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Some Remarks on the Report "Science and Higher Education vs. GDP" Prepared at the Initiative of the Conference of Rectors of Polish Economic Universities: An Analysis of the Convergence Processes in Selected Central and Eastern European Countries

Abstract

Objectives: This paper summarises the findings of a report by Acedański et al. (2023) that focuses on the relationship between science and economic growth. The report was commissioned by the Conference of Rectors of Economic Universities (KRUE) and prepared by researchers from five public economic universities in Poland. The authors of the report and the KRUE aim to share their message with a wide audience that includes policymakers, academic experts, and students. Additionally, the article analyses the impact of research and higher education spending on convergence processes in Central and Eastern European countries.

Research Design & Methods: The study examined different indicators, including government expenditure on basic research, higher education, and research and development. We utilised SURE models and observed that there was notable diversity in the convergence processes among the analysed countries. Additionally, we found a correlation between research spending and the rate of catching up. However, it is important to note that this relationship is not universal and varies across countries, even those within the same region.

Findings: Acedański et al. (2023) report quantifies the relationship between science, higher education, GDP, and economic development in Poland. The report states that science and higher education sectors positively impact local economies, and individuals with higher education contribute the most to human capital resources in the economy, leading to GDP growth. However, Poland has a funding gap in research and science compared to highly developed countries as well as many Central and Eastern European countries. The report suggests that investment in a country's education and higher education system is essential for generating developmental impulses and supporting its economy.

Implications / Recommendations: The impact of scientific activity depends heavily on funding, especially through higher education institutions. In Poland, the salaries of academic teachers have decreased compared to other professions, and their position in the wage distribution is the worst it has been in the past two decades. Investing in a country's education and higher education system is essential to support the economy. Acedański et al. (2023) suggest that a 0.1 percentage point increase in research and development expenditure, as a percentage of GDP, can lead to a 0.8 to 1.3 percentage point increase in GDP growth. However, the conclusion was based on panel data from EU countries, and the impact of scientific research on GDP may differ when analysing Central and Eastern European (CEE) countries. In this paper, we also present an extended analysis of the impact of science and education on economic growth through the lens of convergence processes. We show that the relationship above is not straightforward and represents substantial variability across countries, even those of the same region.

Contribution / Value Added: Firstly, the report by Acedański et al. (2023) emphasises the importance of the science and higher education sector for economic growth. Their empirical research helps quantify the relationship between science, higher education, GDP, and economic development, offering a deeper understanding of this connection.

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The report complements previously published analyses and research on the topic. Secondly, our regional research shows that the convergence processes vary greatly among the analysed countries. The inclusion of spending on science, research, or higher education in the convergence equations has a varied impact on the assessment of the pace of the catching-up processes in the CEE region.

Keywords: R&D expenditures, government expenditures on science, convergence processes, SURE

JEL: O47, H5

Introduction

The paper aims to achieve two objectives. Firstly, it summarises the findings of the report by Acedański et al. (2023) that focuses on the role of science in economic development and growth processes. The Acedański et al. (2023) report was commissioned by the Conference of Rectors of Economic Universities. It was prepared by a team of researchers from five public economic universities in Poland, including the Katowice University of Economics, the Cracow University of Economics, the Poznan University of Economics, the Wroclaw University of Economics, and the Warsaw School of Economics. The report’s authors and the Conference of Rectors of Economic Universities aim to disseminate their message to a broad audience, including policymakers, academic experts, and students. Secondly, the article provides an in-depth analysis of the impact of research and higher education spending on real convergence processes in Central and Eastern European countries. This aspect of the analysis was also discussed in Acedański et al. (2023) and represents the author’s contribution to the report.

The article is structured as follows. The second chapter presents the main objectives and results of the report by Acedański et al. (2023). The third chapter discusses the concept of real convergence and proposes an approach to incorporating research and higher education expenditures in catch-up processes. The fourth chapter is dedicated to the discussion of empirical results. The final chapter contains concluding remarks.

Chapter 2 is a compilation of the findings presented in the executive summary of the report by Acedański et al. (2023). Chapters 3 and 4 constitute an expanded version of section 3.3 of the report (pp. 58–62).

Objectives and key findings in the report “Science and Higher Education Impact on GDP”

The aim of the report by Acedański et al. (2023) was to determine the role played by the science and higher education sector in the GDP changes. The analyses presented in the report focused mainly on funding scientific research activities in universities that use public funds, using a macroeconomic empirical approach. The idea that technological progress, science, and human capital play a significant role in economic growth and development is often repeated as a common belief in public discussions. Yet, it is not always grounded in empirical evidence. However, due to strict budget constraints, the science and higher education sector often loses out in competition with other political priorities in many countries. The authors intend to remind us of the importance of the science and higher education sector in economic growth and development, as well as to present the results of empirical research conducted for this study.

Recently, numerous reports have been published in Poland regarding the significance of science and higher education. These reports often highlight institutional issues that are important for the current situation of Polish universities and compare scientific activities through bibliometric and scientometric indicators. However, the report by Acedański et al. (2023) stands out, because it attempts to quantify the relationship between science, higher education, GDP, and economic development. This approach provides an opportunity for a deeper understanding of the connection between science and higher education as well as economic growth and development. The authors’ report is intended to complement previously published analyses and research. Below, we briefly summarise the main conclusions drawn from the analyses.

In the past, economic growth in Central and Eastern European countries, including Poland, was not based on technological progress or scientific activity. The factors contributing to growth, such as catch-up effects and domestic market expansion, have been exhausted. Therefore, new growth engines need to be found.

The science and higher education sectors in Poland have positively impacted local economies. Cities with significant academic centres have grown up to 30% faster than a similar control group. Additionally, an increase of one percentage point in the student population of a district has been associated with a per capita GDP increase of 2,000 to 4,000 currency units in major academic centres.

Individuals with higher education contribute the most to human capital resources in the economy, leading to GDP growth. They are more likely to seek additional skills and competencies through education and training, which helps them find employment more quickly, have lower unemployment rates, and work longer throughout their careers. They also have a higher quality of life, are generally healthier, and live longer. In Poland, individuals with higher education have nearly a fourfold greater chance of receiving a good or very good health assessment and 2.5-3 times greater chances of a life without functional limitations than those with lower education.

The impact of scientific activity is strongly dependent on science funding, especially through higher education institutions. However, Poland has a funding gap in research and science compared to highly developed countries and many Central and Eastern European countries. Academic teachers' salaries in Poland have declined relative to other professions, and their relative position in the wage distribution is the worst over the last two decades.

Investment in a country's education and higher education system is essential for generating developmental impulses and supporting its economy. Research suggests that increasing scientific studies and development expenditures can lead to higher GDP growth. Every 0.1 percentage point increase in research and development expenditure as a percentage of GDP leads to a 0.8 to 1.3 percentage point increase in GDP growth. Investing one currency unit in scientific research can potentially lead to an increase of eight to thirteen currency units in GDP. However, this conclusion was based on the analyses of panel data from all European Union countries, and the impact of scientific research on GDP may vary among Central and Eastern European countries. In the next section, we present an extended analysis of the impact of science and education on economic growth through the lenses of convergence processes. We show that this relationship is not so obvious and represents substantial variability across countries of even the same region.

Real convergence and expenditure on science – the econometric approach within the SURE model

In this section, we utilise the Seemingly Unrelated Regression Equations (SURE) system as our research tool. The model, elaborated by Arnold Zellner (1962), offers a significant advantage in determining the level of convergence within a group of countries without assuming that the pace of "catching up" is uniform across all economies under study. The literature on empirical analyses aimed at verifying the hypothesis of real convergence traditionally relies on panel regression tools, assuming a similarity among the studied countries. However, SURE models enable us to depart from this assumption and investigate the country diversity of the convergence effect. As a result, the SURE regression system allows research in cases of significant heterogeneity in the convergence effect, which cannot be captured within standard econometric proposals.

This approach has been explored in studies by Pipień and Roszkowska (2019), Jarco and Pipień (2020), and Adamczyk and Pipień (2022). Our study aims to provide empirical evidence on how the impact of expenditures on science, research, or higher education on the catching-up processes may differ within a group of countries representing one region.

Barro and Sala-i-Martin (1992), who developed a theoretical model, put forth the idea of a convergence effect. Their construct representing the neoclassical school generalised the standard Solow and Swan growth model while staying within the orbit of the Ramsey, Koopmans, and Cass proposition. The authors demonstrated that economies significantly below their steady state tend to experience stronger growth fluctuations. Concurrently, Mankiw et al. (1992) also conducted analyses based on the convergence hypothesis. Barro and Sala-i-Martin’s (1992) work (1992) presented a theoretical result subject to empirical verification for several decades using various econometric approaches. The presence of the convergence effect for a single economy is tested using a linear regression equation.

$$\Delta ln\left(y_t\right) = \alpha_0 + \sum_{i=1}^{M} \alpha_i z_{it} + \beta ln\left(y_{t-1}\right) + \varepsilon_t, t = 1,\ldots,T \tag{1}$$

where: y_t represents the labour productivity index in year t (i.e. GDP per capita according to purchasing power parity), is the additional model variables influencing labour productivity in the steady state, α_i are parameters determining the impact of the analysed determinants on the growth dynamics $\Delta ln(y_t)$, and β is the parameter determining the convergence rate. In the case of convergence, the parameter β takes a negative value, and its absolute value indicates the pace of “catching up” of the analysed economy.

Sala-i-Martin (1997) conducted a detailed analysis of the factors affecting variations in labour productivity across different countries. Pipień and Roszkowska (2019) have identified the most appropriate variables that reflect the characteristics of the Central and Eastern European region. These variables include the investment rate, government expenditure as a percentage of GDP, the inflation rate, and the square of the inflation rate. The convergence equation developed by Pipień and Roszkowska (2019) takes into account these variables and is expressed as follows:

$$\Delta ln\left(y_t\right) = \alpha_0 + \alpha_1\left(\frac{G_t}{Y_t}\right) + \alpha_2\pi_t + \alpha_3\pi_t^2 + \alpha_4 i_t + \alpha_5 t + \beta ln\left(y_{t-1}\right) + \varepsilon_t, t = 1,\ldots,T \tag{2}$$

where $\alpha_0,\alpha_1,\ldots,\alpha_5$ are regression parameters, and G_t represents the government expenditure level in period t, Y_t is the GDP in period t, π_t is the year-on-year inflation rate, and i_t is the investment rate in period t. Equation (2) also includes a linear trend $\alpha_0 + \alpha_{5t}$, which approximately accounts for institutional changes or technological progress.

The objective of the research problem is to assess the extent to which spending on science, research, or higher education affects convergence processes. To this end, we introduce a new variable in equation (2) to represent such spending and label it ES.

ES: An indicator determining expenditures on science or higher education. (3)

After including the indicator, we obtain the convergence equation in the following form:

$$\Delta ln\left(y_t\right)=\alpha_0+\alpha_1\left(\frac{G_t}{Y_t}\right)+\alpha_2\pi_t+\alpha_3\pi_t^2+\alpha_4 i_t+\alpha_5 t+yES_t+\beta ln\left(y_{t-1}\right)+\varepsilon_t, t=1,\ldots,T \quad (4)$$

where parameter determines the strength of the impact of the value of the indicator (observed at time intervals *t*) on labour productivity.

To determine the impact of expenditure indicators on science, research or higher education, we will compare the estimated values of parameter for regression equations with and without the ES variable (Equations 2 and 4). If there is a statistical change in the inference about the parameter β, it would suggest that expenditures on science, research or higher education play a significant role in determining the pace of real convergence.

We will use panel data for selected CEE countries for the empirical study. To ensure sufficient data, we will require the number of time observations to be greater than the number of analysed countries, referred to as a "long panel". This approach will allow us to analyse the diversity of the convergence effect and the role of expenditures on science, research or higher education in these processes. The convergence equation for the *j*-th country will take the following form:

$$\Delta ln\left(y_{tj}\right)=\alpha_{0\mathrm{j}}+\alpha_{1j}\left(\frac{G_{tj}}{Y_{tj}}\right)+\alpha_{2j}\pi_{tj}+\alpha_{3j}\pi_{tj}^2+\alpha_{4j}i_{tj}+\alpha_{5j}t+y_j ES_{tj}+\beta_j ln\left(y_{t-1j}\right)+\varepsilon_{tj}, t=1,\ldots,T; \mathrm{j}=1,\ldots,n \quad (5)$$

Considering (5) jointly for $j = 1$, we obtain a system of convergence equations with individual parameters for the *n* countries under investigation. In particular, the system of equations (5) convergence processes are characterised by parameters $\beta_j (j = 1,\ldots,n)$, unique to each country. It is also possible to determine the degree of differentiation in the impact of expenditures on science in the convergence processes, due to the variation of the corresponding parameter across countries; y_j, $j = 1,\ldots,n$.

An important aspect to consider is the correlation of random components ε_t – appearing in the regression equations for individual countries, which determines whether the system of equations will be treated as independent or as a Seemingly Unrelated Regression Equations (SURE) model. The specification referred to as M0 is the case in which the random components are uncorrelated, leading to an independent system of regressions. In the M0 model, regression parameters can be estimated separately for each $j = 1,\ldots,n$. This corresponds to a modelling strategy where convergence processes are treated separately for each country.

Model M1 represents a structure allowing simultaneous correlation of the random components. The resulting system of regression equations is a Seemingly Unrelated Regression Equations (SURE) model (Zellner, 1962). The final model specification depends on the form of the variance-covariance matrix Σ, which, for countries, takes the form of an $[n \times n]$ matrix. In cases where $\sigma_{ii}^2 > 0$ and $\sigma_{ii}^2 = 0$, the Σ becomes a diagonal matrix, corresponding to the M0 model. On the other hand, when $\sigma_{ii}^2 > 0$ and $\sigma_{ii}^2 \neq 0$, it signifies the M1 model.

Just as formula (4) extends the convergence equation (2) with a variable representing expenditures on science, research, or higher education, formula (5) also extends the system of convergence equations with the expenditure indicator excluded:

$$\Delta ln\left(y_{tj}\right)=\alpha_{0j}+\alpha_{1j}\left(\frac{G_{tj}}{Y_{tj}}\right)+\alpha_{2j}\pi_{tj}+\alpha_{3j}\pi_{tj}^{2}+\alpha_{4j}i_{tj}+\alpha_{5j}t+\beta_{j}\,ln\left(y_{t-1j}\right)+\varepsilon_{tj},t=1,\ldots,T;j=1,\ldots,n \qquad (6)$$

The above-discussed research procedure enables the analysis of the convergence phenomenon independently of the prevailing approach in the literature, which is based on panel studies. In other words, the proposed solution aims to deviate from the contemporary paradigm dominant in cross-temporal studies by applying a more general model. This approach is exemplified in the works of Pipień and Roszkowska (2019), Jarco and Pipień (2020), and Adamczyk and Pipień (2022).

Empirical results

When conducting empirical analyses, we had to choose the indicators that determined expenditures on science, research, or higher education. Due to the issue’s complexity, we limited the analysis to a specific set of indicators. We had to ensure that the data was available for a long enough period and that we could analyse a group of countries. In this section, we will discuss the results of our parameter estimation for the convergence equation using data from a group of Central and Eastern European countries. These countries include the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia, and Slovenia. Adamczyk and Pipień (2022) also studied this group of countries in relation to the role of capital flows in convergence processes. Annual observations on all the necessary indicators for estimating the convergence equation cover 2004 to 2019.

The government’s expenditures on science, research, or higher education were evaluated based on five categories. The first category, denoted by BR, refers to government spending on basic research. The second category, TE, refers to government spending on tertiary education. The third category, RD, refers to government spending on research and development. These categories are expressed as a ratio to the GDP for a given year. Two additional categories were analysed, which do not directly reflect expenditures on science but describe research outcomes from a bibliometric perspective. Therefore, the fourth category, FWCI, is the citation index weighted by each discipline’s share. In contrast, the fifth, PAJQ, is the number of significant scientific publications per 100,000 citizens of a given country. Table 1 provides detailed information on the sources of the analysed indicators.

The results were obtained by estimating four models, namely two equations or two systems of convergence equations. In order to estimate the parameters determining the convergence rate in both specifications where no variable describes expenditures on research, science, or higher education, we followed formulae (2) and (6) in a stepwise process. We analysed the convergence equation (2), where constraints were imposed on the constancy of all parameters, including the parameter β, and the system of equations (6), where parameter variations across countries were allowed. The results of the estimation for the convergence parameter are presented in Table 2.

In the second step, we estimated the parameters of the convergence equation (4) and the system of equations (5). These equations include a variable representing the analysed expenditures on science, research, or higher education. We present the estimation results for the convergence parameters and the parameters related to expenditures on science, research, or higher education in Tables 3, 4, 5, 6, and 7. These tables use the TE, BR, R&D, FWCI, and PAJQ indicators.

Table 1. Analysed indicators for expenditures on science, research, and higher education

Indicator	Definition	Source
BR	Government expenditures on basic research	Eurostat, General government expenditure by function (COFOG) Sector: General government Classification of the functions of government (COFOG 1999): Basic research https://ec.europa.eu/eurostat/databrowser/product/page/GOV_10A_EXP__custom_4708189
TE	Government expenditures on higher education	Eurostat, General government expenditure by function (COFOG) Sector: General government Classification of the functions of government (COFOG 1999): Tertiary education https://ec.europa.eu/eurostat/databrowser/product/page/GOV_10A_EXP__custom_4708189
RD	Government expenditures on research and development	Eurostat/OECD Gross domestic expenditure on R&D (GERD) by sector of performance and fields of R&D Sector: Government Fields of research and development classification: Total https://ec.europa.eu/eurostat/databrowser/product/page/RD_E_GERDSC__custom_4948022
FWCI	Field-Weighted Citation Impact (excl. self-citations)	Scopus
PAJQ	Publications in all Journal Quartiles by SNIP per 100,000 inhabitants	Scopus

Table 2. The results of estimating the β parameter in the convergence equations (2) and (6), which do not include a variable describing spending on education, research, or higher education

	Equation (2)		SURE system (6)	
	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE	–0.1122*** (0.0183)	X	–0.5897*** (0.0023)	X
EST			–0.2121*** (0.0767)	X
HUN			–0.2921* (0.1649)	X
LTU			–0.3296*** (0.0755)	X
LVA			–0.4084*** (0.1200)	X
POL			–0.4335** (0.1649)	X
SVK			–0.2048* (0.1046)	X
SVN			–0.4553*** (0.1517)	X

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Table 3. The results of estimating the parameters β and γ of the convergence equations (4) and (5), including the TE indicator

	Equation (2)		SURE system (6)	
	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE	–0.1269*** (0.0188)	–0.0200** (0.00929)	–0.5831*** (0.1111)	–0.0817** (0.0380)
EST			–0.3295*** (0.0998)	0.0662 (0.0434)
HUN			–0.2568 (0.1870)	–0.0560 (0.2085)
LTU			–0.3489*** (0.1107)	0.00129 (0.0303)
LVA			–0.6298** (0.2084)	0.0747*** (0.0077)
POL			–0.3833* (0.2083)	–0.0336 (0.0471)
SVK			–0.4274*** (0.1307)	0.2843** (0.1094)
SVN			–0.7390*** (0.2010)	0.1359 (0.0997)

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Table 4. The results of estimating the parameters β and γ of the convergence equations (4) and (5), including the BR indicator

	Equation (2)		SURE system (6)	
	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE	–0.1106*** (0.0186)	–0.00062 (0.0137)	–0.5902*** (0.1249)	–0.0291 (0.0339)
EST			–0.2326** (0.0925)	–0.0182 (0.0578)
HUN			–0.3500** (0.1426)	0.2466** (0.0964)
LTU			–0.3573*** (0.0750)	–0.0425 (0.0466)
LVA			–0.5850*** (0.1425)	0.0765 (0.0470)
POL			–0.5217*** (0.1593)	–0.1968** (0.0876)
SVK			–0.1853 (0.1119)	–0.1402** (0.0599)
SVN			–0.5122*** (0.1714)	0.0407 (0.0976)

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Table 5. The results of estimating the parameters β and γ of the convergence equations (4) and (5), including the R&D indicator

	Equation (2)		**SURE system (6)**	
	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE			–0.7359*** (0.1189)	–0.1811 (0.1226)
EST			–0.1388 (0.1073)	–0.6808** (0.3104)
HUN			–0.3542* (0.1758)	1.1594** (0.5486)
LTU	–0.1061*** (0.0232)	–0.0142 (0.0322)	–0.3770*** (0.0817)	0.1286 (0.2230)
LVA			–0.8252*** (0.1683)	0.7510*** (0.2302)
POL			–0.6508*** (0.2262)	0.1047 (0.0807)
SVK			–0.1847 (0.1129)	–0.2093 (0.2627)
SVN			–0.7810*** (0.2589)	0.2912 (0.2465)

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Table 6. The results of estimating the parameters β and γ of the convergence equations (4) and (5), including the FWCI indicator

	Equation (2)		**SURE system (6)**	
	$\hat{\beta}$	ˆ	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE			–0.4793*** (0.1618)	–0.2584 (0.2445)
EST			–0.0833 (0.1356)	0.0161 (0.0423)
HUN			–0.7911*** (0.2260)	–0,4387*** (0,1467)
LTU	–0.1360*** (0.0269)	–0.0081 (0.0135)	–0.4308*** (0.0984)	–0.0756 (0.0589)
LVA			–0.4167 (0.3666)	–0.0015 (0.0760)
POL			–0.4426 (0.2253)	–0.4287 (0.2397)
SVK			–0.0885 (0.1230)	–0.2573 (0.1384)
SVN			–0.7852 (0.2259)	–0.0828 (0.0986)

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Table 7. The results of estimating the parameters β and γ of the convergence equations (4) and (5), including the PAJQ indicator

	Equation (2)		SURE system (6)	
	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\beta}_j$	$\hat{\gamma}_j$
CZE	–0.1253*** (0.0295)	–0.000052 (0.000077)	–1.1292 (0.3113)	–0.0027** (0.0013)
EST			–0.1165 (0.1174)	–0.00099 (0.0015)
HUN			–0.4727** (0.2274)	0.0060 (0.0044)
LTU			–0.4677*** (0.0923)	–0.0029 (0.0013)
LVA			–0.6128 (0.2343)	–0.0026 (0.0018)
POL			–1.1245 (0.2137)	–0.0088*** (0.0017)
SVK			–0.1446 (0.1540)	–0.0012 (0.0014)
SVN			–1.1559 (0.1924)	0.0035 (0.00089)

*, ** and *** denotes the statistical significance of estimation at levels of 0.1, 0.05, and 0.01, respectively.

Figure 1 depicts the effect of including the indicator for spending on science, research, or higher education on the inference about the convergence parameter β. Figure 2 visualises the direction and potency of the influence of variables associated with spending on science, research, etc., on the real convergence processes in the chosen group of countries.

The conclusions drawn from the results presented in Table 2 align with findings from previous studies. The β-convergence effect is not universal among the examined countries despite their shared geopolitical location, history, and economic and social similarities. This is strongly supported by the research of Pipień and Roszkowska (2019), Jarco and Pipień (2020), and Adamczyk and Pipień (2022). The methodology used to calculate the convergence rate of approximately 0.11 for the analysed countries highly depends on arbitrary assumptions about similarities in the studied economies. These assumptions serve as the starting point for panel regression analyses and can significantly influence the results obtained from model (2).

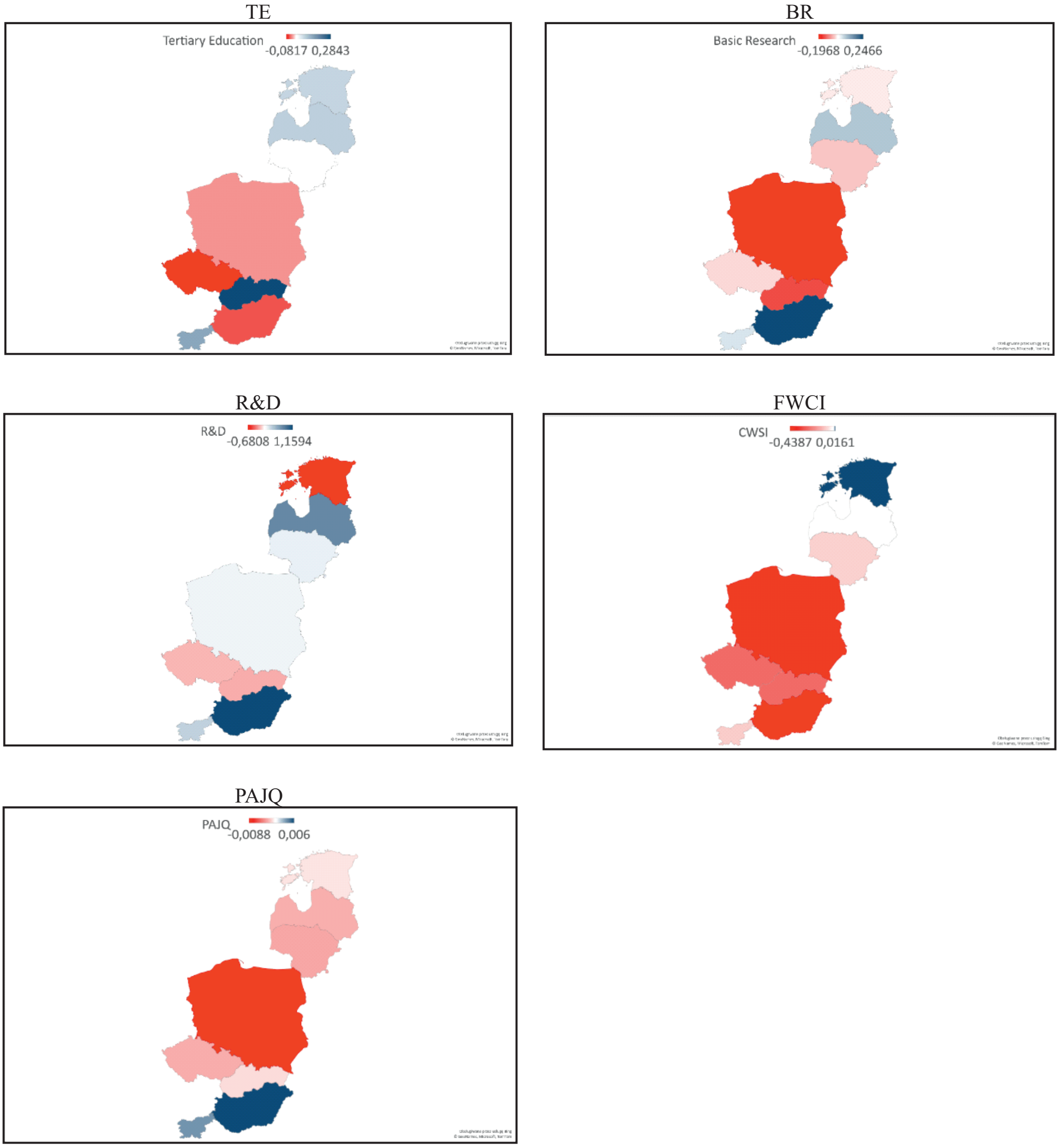
The results obtained from the Seemingly Unrelated Regression Equations (SURE) system indicate that the rate of convergence among the countries studied can vary considerably. Generally, the estimates it provides are higher than those obtained from panel regression. According to the estimated parameter β, the Czech Republic has the fastest catch-up rate, while Slovakia and Estonia have the slowest rates. The convergence effect for the Polish economy can be considered moderately high.

The effect of incorporating variables that describe spending on research, science, or higher education on the estimated catch-up rate is considerable. Still, it varies depending on the chosen metric and country. Figure 1 shows that introducing the R&D indicator into the system of convergence equations (5) results in the most diverse estimates of across countries, compared to the initial

Figure 1. Variability in the estimates of the convergence parameter obtained in all analysed SURE models

model (6) and the other two models with the BR and TE variables introduced, respectively. In the case of the model (5) with the R&D variable, the estimated catch-up effect is most strongly amplified in Latvia, Slovenia, the Czech Republic, and Poland. Estonia and Slovakia show a slower estimated catch-up rate than the results obtained from the other models. To some extent, a similar effect is observed for the model (5) with the TE indicator, but it is much less pronounced. Incorporating the BR indicator in the convergence model does not fundamentally change the obtained convergence parameter estimates. The analysis of the impact of the FWCI and PAJQ

Figure 2. The diversity of the impact of analysed expenditure indicators on science, research, or higher education in the selected group of countries. Results obtained from model (5)



indicators does not alter the above picture. An additional noteworthy effect is the insignificance of the parameters determining the relationship between growth and these measures of scientific sector outcomes. For the FWCI indicator, this effect is statistically significant for Hungary, while for the PAJQ indicator, it is significant for the Czech Republic and Poland.

The role of indicators that describe spending on research, science, or higher education in economic convergence processes is highly diverse. This is because the group of countries being studied is highly heterogeneous due to the sources of economic growth and the structure of public spending. Figure 2 shows the impact of each analysed indicator of spending on research, science, or higher education on the rate of labour productivity. Countries with a negative influence are marked in red shades, while blue shades represent a positive impact. It is important to note that negative relationships sometimes do not necessarily imply that increasing spending on science will slow down economic growth. These relationships are based on historical data and indicate the short-term relationship between economic growth from different sources and spending on science. The sign and value of the estimated coefficients in equation (1) provide information on how much the rate of labour productivity could change in a steady state if the observed value of a given variable were to increase in that state. The negative impact of the explanatory variable in the convergence equations should be interpreted as indicating that this variable has a stabilising effect on observed economic fluctuations, as measured by the rate of changes in labour productivity. Conversely, a positive influence of the analysed variable should be interpreted similarly as evidence that it amplifies economic fluctuations.

When analysing indicators of expenditures on research, science, and higher education, it is possible to distinguish between countries with positive and negative relationships. The TE indicator negatively impacts Slovakia, Hungary, and Poland. Slovenia, Latvia, and Estonia experienced a positive effect. The BR variable negatively impacts growth fluctuations in Poland, Slovakia, the Czech Republic, Lithuania, and Estonia, while Hungary shows a strong positive effect. A weak positive effect of the BR variable is also observed in Latvia and Slovenia. The R&D variable has a positive impact on labour productivity in most countries, except for Estonia, Slovakia, and the Czech Republic. It is important to note that not all of the relationships described above are statistically significant. The results indicate that the relationship between the pace of labour productivity changes and science expenditures is complex and difficult to identify conclusively. In the case of the TE indicator, Slovakia and Latvia have a statistically significant positive relationship, with the latter case reaching significance at the 0.01 level. The results show one statistically significant negative relationship for the Czech Republic. For the BR indicator, a strong positive relationship exists with Hungary's labour productivity pace. At the same time, Poland and Slovakia have a negative and statistically significant relationship at the same significance level. The R&D indicator positively affects the pace of labour productivity in most countries, but this relationship is statistically significant only for Latvia and Hungary. Except for Estonia, the FWCI indicator negatively impacts labour productivity in all the analysed countries, but it is statistically insignificant in many cases. Similarly, the PAJQ indicator shows a negative relationship with the pace of labour productivity in all analysed economies except Hungary and Slovenia.

Concluding remarks

The impact of science expenditures on economic growth can be analysed from different perspectives. In this paper, we present empirical results that aim to determine the extent to which these expenditures affect real convergence processes. Research conducted in our region using Seemingly Unrelated Regression Equations (SURE) systems indicates significant diversity in convergence processes among analysed countries and a complex relationship between real convergence (catching up) and government spending on science.

The obtained results are heavily influenced by the selected indicator that describes the category of expenditures under consideration. The inclusion of expenditures on science, research or higher education in the convergence equations strengthens the hypothesis that convergence processes are heterogeneous in nature. It confirms that the catching-up processes should be determined for each economy separately rather than for regions or groups of countries.

The analysed category of government spending interacts in a highly diverse manner with economic fluctuations, with some countries having a stabilising effect on growth dynamics while others possibly leading to an increase. In the case of the Polish economy, expenditures on science play a relatively minor role in the growth process. However, it is important to note that these results only reflect the current state, and measures should be taken to increase the role of science, research, and higher education in the future development of the Polish economy.

The economic growth of our country has been dependent on a large internal market for at least two decades and is consequently driven by solid consumption dynamics. Government expenditures on science, research, or higher education should primarily influence investments. However, among the possible sources of economic growth, investments have not played a primary role in the past for the Polish economy.

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