Analysis of the Impact of Expenditures on Education and R&D on GDP in Central European Countries

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Abstract

The main purpose of this paper is to identify the impact of public spending on education and research and development (R&D) on the formation of gross domestic product (GDP) in nine Central European countries, which are divided into two clusters – "old" and "new" EU members.

The study took into account official Eurostat data of both the EU and national statistical organizations for the period 2010–2019. The analysis of this impact was carried out using a system approach, statistics and econometric framework including panel data regression, Wald, Breusch-Pagan, Hausman tests. The main finding of the present study is the identification of additional income in terms of GDP in Euro per capita for selected countries, which is obtained from adequately spent public funds for education and R&D. Our results showed that the strongest influence of these expenditures for the "old" members was in Germany and Austria, and for the "new" – in Slovenia and Czechia. It is proved that this impact is different in individual countries and is determined by the public financial policy of national governments.

Keywords	***DOI***	***JEL code***
Government spending, economic growth, econometric modeling, panel data regression	*https://doi.org/10.54694/stat.2021.20*	*H52, I25, O32, C23*

INTRODUCTION

In today's globalized world, EU countries are trying to ensure dynamic economic growth and improve the welfare of the population. According to many economists in the realities of the XXI century, the main

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driving force of social development is digitalization, introduction of new technologies, intellectualization of production processes.

It should be noted that in this context the fundamental basis for using these driving forces is to ensure the implementation of the following algorithm: *education → research → innovation*.

The study focuses on the impact on GDP of only two factors – education and R&D, as the most relevant at present. It should be noted that in some EU countries there may also be a significant impact on GDP and other factors, such as spending on economic programs, the investment climate, etc. However, a significant increase in the number of factors markedly expands the scope of research and such an approach is appropriate in fundamental research.

Education provides an opportunity for intellectual development of certain social strata, which then transform the acquired knowledge into scientific products with a corresponding innovative focus on real or virtual goods and services.

Such economically powerful EU countries as Germany, Great Britain, France attach great importance to these social levers, because they determine economic growth, which in turn provides the welfare of the population in the medium and long term.

Basic modern economic theories that study social development (a new Theory and Narrative of Economic Growth, Grounded in Innovation, Behavioral Economics, Experimental Economics, Ethical Economic Theory, Economic Theory of Happiness) in their methodological tools have appropriate provisions for education, science, and innovation.

Now experts characterize the modern economy as a knowledge economy, which is based on the relevant actions of the authorities. Public funding for education and R&D in the EU is constantly growing. Agreeing with this approach, we note that the modern economy also has other characteris.

Thus, if the total public spending on education in the EU-27 in 2016 amounted to 265.8 billion Euro, then in 2019 – 307.8 billion Euro, which is 15% growth over four years (Eurostat, 2021a). Accordingly, R&D expenditures for the same period amounted to 590.0 billion Euro and 656.3 billion Euro, an increase of 11.3% (Eurostat, 2021b).

These levers of economic growth in the EU are given significant importance. Therefore, an increasing spending on education and R&D is an important component of the fiscal policy of governments that adjust these expenditures according to public demand and real opportunities.

1 LITERATURE REVIEW

Given that the EU pays close attention to education and science at both the interstate and national levels, it should take these levels into account when analyzing strategic legal acts and the point of view of scientists.

At the EU level, several strategic documents have been approved, which define the directions of development. One of the defining perspective documents of Project Europe 2030 (European Commission, 2010) postulates that intelligence; innovation and creativity have now become the relevant standards of social development.

Another strategic document "EU Delivering on the UN 2030 Agenda" (European Commission, 2017) states that sustainable development is at the heart of the development of the European Union, and each initiative aims to improve the life of citizens.

These documents also stipulate that the key factors contributing to the transition to sustainability are education, science, technology, R&D, and innovation.

Considering the important role of universities in the development of both individual countries and the EU as a whole, the European University Association with more than 100 representatives proposed the Europe's Universities 2030 program, which defines the role of universities in shaping sustainable development (European University Association, 2021).

Bernadette et al. (2011) conducted a study aiming to map out the policies and strategies that exist in Europe to improve and promote the teaching of subjects academic research.

An original study of the impact of education quality on GDP was carried out by Hanushek and Woessmann (2020) who argued that increasing student achievement by 25 PISA scores across the EU would add 71 trillion Euros in reduced value to EU GDP compared to the current state of affairs.

A group of researchers (Pastor et al., 2018) assessed the contribution of universities to economic growth and GDP per capita in the EU during 2000–2015. They identified the impact of universities on supply in their national economy, especially the R&D universities contribution in technological assets and found out that GDP per capita was now more than 11% higher than in the scenario without universities contribution.

In the paper of Dima et al. (2018), the Global Competitiveness Index (GCI) for R&D spending as a percentage of GDP was analyzed by determining the impact of various indicators related to the knowledge economy using a regression model and panel data. The authors identified the crucial role of both innovation and education as determinants of EU competitiveness.

Taking into account unforeseen events in the organization of the educational process, in particular, the COVID pandemic, government spending on education in their EU countries has not decreased significantly, although face-to-face communication between faculty and students has been limited. To maintain appropriate contacts, a key concept of learning status and learning space was developed, which is based on prior learning and further online learning using appropriate algorithms and neural networks (Bukovsky et al., 2020).

Let's analyze the empirical studies in terms of individual EU countries. The reduction in public spending due to the economy has led to negative consequences of the reduction of public research and university budgets in Italy, so it is proposed to increase public R&D and increase universities funding (Nascia and Pianta, 2018).

Examining the problems of public debt in Czechia during the decline in GDP, Chekina and Vorhach (2020) found that the general government sector is in deep deficit, and debt is growing rapidly. They proposed a solution that should include increasing revenue over costs and stimulating economic growth, and as an exception to the concept, reducing the deficit which is necessary to stimulate investment activities, in particular, focused on new technologies, science, R&D and debt reduction in the long term.

The analysis of the impact of higher education funding on GDP growth in a number of countries, including Poland, Estonia, Czechia, Slovakia, Latvia, Lithuania, and Slovenia, reveals a trend when higher education expenditures correspond to higher qualifications, which contributes to higher GDP.

At the same time, a significant dependence of education expenditures on GDP growth in interstate comparisons has not been established, which is explained by the historical features of economic development of individual countries, the specifics of the national economy, labor markets and others (Chekina and Vorhach, 2020; UNESCO, 2010; UNESCO, 2012).

A comprehensive study by Anderson and Odei (2018), Hronova (2019) on the importance of research and development funding as part of ancillary government policy to coordinate interactive relations between firms and research institutions in Czechia, Slovakia, Hungary and Romania with the analysis of research papers revealed trends formation of the dynamics of economic growth.

In the context of economic growth at the micro level, the importance of research and development costs for the competitiveness of manufacturing enterprises in Poland has been proven Grzelak et al. (2018), and Roszko-Wójtowicz et al. (2019).

The study of current issues on the impact on GDP of the economic sentiment indicator (ECI), which includes five indicators, was conducted using a panel co-integration analysis for EU countries during 2000–2018, which explained the current and future values of relevant macroeconomic parameters performed by Tomic et al. (2020).

A fundamental study of the impact of R&D on long-term economics using the Bayesian model averaging (BMA) on the example of Czechia was conducted by Horváth (2011). These studies proposed to capture the R&D intensity by the number of Nobel prizes in science. Using this indicator, obtained estimates show that R&D exerts a positive effect on long-term growth.

2 MATERIALS AND METHODS

According to the purpose of this study, approaches to the classification of Central European countries were used, data for analysis were prepared, methods were selected and appropriate models were substantiated.

2.1 Selection of a statistical base and modeling tools for research

Regarding the choice of Central European countries, individual researchers, depending on the purpose of the study, include in this group different countries. Thus, Dlouhá et al. (2016) when considering the problems of higher education in Central Europe include in this group such "new" countries as Czechia, Hungary, Poland, Serbia, Slovakia, and Slovenia. In this context, the "new" are the countries that joined the EU after 2014.

Römisch (2020) analyzing medical processes, respectively distinguishes Italy, Croatia, Slovakia, Czechia, Austria, Slovenia, Hungary, Germany, Poland. The Czech Geographical Directory (Svobody, 2007) includes Poland, Czechia, Slovenia, Hungary, Austria, Switzerland, Liechtenstein, and Germany.

Thus, this group of countries is variable, but since this study uses Eurostat data, we turn to the grouping, which is officially recognized in statistics. European Commission in the allocation of funds in the field of innovation, low-carbon strategies, natural and cultural resources for sustainable growth, as well as in the field of transport, which were then accounted for by Eurostat, identified the countries of Central Europe as follows: Czechia, Croatia, Germany, Hungary, Italy, Poland. Slovenia, Slovakia (European Commission, 2014).

This is the list of Central European countries that we will serve a basis for our research, and we will choose these identified nine European countries for the specification and modeling. To compare the results of the study among these countries, we distinguish two clusters – "old" EU countries – Austria, Germany, Italy and "new" – Czechia, Croatia, Hungary, Poland, Slovenia, and Slovakia.

It should be noted, that economic growth is complex multidimensional process, which is influenced directly and indirectly by many factors: capital, innovation, entrepreneurship, human capital, education, demographic processes, labor productivity, the level of development of technologies, political and social institutions, etc.

In our research, we focused on two main aspects related to Government incentives (funding) of economic growth in:

(i) innovative technologies (R&D expenditures);

(ii) education, which is one of the aspects of improving the quality of human capital.

Moreover, using more explanatory factors can lead to a multicollinearity problem.

Thus, for our analysis we used annual data of GDP (y, target variable), domestic R&D expenditures (X_1) and expenditures on education (X_2) as independent variables according to Eurostat (Eurostat, 2021; Annex: Tables A1, A2, A4, A6). All data were taken in Euro per capita in order to make the sample comparable, leveling the difference in GDP and population between countries (Annex: Tables A3, A5, A7).

As time period for our analysis, it was selected period from 2010 to 2019. We did not use earlier data because the period before the global crisis of 2008–2009 was characterized by other trend of economic development. Therefore there is no reason to believe that the data belong to one statistical sample, or generated by the same dynamic system. Data for 2020 are also not representative due to the global economic recession caused by the COVID 2019 pandemic.

As was noted in the Introduction, the purpose of present study is to assess the impact of public expenditures on Research and Development (R&D), and Education on economic growth in several European countries. Therefore, we used panel (longitudinal) regression as a modeling tool. Panel data combines both cross-sectional and time-series data (Baltagi, 2021; Croissant and Millo, 2008). At each time point there are spatial data for economic "units" (in our case, GDP per capita in several countries), and for each such unit are available the corresponding data form one or more time series (for each country there are time series for expenditures on R&D and education).

As software tool for simulation panel data models in our research were used STATA.

2.2 Panel data model notation

Let is the dependent variable (GDP per capita) for the i-th country at time (year) t; x_{it} – set of explanation (independent) variables (k-dimension vector); ε_{it} – regression error vector; $i = 1, 2, \dots, n$; $t = 1, 2, \dots, T$.

Let's introduce the following notation for each i-th country:

$$y_i = \begin{bmatrix} y_{i1} \\ \vdots \\ y_{iT} \end{bmatrix}, X_i^{(j)} = \begin{bmatrix} x'_{i1} \\ \vdots \\ x'_{iT} \end{bmatrix}, \varepsilon_i = \begin{bmatrix} \varepsilon_{i1} \\ \vdots \\ \varepsilon_{iT} \end{bmatrix}. \tag{1}$$

In the case of this study the number of independent variables $k = 2$, so in Formula (1) the superscript in parentheses (j) denotes the ordinal number of the explanatory variable ($j = 1, 2$): X_1 – is domestic R&D expenditures in Euros for each country; X_2 – expenditures in Euros for education in each country. In Formula (1) superscript in middle term (such as x'_{i1}) denotes transpose operator.

Typically, majority panel data applications use a one-component random error composition model (Baltagi, 2021; Croissant and Millo, 2008):

$$\varepsilon_i = u_i + \mu_{it}, \tag{2}$$

where u_i characterize individual effects that are unobservable and constant over time (individual heterogeneity); μ_{it} residual error.

Let's also defined "pooled" variables:

$$y = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix}, X = \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix}, \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_n \end{bmatrix}, \tag{3}$$

where y, ε – are $nT \times 1$– dimension vectors, X is $nT \times k$ matrix.

$$y = X\beta + \varepsilon. \tag{4}$$

Formula (2) assumes that all μ_{it} errors are uncorrelated with each other in both i (for different units) and t (for different time periods), and are uncorrelated with all explanatory variables x_{it}.

Consider the most common panel regression model specifications: Pooled Regression model, Fixed Effect model, and Random Effect model.

The Pooled Regression model (PR) specifies constant coefficients, the usual assumptions for cross-sectional analysis.

$$y_{it} = \alpha + x'_{it}\beta + \varepsilon_{it}. \tag{5}$$

This is the most restrictive panel data model. PR is usually applied in the absence of significant differences (heterogeneity) between the sampled units.

Panel data allows taking into account differences in economic units. Let's write one of the possible implementations in the following form:

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it},\ i = 1, 2, \dots, n;\ t = 1, 2, \dots, T. \tag{6}$$

In Formula (6) expresses the individual effect of the unit i, which does not depend on time while the regressors do not contain the constant. In this notation it is generally accepted assumption that errors ε_{it} are (Baltagi, 2021; Croissant and Millo, 2008):

(i) ε_{it} are uncorrelated with each other by i and t: $E(\varepsilon_{it}) = 0$, $Var(\varepsilon_{it}) = \sigma_\varepsilon^2$,

(ii) ε_{it} are uncorrelated with repressors for all i and t.

These assumptions guarantee unbiased and consistency OLS parameter estimates.

Intra-group ("within") and inter-group ("between") estimates are often used to find the parameters of a panel data model. "Within" estimates can be obtained by building a model for deviations from group means, and between estimates by building a model for group means.

Regression "between" is the original model rewritten in terms of time-averaged values of variables:

$$\bar{y}_i = \alpha_i + \bar{x}'_i\beta + \bar{\varepsilon}_i, \tag{7}$$

where:

$$\bar{y}_i = \frac{1}{T}\sum_{t=1}^{T} y_{it},\ \bar{x}_i = \frac{1}{T}\sum_{t=1}^{T} x_{it},\ \bar{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_{it},\ i = 1, 2, \dots, n. \tag{8}$$

The "within" regression or Fixed Effect (FE) models is the original regression model (6) which is rewritten in terms of the deviations from the time mean values of the variables. If subtract (8) from (6) term by term ("within" transform), than it's possible to get:

$$(y_{it} - \bar{y}_i) = \alpha_i + (x'_{it} - \bar{x}_i)\,\beta + (\varepsilon_{it} - \bar{\varepsilon}_i). \tag{9}$$

In Formula (9) α_i also expresses the individual effect of the unit i, which does not depend on time. Then the FE estimator is equivalent to the "within" estimator and can be written in this form:

$$\hat{\beta}_{FE} = \left(\sum_{i=1}^{n}\sum_{t=1}^{T}(x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)'\right)^{-1}\left(\sum_{i=1}^{n}\sum_{t=1}^{T}(x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i)'\right). \tag{10}$$

If unobservable factors do not correlate with regressors, to obtain more efficient estimates, it is possible to consider a panel data model with Random Effects (RE): it is assumed that the missing variables are one of the components of errors.

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} + u_t,\ i = 1, 2, \dots, n;\ t = 1, 2, \dots, T. \tag{11}$$

In Formula (11) u_t characterize within-units errors, invariant in time for each economic unit; ε_{it} – between-units errors. In other words, RE models assume that individual differences are random.

In addition to the assumptions (i) and (ii) about errors for the FE model, we will also assume that u_t are $IID(0, \sigma_u^2)$:

(iii) errors u_i are uncorrelated, $E(u_i) = 0$, $Var(u_i) = \sigma_\varepsilon^2$,

(iv) errors u_i are uncorrelated with repressors for all i and t.

2.3 Choosing the best model specification

It should be noted that for panel data models of regions and countries, the model with FE is most often used, since each of the objects (unit) of such a sample has its own individual characteristics, and the purpose of building a model is, in particular, to obtain a forecast for a specific sample object.

There are several effective statistical approaches for choosing the most adequate panel data model (Baltagi, 2021).

To test the model Pooled Regression vs. Fixed Effects and select the best specification, the Wald test (based on Fisher's F-test) and the Likelihood-Ratio test (LR test) are the most frequently used. Wald's test checks the hypothesis that all individual effects are equal to zero in the FE model. The null hypothesis (H0) is that all in (6) $\alpha_i = 0$ (Baltagi, 2021; Croissant and Millo, 2008).

To select RE model vs. FE model, as a rule, it is usually applied the Hausman test. The RE model takes place only when the random effects are uncorrelated with regressors. So in this test the null hypothesis (H0) is that $cov(\alpha_i, X_{it}) = 0$ and model is correctly specified. Thus, to accept the FE model, the null hypothesis must be rejected both in the F-test (there is a panel structure) and in the Hausman test (only the estimates of the model with FE are consistent, and the estimates of the model with RE are inconsistent).

The Breusch-Pagan test is a test for the presence of a random individual effect and tests a hypothesis $Var(u_i) = 0$.

3 EMPIRICAL RESULTS

3.1 Correlation analysis

To test our hypothesis about the dominant influence of spending on education and research on economic growth (and as a consequence population income), we conducted a correlation analysis.

The average values of the selected factors, grouped by country are shown in Table 1. All data are presented in Euro per capita.

Table 1 Average values of the selected factors, grouped by countries

	Y	X1	X2
2010	18 830.0	339.4	918.3
2011	19 250.0	367.1	923.4
2012	19 098.9	395.8	915.4
2013	19 034.4	404.7	928.1
2014	19 302.2	420.5	930.4
2015	19 687.8	354.5	983.7
2016	20 067.8	435.6	981.3
2017	20 688.9	366.3	1 013.4
2018	21 241.1	499.1	1 079.7
2019	21 614.4	528.7	1 131.2

Source: Authors calculations based on Eurostat (2021a, 2021b)

The correlation coefficients between the target variable (y) and the corresponding factors are given in the last row. As one can see, there is a high statistical relationship between the factors and the target variable: the correlation between GDP per capita and expenditure on R&D and education is 0.76 and 0.98, respectively. At the same time, there is also a significant correlation between the explanatory variables (0.78), which can lead to instability of the OLS estimates and their variances.

It was also calculated correlation coefficients for "between" regression, in which factors were grouped by the time (Formula 8). Results are presented in Table 2.

Table 2 Average values of the selected factors, grouped by the time

Country	GDP per capita	R&D expenditures	Education expenditures
I	$\bar{y}$	$\bar{x}_1$	$\bar{x}_2$
Austria	36 592	1 199.5	1 948.0
Czechia	16 291	299.6	751.3
Croatia	10 979	95.3	541.4
Germany	34 135	1 064.8	1 554.6
Hungary	11 195	154.1	585.2
Italy	26 279	370.6	1 118.3
Poland	10 911	111.8	585.3
Slovenia	18 465	424.1	1 139.2
Slovakia	14 087	121.6	601.3
	Correl.	0.95	0.97

Source: Authors calculations based on Eurostat (2021a, 2021b, 2021c)

Results of Table 2 also show a high relationship between the target variable and factors for the case of inter-group inter-group ("between") estimates.

Thus, the results of the correlation analysis confirm our hypothesis regarding the main drivers of economic growth.

3.2 Models specification

Parameter estimates for various model specifications presented in Section 2.2, as well as the results of statistical tests, are given in the Annex. Summarized estimations for panel data models are shown in Table 3.

As one can see (final estimation results are summarized in the Annex: Tables A8–A12), all model specifications showed good fit accuracy by R-squared criterion: within 0.93–0.94.

The best results were obtained with «between» regression (7). In this case, the R-squared between value reflects the quality of the regression fit and is large enough (0.94), i.e. the change in the average over time factors for each country has a more significant impact on each variable than the temporal fluctuations of these factors relative to the average. This is an additional argument for the need to take into account individual effects against the pool model. But the coefficients of this model (in particular, β_1) turned out to be insignificant according to the *t*-criterion (Table A9 in the Annex).

To select the most adequate model of the dependence of the level of economic growth on expenditures on education and R&D, we except R-squared criterion applied the following statistical tests:

a) Wald test: for comparison the FE (9) model versus the PR model (5).

b) Breusch-Pagan test: for comparison the RE (11) model versus the PR model (5).

c) Hausman test: for comparison the RE (11) model versus the FE regression model (9).

Wald's test checks the null hypothesis that all individual effects are equal to zero. STATA automatically tests this hypothesis at the same time as evaluating the FE model and displays the result in the last row of Table A10 in the Annex. In this case the null hypothesis is rejected at any level of significance. Thus, the FE regression model is better fit data than the PR model.

Table 3 Summarized estimations for panel data models

		Pooled regression model, PR	Between	Fixed effect (within), FE	First differences	Random Effect, RE
R&D	X1	7.12	6.48	3.31	4.85	4.23
Education	X2	12.23	14.08	6.74	2.55	7.50
Constant		3 853.90	3 307.64	11 851.77	-	10 716.04
R2		0.93			0.35	
R2-within			0.61	0.61		0.61
R2-between			0.94	0.94		0.94
R2-overall			0.93	0.93		0.93

Source: Authors calculations by using STATA software

The Breusch-Pagan test checks the presence of a random individual effect and tests the following null hypotheses: $Var(u_i) = 0$. As one can see in Table A12 in the Annex, the null hypothesis is rejected and so model RE is preferred over model PR.

Finally, the Hausman test was used to choose between the FE and RE model specification, which tests for correlation between random effects with regressors. The null hypothesis is $H0$: $corr(u_i, x_{it}) = 0$. The test results not allow reject or assume the null hypothesis, because model fitted on these data fails to meet the asymptotic assumptions of the Hausman test (Table A13 in the Annex).

3.3 Analysis of empirical result

Our results show that, other things being equal, higher level of economic development is associated with (caused by) higher values of expenditures on education and R&D. In all models, we obtained the expected positive signs at the coefficients of the regressors.

At the same time, an interesting fact is that additional spending on education, on average, has almost twice the effect on economic growth than spending on R&D. So, according to the RE model, each additional Euros invested in education leads to an increase in GDP per capita by 7.5 Euro, and additional Euros invested in R&D – about 4.23 Euro.

In this specification constant (10 716.04 Euro) characterizes the impact (or contribution, share) on economic growth (GDP per capita) of unobservable variables (individual characteristics of countries (averaged). Moreover, in this model, it is postulated that the differences are of a random nature and, on average, are leveled. Thus, this value can be interpreted as the average level of GDP per capita across countries, independent of spending on education and research. In particular, this level may be due to factors of the neoclassical production function of the Cobb-Douglas type: labor and capital.

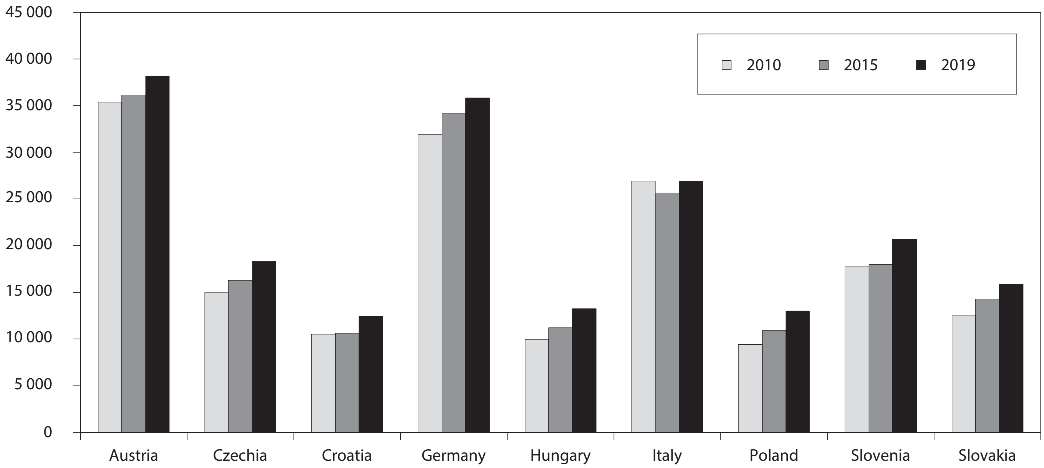
Smaller values are given by the FE model: 6.74 and 3.31 Euro, respectively. Constant (11 851.77) also characterizes the impact on economic growth of missed and unobservable variables (individual characteristics of countries that do not change over time).

Value of by R-squared criterion allows us to conclude that the variation of the factors (expenditure on R&D and education per capita) explains 93–94% of variations in the dynamics of GDP per capita.

This fact confirms our hypothesis that the main drivers of economic development in the medium term are human capital (which we approximated by Education expenditures) and innovative technologies (in our models, this factor is described by R&D expenditures).

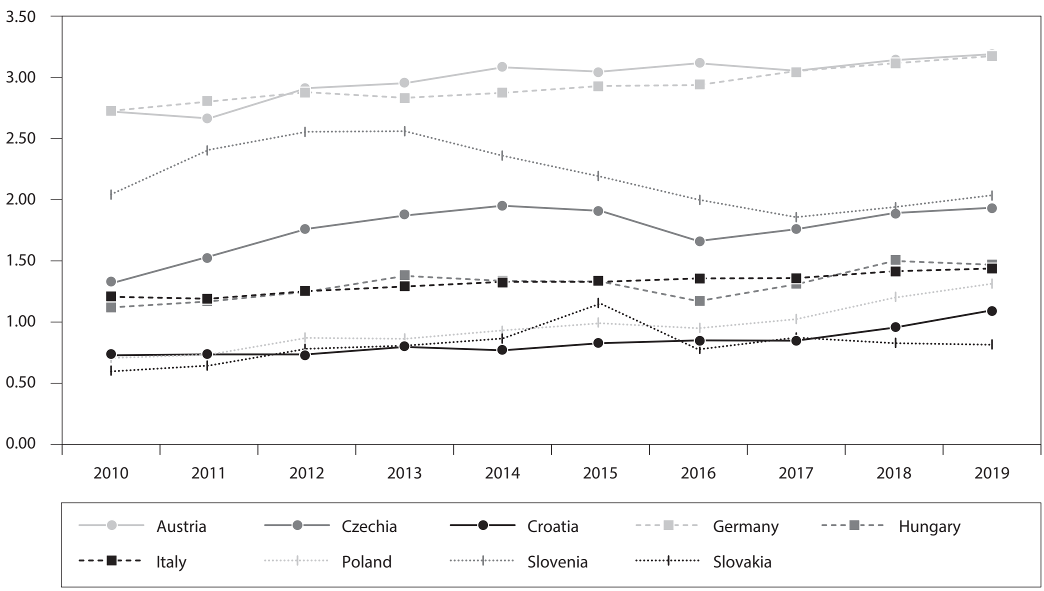
An additional analysis was also carried out for two clusters: for "old" EU members (Germany, Italy, and Austria – the 1st cluster) and countries that joined the EU after 2000 (the 2nd cluster). As we can

Figure 1 Real GDP per capita for selected counties in 2010, 2015, and 2019 (Euro)



Source: Authors calculations based on Eurostat (2021c)

Figure 2 Expenditure on R&D (% GDP)



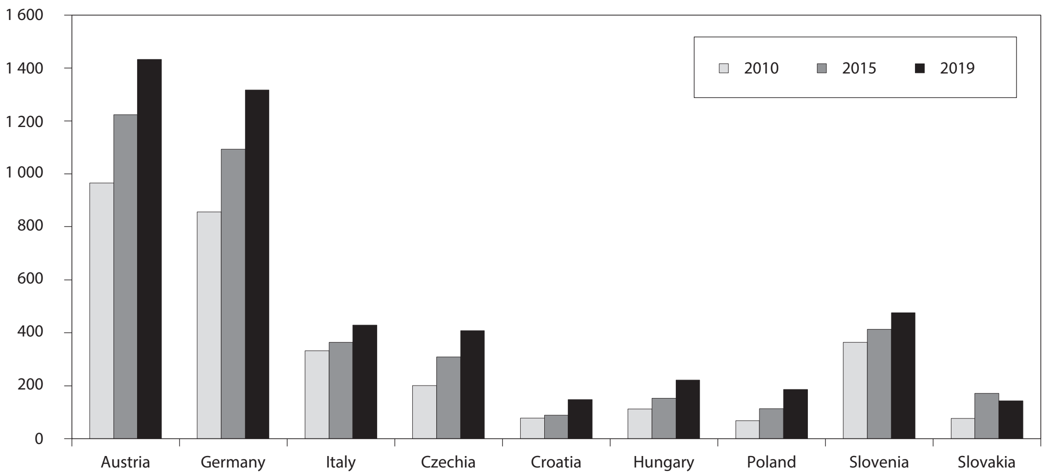
Source: Authors calculations based on Eurostat (2021b, 2021c) see (Figure 1), the old members of the EU both led in terms of living standards in 2010 and continue to outstrip other countries now.

At the same time, it can be noted that for Germany and Austria the living standards (in Euro per capita) is gradually increasing, for Italy it has remained at the same level for last 10 years. This may also be due to the fact that Italy spends much less on R&D in both absolute (% of GDP, Figure 2) and relative terms (Euro per capita, Figure 3).

As for the countries of the 2nd cluster, the greatest absolute increase in the living standard during the study period was observed in Slovenia and Czechia.

Moreover, in relative terms for R&D expenditures, Slovenia has already surpassed Italy, and Czechia has practically caught up with it.

Figure 3 Expenditure on R&D per capita in 2010, 2015, and 2019 (Euro)



Source: Authors calculations based on Eurostat (2021b)

With regard to spending on education, the situation is not so clear here. In absolute terms, the countries of the 1st cluster are not leaders, but at the same time they maintain high standards: about 4–5% of GDP (Figure 4). As to the countries of the 2nd cluster, then for the period under study, expenditures on education were within the same limits: at the level of 4–5% of GDP.

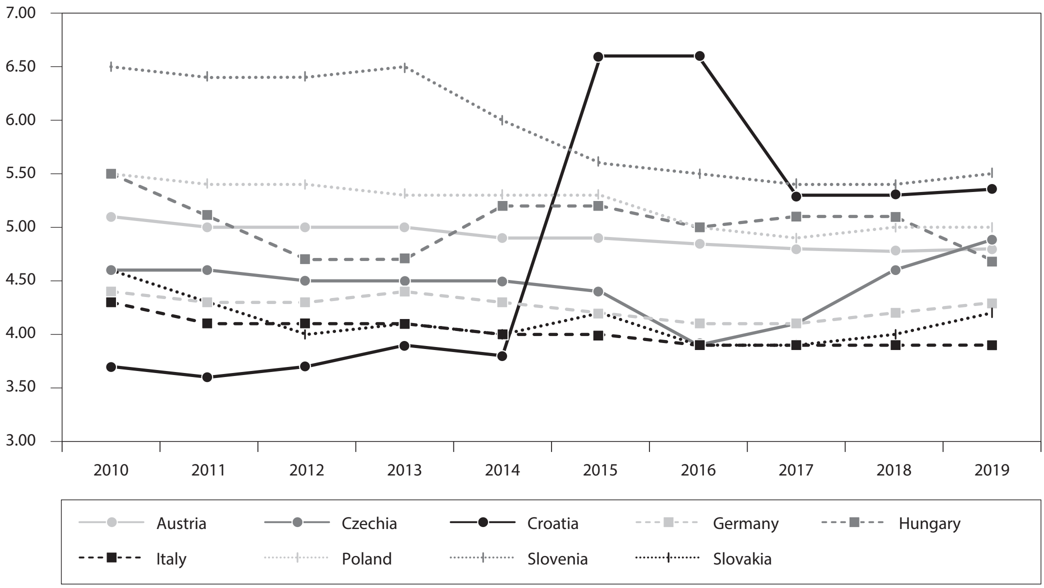
At the same time, unlike other countries, the data for Croatia are somewhat anomalous: in 2015–2016, spending on education was almost doubled (from 3.5 to 6.5%), and then decreased to 5.4% (Figure 4). But spending on education per capita in 2015 and 2019 was almost the same (Figure 3). At the same time, the standard of living (GDP per capita) during this period increased by 17% (1 800 Euros per capita). This fact requires additional analysis.

In relative terms, the situation is similar to R&D expenditure: Germany and Austria are the leaders during the selected period. And Slovenia by 2019 outstripped Italy in this indicator, and the Czechia came close to it (Figure 5).

These empirical facts allow us to make a preliminary conclusion that, all other things being equal, if the existing trends continue for 5 years, Slovenia will catch up with Italy in terms of living standards, and Czechia will come close to it.

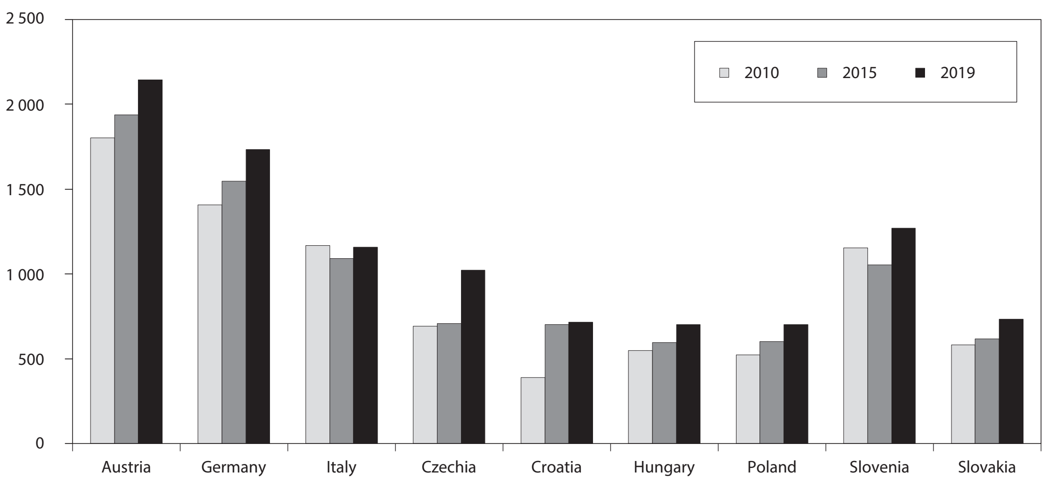
To test our hypotheses, we also performed panel data regression analyzes for selected clusters. Final results for model selection which based on the Hausman test are presented in the Annex (Table A14

Figure 4 Expenditure on education (% GDP)



Source: Authors calculations based on Eurostat (2021a, 2021c)

Figure 5 Expenditure on education per capita in 2010, 2015 and 2019 (Euro)



Source: Authors calculations based on Eurostat (2021a)

for the 1st cluster and Table A15 for the 2nd) and summarized estimations for panel data models for the 2nd cluster are shown in Table 4.

The results of the Hausman test do not allow for rejecting the main hypothesis about the presence of random effects for the 2nd cluster (Table A 15 in the Annex). However, the coefficients of models 1 and 2 are practically the same. Models are also adequate in terms of multiple determination R-squared.

Table 4 Summarized estimations for panel data models for the 2nd cluster

		Pooled regression model, PR	Between	Fixed effect (within), FE	Random Effect, RE
R&D	X1	17.27	19.63	15.25	15.36
Education	X2	3.04	1.61	4.11	4.07
Constant		8 051.50	8 575.29	7 707.08	7 710.37
R2		0.82			
R2-within			0.64	0.64	0.64
R2-between			0.85	0.85	0.85
R2-overall			0.82	0.82	0.82

Source: Authors calculations by using STATA software

For both specification (FE and RE) one can see that the importance (elasticity) of the research expenditure factor (X_1) has increased significantly: for FE almost 5 times (from 3.31 to 15.25). At the same time, the significance of the factor of spending on education has slightly decreased (from 6.74 to 4.11 for FE specification).

From our point of view, this can be explained by the fact that in terms of education expenditures, the countries of the 2nd cluster in relative terms are not so far behind the leaders.

Thus, the results of our modeling show that for the countries of the 2nd cluster (which became EU members after 2 000), an additional 1 Euro (per capita) invested in research brings an effect of 15 Euro (per capita), and 1 Euro invested in education brings an effect of 4 Euro (per capita).

The analysis shows that among the selected countries the most positive dynamics are shown by Slovenia and Czechia.

4 DISCUSSION

Public spending on education and R&D in the context of economic growth is an important aspect of government policy, and in Central Europe this issue is also discussed by scholars who study spending, impact factors, households' response, and so on.

Note that in our research, as a strong argument was used economic and mathematical methods, based on econometrics framework using real Eurostat data

Evaluating the impact of educational changes in primary, secondary and higher education using the following decomposition on the effects of level and substitution between 2005 and 2017 in Hungary, Poland, Slovakia, and Czechia (Fischer et al., 2020) identified the effect of differences in education structure of households whose incomes significantly affect economic growth.

However, there are other studies (Delgado et al., 2014) where using nonparametric local-linear regression estimation and test for the relevance of nonparametric transformations to conduct a nationwide and systematic search for the significance of average learning duration while studying the most complete databases on education, it was found that the average duration of schooling is not a statistically significant variable in economic growth regression.

At the same time, empirical studies often show that the scope and importance of training depends on the choice of observations or model specifications.

Earlier it was hypothesized that education has a greater effect in those countries where economic change is faster. Its examination in a wider set of 32 countries (Hanushek et al., 2015) found that the range of differences in skill levels in different countries is even greater than previously thought.

The main observed pattern was economic growth, which corresponds to the ability of skilled workers to adapt more easily to economic change. This refined hypothesis, of course, is subject to questions of causality, but taking into account a number of alternative effects does not change the general trend.

Several studies have identified the link between education, research and innovation, and substantiated the positive impact on the economy (Power, 2015; WEF, 2016–2017; Grant, 2017; Rundle, 2021), but in practice governments in some countries will send different amounts funding for these public goods depending on the defined state policy.

Our study presents examples of different levels of funding for education and research in nine Central European countries where, in general, the relationship between these government expenditures and the level of GDP in the compared units of measurement is confirmed (Figure 1, Figure 5).

Sometimes research focuses on situations in which investment in education and human capital development affects the economic growth of middle-income countries. The problem is that the return on accumulated physical capital is declining, and the rate of productivity growth and technological innovation depend to a large extent on skilled human capital.

Therefore, no matter what policy options a country chooses, it still faces the challenge of implementing them because over time they have different opportunities than those that originally led them to middle-income status (Larson et al., 2016).

The calculations of the experts of the International organizations convince of the importance of acquiring the appropriate level of education in school, which is vital for reducing the level of unemployment, inequality and poverty and promoting growth. Thus, for every US dollar spent on education, there can be 10 to 15 US dollars of economic growth.

Also, if 75% of 15-year-olds in the world's 46 poorest countries could reach the lowest level in mathematics in OECD countries, economic growth would increase by 2.1% from baseline, and 104 million people could be brought out of extreme poverty (UNESCO, 2012).

At the same time, according to our calculations for Central European countries, the additional costs of education on average have almost twice the effect of economic growth than the costs of R&D. Thus, according to the RE model, each additional Euro invested in education leads to an increase in GDP per capita of 7.5 Euros, and each Euro invested in R&D leads to an increase of 4.23 Euros. Fewer values are given by the FE model: 6.74 and 3.31 Euros, respectively, due to different model specifications.

Comparing the views of experts from international organizations and scientists highlighted different approaches to the role and importance of public spending on education in R&D in ensuring economic growth. These differences are due to the objectives of the study, the applied scientific apparatus, in particular analytical, the amount of data analyzed, and so on.

CONCLUSION

Ensuring dynamic economic growth is an important societal challenge in any country. That is why governments use certain expenditures, in particular on education and R&D, as important levers to achieve this goal. Achieving the highest possible rate of economic development is especially important for EU countries, where living standards in most countries are quite high compared to other regions of the world and governments are constantly trying to prevent its decline.

In this context, scientists are involved in solving this problem. They publish relevant scientific developments that analyze the situation with the dynamics of economic growth, the factors influencing these processes, propose levers, forms, methods that should promote the GDP growth and increase incomes with the solution of related life problems.

Our study confirmed the importance of investing in these expenditures, as education provides from 6.7 to 7.5 Euros, and R&D – from 3.3 to 4.3 Euros of growth (GDP per capita). At the same time, despite compelling arguments, not all of the nine countries identified are following the growing dynamics of these costs.

Thus, during 2010–2019, in the "old" EU members, expenditures on education in absolute terms increased the most in Germany – 31.3%, and among the "new" – in Croatia 64.6%. R&D is given more importance, and in the "old" EU member states these expenditures increased the most in Austria – 1.57 times, and in the "new" ones in Poland – 2.64 times. These data confirm the existence of different government approaches in policy-making with respect to the priority of the use of certain levers of economic growth.

It should also be noted that the "Europe 2030 Strategy" emphasizes the importance of the role of education, science, technology, research and innovation in ensuring the sustainable development of the European Union and recommends that national governments take action to improve the living standards of citizens.

The study compares the approaches of scientists to the role and importance of the impact of public spending on education and R&D in Central Europe. It is revealed that various approaches are used to perform the research by scientists from different countries, which include algorithms, research methods, mathematical apparatus, economic theories, a set of statistical data.

The analysis of scientific achievements revealed some relevant aspects – the importance of obtaining quality knowledge in schools and universities, the positive increase in the number of young people covered by training in relevant institutions at the pace of development, employment prospects after graduation, levers of economic growth, the feasibility of increasing education and R&D.

Despite the postulates of economic theory on the importance of these expenditures on the dynamics of economic growth revealed, only their absolute increase will not lead to simultaneous GDP growth, because it is necessary to take into account the quality of education, long-term economic growth programs, and initiative in the government policy.

The peculiarity of this study is that, despite the diversity of scientific research on this issue, the relationship between such expenditures as education and R&D in the context of the overall impact on GDP is insufficiently covered. Based on the results of the correlation analysis, two models were formed, which made it possible to identify the significance of the impact of these expenditures on GDP separately for the "old" and "new" EU members.

The use of the obtained results will help to guide the governments of Central European countries in the formation of public policies, given that the study was performed with appropriate scientific justification. In addition, in the process of making government decisions to increase GDP, it is advisable to adjust them with other levers of influence.

As for the direction of further research, it seems promising to us to test other classes of econometric models, which allows incorporate time lag effect between factors and target variable. In particular, there are Vector Autoregressive Models (VAR) and Models with Distributed Lags (DLM).

VARs take into account the fact that, on the one hand, innovations stimulate economic growth, and on the other hand, funding for innovation and R&D depends on GDP. This creates a multiplier effect.

DLM have such advantage that they take into account the presence of a time lag between economic growth and an increase in labor productivity and competitiveness due to an improvement in the quality of human capital and the level of technology.

It also seems promising to test a longer time period to obtain more reliable estimates of the model parameters. In this case, however, it is necessary to conduct additional research on the statistical properties of the model factors. It is need to define whether the time series before 2008 describe the same statistical process, or after 2008 there have been significant structural changes that do not allow considering the dynamics of economic growth in different sub-periods as a single process.

Moreover, it would be advisable to expand the set of explanatory variables that characterize the contribution of human capital and innovations to economic growth.

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ANNEX

Table A1 Real GDP (million Euro), National accounts indicator (ESA 2010)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	295 896.6	310 128.7	318 653.0	323 910.2	333 146.1	344 269.2	357 608.0	369 341.3	385 361.9	397 575.3
Czechia	157 920.8	165 202.2	162 587.5	159 461.5	157 821.3	169 558.2	177 438.5	194 132.9	210 927.8	223 950.3
Croatia	45 195.1	44 924.6	44 007.9	43 806.3	43 398.6	44 612.0	46 619.3	49 238.5	51 950.1	54 237.9
Germany	2 564 400.0	2 693 560.0	2 745 310.0	2 811 350.0	2 927 430.0	3 026 180.0	3 134 740.0	3 259 860.0	3 356 410.0	3 449 050.0
Hungary	99 576.3	102 020.6	99 984.0	102 034.3	106 061.3	112 701.0	116 129.8	126 891.0	135 931.0	146 061.8
Italy	1 611 279.4	1 648 755	1 624 358.7	1 612 751.3	1 627 405.6	1 655 355.0	1 695 786	1 736 593	1 771 063	1 789 747.0
Poland	362 190.9	379 860.0	387 947.0	392 310.7	408 967.8	430 465.8	427 091.8	467 426.6	497 842.3	532 329.2
Slovenia	36 363.9	37 058.6	36 253.3	36 454.3	37 634.3	38 852.6	40 443.2	43 009.1	45 862.6	48 392.6
Slovakia	68 188.7	71 304.5	73 575.8	74 448.8	76 269.8	79 767.6	81 051.5	84 532.2	89 505.5	93 865.2

Source: Eurostat (2021a), <*https://appsso.eurostat.ec.europa.eu/nui/show.do*>

Table A2 Population on 1 January (persons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	8 375 164	8408121	8 451 860	8 507 786	8 584 926	8 700 471	8 772 865	8 822 267	8 858 775	8 901 064
Czechia	10 486 731	10505445	10 516 125	10 512 419	10 538 275	10 553 843	10 578 820	10 610 055	10 649 800	10 693 939
Croatia	4 289 857	4275984	4 262 140	4 246 809	4 225 316	4 190 669	4 154 213	4 105 493	4 076 246	4 058 165
Germany	80 222 065	80327900	80 523 746	80 767 463	81 19 7537	82 175 684	82 521 653	82 792 351	83 019 213	83 166 711
Hungary	9 985 722	9931925	9 908 798	9 877 365	9 855 571	9 830 485	9 797 561	9 778 371	9 772 756	9 769 526
Italy	59 364 690	59394207	59 685 227	60 782 668	60 795 612	60 665 551	60 589 445	60 483 973	60 359 546	60 244 639
Poland	38 062 718	38063792	38 062 535	38 017 856	38 005 614	37 967 209	37 972 964	37 976 687	37 972 812	37 958 138
Slovenia	2 050 189	2055496	2 058 821	2 061 085	2 062 874	2 064 188	2 065 895	2 066 880	2 080 908	2 095 861
Slovakia	5 392 446	5404322	5 410 836	5 415 949	5 421 349	5 426 252	5 435 343	5 443 120	5 450 421	5 457 873

Source: Eurostat (2021), <*https://ec.europa.eu/eurostat/databrowser/view/tps00001/default/table?lang=en*>

Table A3 Real GDP per capita (Euro)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	35 390	36 300	36 390	36 180	36 130	36 140	36 390	37 030	37 800	38 170
Czechia	15 020	15 310	15 170	15 160	15 480	16 290	16 670	17 490	17 990	18 330
Croatia	10 520	10 530	10 310	10300	10 310	10 630	11 100	11 600	12 040	12 450
Germany	31 940	33 200	33 280	33 330	33 920	34 130	34 610	35 380	35 720	35 840
Hungary	9 960	10 180	10 090	10 310	10 770	11 210	11 480	12 010	12 680	13 260
Italy	26 930	27 020	26 090	25 480	25 420	25 640	26 020	26 490	26 780	26 920
Poland	9 400	9 850	9 980	10 100	10 440	10 890	11 240	11 790	12 420	13 000
Slovenia	17 750	17 870	17 360	17 160	17 620	17 990	18 550	19 430	20 220	20 700
Slovakia	12 560	12 990	13 220	13 290	13 630	14 270	14 550	14 980	15 520	15 860

Source: Eurostat (2021c), <*https://appsso.eurostat.ec.europa.eu/nui/show.do*>

Table A4 Total expenditure on education (million Euro)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	15 090.7	15 506.4	15 932.6	16 195.5	16 324.2	16 869.2	17 322.7	17 728.3	18 401.3	19 083.6
Czechia	7 264.4	7 599.3	7 316.4	7 175.8	7 102.0	7 460.6	6 920.1	7 959.4	9 702.7	10 937.6
Croatia	1 672.2	1 617.3	1 628.3	1 708.4	1 649.1	2 944.4	3 076.8	2 609.6	2 753.3	2 904.4
Germany	112 833.6	115 823.1	118 048.3	123 694.4	125 879.5	127 099.6	128 524.3	133 654.3	140 969.2	148 180.2
Hungary	5 476.7	5 203.0	4 699.2	4 795.6	5 515.2	5 860.5	5 806.5	6 471.4	6 932.5	6 855.5
Italy	69 285.0	67 599.0	66 599.0	66 122.2	65 096.2	66 214.2	66 135.7	67 727.1	69 071.5	69 800.0
Poland	19 920.5	20 512.4	20 949.1	20 792.5	21 675.3	22 814.7	21 354.6	22 903.9	24 892.1	26 619.6
Slovenia	2 363.6	2 371.7	2 320.3	2 369.5	2 258.0	2 175.7	2 224.4	2 322.5	2 476.6	2 661.6
Slovakia	3 136.7	3 066	2 943	3 052.4	3 050.1	3 350.2	3 161.0	3 296.8	3 580.2	3 942.3

Source: Eurostat (2021a)

Table A5 Education expenditure (Euro per capita)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	1 801.8	1 844.2	1 885	1 903.6	1 901.5	1 938.8	1 974.5	2 009.5	2 077.2	2 144
Czechia	692.7	723.4	694.7	682.6	673.9	706.9	654.6	750.2	911.1	1 022.8
Croatia	389.8	379.5	382.0	402.2	390.3	702.6	740.6	635.6	675.4	715.6
Germany	1 406.5	1 441.9	1 466.0	1 531.5	1 550.3	1 546.7	1 557.5	1 614.3	1 698	1 733.6
Hungary	548.5	523.9	474.2	485.5	559.6	594.6	592.6	661.8	709.4	701.7
Italy	1 167.1	1 138.1	1 115.8	1 087.8	1 070.7	1 091.4	1 091.5	1 117.9	1 144.3	1 158.6
Poland	523.3	538.9	550.4	546.8	570.3	600.9	562.4	603.1	655.2	701.2
Slovenia	1 152.9	1 153.8	1 127.0	1 149.6	1 094.6	1 054.0	1 076.7	1 123.7	1 190.2	1 269.9
Slovakia	581.7	567.3	543.9	563.6	562.6	617.4	581.6	604.9	656.9	733.3

Source: Authors calculations based on Eurostat data

Table A6 Internal expenditure on R&D (million Euro)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	8 066.4	8 276.3	9 287.8	9 571.3	10 275.2	10 499.1	11 145.0	11 289.8	12 110.2	12 688.8
Czechia	2 095.1	2 552.0	2 877.3	2 996.7	3 090.7	3 250.2	2 963.3	3 433.3	4 006.5	4 348.3
Croatia	335.1	336.4	330.0	354.7	339.9	374.8	402.4	423.5	501.8	600.8
Germany	70 014.2	75 569.1	79 110.4	79 729.5	84 246.8	88 781.8	92 173.6	99 553.6	104 669.0	109 544.4
Hungary	1 126.1	1 204.6	1 257.3	1 415.1	1 428.8	1 510.9	1 371.7	1 672.9	2 051.4	2 158.6
Italy	19 624.9	19 810.6	20 502.5	20 983.1	21 781.3	22 157.0	23 171.6	23 793.7	25 232.2	25 909.6
Poland	2 607.5	2 836.2	3 429.9	3 436.3	3 864.0	4 316.5	4 112.3	4 834.0	6018.5	7 046.9
Slovenia	745.9	894.2	928.3	935.0	890.2	853.1	812.0	802.3	892.7	989.3
Slovakia	416.4	468.4	585.2	610.9	669.6	927.3	640.8	749.0	750.9	776.6

Source: Authors calculations based on Eurostat data

Table A7 Internal expenditure on R&D (Euro per capita)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	965.9	988.2	1 104.6	1 132.4	1 207.7	1 223	1 281	1 286.9	1 372.7	1 432.3
Czechia	200.3	243.4	273.9	285.0	294.0	308.4	280.8	324.5	377.6	408.3
Croatia	77.9	78.4	77.2	83.2	80.0	88.7	96.0	101.9	122.2	147.4
Germany	855.9	942.0	984.8	990.1	1 043.1	1 093.4	1 121.7	1 206.4	1 264.2	1 316.8
Hungary	112.4	120.6	126.6	142.8	144.7	153.3	139.5	170.8	209.8	220.9
Italy	331.6	333.7	345.2	351.6	358.3	364.5	382	392.7	417.2	429.3
Poland	68.6	74.5	90.1	90.3	101.6	113.6	108.3	127.3	158.5	185.6
Slovenia	364.4	436.2	451.6	454.1	431.9	413.5	393.4	388.4	431.9	475.4
Slovakia	77.2	86.9	108.3	112.9	123.6	171.0	118.1	137.8	138.0	142.5

Source: Eurostat (2021c), <*https://appsso.eurostat.ec.europa.eu/nui/show.do*>

Table A8 Pooled Regression Model estimates

```
. * Pooled OLS estimator

.
. reg $ylist $xlist

      Source |       SS           df       MS      Number of obs   =        90
-------------+----------------------------------   F(2, 87)        =    546.89
       Model |  7.5623e+09         2  3.7811e+09   Prob > F        =    0.0000
    Residual |   601505049        87  6913851.14   R-squared       =    0.9263
-------------+----------------------------------   Adj R-squared   =    0.9246
       Total |  8.1638e+09        89  91728049.2   Root MSE        =    2629.4

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          X1 |    7.12156   2.418518     2.94   0.004     2.314494    11.92863
          X2 |   13.23238   2.032005     6.51   0.000     9.193551    17.27121
       _cons |   3853.903   1076.697     3.58   0.001     1713.851    5993.955
------------------------------------------------------------------------------
```

Source: Authors' calculations by using STATA

Table A9 Between Regression Model estimates

```
Between regression (regression on group means)  Number of obs     =         90
Group variable: id                              Number of groups  =          9

R-sq:                                           Obs per group:
     within  = 0.6090                                         min =         10
     between = 0.9376                                         avg =       10.0
     overall = 0.9262                                         max =         10

                                                F(2,6)            =      45.05
sd(u_i + avg(e_i.))=  2897.838                  Prob > F          =     0.0002

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          X1 |     6.4787   9.777829     0.66   0.532    -17.44679    30.40419
          X2 |   14.07058   8.220808     1.71   0.138    -6.045009    34.18618
       _cons |   3307.643   4244.991     0.78   0.465    -7079.475    13694.76
------------------------------------------------------------------------------
```

Source: Authors' calculations by using STATA

Table A10 Fixed Effects Regression Model estimates

```
Fixed-effects (within) regression               Number of obs     =         90
Group variable: id                              Number of groups  =          9

R-sq:                                           Obs per group:
     within  = 0.6091                                         min =         10
     between = 0.9376                                         avg =       10.0
     overall = 0.9263                                         max =         10

                                                F(2,79)           =      61.55
corr(u_i, Xb)  = 0.8791                         Prob > F          =     0.0000
```

Y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	3.308877	1.334922	2.48	0.015	.6517805	5.965974
X2	6.742611	1.100305	6.13	0.000	4.552509	8.932713
_cons	11851.77	803.4874	14.75	0.000	10252.47	13451.07
sigma_u	5576.6761					
sigma_e	681.79508					
rho	.98527303	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(8, 79) = 151.87                     Prob > F = 0.0000
```

Source: Authors' calculations by using STATA

Table A11 Random Effects Regression Model estimates

```
Random-effects GLS regression                   Number of obs     =         90
Group variable: id                              Number of groups  =          9

R-sq:                                           Obs per group:
     within  = 0.6087                                         min =         10
     between = 0.9375                                         avg =       10.0
     overall = 0.9263                                         max =         10

                                                Wald chi2(2)      =     160.03
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000
theta          = .92559883
```

Y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1	4.234197	1.437408	2.95	0.003	1.41693	7.051464
X2	7.496329	1.187942	6.31	0.000	5.168007	9.824652
_cons	10716.04	1348.892	7.94	0.000	8072.257	13359.82
sigma_u	2889.8064					
sigma_e	681.79508					
rho	.94727158	(fraction of variance due to u_i)				

Source: Authors' calculations by using STATA

Table A12 Breusch and Pagan test results

```
Breusch and Pagan Lagrangian multiplier test for random effects

        Y[id,t] = Xb + u[id] + e[id,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                       Y |   9.17e+07       9577.476
                       e |   464844.5       681.7951
                       u |    8350981       2889.806

        Test:   Var(u) = 0
                             chibar2(01) =   274.96
                          Prob > chibar2 =   0.0000
```

Source: Authors' calculations by using STATA

Table A13 Hausman test results

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
          X1 |    3.308877     4.234197       -.9253197                .
          X2 |    6.742611     7.496329       -.7537182                .
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =  -138.87    chi2<0 ==> model fitted on these
                                        data fails to meet the asymptotic
                                        assumptions of the Hausman test;
                                        see suest for a generalized test
```

Source: Authors' calculations by using STATA

Table A14 Hausman test results for the 1st cluster

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
          X1 |    3.308877     4.234197       -.9253197               .
          X2 |    6.742611     7.496329       -.7537182               .
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =  -138.87    chi2<0 ==> model fitted on these
                                        data fails to meet the asymptotic
                                        assumptions of the Hausman test;
                                        see suest for a generalized test
```

Source: Authors' calculations by using STATA

Table A15 Hausman test results for the 2nd cluster

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
          X1 |    15.25227     15.36214       -.1098746        1.256156
          X2 |    4.111231     4.074996        .0362358        .2873838
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.02
                Prob>chi2 =      0.9916
```

Source: Authors' calculations by using STATA