

**Publisher**<http://jssidoi.org/esc/home>

THE ASSESSMENT OF RELATIONSHIP BETWEEN HUMAN CAPITAL AND ECONOMIC PERFORMANCE IN SLOVAKIA, POLAND AND SWEDEN*

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Received 10 October 2025; accepted 23 December 2025; published 30 March 2026

Abstract. The role of human capital as an important driver of economic and social development is well-established. Economic theory, and even more so economic practice, seeks to assess its impact on labor productivity and economic growth. The goal of this paper is to design and construct a human capital index comprising pertinent indicators, use it to evaluate human capital in selected European Union countries (Slovakia, Poland and Sweden), and then to identify the relationship between human capital and economic growth in the three countries. Unlike the HCI compiled by the World Bank, which focuses primarily on outcome indicators and evaluates more than 170 different countries, our proposed index also includes cost indicators. This index is designed for developed countries, where indicators such as the under-five mortality rate or expected length of schooling up to a certain age are less meaningful. The analysis was conducted for the period spanning 2014 to 2023 using statistical country data from Eurostat. Descriptive statistics, one-factor analysis of variance, Tukey HSD test, base index, geometric mean, correlation, regression, and comparative analysis were employed to fulfill the objectives of the paper. The Human Capital Index (HCI) showed the lowest value at the beginning of the observed period in Poland. However, in the subsequent years, Poland exhibited a more pronounced trajectory of human capital, as evidenced by its surpassing Slovakia in terms of HCI growth. In Sweden, the human capital index in 2014-2023 was significantly higher than in Slovakia and Poland. The GDP growth rate exceeded the average growth rate of the human capital index in all three countries, i.e. in all countries economic growth outpaced human capital growth, but the differences in favor of economic growth were modest. Nevertheless, it can be reasonably assumed that the differences in favor of economic growth would have been more pronounced if economic development had not been slowed down by the Covid-19 outbreak.

Keywords: economic performance; HDI; human capital; human capital indicators; investment

Reference to this paper should be made as follows: Ivanová, E., Žárská, V. 2026. The assessment of relationship between human capital and economic performance in Slovakia, Poland and Sweden. *Entrepreneurship and Sustainability Issues*, 13(3), 53-68. <http://doi.org/10.9770/n2448723238>

JEL Classifications: I25, J24, O11

* This study was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic [grant VEGA, Reg. No. 1/0396/23], "Smart solutions and their impact on social and economic regional development in terms of Agenda 2030" and also by the project "The investments in human capital in the context of achieving sustainable economic growth in the Slovak Republic and strengthening its competitiveness", code of project MVP07_2024, based on the financial support from the European Union within the call Early Stage Grants of the Recovery and Resilience Facility (Code of the project: 09I03-03-V05-00010, Component 9: More effective management and strengthening of research, development and innovation funding), and with the financial support of the Internal Grant Scheme of the Alexander Dubček University of Trenčín.

1. Introduction

The concept of human capital was introduced into economic theory by Becker, who defined this category in his seminal work, *Human Capital* (1964), and emphasized the importance of investment in human capital (Becker, 1964). In his other works he emphasized the impact of human capital development, education and training on income and economic growth. He argued that that all countries which have managed persistent growth in income have also had large increases in the education and training of their labor forces (Becker, 1994).

Human capital is of interest to both developing and developed countries, as it is the basis for both economic and social progress. Particular focus has been on its impact on the economic performance of individual countries. It has already been established that human capital can become an important factor in economic growth, especially for small economies that lack natural resources. However, the development of knowledge economy processes and emergence of the Industry 4.0 concept, its value has increased in all countries. The knowledge economy, along with the technological revolution, is precipitating fundamental changes in labor markets. In the modern era, employment is increasingly dependent on individuals possessing specific knowledge, skills, and critical or abstract thinking abilities. This places greater emphasis on the development of human capital. The utilisation of specific knowledge and skills, as well as critical or abstract thinking, in the workplace is becoming increasingly prevalent, thereby placing greater demands on the elevation of human capital. While developed countries are engaged in systematic efforts to enhance their human capital, the majority of research on this topic originates from developing countries. While the economic performance of countries can be readily quantified in terms of macroeconomic indicators, the assessment of human capital is more challenging due to its qualitative nature. In light of these considerations, international organizations are increasingly proposing alternative indicators for the assessment of human capital and for the ranking of countries. This is because the interdependence between human capital and economic growth is easier to demonstrate in developing countries. While economic performance is relatively easy to be expressed through macroeconomic aggregate indicators, the process is more complex for human capital as it is a qualitative variable. For this reason, international institutions are increasingly proposing various indicators by which human capital can be assessed or quantified and are issuing rankings that include countries across the world. At present, the most comprehensive indicator of human capital levels is the Human Capital Index (HCI), as reported by the World Bank. The HCI quantifies the potential for human capital accumulation in adulthood, taking into account the risks associated with health conditions and inadequate levels of education (World Bank, 2018). The index assesses the level of human capital in more than 170 countries around the world. The same methodological approach is applied in each of the countries included in the analysis, thereby avoiding the potential for significant differences between them to have an impact on the findings. However, not all indicators through which the level of human capital in developing countries is expressed can be used in the conditions of developed countries, as diametrically different initial conditions need to be considered. However, the indicators utilized for developing countries are frequently not applicable to developed countries, including those within the European Union. Moreover, although human capital in developed countries, including EU countries, is frequently quantified through a multitude of sub-indicators, the lack of a more comprehensive indicator that encompasses the level of human capital in these countries offers significant opportunities for research, particularly in the development of novel indicators and the examination of their correlation with economic growth. both in terms of constructing the indicator and, subsequently, in terms of examining the relationship between the level of human capital in a society and the economic situation of a country.

The objective of this paper is to design and construct a human capital index comprising pertinent indicators, utilize it to evaluate human capital in selected European Union countries (Slovakia, Poland, and Sweden), and subsequently identify the correlation between human capital and economic growth in these three countries. To achieve the stated objective, a number of scientific methods were employed, including time series analysis (base index, geometric mean) and correlation and regression analysis. The latter was used to evaluate the relationships between the variables under study. These methods were complemented by the one-factor analysis of variance and by the method of comparison, which provides a useful framework for comparing different data sets in order to identify differences or similarities in their evolution.

The literature review identifies the theoretical approaches that have been proposed to address the issue, identifies the key determinants that influence the level of human capital, and summarizes the findings of previous research in the observed area. In the methodology section, the construction of the human capital index was discussed in greater detail. Furthermore, additional methods employed during the preparation of this document are discussed, including correlation and regression analysis, one-factor analysis of variance, Tukey HSD test, as well as the calculation of the geometric mean. In the Results section, the differences between Poland, Slovakia, and Sweden, as identified through the chosen analyses, are compared. Through discussion, our findings were compared with those of other authors who have dealt with the same or similar issues. In the final part of the paper, in addition to a summary of the research findings, the limitations of the study and suggestions for further research in this area were also presented.

2. Theoretical background

Economic growth in modern societies is driven by innovations, with highly skilled professionals acting as the primary generators (Gruzina et al., 2021; Ahmed, Piccinetti & Rezk, 2024; Laužikas et al., 2025). This is a reality for the majority of countries in the 21st century, which has led to a growing focus on human capital. Some economies with abundant mineral wealth have historically placed a significant emphasis on natural resources. However, in light of global developments, they are beginning to recognize the necessity of prioritizing the advancement of human capital to ensure long-term economic sustainability (Aljarallah, Angus, 2020). However, despite these global trends, the situation in some countries does not indicate that they have implemented substantial changes in their approach to human capital. This also applies to the Slovak economy, which is relatively undercapitalized in terms of human capital, lagging behind the most advanced EU countries. Furthermore, this issue is exacerbated by the emigration of skilled individuals with knowledge to higher-income countries such as Germany, Austria, and, more recently, the Czech Republic (Palaščíková et al., 2019; Steyn & Ndofirepi, 2024).

While economic growth can be relatively easily expressed through macroeconomic aggregate indicators, even these are sometimes a subject to criticism (Gonos et al., 2022), the level of human capital development is more complicated to express. One issue arises from the fact that there is no consensus on the definition of human capital. A further issue is that human capital is a qualitative attribute of human beings. In order to facilitate its use in relation to economic indicators, it must therefore be expressed quantitatively. Furthermore, it is important to acknowledge that human capital exerts a more pronounced influence on economic growth over the long term, as opposed to its impact in the immediate future (Rahman et al., 2023).

The Organisation for Economic Cooperation and Development (OECD, 2007) defines human capital as a set of human capabilities that are formed by upbringing and education and shaped by the health situation of the individual in question. A substantial body of research (e.g., Tahsin, 2019; Balsmeier & Woerter, 2019; Ershova et al., 2019; Wolf, 2020) has examined the relationship between human capital and economic growth, particularly within the context of education. This is because education is widely regarded as a fundamental prerequisite for the development of human capital. According to Boachie and Adu-Darko (2024), supporting human capital development through improving its unique skills and competencies can lead to a more significant improvement in economic growth. Dore and Teixeira (2023) have demonstrated that formal education is a critical factor in promoting economic growth. The same fact is also pointed out by Simmons (2024), according to whom education plays a significant role in increasing the level of human capital and creating innovations, which subsequently translates into the economic prosperity of the country. Other authors, such as Madsen (2012), contend that health is of greater consequence than education. The state of health has a significant influence on the quantity and quality of learning, innovation, and growth. Health affects the capacity to learn, to think, and to introduce novel concepts. Consequently, the importance of healthy human capital for economic growth outstrips that of educational attainment. Gulcemal (2020) also addressed the health of human capital, establishing a correlation between it and life expectancy. He concluded that extending life expectancy has positive economic consequences. As life expectancy rises, the workforce is likely to remain employed for longer periods, which should help to reduce the financial burden of pension expenditure and improve the health of the elderly. Railaite and Čiutienė (2020) established a correlation between the growth in life expectancy and the level of expenditure allocated to the healthcare sector. The importance of health spending is also confirmed by

Magida et al. (2025), who find that government spending on health significantly improves human capital development, but its impact varies depending on the level of economic development of countries, with government spending having a greater impact on human capital in more developed countries. In addition to the aforementioned authors, numerous other scholars have emphasized the importance of investing in specific areas that directly influence human capital levels. Nezhnikova (2020) posits that investment in human capital represents a fundamental driver of future economic progress at the national level. She specifically highlights the necessity of allocating resources towards three key domains that are integral to its advancement: investment in education, healthcare, and science and research. Similarly, Di Cataldo and Rodríguez-Pose (2017) establish a connection between human capital and investment in a range of areas beyond education. However, Bedianashvili et al. (2024) point out in this regard that increased spending on human capital may not be immediately reflected in economic growth rates due to long-term effects and structural inefficiencies.

In their 2016 study, Laskowska and Danska-Borsiak emphasized the necessity of considering the three phases of the human capital life cycle—creation, maintenance, and utilization—in order to gain a comprehensive understanding of the relationship between human capital and economic performance across EU countries. The formation of human capital must take into account not only the reproductive capacity of the population but also the accessibility of healthcare and education. The maintenance of human capital, as well as its creation, is contingent upon access to healthcare and also to lifelong learning and culture. The utilization of human capital is reflected, for instance, in the documented rate of employment (proportion of employment in sectors other than agriculture, employment in knowledge- and technology-intensive sectors, etc.) or unemployment. Moreover, the capacity for innovation and involvement in research activities in countries can be observed in terms of human capital utilization. As Leite and Cardoso (2023) posit, the advancement of R&D and engagement in research activities are similarly crucial, as R&D fosters innovative capacity creation, which in turn enhances the overall economic structure. Similarly, Ivanová and Čepel (2018) emphasize the necessity for countries to enhance their innovation performance. These factors are regarded as instrumental in the prosperity of developed economies. Garbuz and Topala (2017) highlight the necessity for consistent investment in research and the training of professionals in this field in order to address the aforementioned issue, as the main source of sustainable economy development.

In the context of the ongoing pandemic, numerous studies have commenced investigations into the influence of human capital on economic performance, as evidenced by the works of Dvorak et al. (2020), Ismayilzade et al. (2021), and Sun et al. (2022). In a study published in 2023, Chaabouni and Mbarek examined the relationship between human capital and economic growth in the Euro Area before and after the onset of the pandemic. Their findings indicated that prior to the crisis, investments in education and health had a positive impact on economic growth. After the pandemic, however, this positive effect ceased. In their study conducted in Azerbaijan, Ismayilzade et al. (2021) found that during the ongoing pandemic and subsequent crisis, the qualitative characteristics of human capital have a greater impact on economic development than the quantitative characteristics typically used in research. However, the authors contend that these findings cannot be evaluated over the long term, as they only observed the short-term impact of human capital on a country's economic development. Nevertheless, this correlation is more distinctive in the long run (Rahman et al., 2023). Furthermore, in the context of social isolation during the pandemic, there has been a notable shift in focus towards digitization processes in economies. In light of these considerations, other authors (Osipov et al., 2021; Chernenko et al., 2021; Medennikov et al., 2021) have underscored the significance of digitization development in economies and have examined its impact on the demands placed on the quality of human capital.

The majority of studies examining the relationship between human capital and economic growth address the interdependence between the two. Jaghoubi & Alfalih (2025) state that there is a bidirectional causal relationship between GDP development and human capital development. However, Wang et al. (2022) argue that despite the existence of relevant findings in this area, it is essential not to prioritize the examination of the causal relationship between the variables under investigation. Instead, the emphasis should be on research examining the factors influencing the interrelationship and coordination of these variables. Only when these variables are congruent and mutually supportive will this result in mutually beneficial development outcomes.

As evidenced by the literature review, human capital can be expressed through a variety of sub-indicators. However, as previously indicated in the introduction, a more comprehensive indicator is lacking in developed countries, including those in the EU, that could effectively express the level of this capital. This fact prompts us to attempt to construct a human capital index appropriate for the circumstances of European countries in the empirical section of this study, based on the aforementioned background. This will then become the subject of further analyses examining the correlation between the level of human capital and the rate of economic growth in the selected three countries (Slovakia, Poland, Sweden).

3. Research objective and methodology

The objective of this study is to develop a human capital index comprising relevant indicators, utilize it to assess human capital in selected European Union countries (Slovakia, Poland, and Sweden), and subsequently identify the relationship between human capital and economic growth in the three countries. The countries of Poland and Slovakia were selected for comparison due to their geographical proximity and shared membership in the Central European region, as well as their similarities in socioeconomic conditions. In order to highlight the differences between developed and less developed countries, Sweden, which is one of the most developed countries in the EU, was included in the comparison. The analysis was conducted using statistical data from Eurostat for the period between 2014 and 2023. The analysis is constrained to the period between 2014 and 2023 due to the unavailability of essential indicators required for the computation of the human capital index. While some of the indicators are also available for the year 2024, the Healthy Life Years indicator is not, having last been updated in July 2025 with a two-year lag and a validity period of 2023. Similarly, the indicator on the share of professionals in research and development (R&D) is only available until 2023. Accordingly, in order to ensure the consistency and compatibility of the data throughout the analysis, it was not feasible to utilize more recent data.

Firstly, we designed and calculated a Human capital index. In the index calculations we included six indicators from three areas: education, health, and R&D, through which it was possible to capture human capital in 3 stages of its life cycle (Laskowska & Danska-Borsiak, 2016). Thus, the following sub-indicators were part of the index calculations:

1. the evolution of population share aged 15-64 with tertiary education
2. per capita public expenditure on education
3. Healthy Life Years in absolute value at birth
4. per capita public expenditure on health
5. per capita expenditure on research and development
6. share of R&D workers in the total active population.

Hence, we included both outcome and cost indicators in the index (Kwon, 2009), all of which were first recalculated by a base index relative to the European Union average in 2014, set as the base year. In the next step, the reported values of the base index were converted into points as follows: the base index value reached 0 % to 20 % → 0.1 point assigned; 21 % to 40 % → 0.2 point; 41 % to 60 % → 0.3 point; 61 % to 80 % → 0.4 point; 81 % to 100 % → 0.5 point; 101 % to 120 % → 0.6 point; 121 % to 140 % → 0.7 point; 141 % to 160 % → 0.8 point; 161 % to 180 % → 0.9 point; 181 % and more → 1 point. The scores were then incorporated into the formula for the index, which was subsequently multiplied by the weights assigned to each indicator. As the theoretical studies conducted by other authors have primarily focused on the significance of individual indicators, without providing a precise assessment of their impact on human capital development, we have elected to assign equal weight to each of the included indicators.

1. population share with tertiary education: weight assigned 16.66%
2. public expenditure on education: weight assigned 16.66%
3. Healthy Life Years at birth: weight assigned 16.66%
4. public expenditure on health: weight assigned 16.66%
5. research and development expenditure: weight assigned 16.66%.
6. share of R&D workers in the total active population 16.66%.

Formula: $AHCI = 0.1666 \cdot AVI1 + 0.1666 \cdot AVI2 + 0.1666 \cdot AVI3 + 0.1666 \cdot AVI4 + 0.1666 \cdot AVI5 + 0.1666 \cdot AVI6$, where:

AHCI - actual human capital index

AVI1 - achieved value for indicator 1 (population share with tertiary education)

AVI2 - achieved value for indicator 2 (public expenditure on education per capita)

AVI3 - achieved value for indicator 3 (healthy life years in absolute value at birth)

AVI4 - achieved value for indicator 4 (public expenditure on health per capita)

AVI5 - achieved value for indicator 5 (research and development expenditure per capita).

AVI6 - achieved value for indicator 6 (share of R&D workers in the total active population).

Following the creation and calculation of the index values for the observed countries, we proceeded to the subsequent phase of the research. The correlation analysis method was used to determine the degree of dependence between the level of human capital and economic growth in Poland, Sweden and Slovakia. The dependent and independent variables were defined as GDP per capita and the value of the index of human capital created. The Pearson correlation coefficient was used in the calculations:

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

Furthermore, a significance test of the correlation coefficient was conducted to ascertain whether the observed dependence is statistically significant in the observed countries. This would indicate whether the results can be generalized to the entire base population. The following formula was used in the calculations:

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

To identify differences between the countries studied in the area of human capital, we applied the one-way analysis of variance (ANOVA) method. To refine the results and determine statistically significant differences between individual pairs of countries, the one-way analysis of variance was supplemented with the Tukey HSD test. We based our calculations on the formula:

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

For the regression calculations, it was necessary to find the data (regression coefficient b_1 and constant b_0) necessary to be put into the linear regression function: $y = b_0 + b_1 x + \varepsilon$.

By means of the geometric mean $x_G = \sqrt[n]{x_1 \cdot x_2 \cdot \dots \cdot x_n}$ we calculated the average growth coefficient of Human capital index and the average growth coefficient of GDP to figure out whether in observed countries the human capital growth exceeds the economic growth or vice versa.

4. Results

In accordance with the methodology outlined in the preceding section, we have calculated a human capital index for Poland, Slovakia, and Sweden based on the six sub-indicators (share of population with tertiary education, public expenditure on education, healthy life years at birth, public expenditure on health, expenditure on research and development, and share of R&D workers in the total active population) using the aforementioned procedure (see Table 1). The individual sub-indicators included in the index calculation were evaluated in comparison to the EU average for 2014. In comparison to the EU average, Sweden demonstrated superior

performance across all indicators. This was not the case for Slovakia and Poland. This discrepancy in the level of countries is also reflected in the reported index values.

Table 1. The Human Capital Index

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Poland	0.32	0.33	0.33	0.37	0.38	0.38	0.38	0.42	0.45	0.46
Slovakia	0.33	0.33	0.35	0.35	0.37	0.37	0.38	0.42	0.42	0.45
Sweden	0.83	0.83	0.85	0.85	0.85	0.85	0.86	0.91	0.91	0.91

Source: Eurostat, own calculating

As illustrated in Table 1, the Human Capital Index exhibited the lowest value at the outset of the observed period in Poland. Nevertheless, the country subsequently surpassed Slovakia. In Poland, however, the value of the index exhibited a more pronounced increase, although this country is slightly behind Slovakia in economic terms. The Human Capital Index for Sweden exhibited a markedly higher value than that observed in Slovakia or Poland during the 2014-2023 period. This is an unsurprising outcome, given that Sweden is one of the most advanced countries in the EU. The dynamics of development were highest in Poland, where the human capital index increased by 0.14 points in the period under review 2014-2023, followed by Slovakia with an increase of 0.12 points and Sweden with an increase of 0.8 points. As the subsequent section of the study will examine the relationship between the human capital index and economic performance in the selected countries, it is essential to provide a concise overview of their economic circumstances. In accordance with the majority of existing studies, we have employed gross domestic product as an indicator of economic performance (see Table 2).

Table 2. GDP in market prices per capita in €

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Poland	10 750	11 390	11 270	12 360	13 280	14 190	14 310	15 770	17 520	19 980
Slovakia	14 130	14 820	15 030	15 620	16 580	17 340	17 270	18 730	20 150	22 640
Sweden	44 930	46 160	46 790	47 210	45 770	46 110	46 180	51 260	51 980	50 490

Source: Eurostat

The economic situation in the observed countries was relatively favorable until 2019. In the majority of years, both Poland and Slovakia have demonstrated positive economic growth. However, in 2020, the world was struck by the global pandemic of the novel coronavirus, which disrupted the previously established stability. All three countries were affected by a decline in GDP. However, the economies demonstrated a rapid capacity to adapt to the new circumstances. In 2021, despite the persistence of the pandemic, economic growth was already being observed in these countries. However, in addition to the impact of the pandemic, the overall economic development in Sweden has exhibited some anomalies in comparison to the rest of the countries. In 2018, the country experienced a more pronounced economic deceleration than in the pandemic year of 2020. Following the identification of the development of human capital and GDP in the observed countries, further analyses could be conducted. Correlation and regression analyses were conducted for each country at the $\alpha = 0.05$ significance level.

Table 3. Testing statistics

	Poland	Slovakia	Sweden
Pearson correlation coefficient r	0.981	0.977	0.953
Correlation coefficient significance test	0.000	0.000	0.000
Determination coefficient r^2	0.962	0.954	0.908
Constant b_0 (p-value)	8394.8 (0.000)	-7509.7 (0.004)	-13 174 (0.090)
Regression coefficient b_1 (p-value)	58 870 (0.000)	65 947 (0.000)	70 372 (0.000)
$y = b_0 + b_1x$	$y = -8394.8 + 58 870x$	$y = -7509.7 + 65 947x$	$y = -13 174 + 70 372x$
F test p-value	0.000	0.001	0.000

Source: Eurostat, own calculating

The correlation coefficient in Poland takes the value of 0.981, which indicates an almost perfect positive tightness of the relationship between the Human capital index and the level of GDP per capita. A significance test p-value of $0.000 < \alpha (0.05)$ for the correlation coefficient indicates that the correlation coefficient is statistically significant, i.e. the result is not random. The determination coefficient (r^2) for Poland indicated that the selected model explained 96.2 % of the total variability, thereby confirming the appropriateness of the model selection. It may be posited that the elevated value of the correlation coefficient is attributable to the fact that both variables (human capital index and GDP) were undergoing considerable development in Poland.

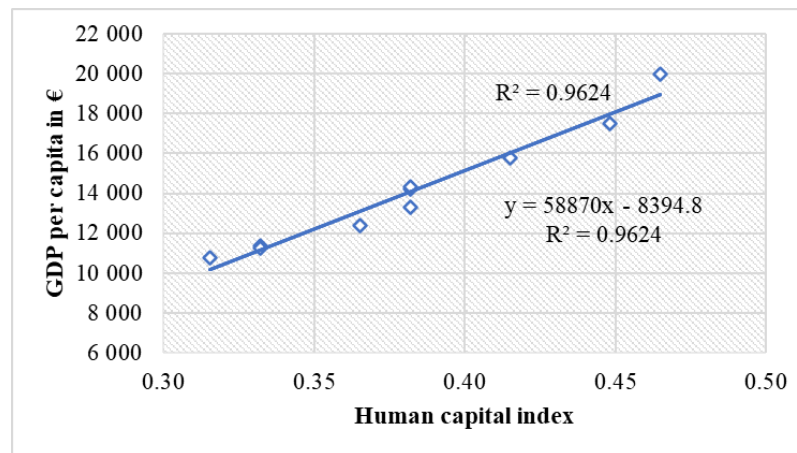


Figure 1. Correlation analysis – Poland
Source: Eurostat, own elaboration

The regression equation $y = -8394.8 + 58870x$ indicates that the function is monotonic and increasing (see Figure 1), as evidenced by the positive value of the coefficient b_1 . Substitution of any value of the Human capital index for x would yield the GDP per capita in Poland that would have been achieved at a given value of the index. If the p-value for b_0 is less than 0.05, this constant is statistically significant. Additionally, an F-test was conducted to assess the null hypothesis that the selected model is inadequate for explaining the observed relationship between the variables. The p-value of the F-test is $0.000 < \alpha (0.05)$, indicating that the null hypothesis can be rejected, and the selected model is appropriate for explaining the observed relationship in the Polish context. In light of the calculated values of the sub-variables during the conducted correlation and regression analysis, it can be concluded that in Poland, there is an almost perfect positive dependence between the development of the Human Capital Index and the development of the GDP per capita level. The significant correlation between the variables indicates a proportional relationship in their development. In light of these considerations, it seems reasonable to posit that the expenditure indicators included in the index calculation are increasing in line with GDP growth, and that they contribute positively to the development of the outcome indicators. These include the growth of the population with tertiary education, the growth in the number of healthy life years, and the increase in the share of workers in research and development.

In Slovakia, the correlation coefficient value was 0.977 during the observed period, indicating a strong and statistically significant relationship between the human capital index and the GDP level per capita. The p-value of the significance test of the correlation coefficient $0.001 < \alpha (0.05)$ indicates that in Slovakia as well as in Poland, there is a statistically significant dependence between the examined variables. It can be posited that this is due to the relatively dynamic development of both the human capital index and the GDP. Additionally, in the case of Slovakia, the suitability of the model was verified through the determination coefficient. This demonstrated that 95.3 % of the total variability was explained by the model, which can be considered sufficient.

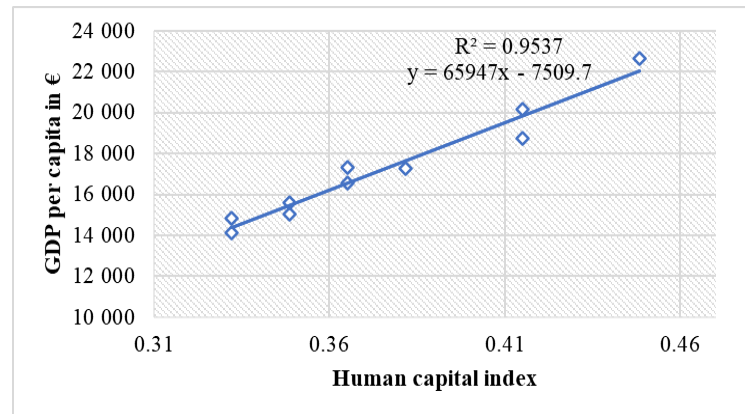


Figure 2. Correlation analysis – Slovak Republic

Source: Eurostat, own elaboration

The regression equation for the Slovak Republic has the form $y = -7509.7 + 65\,947x$, indicating a monotonic increasing function (see Figure 2), similar to that observed in Poland. Substitution of any value of the human capital index for x would yield the GDP per capita in Slovakia that would have been achieved at a given value of the index. This could be used, for example, in estimating future development. The p-value for the regression coefficient b_1 is 0.000, which is less than the alpha value of 0.05, indicating that this coefficient is statistically significant. In the case of the constant b_0 , the p value is 0.000, so this constant is also statistically significant. The p value of the F-test $0.000 < \alpha (0.05)$ indicated that the chosen model was appropriate, as was observed in the case of Poland. In conclusion, it can be stated that the development in Slovakia exhibits only minor deviations in comparison to the development in Poland. Furthermore, a significant positive correlation was observed between the development of the Human Capital Index and the development of GDP per capita in Slovakia.

The correlation analysis conducted in Sweden yielded results that were comparable to those observed in Poland and Slovakia. The correlation coefficient of 0.953 indicates a robust and statistically significant relationship between the human capital index and the level of GDP per capita. The p-value of the significance test of the correlation coefficient was 0.000, which is less than the alpha value of 0.05. This indicates that there is a statistically significant relationship between the evolution of the human capital index and the evolution of GDP per capita. These findings are consistent with expectations, given the proportional evolution of both variables in Sweden. In light of the aforementioned evidence, it can be posited that the expenditure variables incorporated into the calculation of the human capital index have increased in parallel with GDP growth. Such a development had a favorable impact on the value of the correlation coefficient. The coefficient of determination (r^2) indicates that the model was able to explain 90.8 % of the total variability, which is a sufficient value, as was the case for the other two observed countries.

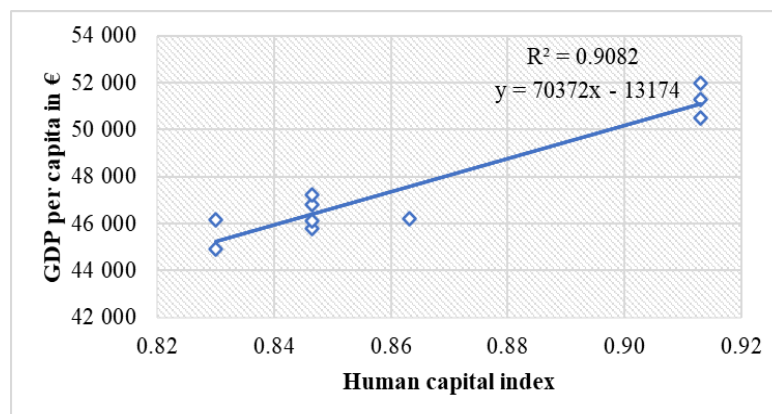


Figure 3. Correlation analysis – Sweden

Source: Eurostat, own elaboration

From the regression equation $y = -13\,174 + 70\,372x$, it can be inferred that the function is monotonic and increasing (see Figure 3), a conclusion that is also supported by the data from the remaining two observed countries. Substitution of any value of the human capital index for x would yield the GDP per capita of Sweden at that value of the index. The p-value for the regression coefficient b_1 was found to be less than α (0.05), indicating that this coefficient is statistically significant. However, in the case of the constant b_0 , the p-value was 0.090, which is greater than α (0.05), indicating that this constant is not statistically significant. Accordingly, the selected model is validated, and an F-test is performed. The null hypothesis was tested to ascertain the appropriateness of the selected model for explaining the relationship between the observed variables. The p-value of the F-test $0.000 < \alpha$ (0.05) indicated that the null hypothesis could be rejected in the case of Sweden, as well as in the cases of Slovakia and Poland. This leads to the conclusion that the model used was indeed the appropriate one.

Although the correlation analysis did not reveal significant differences in the strength of the relationship between the variables studied, we decided to verify whether the HCI values differ statistically significantly between the countries. For this purpose, we used a one-factor analysis of variance (ANOVA), within which we formulated and tested the following hypotheses:

H0: There is no statistically significant difference in the average HCI value between the countries studied.

H1: There is a statistically significant difference in the average HCI value between the countries studied.

Table 4. One-factor analysis of variance

SUMMARY						
Groups	Count	Sum	Average	Variance		
Poland	10	3.82	0.382	0.0024		
Slovakia	10	3.7534	0.37534	0.00157		
Sweden	10	8.6456	0.86456	0.00116		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.57415	2	0.78707	460.451	1.37122E-21	3.35413
Within Groups	0.04615	27	0.00171			
Total	1.6203	29				

Source: Eurostat, own calculations

We performed the analysis at a significance level of $\alpha = 0.05$. The calculated value of the test statistic F was 460.451, which was higher than the critical value $F_{crit} = 3.354$. The p-value = 0.000 was extremely low. Based on such results, we have sufficient evidence to reject H0 that there is no statistically significant difference in the average HCI value between the countries studied. We accept the alternative hypothesis, which assumed that there are statistically significant differences in the average HCI value between the countries studied. In order to identify between which countries these differences are significant, we supplemented the one-way analysis of variance with the Tukey HSD test (see Table 5).

Table 5. Tukey HSD test

Groups	Difference	n1	n2	HSD	Significance
Sweden - Poland	0.483	10	10	0.05	yes
Sweden - Slovakia	0.489	10	10	0.05	yes
Poland - Slovakia	0.007	10	10	0.05	no

Source: Eurostat, own calculations

Tukey's HSD test was performed at a significance level of $\alpha = 0.05$. The results indicate that the differences in the average HCI between Sweden and Poland, as well as between Sweden and Slovakia, are statistically

significant. For the given pairs of countries, the calculated difference between their means was higher than the HSD = 0.05 value, which represents the minimum difference required to be statistically significant. On the contrary, the difference between Poland and Slovakia, which reached a value of 0.007, was lower than the specified HSD value. This difference was therefore not statistically significant, indicating that the average HCI value in these two countries is similar.

Additionally, some authors (Wang et al., 2022) have examined the discrepancy between the growth rate of human capital and the rate of economic growth. Furthermore, our objective was to ascertain the circumstances prevailing in the three countries under examination from the aforementioned perspective. A comparison of the growth rates of the human capital index and GDP was conducted using the average growth rate (see Table 6).

Table 6. Growth rate in % - the average growth rate of GDP and Human capital index (HCI)

	Poland		Slovakia		Sweden	
	GDP	HCI	GDP	HCI	GDP	HCI
2014	-	-	-	-	-	-
2015	106.0	105.3	104.9	100.0	102.7	100.0
2016	98.9	100.0	101.4	105.0	101.4	102.0
2017	109.7	110.0	103.9	100.0	100.9	100.0
2018	107.4	104.5	106.1	104.8	96.9	100.0
2019	106.9	100.0	104.6	100.0	100.7	100.0
2020	100.8	100.0	99.6	104.5	100.2	102.0
2021	110.2	108.7	108.5	108.7	111.0	105.8
2022	111.1	108.0	107.6	100.0	101.4	100.0
2023	114.0	103.7	112.4	108.0	97.1	100.0
Average growth coefficient	1.071	1.044	1.054	1.034	1.013	1.011

Source: Eurostat, own calculations

As illustrated in Table 6, the mean GDP growth rate exceeded the mean growth rate of the human capital index in all three observed countries. However, the discrepancies in favor of economic growth were relatively minor. In Poland, the value of the difference in average growth coefficients expressed as a geometric mean in favor of economic growth was 0.027, in Slovakia 0.02, and in Sweden 0.002. It seems reasonable to posit that the discrepancies in favor of economic growth would have been even more pronounced had there been no decline in GDP due to the pandemic crisis in each country in 2020. The correlation and regression analysis yielded no statistically significant differences between the observed countries. Moreover, the comparative analysis of average GDP growth rates and the human capital index did not yield any statistically significant discrepancies between countries at different stages of development. Irrespective of the economic performance and the level of human capital in the observed countries, the GDP growth rate was slightly higher than the growth rate of the human capital index in these countries. This indicates that the result is not influenced by the extent of the interdependence between the variables of interest or the socio-economic level of the countries in question. Therefore, further research is required to identify the relevant factors that may be influencing this relationship. This provides an opportunity for further investigation into this issue, with a view to identifying other factors that may influence the relationship between these two indicators, including the significant impact of artificial intelligence.

5. Discussion

The conducted analysis has demonstrated that countries typically attain both elevated economic levels and augmented levels of human capital (as exemplified by Sweden), whereas conversely, they often exhibit diminished economic levels and diminished levels of human capital (as evidenced by Slovakia and Poland). It has been demonstrated that Slovakia exhibits a lower level of human capital than the most advanced EU countries (Palaščáková et al., 2019). In comparison to Poland, however, Slovakia exhibits a relatively minor deficit. In light of the limitations of the World Bank's human capital index (HCI) in accurately reflecting the

specific circumstances of European countries, our own index has been developed to address this gap. Additionally, the President of the World Bank has cautioned about potential deficiencies (World Bank, 2019). Our index incorporates cost and outcome variables. While some scholars (Kwon, 2009) have advised incorporating revenue indicators, we did not prioritize this due to the prevalence of cost indicators in existing studies (Nezhnikova, 2020; Linhartova, 2020; Di Cataldo, Rodríguez-Pose, 2017; Leite & Cardoso, 2023) or outcome indicators (Storesletten & Zilibotti, 2000; Tahsin, 2019; Madsen, 2016). The requisite indicators for calculating the human capital index were derived from three domains: education, health, and research and development. The significance of evaluating human capital, particularly through the use of indicators that reflect educational and health status, has been emphasized by Turganbayev (2023), for instance. In conducting the correlation analysis, the gross domestic product (GDP) was designated as the dependent variable. Accordingly, we employed a methodology analogous to that utilized by Alam (2023), who discovered that the human capital index and GDP exhibit a correlation precisely when GDP is employed as the dependent variable. The correlation between the level of human capital development and the economic growth rate was statistically significant in the countries under study. However, the Human Development Index was employed as a proxy for the level of human capital in the study. The significance test of the correlation coefficient revealed that the observed relationship is statistically significant in all three countries under consideration. In all three observed countries, human capital growth was slower than economic growth, which is at odds with the findings of Wang et al. (2022). In their study, the authors identified regions where human capital growth exceeded economic growth. However, some studies have demonstrated that increasing the level of human capital can promote economic growth (Tahsin, 2019; Diebolt & Hippe, 2019, among others). Consequently, it could be argued that enhancing and fostering human capital growth in a country is beneficial for its future economic and social development. These studies have demonstrated that even a relatively modest expansion of human capital can result in a significant enhancement of economic growth (Boztosun et al., 2016). This may provide an explanation for our findings that, irrespective of economic development, the growth of GDP has exceeded the growth of human capital in the observed countries.

Conclusions

The objective of this study was to develop a human capital index comprising pertinent indicators, utilize it to evaluate human capital in select European Union countries (Slovakia, Poland, and Sweden), and subsequently ascertain the correlation between human capital and economic growth in these three countries.

When creating the index, we drew on existing approaches to measuring human capital, but with the aim of adapting them to the conditions of developed countries. Unlike existing summary indicators of human capital, such as the HCI compiled by the World Bank, which assesses more than 170 countries worldwide from the least to the most developed, our proposed own actual human capital index (AHCI) focuses exclusively on European Union countries. Another difference is that while the HCI compiled by the World Bank focuses mainly on outcome indicators, our index also includes cost indicators, providing a more comprehensive view of the state and development of human capital, as it can be assumed that cost indicators create potential for the development of outcome indicators. The indicators assessed in the HCI (e.g., under-five mortality rate or expected years of schooling at age 18) may not be sufficiently informative for developed countries (the under-five mortality rate is low in developed countries and the expected length of schooling up to age 18 reaches its maximum limit, as most of the population in these countries completes secondary education). The novelty of the AHCI therefore lies precisely in its regional specialization and in taking into account indicators that are meaningful to evaluate in developed countries.

The results demonstrate that the country with the highest Human Capital Index value (Sweden) also exhibits superior economic performance. The results of the correlation analysis indicated a statistically significant relationship between the level of human capital development and economic growth. The results of the one-factor analysis of variance showed the existence of statistically significant differences in the mean HCI value between the analyzed countries. Subsequent post hoc analysis using Tukey's HSD test identified that statistically significant differences occur between Sweden and Poland and between Sweden and Slovakia.

Another noteworthy observation is that, irrespective of the level of economic performance and human capital in the observed countries, GDP growth exhibited a slight excess over human capital growth in these countries. In light of the aforementioned results, it can be posited that this phenomenon is not contingent upon the degree of correlation between the observed variables or the socio-economic standing of the countries in question. It can be posited that this result is contingent upon additional factors that would necessitate future identification, as they may potentially influence future economic development in countries.

While the research has yielded insights into the relationship between economic performance and human capital development in Sweden, Poland, and Slovakia, it is important to acknowledge the limitations of the conducted research. To measure human capital, it is recommended that integrated indicators be used that are a combination of income, cost, and learning-based approaches. In addition, other aspects that determine the quality of human capital should be included (Kwon, 2009). However, the income aspect has not been considered, nor have other factors such as the level of democratization in each country or the level of poverty in each country. Furthermore, the research has not considered the impact of digitalization on human capital quality requirements, despite the growing recognition of this issue in recent years. Several studies have addressed this topic, including those by Osipov et al. (2021), Chermenko et al. (2021), Medennikov et al. (2021), and Zaborovskaia et al. (2020). Furthermore, the human capital index proposed here can be applied only when assessing the development of a country or countries in relation to a certain basic starting point. The index has been calculated in relation to the EU average for 2014, which may limit its use in other contexts or time periods, particularly in long-term comparisons.

The conducted research has yielded valuable insights into the relationship between human capital and economic growth in the three EU countries. The practical value of AHCI lies in the fact that it allows for better identification of the strengths and weaknesses of human capital development in individual countries, as it captures not only investments in human capital, but also their real effects, which should be reflected in performance indicators. However, it is also important to recognize the limitations of the research and the need for further extensions of the research to gain a more comprehensive understanding of the subject matter. The identification of additional factors or a correction of the methodology could contribute to a more comprehensive understanding of this issue and to more accurate predictions of future economic development in countries.

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Funding: This study was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic [grant VEGA, Reg. No. 1/0396/23], “Smart solutions and their impact on social and economic regional development in terms of Agenda 2030” and also by the project „The investments in human capital in the context of achieving sustainable economic growth in the Slovak Republic and strengthening its competitiveness“, code of project MVP07_2024, based on the financial support from the European Union within the call Early Stage Grants of the Recovery and Resilience Facility (Code of the project: 09I03-03-V05-00010, Component 9: More effective management and strengthening of research, development and innovation funding), and with the financial support of the Internal Grant Scheme of the Alexander Dubček University of Trenčín.

Author Contributions: Conceptualization: *Eva Ivanová, Veronika Žárská*; methodology: *Veronika Žárská*; data analysis: *Eva, Ivanová, Veronika Žárská*, writing—original draft preparation: *Eva Ivanová, Veronika Žárská*, writing; review and editing: *Eva Ivanová, Veronika Žárská*; visualization: *Eva Ivanová*. All authors have read and agreed to the published version of the manuscript.

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