HDI values. This ambiguous effect of spending is further underscored by the fact that no statistically significant relationship has been found between spending on education and HDI levels. Since it has been shown that higher spending does not automatically lead to better human capital development, we decided to use multiple regression analysis to identify other factors that could influence the level of human capital. In addition to research and development expenditure, statistical significance was also demonstrated for average life expectancy at birth and the proportion of the population with tertiary education. Other variables analysed, despite their positive correlation with HDI, did not show a statistically significant impact, which is probably related to the problem of multicollinearity in the regression model.

Although we succeeded in achieving our goal of identifying regional differences in the level of human capital in EU countries and demonstrating that expenditure alone, without the simultaneous influence of other factors, may not ensure better conditions for human capital development, we consider it important to point out the possible limitations of the research carried out. Although the HDI is an internationally recognized index, its ability to express the level of human capital is limited, as it only considers three basic areas (average life expectancy, educational attainment, and per capita income), while neglecting qualitative determinants. For example, Raghuvanshi & Verma (2024) point to the need to supplement the HDI with alternative indices and qualitative assessments to ensure a deeper understanding of human development. Another limitation is that our analyses were based on average values for the period 2014–2023, which did not allow us to capture the dynamics of development and potential improvements or deteriorations, or responses to external shocks such as the Covid-19 pandemic. In addition, the statistical methods used (ANOVA, Mann-Whitney U test) allow us to test differences between groups, but do not prove a causal relationship between variables, because of which it cannot be convincingly argued that higher spending directly causes a higher HDI, but only that there is a certain relationship between them.

Based on the findings and identified limitations, further research should consider a more comprehensive approach to human capital assessment using multiple indicators, not just the HDI. Another challenge for future research could be to focus not only on the level of states, but also on regional differences within individual EU countries, as many differences in human development levels may be rooted in uneven regional development within individual member states. In addition, from a methodological point of view, it would be necessary in the future to pay increased attention to the problem of multicollinearity in the regression model and its mitigation, e.g., by removing highly correlated independent variables or other methods.

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