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THE IMPACT OF HUMAN CAPITAL IMPROVEMENT ON PER CAPITA INCOME DYNAMICS IN THE CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Theoretical and empirical findings confirm the thesis that the accumulation of physical capital partly explains the movement of countries' economic growth rates. Researchers in the field of development economics, as well as creators of economic policies, are shifting their focus from physical (PC) to human capital (HC) as a determinant of countries' economic development. The subject matter of this paper is the analysis of the impact of HC on achieving higher *per capita* income growth rates. According to the "Lisbon Strategy" and the "Europe 2020 Strategy", HC is placed on a pedestal of importance, all with the aim of making the EU-27 the most competitive market in the world. The empirical part was conducted using a panel regression model. The research results indicate a significant impact of HC on the *per capita* income of the CEE-10 countries. This research study contributes by reducing a gap in the scientific literature by examining the impact of HC on the *per capita* income of the European countries. The concluding implications point to the importance of HC development as an effective instrument for ensuring countries' greater economic growth.

Keywords: human capital, GDP *per capita*, economic growth, CEE-10, panel data

JEL Classification: E24, C33, O15, O47

INTRODUCTION

Human capital is defined as one of the leading factors of countries' economic growth and economic development, as recognized in a scientific research study from the second half of the 20th century (Mincer, 1958; Schultz, 1961). An analysis of the influence of human capital as an effective instrument for economic development was carried out with the establishment of the first growth theories in the 1950s and 1960s by R. M. Solow (1956) (Nguyen, 2023; Aslam, Mudassir, Ghouse & Farooq, 2024). In this context, the term "human capital" was defined in both a narrow and a broader sense.

According to the narrower approach, human capital refers to the education level of an individual or the entire population, as well as the quality of training

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for work operations (Petrović, 2010). It is enhanced through various measures, including the allocation of funds to the education sector, subsidizing patents and start-up products, the improvement of workers' skills, the regulation of occupational safety measures, ensuring the social and health care of the workforce, increasing the share of human capital in exported products and services, as well as the other factors that contribute to increased labor productivity (Balogh, 2013).

The assumptions of the neoclassical model of economic growth indicate that improvements in the quality of human capital have only a short-term effect, which results in the absence of further increases once the long-term equilibrium point is reached (Solow, 1999). The neoclassical growth model also implies the exogeneity of the variables representing the total workforce and physical capital, both of which directly affect changes in labor productivity (Pelinescu, 2015). One of the criticisms of the neoclassical growth model is its omission of the effect of educating population on economic growth, as well as subsidizing resident and nonresident patents, and an insufficient budget allocation to the education sector. Investing in R&D activities and human capital ensures the application of new technologies in order to achieve higher labor productivity, which causes the growth of *per capita* income (Borović, Tomaš & Trivić, 2023). According to traditional growth models, the accumulation of physical capital, the initiation of technological progress and the development of human capital lead to higher labor productivity (Solow, 1999). The neoclassical growth model neglects the education of the workforce and the innovation of production processes, i.e. the size of the volume of the workforce is analyzed instead of the efficiency in performing work operations (Hanushek & Woessmann, 2012). Therefore, the quality of human capital causes growth in labor productivity and the profitability of companies across markets (Yahaya, Salman, Abdulsalam & Adegbayibi, 2022).

At the beginning of the 1980s, the endogenous growth model was developed, which observes the effect of human capital on the economic growth rates of countries (Barro, 2015). The proponents of this model point out the fact that the allocation of funds to the education system, the subsidizing of patents, and technological innovations are an indispensable part of the structure of human capital (Aghion & Howitt, 1998). Achieving higher rates of economic growth requires improving the quality of human capital by encouraging entrepreneurial activities and enhancing the education of the working-age population (Molnar, Josipović & Baškot, 2024). The modified model suggests that human capital has a long-term effect on changes in *per capita* income (Ogbeifun & Shobande, 2022). This effect is seen in the development of the education system and the growth of the human capital stock, both of which contribute to greater economic development (Benos & Zotou, 2014).

In the economic policy measure adoption process, the role of human capital is emphasized as a significant determinant for increased labor productivity, which further reflects in the growth of income *per capita* (Lucas, 2015). Therefore, the countries that allocate a larger portion of their budgetary funds to the education system - as an incentive for technological progress - achieve higher rates of convergence, or the "catch-up effect", in *per capita* income levels compared to more developed economies (Wolff, 2013). Motivated by these considerations, the European Union has adopted a series of strategies based on knowledge and investment in research and development activities so as to become the most competitive and the most dynamic market in the world in the foreseeable future (Lucian, 2015). In March 2000, the Lisbon Summit was organized, at which the representatives of the governments of the European Union developed a strategy based on knowledge, innovation, and the optimization of human capital, all directed at achieving higher labor productivity, higher rates of economic growth and greater social cohesion. During 2005, a revised version of the Lisbon Strategy was adopted, which aimed to place human capital on a pedestal in terms of importance, so that knowledge and innovation would be used in support of economic growth (Mićić, 2009).

The recognition of the importance of human capital as an instrument for improving the state of the economies of different countries was achieved through the implementation of a new development strategy, whose draft was published by the European Commission in 2009, the final version being released in 2010 (Silander, 2019). The priorities of the aforementioned strategy relate to ensuring intelligent growth, i.e. the development of an economy based on knowledge and innovation.

Within the "Europe 2020" Strategy, several initiatives have been established, namely the Innovation Union, Youth on the Move, the Digital Agenda for Europe, and the Agenda for New Skills and Jobs (European Commission, 2010). The strategy aims to drive smart growth by investing in innovation and technical and technological advancement, and by increasing the share of the population with secondary and tertiary education (European Commission, 2010). Numerous studies have confirmed that the influence of human capital on economic growth is significantly greater than the effect of physical capital. Along with the improvements of the education structure of the population, human capital also grows through investment in the development of patents and technological innovations (Habibi & Zabardast, 2020). A country exports products that make intensive use of human capital. Therefore, foreign trade openness is considered when analyzing the relationship between human capital and economic growth (Petrović, 2010).

According to the subject matter and aims of the research, the following hypothesis is set and tested:

H1: The improvement of human capital has a positive effect on an increase in income *per capita* on the sample of ten Central and Eastern European countries.

The empirical tools used in this research include the descriptive, analytical and synthetic methods. The methodological part of the study employs econometric tests involving the application of a balanced panel regression model. In the Introduction, theoretical implications are presented, and the objectives and the subject matter of the research are explained. In the second chapter, other empirical scientific studies that confirm a positive impact of human capital on increases in *per capita* income are reviewed. In the third section, an overview of the data sources used to form the research sample frame is given. Additionally, this chapter also explains the methodological approach, focusing on the use of the balanced panel regression model. In the Conclusion, the results obtained from this research are interpreted.

LITERATURE REVIEW

Since the 1980s, alongside the modification of traditional growth models, a series of scientific studies have been conducted, examining the influence of human capital on changes in income *per capita*. However, a distinction is made between the research investigating the impact of the education level on earnings *per capita* and those examining the effect of human capital on income *per capita*, which include a broader range of variables.

According to M. R. Guisan and I. Neira (2006), the influence of human capital on the economic development of the countries of North America, Europe, Asia, and Africa, was confirmed for the period from 1960 to 2004. The authors carried out panel regression analysis to demonstrate a statistically significant relationship between the average number of the years of schooling, the state investments in the education system and research and development, population growth incentives, and foreign trade openness on population income growth. The results of this research are consistent with the previously obtained results of a number of studies. In a research study conducted by R. J. Barro (1991), a direct effect of the population's primary and secondary levels of education on economic growth was confirmed in the period from 1960 to 1985. In their research, K. Lee and B. Y. Kim (2009) prove that there is a statistically significant impact of population growth with secondary and tertiary education on *per capita* income on a sample of 63 countries in the period from 1965 to 2002. Additionally, the authors T. Suri, M. A. Boozer, G. Ranis and F. Stewart (2011) confirmed a statistically significant effect of secondary education on an increase of *per capita* income on a sample of 79 countries.

In their research, F. Habibi and M. A. Zabardast (2020) point out the importance of investing budgetary funds in education and technological progress in the countries of the Middle East and the OECD countries. The results of the research conducted by Q. Kong, D. Peng, Y. Ni, X. Jiang, and Z. Wang (2021) confirm the impact of a country's foreign trade openness on achieving higher growth rates and population income. This effect is attributed to the incorporation of human capital in the production of export goods and services. The same result was obtained by the authors D. Dekkiche and O. B. Leila (2024), who confirmed a statistically significant correlation between foreign trade openness and economic development within the BRICS countries by applying the ARLD panel method.

According to I. Hasan and C. L. Tucci (2010), countries with high-quality patents achieve higher rates of economic growth, as demonstrated on a sample of 58 countries from 1980 to 2003. The same conclusion was reached by A. M. Pece, O. Simona, and F. Salisteanu (2015), who found that investment in technological innovation led to higher *per capita* income in the CEE-10 countries. According to C. P. Nguyen and N. Doytch (2022), the impact of registered patents on *per capita* income was demonstrated in a study of 43 countries from 1998 to 2016. The above-mentioned references are a motivation to examine the impact of human capital on the income *per capita* of the CEE-10 countries.

METHODOLOGY AND DATA

The methodological part of this research concerns the formation of a research sample consisting of the European Union countries that joined the Union during or after 2004. The study uses data from a group of ten Central and Eastern European countries for the purpose of constructing the sample frame. The analysis includes the new members of the European Union, namely Bulgaria, Hungary, Romania, Poland, the Czech Republic, Latvia, Lithuania, Estonia, Slovakia and Slovenia. The sample does not include data for five members of the European Union that are geographically located in Central and Eastern Europe. Specifically, Malta, Croatia, Luxembourg, Ireland and Cyprus were excluded from the analysis, the reason for their exclusion being primarily economic. These prominent EU member states have significantly smaller economies and notably lower annual *per capita* income growth rates compared to the ten countries of Central and Eastern Europe included in the study. An additional reason for their exclusion lies in the partial unavailability of data on *per capita* income over the entire observed period. Similarly, these countries have incomplete time series data on human capital indicators. Therefore, the time series for the ten countries of Central and Eastern Europe will be used for the sampling frame of this research, which will be marked with the three-digit abbreviation CEE-10, according to the instructions of the International Organization for Standardization (ISO standard).

The research period includes the interval from the first quarter of 2012 to the fourth quarter of 2023. The research refers to the period after the appearance and duration of the negative effects of the world financial crisis (2008), which avoids the negative impact of structural breaks on the movement of the time series of the income *per capita* of the CEE-10 countries. The collected data pertain to the period up to the last quarter of 2023 as the last year with available data at the time of conducting the research. For the purpose of data collection, the publicly available database of the World Bank was used, as well as the publicly available database of Eurostat.

In order to complete the methodological part of the research and obtain relevant research results, the panel data method was applied. This approach involves the analysis of several different units of observation , where , across the previously defined time period , which, in this model, is , providing a sufficient number of observations for conducting panel analysis. The applied panel data are balanced, which means that there is an equal number of observations for each unit . The relation N<T is characteristic of the panel model in this research study - the number of the observation units is smaller than the number of the period, which classifies this dataset as a micro-panel, which falls into the group of linear models.

The primary advantages of using panel data as a methodological tool include control of individual heterogeneity, the absence of multicollinearity among the included variables, increased variability, and the provision of more precise and more robust research results (Hsiao, 2022). By analyzing the impact of several different units of observations of the economics variables for multiple countries or companies within a single period, the method including comparative data is applied. However, time series analysis models are implemented when measuring the effects of a certain variable for a single company or country across different periods.

The empirical analysis of the simultaneous effect of different observation units across multiple time units will require the use of panel data methods (Baltagi, 2008). The research includes ten units of observation in different time periods, which suggests that the use of the methods including comparative data or a multiple model for time series analysis will lead to biased evaluations of the research, as well as unreliable results and conclusions (Wooldridge, 2010). Therefore, the impact of human capital on the change in the growth rate of *per capita* income will be assessed using the panel method. The analysis starts with the use of a pooled effects panel model (the Pooled OLS model). To implement the panel model, the regression equation is estimated as follows:

$$Y_{it} = \alpha + \beta_1 X_{1,it} + \beta_k X_{k,it} + V_t + \varepsilon_i + u_{it},$$
$$i = 1,\dots,N,\ t = 1,\dots,T,\ k = 2, 3, 4,\dots,n \qquad (1)$$

where the symbols represent:

N - the number of the observation units, T - the number of the periods,

α - this symbol implies an intercept and predicts where the regression line will cross the y axis,

Y_{it} - the value of the growth rate of income *per capita*, for the *i*-th unit of observation in the unit of time *t*,

β_k - predicts the change in for each unit change in the *k*-th independent variable for the *i*-th unit of observation in the unit of time *t*,

$X_{k,it}$ - the value of the independent variable X_k, for the *i*-th unit of observation in the unit of time *t*,

V_t - the time effects,

ε_i - the individual effects,

u_{it} - the random error value, which follows a normal distribution with a mean of zero and constant variance.

The pooled effects model (Pooled OLS model) is rejected due to the thesis that the model neglected the assumption of heterogeneity between different units of observation, which leads to the conclusion that the included countries within the panel model react according to the identical principle (Hsiao, 2022). In order to overcome the potential absence of heterogeneity between different observation units, fixed effect panel models or stochastic effects panel models are applied. In the first phase of the methodological part, the analysis of the fixed effect panel model is carried out, followed by data analysis using the random effects model. Within the fixed effects model, individual effects are directly included in the model as the fixed parameters through the free terms or the intercept and predict where the regression line crosses the y axis. To obtain results and evaluate the equation using the fixed effects model, the following equation is formulated:

$$Y_{it} = \alpha + \alpha_i + \beta_1 X_{1,it} + \dots + \beta_k X_{k,it} + \varepsilon_{it},$$
$$i = 1,\dots,N,\ t = 1,\dots,T,\ k = 2,3,4,\dots,n \qquad (2)$$

The fixed-effects panel model assumes that the random errors and explanatory variables in the model are uncorrelated. However, the fixed effects panel model allows for the correlation of individual effects and independent variables (Baltagi, 2008). For the purposes of overcoming the problem of the correlation of individual effects and random errors and testing which of the models is more representative, i.e. which of the models provides more scientifically robust results, the random effects model is applied. Thus, the regression equation is evaluated, which is set in the following form:

$$Y_{it} = \alpha + \beta_1 X_{1,it} + \dots + \beta_k X_{k,it} + V_{it},$$
$$V_{it} = \alpha_i + \varepsilon_{it},\ i = 1,\dots,N,\ t = 1,\dots,T \qquad (3)$$

In support of the explanatory variables of this research study, whose impact on the dependent variable is assessed using the panel data method, there are the following variables:

$X_{1,it}$ - the explanatory variable that implies the education level of the total population by measuring the number of the residents with a high-school and university degrees. The variable refers to the share of the population with secondary and tertiary education in the total population.

$X_{2,it}$ - the explanatory variable that monitors the total number of the patents registered annually, which is in the domain of intellectual property. The variable represents the patents registered by residents and nonresidents for the observation unit *i* in the time unit *t*.

$X_{3,it}$ - the explanatory variable that refers to the total investment of the state, i.e. investment in the education sector. It is measured by the percentage share in the gross domestic products of the observation units *i* in the period *t*.

$X_{4,it}$ - the explanatory variable that implies the total amount of the products and services exported from one country to the other countries in a certain period (the annual data). The export of products and services is a measure of the trade openness of the observation units *i* in the time unit *t*.

$X_{5,it}$ - the explanatory variable that is an indicator of the population health and is measured by predicting the average life expectancy of newborns, provided that the mortality level of certain years-of-age categories remains constant in the observation unit *i* in the period *t*.

$X_{6,it}$ - the explanatory variable that measures change in the prices of the products and services purchased by households in order for them to satisfy their own needs in the observation unit *i* in the time *t*.

$X_{7,it}$ - the explanatory variable that measures the percentage share of the urban population in the total population, which means the share of the population living in the biggest cities of the observation units *i* in the period *t*.

The dependent variable of this research implies the variable that measures the total annual income *per capita* of the CEE-10, i.e. the GDP *per capita* of these countries. The abbreviation for the dependent variable in the model is Y_{it}. According to E. N. Wolff (2013), *per capita* income is equated with labor productivity, which is an alternative measure of the economic growth rate. Namely, the movement of GDP *per capita* follows GDP per employee, which refers to the definition of labor productivity. The condition for the previously said refers to the stability of the measured unemployment level, i.e. the absence of sudden changes in the movement of the unemployment rate. Therefore, in the sampling frame of the research, the income *per capita* variable is used as the measure of the economic growth of the countries (Wolff, 2013).

The analysis of the influence of the explanatory variables on the dependent variable is initially conducted using the fixed effects model, after which the random effects model is applied. For the purpose of obtaining a more representative panel model, the Hausman test is used. The assessment of the validity of the obtained research results is carried out using the panel regression equation, only to be followed by testing for multicollinearity, the autocorrelation of the variables, and the heteroskedasticity of the random error. The Wooldridge test is performed so as to assess the presence of autocorrelation between the variables in the selected panel model. If the results of the Hausman test point to the application of the model with fixed effects, the Wald test will be used to examine the presence of the heteroskedasticity of the random error.

The Breusch Pagan Lagrange multiplier test was used to examine the heteroskedasticity of the random error, which is characteristic of the random model (the RE model). Fulfilling the assumptions about random error in the panel regression model is stated as a prerequisite for obtaining relevant research results.

In Table 1, the data sources are listed along with the presentation of the research variables. In the following table, the results of the panel test of the explanatory effects on the dependent variable are interpreted. To obtain relevant results, a regression equation is set and evaluated applying diagnostic tests. Table 2 The descriptive statistics of the variables included in the panel model

The descriptive statistics were calculated based on the included variables in the panel regression model presented in Table 2. The dependent variable represents the annual value of income *per capita*, reaching an average value of 31,502.48 dollars. The first explanatory variable is the fundamental measure of the quality of human capital, where the share of the population with secondary and tertiary education is 86.41% of the total population. Average investment in education amounted to 4.87% of the GDP of the CEE-10 countries.

The average number of the patents registered by the residents and nonresidents of the CEE-10 countries is 17.77. The estimated average trade openness of the CEE-10 countries is 8.45e+10 dollars. The average life expectancy of newborns is 76.44 years of age. The average share of the urban population in the total

Table 1 The definition of the dependent and explanatory variables, the labels and the data sources

The names of the variables	Label	Description of the variables	Data sources
Income *per capita* (GDP *per capita*)	Y_{it}	The annual value of the realized income in one unit of observation in the period measured *per capita*. The variable mentioned is calculated as the ratio of the value of the annual gross domestic product and the total number of the country's inhabitants. Per capita income is measured in constant prices expressed in US dollars.	The World Bank data (2023)
Education level (% of population)	$X_{1,it}$	The education level of the population refers to the total number of the residents with a high school diploma and a college degree ranging in the interval from 18 to 64 years of age. The variable is a measure of the percentage of the citizens with secondary and tertiary education in the total population.	Eurostat database -European Commission
Number of registered patents	$X_{2,it}$	This variable is a measure of the annual number of the patents registered by the residents and nonresidents of the observed country in the observed period. It is expressed in natural numbers for the unit of observation measured at the annual level.	The World Bank data (2023)
State investments in the education sector (% of GDP)	$X_{3,it}$	This variable represents the share of the country's GDP allocated to the development of the education sector and the production of highly educated personnel on the labor market. The variable represents the share of the country's GDP invested in the improvement of the education sector.	Eurostat database - European Commission
Trade openness (% of GDP)	$X_{4,it}$	This variable is measured through the percentage share of the exports of products and services in the formation of the total value of the country's GDP. The variable implies the annual volume of foreign trade exchange with foreign countries' markets in constant prices and expressed in US dollars.	The World Bank data (2023)
Total life expectancy at birth, total (years)	$X_{5,it}$	This variable measures the life expectancy of newborns, provided that the mortality rate, which is specific to a certain population cohort, remains constant. The variable is an indicator of the general health status of the population.	The World Bank data (2023)
Consumer Price Index (CPI)	$X_{6,it}$	This variable measures the weighted average market price for the basket of goods and services bought by consumers. The CPI indicator reflects the change in the cost of living over time.	The World Bank data (2023)
Population in the biggest city (% of Urban Population)	$X_{7,it}$	This variable implies the percentage share of the urban population in the countries' total populations, which refers to the segment of the population living in the biggest cities, i.e. the metropolises of the observed countries.	The World Bank data (2023)

Source: Authors

Table 2 The descriptive statistics of the variables included in the panel model

Variables	Mean	Standard deviation	Minimum	Maximum
id	5.5	2.884324	1	10
Y_{it}	31502.48	8292.13	15747.39	51695.17
$X_{1,it}$	86.41417	4.798534	73.6	93.6
$X_{2,it}$	17.77317	17.79044	0.99	78.48
$X_{3,it}$	4.8725	0.9662335	2.8	6.9
$X_{4,it}$	8.45e+10	7.61e+10	1.36e+10	3.59e+11
$X_{5,it}$	76.44309	2.146859	71.46341	81.52927
$X_{6,it}$	114.7837	10.92856	101.8029	151.9433
$X_{7,it}$	28.29007	15.30413	7.419745	55.751

Source: Authors

Table 3 The results of the causality testing between the variables (Dumitrecsu and Hurlin-Granger test)

Causality Direction	Zbar-Stat.	Prob.	Causality Direction	Zbar-Stat.	Prob.
Y_{it} does Granger-cause $X_{1,it}$	3.6126	0.000	$X_{1,it}$ does Granger-cause Y_{it}	3.6488	0.003
Y_{it} does Granger-cause $X_{2,it}$	7.3710	0.000	$X_{2,it}$ does Granger-cause Y_{it}	2.0158	0.043
Y_{it} does Granger-cause $X_{3,it}$	3.8869	0.001	$X_{3,it}$ does not Granger-cause Y_{it}	-1.1338	0.256
Y_{it} does not Granger-cause $X_{4,it}$	0.9272	0.353	$X_{4,it}$ does not Granger-cause Y_{it}	-0.7324	0.463
Y_{it} does Granger-cause $X_{5,it}$	7.9841	0.000	$X_{5,it}$ does Granger-cause Y_{it}	5.6542	0.000
Y_{it} does not Granger-cause $X_{6,it}$	-0.968	0.333	$X_{6,it}$ does not Granger-cause Y_{it}	0.9522	0.341
Y_{it} does Granger-cause $X_{7,it}$	8.9933	0.000	$X_{7,it}$ does Granger-cause Y_{it}	4.3292	0.000

Note: If the p-value is less than the significance level of 0.05, the null hypothesis is rejected, which leads to the conclusion that there is causality between the variables within the model

Source: Authors

population living in the biggest cities is 28.29%. The relevance of the selection of the research variables is confirmed by testing causality applying the E. I. Dumitrescu and C. Hurlin (2012) Granger test.

The causality test results indicate a causal relationship between the explanatory variables and the dependent variable, such as the education level, life expectancy, the population of the biggest city, and the number of the registered patents. Conversely, the results confirm a causal effect of the dependent variable on the explanatory variables, namely education, the number of the registered patents, life expectancy, public investment, and the population of the biggest city.

RESULTS AND DISCUSSION

The stationarity of the time series included in the panel model is tested using unit root tests, which, commonly used in the panel data analysis, share a similar characteristic with the unit root tests employed in the time series analysis. In this research, both first- and second-generation unit root tests are applied. According to first-generation tests, events and changes in economic conditions in one country do not affect economic conditions in neighboring countries, which makes these tests applicable to independent panels. In contrast, second-generation tests indicate that changes in economic conditions in one country can influence economic conditions in neighboring countries, which makes them suitable for dependent panels. In various scientific studies, the use of first-generation unit root tests has been found to be prevalent in comparison with that of second-generation tests (Pesaran, 2012). In our research, however, both first- and second-generation tests are equally applied in order to examine the stationarity of the series in the constructed panel model. To obtain robust research results, an examination of the stationarity of the panel is carried out by performing the following tests: the Levin-Lin-Chu test (2002), the Harris-Tzvalis test (1999), the Im-Pesaran-Shin test (2003), Fisher's test (2001), the Breitung test (2000) and so on. The previously mentioned unit root tests have a null hypothesis stating that the observed series has a unit root, whereas an alternative hypothesis indicates the absence of a unit root in the time series. By rejecting the null hypothesis at the significance level (α = 0.05) the stationarity of the panel model is confirmed.

According to the results in Table 4, the stationarity of the panel model is confirmed. The application of the logarithmic data ensures the stationarity of all the time series included in the panel model through the use of the first difference. The calculated probability of the unit root tests is less than *prob.=0.05%*, which confirms the stationarity of the observed time series. To examine the nature of the relationship and the collinearity among the explanatory variables, the Pearson correlation coefficient is calculated. The results of the linear correlation analysis between the dependent variable and the set of the explanatory variables are presented in Table 3.

Based on Table 5, it is concluded that there is a weak correlation among the variables included in the panel regression model, the highest being observed between investment in education (% of GDP) and the number of the registered patents, with the value of 0.5771, and the lowest being found between trade openness (% of GDP) and income *per capita* (% of GDP) at the level of 0.0187. In this sense, the correlation between any of the included variables in the model formed is not higher than 0.58, which points to the conclusion that there is no multicollinearity between the variables included in the set panel regression model.

Table 4 The examination of the stationarity of the time series included in the panel model

Variables	Y_{it}	$X_{1,it}$	$X_{2,it}$	$X_{3,it}$	$X_{4,it}$	$X_{5,it}$	$X_{6,it}$	$X_{7,it}$
Levin-Lin-Chu test	-6.0618 (0.0000)	-6.7577 (0.0000)	-6.9503 (0.0000)	-5.3366 (0.0000)	-2.8981 (0.0019)	-4.0417 (0.0000)	-4.8864 (0.0000)	-1.4922 (0.0678)
LLC trend test	-4.3686 (00000)	-10.9779 (0.0000)	-8.2728 (0.0000)	-7.3692 (0.0000)	-2.7105 (0.0034)	-5.4342 (0.0000)	-3.3946 (0.0003)	-1.4922 (0.0678)
Harris-Tzvalis test	0.0165 (0.0000)	-0.0787 (0.0000)	-0.2343 (0.0000)	-0.0603 (0.0000)	-0.1734 (0.0000)	-0.4484 (0.0000)	0.5274 (0.0000)	-0.8734 (0.0000)
HT trend test	0.0995 (0.0011)	0.0889 (0.0008)	-0.1930 (0.0000)	-0.0412 (0.0000)	-0.1140 (0.0000)	-0.4270 (0.0000)	0.0392 (0.0015)	-0.7668 (0.0000)
Breitung test	-3.7943 (0.0001)	-3.2997 (0.0005)	-4.3196 (0.0000)	-3.8587 (0.0001)	-5.0245 (0.0000)	-6.9674 (0.0000)	-3.6131 (0.0002)	-2.4694 (0.0068)
BT trend test	-2.9848 (0.0014)	-1.7860 (0.0370)	-4.2417 (0.0000)	-2.3293 (0.0099)	-3.6599 (0.0001)	-1.5905 (0.0597)	-1.3885 (0.0825)	-2.0780 (0.0189)
Im-Pesaran-Shin test	-2.9219 (0.0017)	-3.6562 (0.0001)	-4.9999 (0.0000)	-3.0436 (0.0012)	-4.2613 (0.0000)	-4.0766 (0.0000)	-2.2107 (0.0135)	--6.2933 (0.0000)
IPS trend test	-4.2730 (0.0000)	-3.7333 (0.0001)	-4.9800 (0.0000)	-3.8170 (0.0001)	-4.4512 (0.0000)	-3.8551 (0.0001)	-2.2243 (0.0131)	-1.7654 (0.0388)
Fisher dfuller test	7.4440 (0.0000)	9.3479 (0.0000)	29.9766 (0.0000)	6.6583 (0.0000)	10.8235 (0.0000)	9.6253 (0.0000)	29.9766 (0.0000)	6.8505 (0.0000)

Source: Authors

The value of the Hausman test was used for the selection of the methods for evaluating the panel data on a sample of ten CIE-10 countries in the period from 2012 to 2023. According to the calculated statistics of the Hausman test, which are higher than x^2 (the number of the freedom degrees) with the confidence interval the null hypothesis is rejected, and the alternative hypothesis of the test is accepted. The alternative hypothesis suggests that the random effects model is a more relevant methodological approach than the fixed effects model. Namely, to evaluate the regression equation and come to a valid conclusion, the method of random effects is applied, whereby $x^2(6) = 1.95$, while *prob.* > $x^2(5) = 0.9245$. To calculate the statistical significance of the influence of the variables representing the quality of human capital to an increase in the annual growth rate of income *per capita*, as well as the overall economic development of the Central and Eastern European countries, a regression equation is set and evaluated as follows:

$$YCEI(10)_{it} = \alpha + \beta_1 X_{1,it} + \beta_2 X_{2,it} + \beta_3 X_{3,it} + \beta_4 X_{4,it} + V_{it} \quad (4)$$

Immediately before evaluating the regression equation using the random effects model, an analysis of the results of the diagnostic tests is conducted. The original Breusch Pagan Langrange multiplier test is used to test heteroskedasticity in the random effects model. The assumptions of the random effects model include: $E(\alpha)=0$ and $Var(a_i) = \sigma_\alpha^2 > 0$. The value of the Breusch Pagan LM test statistic is $x^2(45)=91.64$, while the probability value implies *prob.=0.0000*. Based on the obtained value of the Breusch and Pagan LM test, the null hypothesis is rejected, and the alternative hypothesis of the test is accepted with the significance level of 0.05. The residual heteroskedasticity in the model is confirmed, i.e. the variance of the residual deviations is not constant. To examine the presence of autocorrelation in the random effects model, the Wooldridge test is used. The value of the Wooldridge test statistic is $x^2(7) = 589.61$, while the calculated probability is *prob.* = 0.0000. By calculating the

Table 5 The examination of multicollinearity in the panel model

	Y_{it}	$X_{1,it}$	$X_{2,it}$	$X_{3,it}$	$X_{4,it}$	$X_{5,it}$	$X_{6,it}$	$X_{7,it}$
Y_{it}	1.0000							
$X_{1,it}$	0.1755	1.0000						
$X_{2,it}$	0.1063	-0.0882	1.0000					
$X_{3,it}$	0.1523	0.0587	-0.2713	1.0000				
$X_{4,it}$	0.5771	0.0187	0.1465	-0.1649	1.0000			
$X_{5,it}$	0.2477	-0.0260	0.1115	-0.1932	0.1855	1.0000		
$X_{6,it}$	0.5326	0.0503	0.0987	0.0395	0.3563	0.4627	1.0000	
$X_{7,it}$	0.0892	-0.0618	0.0523	-0.0938	-0.0472	0.0826	0.1272	1.0000

Source: Authors

Table 6 The diagnostic tests of the panel model

Central and Eastern European countries	Hausman test	Wooldridge test (Random Effects model)	Breusch and Pagan Lagrange multiplier test
The value of the test statistics	$x^2(6) = 1.95$	$x^2(7) = 589.61$	$x^2(45) = 91.646$
Probability test (Prob.)	0.9245	Prob.statist.= 0.0000	Prob. statist.= 0.0000

Source: Authors

probability of the test, with the significance level of α = 0.05, the null hypothesis of this test is rejected, which implies the absence of autocorrelation, i.e. the existence of a mutually correlated relationship between the random errors within the random effects model.

According to D. Hoechle (2007), to overcome the problem of heteroskedasticity and the problem of autocorrelation in the random effects model (*abbreviated the RE model*), robust standard errors are included in the model (*vce robust).* Based on the research conducted by B. H. Baltagi (2008), the random effects model estimation procedure is carried out using robust random errors, which leads to solving the problem of the inconsistency of random errors. The model evaluation method based on the covariance matrix is presented by the scientists H. White (1980), and G. Frahm (2009). By applying the mentioned correction, the consistency of random errors is ensured, regardless of the confirmed heteroskedastic residual. Immediately after overcoming the problems with both heteroskedasticity and autocorrelation in the observed model, a panel regression evaluation is performed, which provides robust results and valid conclusions.

The influence of the level of human capital development on the change in the annual income of the population, i.e. the income *per capita* of the ten Central and Eastern European countries, is examined using the regression equation and the results obtained presented in Table 7. Obtaining a higher income *per capita* of the population represents an alternative measure of economic growth and the development of countries (Wolff, 2013). In analyzing the individual

Table 7 The estimation of the panel regression equation

Model Variables	Panel model (Random-effects GLS regression)	
Income *per capita* (GDP *per capita*)	Estimated regression coefficients	Standard error values
Education level (% of the population)	0.8843876** (0.028)	0.4033031
Number of the registered patents	0.0097988** (0.021)	0.0422565
State investments in education (% of GDP)	0.14818*** (0.002)	0.0477228
Trade openness (% of GDP)	0.3847617*** (0.000)	0.0431631
Consumer price index (CPI)	0.2829279*** (0.003)	0.096777
Total life expectancy at birth, total (years of age)	0.1356885 (0.488)	0.1958549
Population in the biggest cities (% of the urban population)	0.4570091 (0.107)	0.2839146
Constant	0.0273071*** (0.000)	0.0038577
Number of the observations	120	N = 1,2,3, … ,8,9, 10 T= 1,2,3, … , 10, 11, 12
Coefficient of determination (R^2)	0.7350	
Probability test	Prob. > (x^2) = 0.0000	

Note: The marks ***, **, * imply a significance level of 0.01, 0.05, and 0.10, respectively, based on which a decision is made

Source: Authors

elements considered under the term human capital, the coefficients of each of those variables are estimated using the regression equation with the measurement of their influence on the dependent variable. In the further course of the research, the results obtained are interpreted. The validity of the set model is ensured by the value of the total statistics of the model 589.61, with the level of significance of 0.01. Based on the coefficient of determination, whose value is 0.7350%, it has been proven that approximately 74% variability in income *per capita*, i.e. in GDP *per capita*, is explained by the independent variables of the model. The regression coefficients were estimated so as to explain the model's variables and ensure the statistical significance of the influence of the independent variables on the dependent variable.

Based on the calculated values of the regression coefficients which measure the impact of education on *per capita* income (i.e. GDP *per capita*), the statistical significance of the effects of education on income has been confirmed for the sample of the CEE-10 countries. According to the results shown in Table 7, the education level of the population has a statistically significant and positive influence on the changes in *per capita* income among the CEE-10 countries. A 1% increase in the education level results in a 0.8843% increase in income *per capita*. Namely, the population with a higher level of education achieves an average higher income *per capita* compared to the less educated segment of society. Therefore, an individual's education represents a signal of their ability and work efficiency, which leads to the achievement of potentially higher income levels. Within the Eurozone, the residents with primary education earned an average annual salary of 17,590 euros, the residents with secondary education 23,006 euros, while the residents with tertiary education earned 30,081 euros, according to the measurement data at the end of 2023 (Eurostat, 2024).

According to the results obtained, the variable number of the patents registered by the residents and nonresidents of the CEE-10 countries has a positive and statistically significant effect on the change in the countries' income *per capita* during the observed period. Due to the 1% increase in the number of patents in the country, the income *per capita* increases by 0.009%. Also, the 1% increase in the weighted average value of the market basket of goods and services (CPI) affects the increase in *per capita* income by 0.2829% in the sample of the CEE-10 countries in the observed period. The results of the panel model indicate a positive and statistically significant influence of the countries' trade openness on the change in income *per capita* observed in the sample of the CEE-10 countries. The countries' trade openness is measured by the annual amount of the products and services produced and exported from the CEE-10 countries. The increased level of labor productivity developed through the process of improving working skills and technological progress and the participation of human capital in the production of export outputs has effects on the growth of income *per capita*. With that in mind, the 1% increase in the exports of goods and services of the CEE-10 countries leads to an increase of 0.3847% in *per capita* income.

Investing into the education sector implies an important measure within the education development strategy which implies increasing the literacy of the total population. Above-average investment in the education sector through the improvement of the education system infrastructure and the implementation of educational reforms lead to an increase in the quality of human capital and ensure greater economic growth in the CEE-10 countries. The research has proved a positive and significant relationship between investing in education and higher *per capita* income. The 1% increase in the share of the countries' budgetary funds in the education sector leads to the increase in *per capita* income of 0.1481% in the sample of the CEE-10 countries in the observed period. In conclusion, increasing state investment in the development of the education sector increases *per capita* income. A positive and statistically significant influence of the variables representing the measure of the quality of human capital on the growth of the income *per capita* of the CEE-10 countries is also confirmed.

CONCLUSION

Human capital, or the alternatively used term "human value", refers to the measure of the education of a country's population, their possession of working skills, efficiency in performing tasks, propensity to start patents and develop innovations. From one point of view, human capital implies the starting point for the development of technical-technological innovations, on the one hand, and the functions of human capital refer to the possession of the capacities needed to create a modern technologies acceptance infrastructure, as well as their implementation and further development, on the other.

The results of this research study reveal the positive and statistically significant influence of human capital on the change in income *per capita* on the sample of the ten Central and Eastern European countries (CEE-10). Therefore, the increased participation of the population with secondary and tertiary education, accompanied by the increase in the number of registered patents, a greater allocation of the budgetary funds to research and development activities, the encouragement of start-up ideas and the increase in the amount of export products and services significantly affects the achievement of a higher level of the income *per capita* of the observed countries. Based on the empirical results obtained, the initial research hypothesis is confirmed. Contemporary criticisms of human capital theory are stated as a limitation of this research. Namely, a higher level of the education of the population does not necessarily lead to an increase in the labor productivity of individuals, but rather represents an indicator of their cognitive abilities, talents and working skills, which potentially affect the achievement of higher labor productivity. The recommendation for future research is to expand the regression equation by including the variable measuring the average number of the years of education along with an analysis of its impact on the *per capita* income of the CEE-10 countries. The recommendation involves conducting future research after the prior expansion of the sampling frame by including the other regions of the European Union (27) and making a comparative analysis of another group of countries with the results for the CEE-10 group of countries.

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