How Universities Determine Economic Development in 27 EU Member States

Olesya Petrenko
University of West Bohemia, Faculty of Economics,
Department of Economics and Quantitative Methods;
Univerzitní 22, 301 00 Pilsen, Czech Republic
e-mail: petrenko@ujp.zcu.cz

Abstract

Many European countries nowadays are collaboratively focused on bringing together the most up-to-date technologies and the brightest minds to deal with social, economic, and ecological matters and find a sustainable equipoise. Universities may help to produce appropriate knowledge for such challenges and foster economic and social innovation. This paper reviews evidence of existing bonds between tertiary education and economic growth measured in GDP per capita providing a quantitative evaluation of such dependencies using the now widely criticized Cobb-Douglas production function for building Ordinary Least Squares (OLS) and Bayesian Averaging of Classical Estimates (BACE) econometric models. The results obtained in this research showed that tertiary education expenditures and the numbers of mainly male BA and MA graduates (in technologies, sciences and medicine robustly and partially correlate with economic growth. Well-distributed investment in the development of tertiary education STEM majors can potentially strengthen universities' positive impact on sustainable economic growth.

Keywords

Economic growth; Tertiary education; Sustainable development; STEM majors.

Introduction

Rising interest in the role of tertiary institutions in economic growth is creating space for scientific discussions and research in education, the economics of education and human resources management [17], [2], [26]. It might therefore be important to determine what impact tertiary education organizations have on economic growth. One major theoretical issue that has dominated the field for many years is whether GDP and its derivatives are an adequate measure of economic growth and development. This concept has been challenged by a number of empirical studies [7], [16], [36], [37]. Moreover, scholars are now working hard to establish the definition of 'effective' universities and their impact on innovation implementation and the growth of regional economies. Huggins and Johnston described universities as drivers of the regional innovation system in 2009. According to some researchers [1], [25], [15], universities are viewed by society as a whole as social and educational venues that help individuals acquire specific skills to be able to meet economic needs, be capable of making an effective contribution to economic development and meet current market demands. According to contemporary research and related policies, economic growth is closely connected to the human capital endowment. For instance, Barro and Lee [5] point at causal relation between years of education and economic growth. Nevertheless, the relation seems less straightforward than defined in [16]. A simple causation relationship between education and growth may not always suit all the economies and is being questioned especially during economic crises like the Global Financial Crisis (GFC) or the current Covid-19 pandemic. What might be of greater importance than the number of school years or the ratio of a well-educated population related to the whole population in general, is strategic planning of tertiary education. It was demonstrated in [26] that imposing strategical thinking (aligning priorities, values, and incentives of the university to those defined by local, regional, and or national authorities) for university management is one of the key elements needed to enhance a university's performance and efficiency. Several studies dealing with this issue have been published and serve as the outlook on performance measurement in higher education [8], [23], although very few models of performance measurement are to this day transferred from the for-profit sector and later adjusted to suit such public organizations.

1 Research Objectives

The process of building a transparent system that could help to determine the efficiency of a higher education organization would greatly need to be explained clearly to managers and policy makers so that synergy among policy makers, management, human resources, professionals, and students can be reached and the overall system can work more effectively, providing the world with better opportunities for sustainable growth. Statement of the problem: The cause-effect relationship between tertiary education and economic growth and development has been a focus of multiple research projects. However, so far there has been little discussion about the economic effects of tertiary education in European countries. This study attempts to determine the impact of higher education systems on economic growth within 27 EU Member states over the past few decades, as well as the effects of Master's and Ph.D. level graduates overall and divided by gender in the fields of science, medicine, and technology. The aim of the research: this study attempts to carry out reliable empirical estimates of the relationship between tertiary education and economic development in the selected European Union countries during the period of 2013-2019 in order to determine the impact of tertiary education on the economic development of the EU member states. Limitation of the research: In the framework of this study, several indicators of economic growth and development were used – the growth rate of real GDP per capita, GDP per capita in PPP price rates, and tertiary education represented by a share of the population holding a tertiary degree. Relationships between specific tertiary degrees in social sciences, technical sciences, chemistry, biology, etc., and economic growth were not considered in this paper, which is another limitation of the current research. Alternative measurements of economic growth were not used to create a data set. Despite these limitations, it is expected that the results of this research will be able to be used to consider further steps towards building sustainable education in the EU Member States.

Research Questions

1. What is the impact of the characteristics of higher education systems on economic growth in European countries?
2. What is the impact of human capital educated in science, technology, and medicine (Bachelor's and Master' level) on the economic growth?
3. What is the impact of male and female graduates (Bachelor's and Master' level) of all majors on the economic growth?
4. What is the impact of male and female graduates (Bachelor's and Master' level) majoring in science, technologies and medicine on growth?

2 Theoretical Background

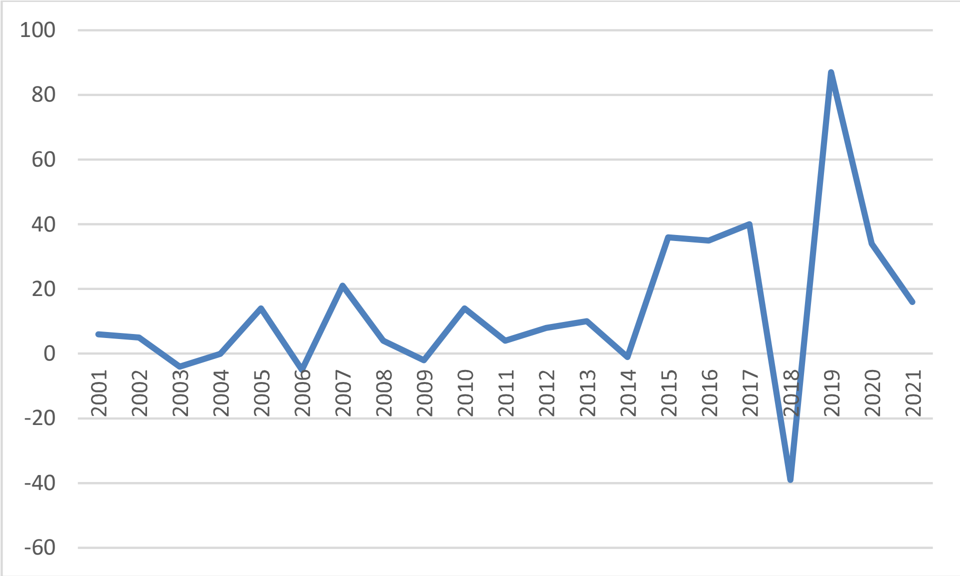
In today's economy, tertiary educational services have become an important commodity as HR specialists recognize the employee's qualifications, knowledge, and skills to ensure productivity and innovation within a number of businesses (trans-national corporations, medium-sized companies operating globally). Three key directions of education-growth relationship are defined in [14]: it is crucial to enhance the levels of knowledge, expertise, and skills of the population, transfer new knowledge and ideas responsibly and provide incentives for innovation within organizations and the economy as a whole.

In general, education can be considered one of the main factors of economic growth and technological progress [5], [21]. It has been claimed that economic growth leads to higher participation in tertiary education as well-educated human capital promotes greater economic performance. A lot of research has been focused on the cause-effect relationship between education in general (and tertiary education in particular) and economic growth [17], [5], [2], [9], [13], [14] with data gathered from developing and developed countries from 1960 to 2019. Both variables for education (tertiary education) and economic growth were measured in numerous ways. Therefore, the causal relationship between tertiary education and economic growth can be formally described by three main approaches: 1) education causes economic growth; 2) economic growth causes more people to seek tertiary education 3) the cause-effect relationship may function both ways. According to Hanushek and Woessman [19] who studied the relationship of cognitive skills in education and growth in multiple countries, adding more years of education on average does not ensure economic growth. The researchers argued that the differences in cognitive skills – in other words, what is known in certain countries, can be considered an explanatory variable for some of the differences in the economic development in various countries.

In accordance with UNESCO's Sustainable Development Goal 4 (SDG 4) for education [27] sustainability in tertiary education will be crucial for preparing current students to solve the most challenging tasks that the world's economy encounters in the near future. European Commission representatives stress in their reports that more STEM education in tertiary disciplines is needed by 2050 [38, p.13-14]. Another report clearly states that "we must spend more on research and education", therefore, it might be implied that more students will be supported to graduate from tertiary education programs [39, p. 56]. Sustainable tertiary education goals leave no choice to universities but to supply their potential graduates with global education and training so that fewer negative outcomes arise to be settled by future generations. Therefore, in order to complete SDG 4 it may be important to ensure that tertiary education gives students proper sources of knowledge and motivation to assess problems from various perspectives so that they are able to make informed decisions relying on multiple reputable sources of data available.

Tertiary education organizations need to define what efficiency in tertiary education is because researchers and educators worldwide often feel concerned about techniques how to pursue so-called "efficiency". A few estimation methods were developed in the late 20th century, such as non-parametric: e.g. data envelopment analysis (DEA) described in [12] and [4] and parametric: e.g. stochastic frontier analysis (SFA) operated by [3] and [6]. These methods greatly helped to define efficiency in the context of tertiary education. These concerns mainly stem from the idea that if educators and university staff in general start focusing more on being efficient, the very concept of higher education might suffer as more attention is given to meeting certain requirements, i.e. [20] and [24].

The term "efficiency" is typically explained as the opportunity to provide the best educational product for a given budget. It can generally work in two main directions: universities may use the same amount of resources to potentially acquire better results or lower the amount of resources to receive the same results than in previous periods. Over the last few decades it is becoming increasingly important to calculate and recognize the economic impact of universities and other organizations providing tertiary education, see Figure 1.



Source: Author's own calculations based on data from Clarivate Database 2022

Fig. 1: *Frequency change in the number of scientific research papers in economics per year, in counts, published via Web of Science 2001-2021 that feature the words "economic impact of universities" in their headlines and abstracts*

Huggins and Johnston [20] described universities as drivers of regional innovation system in 2009. It is crucial, however, to look at the structure of the human capital and build up a common system to manage it (recruit, train and sustain) in order to determine possibilities of sustainable growth in results in higher education.

3 Methods

The data was gathered from the Eurostat (2021), OECD (2021) and World Bank (2021) official databases. A list of variables and corresponding data sources can be found in Table 7. The criteria for choosing the variables were as follows: 1) Availability – the data are available for the majority of the current EU Members States from 1990 to present; 2) Consistency – congruent tertiary education data for the 27 EU Member States that was calculated and received by carrying out exactly the same procedure for years 2013-2019. Despite the fact that the period of six years could be considered to be an imitation of the current research, it is expected that a common relationship between tertiary education and economic growth will be found as the list of countries chosen for this study seems to be homogeneous as it consists of countries with developed economies according to the World Bank (2019).

The advantage of analyzing such a data set is data coherence – an important data quality component that ensures uniformity as well as existing logical connections and completeness of the dataset. Coherence could also enable the making of a logical distinction between concepts and target populations, which means that most major problems could be easily detected during the data preparation stage. These restrictions resulted in the selection of a few variables, their means and standard deviations are shown in Table 7.

To analyze the data, it was decided to use the Cobb-Douglas production function (CDPF) (1) using capital stock, capital and labor services, despite the fact that CDPF often returned a negative sign for capital [30], [31] and has been considered as "transformation of income identity" [29] and [10]. The main advantage of this function used in its general form is its ability to explain the aggregate output creation and economic growth visually. The function illustrates constant returns to scale ($\alpha + \beta = 1$) when elasticities of production on production factors equal factor shares, with both coefficients being positive numbers ranging [0, 1].

$$Y_t = A_t \cdot (K_t)^\alpha \cdot (L_t)^\beta, \quad (1)$$

where A is total factor productivity, K is capital, and L is labor.

Due to the fact that most of the uncertainty of the economic growth models' hinders agreement on specific factors that cause economic growth, this paper uses panel data models with country-specific fixed effects. Wooldrigde [28] pointed out that it might be more efficient to use Fixed Effects – Random Effects models instead of the regular OLS regressions while working with panel datasets in which there is heterogeneity. This approach to assess long-term and short-term economic growth has been commonly used in the economic literature due to its general simplicity. The main drawback might be a limited number of variables that could be explained empirically. Their quantity often depends on "whatever list the first researcher happened to select" [33].

To deal with the issue of biases, quite a few researchers also consider using Bayesian model averaging techniques [32] which may help to determine model uncertainty so that the relationship between model-specific estimates is assessed, revealed and explained. Following this idea, economists Sala-I-Martin, Doppelhofer and Miller [35] created a Bayesian Model Averaging of Classical Estimates (a so-called SDM's BACE approach) in order to understand which regressors should be included into cross-country linear regressions. Such models build estimates for every possible combination of variables by applying the weighted averaging OLS method in order to find out which variables do relate to growth robustly and how strong these relationships might be. Therefore, when designing the current research, it was decided to build an alternative model to compare and evaluate the results received from the Fixed Effects model.

More recently, literature on applied econometrics offers "extreme bounds analysis" which was designed to reveal robust empirical relationships for the determinants of economic growth. This test consists of two steps:

1. it is necessary to identify (by prior analysis) which variables could be related to economic growth;
2. to check if a variable z is robust, equation (2) for regressions needs to be solved:

$$\gamma = \alpha_j + \beta_{yj} \cdot y + \beta_{zj} \cdot z + \beta_{xj} \cdot x_j + \varepsilon, \quad (2)$$

where
y is a vector that represents fixed positions of the regressors (certain variables which are always included into regressions – e.g. income, investment rate, secondary school enrollment rate, rate of population growth [34]),
z is the variable to be examined, and
x is a "tool" vector which typically consists of a combination of three variables selected for the analysis.

The first tests performed at the beginning of the 1990s were widely criticized in the economic literature as they discarded most of the variables as not robust due to the fact that these regressors did not systematically correlate with economic growth. Consequently, Sala-i-Martin [35] suggested making a transition from "extreme bounds" to variables that would have a certain degree of confidence. Both theory and statistical calculations based on the BACE approach are explicitly explained in [35] and for that reason further theoretical description is omitted in this paper.

There has been much debate between economists on the subject of whether or not there is a fixed set of variables which can be robustly correlated with economic growth. In order to answer the research questions listed in the introduction of this article, it is considered useful to find out estimates for growth from a much larger set of models with the help of the BACE approach.

4 Results

The null hypothesis to answer the first research question ("What is the impact of the characteristics of higher education systems on economic growth in European countries") was stated as: There is no impact of tertiary education characteristics on economic growth. We constructed an OLS model with fixed effects for the panel dataset having lagged variables of 4 years for bachelor students and 2 years for master students. The dependent variable was current GDP per capita in purchasing power parity (Table 1) with the R-squared of 0.79.

The regressors used for this model included the ones that are generally used by various researchers: gross capital formation, Thousand hours worked(as K and L variables for the Cobb-Douglas function), general economic variables (unemployment rate, population and population growth share, general government consumption expenditures, openness of the economy) and the variables that referred to tertiary education (total number of graduated bachelor and master students, government expenditures on tertiary education and share of the population aged 30-35 with a tertiary diploma). It could be assumed that graduated bachelor and master students have a positive impact on economic growth. The same dataset was used to form multiple BACE models, the results follow in Table 2.

Tab. 1: *Model 1: Fixed-effects, Robust (HAC) standard errors, dependent variable: LOG GDP in current PPP per capita*

	Coefficient	**Std. error**	***t*-ratio**	***p*-value**	
Constant	4.891050000	0.301363000	16.2300	<0.0001	***
Thousand hours worked	−0.000162264	0.000206555	−0.7856	0.4392	
Gross capital formation	0.001290160	0.000750301	1.7200	0.0974	*
Share of age group 30-35 with a tertiary diploma	−0.000644451	0.001286540	−0.5009	0.6206	
Unemployment rate	−0.006935170	0.002318630	−2.9910	0.0060	***
Growth of population share	0.000426793	0.000172614	2.4730	0.0203	**
Graduated bachelor students_4	3.11526e-06	1.53880e-06	−2.0240	0.0533	*
Graduated master students_2	2.02081e-06	8.50523e-07	2.3760	0.0252	**
Graduated Ph.D. students	−2.13229e-06	2.18339e-06	−0.9766	0.3378	
Government expenditures on tertiary education	0.009721160	0.038023200	0.2557	0.8002	
Government consumption expenditures	0.006115850	0.001735630	3.5240	0.0016	***
Openness of the economy	−0.001259470	0.001395340	−0.9026	0.3750	

Source: Own

The BACE modelling analysis method applying posterior moments with unconditional and conditional inclusion returned the following results: gross capital formation, unemployment rate robustly and marginally correlates with economic growth. The numbers of graduated bachelor students robustly moderately correlate with growth. The hypothesis of no impact of tertiary education on economic growth is rejected because total number of bachelor and master students robustly and positively correlate with GDP growth per capita both in the fixed effects model and BACE models.

Tab. 2: *BACE Models (61 models accepted out of 1024). Dependent variable: LOG GDP in current PPP per capita*

	PIP	**Mean**	**Std. dev.**	**Cond. mean**	**Cond. std. dev**
Constant	1.000000	4.296766	0.171460	4.296766	0.171460
Government expenditures on tertiary	0.999996	−0.120231	0.022694	−0.120232	0.022693
Thousand hours worked	0.914534	−0.000166	0.000075	−0.000182	0.000058
Gross capital formation	0.596062	0.002394	0.002323	0.004017	0.001592
Unemployment rate	0.588710	−0.002529	0.002504	−0.004295	0.001750
Graduated bachelor students_4	0.307443	0.000000	0.000000	0.000000	0.000000
Graduated master students_2	0.203128	0.000000	0.000000	0.000000	0.000000
Growth of population share	0.067852	−0.000004	0.000392	−0.000058	0.001503

Source: Own

The hypothesis to answer the second research question was stated as: There is no significant impact human capital educated in science and technology (Bachelor's, Master's and Ph.D. level) on economic growth. We constructed an OLS model with fixed effects for the panel dataset having lagged variables of 4 years for bachelor students and 2 years for master students. The dependent variable was current GDP per capita in purchasing power parity (Table 3) with the R-squared of 0.788. The results for graduated Ph.D. students did not return any statistically significant results which might mean that it is rather costly to educate prospective scientists and it takes time for the economy to positively react to high quality human capital. It could be assumed that graduated bachelor and master students have a positive impact on economic growth. The same dataset was used to form multiple BACE models, the results follow in Table 4.

Tab. 3: *Model 2: Fixed-effects, Robust (HAC) standard errors, dependent variable: LOG GDP in current PPP per capita*

	Coefficient	**Std. error**	***t*-ratio**	***p*-value**	
Constant	4.674090000	0.341751000	13.6800	<0.0001	***
Gross capital formation	0.001252570	0.000755304	1.6580	0.1093	
Share of age group 30-35 with a tertiary diploma	−0.000698896	0.001363940	−0.5124	0.6127	
Unemployment rate	−0.009768940	0.003306760	−2.9540	0.0066	***
Growth of population share	0.000437482	0.000160227	2.7300	0.0112	**
Government expenditures on tertiary education	−0.033137300	0.049195400	−0.6736	0.5065	
Government total education expenditures	0.038256000	0.025660700	1.4910	0.1480	
Government consumption expenditures	0.004575030	0.002762040	1.6560	0.1097	
Openness ratio	−0.000925810	0.001187970	−0.7793	0.4428	
Graduated bachelor students in sciences, technology and medicine_4	4.35001e-06	1.88375e-06	2.3090	0.0291	**
Graduated master students in sciences, technology and medicine_2	2.11347e-06	1.32463e-06	1.5960	0.0227	**

Source: Own

The BACE method returned the following results: Government consumption expenditures, the share of the population with a tertiary education diploma and government spending on tertiary education robustly and marginally correlate with economic growth. The gross capital formation, unemployment rate and numbers of graduated bachelor students robustly moderately correlate with growth. What changed from the first set of BACE modelling results is that the number of bachelor students graduating from majors linked to science, technology and medicine might correlate robustly and marginally with economic growth. The hypothesis of no impact of Master's and Bachelor's science, technologies and medicine students on economic growth is rejected as the number of students in such majors robustly and positively correlate with GDP growth per capita both in the fixed effects model and BACE models.

Tab. 4: *BACE Models (70 models accepted out of 1024), dependent variable: LOG GDP in current PPP per capita*

	PIP	**Mean**	**Std. dev.**	**Cond. mean**	**Cond. std. dev**
Constant	1.000000	4.262602	0.179509	4.262602	0.179509
Government expenditures on HE	0.999910	−0.120103	0.022934	−0.120113	0.022907
Employment by industry breakdowns	0.883652	−0.000154	0.000078	−0.000175	0.000058
Gross capital formation	0.625332	0.002577	0.002358	0.004121	0.001591
Unemployment rate	0.570417	−0.002449	0.002511	−0.004294	0.001770
Total graduated bachelor students in sciences and technology	0.532771	0.000000	0.000000	0.000001	0.000000
Total graduated master students in sciences and technology	0.180553	0.000000	0.000000	0.000000	0.000000
Growth of population share	0.066751	−0.000000	0.000387	−0.000007	0.001498

Source: Own

The hypothesis to answer the third research question was stated as: There is no significant impact the impact of men and women graduates (Bachelor's and Master's level) on the economic growth. We constructed an OLS model and underwent the same procedure (Table 5) with the R-squared of 0.834 and Durbin-Watson statistic of 1.72. It is visible that both female and male master and bachelor students tend to positively influence economic growth, however, the coefficients for men are larger in this model. These findings may point out that there might be a gender pay gap. It could be derived that male and female graduated bachelor and master students have a positive impact on economic growth. The results received with the application of BACE modelling to check the same hypothesis are demonstrated in Table 6 and show that the number of graduated bachelor male students might have robust marginal correlation with economic growth. However, the number of female graduate students, both educated at Bachelor's and Master's levels, demonstrate insignificant correlation with economic growth.

Tab. 5: *Model 3: Fixed-effects, Robust (HAC) standard errors, dependent variable: LOG GDP in current PPP per capita*

	Coefficient	Std. error	*t*-ratio	*p*-value	
Constant	4.746010000	0.301638000	15.730	<0.0001	***
Gross capital formation	0.001393160	0.000674290	2.066	0.0489	**
Unemployment rate	−0.006738990	0.002574910	−2.617	0.0146	**
Growth of population	0.000551393	0.000192559	2.864	0.0082	***
Government expenditures on HE	−0.062667600	0.051709000	−1.212	0.2364	
Openness ratio	−0.001786610	0.001423370	−1.255	0.2206	
Male Graduated bachelor students	1.19535e-06	5.54429e-07	−2.156	0.0405	**
Female Graduated bachelor students	1.21790e-06	5.84251e-07	−2.085	0.0471	**
Male Graduated master students	3.09333e-06	8.97448e-07	3.447	0.0019	***
Female Graduated master students	2.51806e-06	7.73175e-07	3.257	0.0031	***

Source: Own

Tab. 6: *BACE Models (237 models accepted out of 1094), dependent variable: LOG GDP in current PPP per capita*

	PIP	Mean	Std. dev.	Cond. mean	Cond. std. dev
Constant	1.000000	4.247664	0.185112	4.247664	0.185112
Government expenditures on HE	0.999934	−0.118010	0.023213	−0.118020	0.023194
Employment by industry	0.848613	−0.000150	0.000082	−0.000170	0.000059
Gross capital formation	0.602108	0.002442	0.002344	0.004055	0.001607
Unemployment rate	0.600080	−0.002640	0.002556	−0.004400	0.001771
Male graduated bachelor students	0.412162	0	0	0	0
Male graduated master students	0.238469	0	0	0.000001	0
Female graduated master students	0.158910	0	0	0	0.000001
Female graduated bachelor students	0.133351	0	0	0	0
Growth of population share	0.064747	−1e-06	0.000382	−1.3e-05	0.001499

Source: Own

Tab. 7: Summary statistics, using the observations for 27 EU states, 2013-2019

Variables	Data source	Mean	Median	Std. dev.
Dependent variable: LOG GDP in current PPP per capita	National Statistics Office Eurostat	4.58	4.56	0.162
Independent variables:				
Gross fixed capital formation by industry, deflated, mil.euro	Data Browser, Eurostat	9.70e+004	3.96e+004	1.53e+005
Share of age group 30-35 with a tertiary diploma	Data Browser, Eurostat: [edat_lfse_03]	40.9	42.7	9.20
Employment by A*10 industry breakdowns, thousand hours worked	OECD.org Average annual hours actually worked	1.22e+007	6.99e+006	1.54e+007
Government expenditures on tertiary education	Data Browser, Eurostat	0.904	0.900	0.350
Growth of population share	Data Browser, Eurostat	0.444	0.0214	4.05
Population in mil	Data Browser, Eurostat	16.4	8.74	21.6
Unemployment rate	Data Browser, Eurostat	8.79	7.35	4.91
Total graduated bachelor students	Data Browser, Eurostat	7.58e+004	3.88e+004	9.52e+004
Total graduated master students	Data Browser, Eurostat	5.20e+004	2.41e+004	7.22e+004
General government consumption expenditure, % GDP	World Bank National Accounts Data	19.7	19.4	3.26
Openness of the economies: exp-imp/gdp	World Bank National Accounts Data	4.83	3.00	7.61
Gross capital formation GDP	Data Browser, Eurostat	21.6	21.6	4.53
Total graduated bachelor students	Data Browser, Eurostat	7.58e+004	3.88e+004	9.52e+004
Male graduated bachelor students	Data Browser, Eurostat	3.00e+004	1.51e+004	3.94e+004
Female graduated bachelor students	Data Browser, Eurostat	4.58e+004	2.37e+004	5.85e+004
Total graduated master students	Data Browser, Eurostat	5.20e+004	2.41e+004	7.22e+004
Male graduated master students	Data Browser, Eurostat	2.12e+004	9.58e+003	3.13e+004
Female graduated master students	Data Browser, Eurostat	3.08e+004	1.41e+004	4.21e+004
Total graduated Ph.D. students	Data Browser, Eurostat	3.86e+003	1.91e+003	6.09e+003
Total graduated bachelors in technologies/sciences/medicine	Data Browser, Eurostat	2.41e+004	1.48e+004	3.04e+004
Total graduated master students in technologies/sciences/medicine	Data Browser, Eurostat	1.71e+004	6.41e+003	2.48e+004
Total graduated Ph.D. students in technologies/sciences/medicine	Data Browser, Eurostat	1.50e+003	835.	2.45e+003

Source: Own

The hypothesis to answer the last research question was stated as: There is no significant impact of male and female graduates (Bachelor's and Master's level) majoring in science, technologies and medicine on economic growth. The OLS model returned demonstrated that male bachelor and master students have a statistically significant positive effect on economic growth (0.0141 and 0.0108 correspondingly). Female bachelor graduates also have a positive correlation with growth, however, female master students returned a statistically insignificant coefficient of 0.22. The results received with the application of BACE modelling to check the same hypothesis are described below.

With the help of BACE analysis it might be possible to conclude that the number of graduated male bachelor students majoring in technologies, sciences and medicine might be robustly partially correlated with economic growth (0.64 value of PIP). Graduated male master students as well as female graduate students, both of Bachelor's and Master's levels, return insignificant correlation coefficients with economic growth (0.188 for male bachelor students, 0.15 for female bachelor students and 0.13 for female master students in sciences, technology and medicine). These results differ from the panel regression model where coefficients for graduated male bachelor and master students as well as female graduated bachelor students appeared to be significant.

Having performed OLS regression and Bayesian Averaging of Classical Estimates we found that such variables as the number of graduated bachelor and master students positively relate to growth.

It was discovered that bachelor and master male students who graduated majoring in sciences, technologies and medicine overall have higher robust coefficients associated with growth. The results of OLS panel data regression analysis are not always confirmed by BACE: female bachelor graduates also have a positive correlation with growth. However, female master students returned a statistically insignificant coefficient according to the OLS regression model, whereas it might be implied from the results of the same coefficients for BACE models that female graduates generally do not correlate robustly with growth. Therefore, it was particularly interesting to carry out the procedure for the final research question – What impact do male and female graduates (Bachelor's and Master's level) majoring in science, technologies and medicine have on the economic growth? It was confirmed that the number of graduated bachelor male students might have robust marginal correlation with economic growth. However, female graduate students, both Bachelor´s and Master´s levels, return insignificant correlation with economic growth.

5 Discussion

Further development of current research may focus on developing a set of indicators that measure the level of technological development in EU countries and including these into the dataset. Moreover, we find it interesting to perform analyses on STEM education with a further focus on gender, possibly answering the following questions: is STEM tertiary education more important for growth? How many women and men study STEM and does their number have any impact on the gender pay gap and/or the "glass door" or the "glass ceiling".

It is demonstrated that some components of human capital (the share of people with tertiary diploma, the share of young people in the economically active population) in combination with expenditures on higher education have statistically significant robust positive influence on economic growth in the countries of the European Union. It might be interesting to determine the spillover effects. We find it useful for the future analysis to break down the 27 countries into several groups and possibly include more variables for these groups. In this research we admittedly used a limited number of variables which might have caused more biased results.

The following questions still remain relevant:

1. Is there a set of fixed variables in tertiary education that robustly relate to economic growth?
2. What is the strength of this connection – partial or marginal?

Conclusion

It is crucial to proceed with the research of the STEM tertiary education for bachelor and master students and explore the relationship of gender differences between male and female graduates on economic growth to find out whether STEM education promotes economic growth in any way more efficiently than the total number of students. The results of this study might help to demonstrate to what extent the EU governments should invest in STEM tertiary education and foster economic development of prominent economies in other parts of the world.

STEM majors generally attract more male students, who have a statistically significant effect on economic growth, which often may mean that women might not have the same opportunities as men do in their careers. This may result in the finding that women fight both "glass door" and "glass ceiling" (both of these terms refer to horizontal or vertical discrimination of women in companies). To develop governmental strategies for tertiary education it might also be useful to understand how such a trend affects the pay gap between men and women in the countries of the European Union.

Governments may choose to assess these issues of glass door and glass ceiling among men and women with a focus on STEM tertiary education through designing policies on tertiary education that could motivate more women to participate in education programs majoring in STEM subjects. The initiatives to foster sustainable economic development through constant investment in the spheres of tertiary education that bring the most value to the economy seem undoubtedly helpful.

The results obtained by the current research, both methodological and empirical, are important to design regional development policies. These estimation techniques could be potentially used by education ministries to monitor the development of tertiary education organizations strengthening their positive impact on economic growth. Thus, calculations based on BACE modelling showed that higher education expenditures and the numbers of graduated (mainly male) bachelor and master students in technologies, sciences and medicine are significant predictors of economic growth in the EU Member States.

Literature

[1] AGASISTI, T.; BERTOLETTI, A.: Higher education and economic growth: A longitudinal study of European regions 2000–2017. *Socio-Economic Planning Sciences*. 2022, Vol. 81. DOI: 10.1016/j.seps.2020.100940

[2] AGASISTI T.; CATALANO, G.: Governance models of university systems—towards quasi-markets? Tendencies and perspectives: A European comparison. *Journal of Higher Education Policy and Management*. 2007, Vol. 28, Issue 3, pp. 245–262. DOI: 10.1080/13600800600980056

[3] AIGNER., D.; LOVELL, C. A. K.; SCHMIDT, P.: Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*. 1977, Vol. 6, Issue 1, pp. 21–37. DOI: 10.1016/0304-4076(77)90052-5

[4] BANKER, R. D.; CHARNES, A; COOPER W. W.: Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*. 1984, Vol. 30, Issue 9, pp. 1031–1142. DOI: 10.1287/mnsc.30.9.1078

[5] BARRO, R. J.; LEE, J. W.: A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics*. 2013, Vol. 104, pp. 184–198. DOI: 10.1016/j.jdeveco.2012.10.001

[6] BATTESE, G. E.; CORRA, G. S.: Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*. 1977, Vol. 21, Issue 3, pp. 169–179. DOI: 10.1111/j.1467-8489.1977.tb00204.x

[7] BLEYS, B.: *Alternative Welfare Measures*. MOSI Working Paper No. 12. [online]. Vrije Universiteit Brussel, Brussels, 2005. Available from WWW: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1038.4342&rep=rep1&type=pdf

[8] BROADBENT, J. M.: *Performance Management Systems in and of Higher Education Institutions in England: professionalism, managerialism and management*. Roehampton Research Paper. [online]. Roehampton University, 2007. Available from WWW: https://www.researchgate.net/publication/277805172_Performance_management_systems_in_and_of_higher_education_institutions_in_England_professionalism_managerialism_and_management

[9] BENOS, N.; ZOTOU, S.: Education and Economic Growth: A Meta-Regression Analysis. *World Development*. 2014, Vol. 64, pp. 669–689. DOI: 10.1016/j.worlddev.2014.06.034

[10] CADIL, J.; VLTAVSKA, K.; KREJČÍ, I.; HARTMAN, D.; BRABEC, M.: Aggregate Production Function and Income Identity – Empirical Analysis. *International Journal of Economic Sciences*. 2017, Vol. VI, Issue 1. DOI: 10.20472/es.2017.6.1.001

[11] CAPANO, G.; REGINI, M.: Governance Reforms and Organizational Dilemmas in European Universities. *Comparative Education Review*. 2014, Vol. 58, Issue 1, pp. 73–103. DOI: 10.1086/672949

[12] CHARNES, A.; COOPER, W. W.; RHODES, E.: Measuring the efficiency of decision making units. *European Journal of Operational Research*. 1978, Vol. 2, Issue 6, pp. 429–444. DOI: 10.1016/0377-2217(78)90138-8

[13] BELAȘCU, L.; DANANICA, D., E.: The Interactive Causality between Higher Education and Economic Growth in Romania. In: *Proceedings of Annual London Business Research Conference*. 2010.

[14] EARLE, D.: *How can tertiary education deliver better value to the economy?* [online]. Ministry of Education of New Zealand, 2010. [accessed 2022-01-30]. Available from WWW: https://www.educationcounts.govt.nz/publications/tertiary_education_all/205555

[15] EUROPEAN UNIVERSITY ASSOCIATION: *Universities without walls – A vision for 2030*. [online]. 2021. Available from WWW: https://www.eua.eu/resources/publications/957:universities-without-walls-%E2%80%93-eua%E2%80%99s-vision-for-europe%E2%80%99s-universities-in-2030.html

[16] GOOSSENS, Y. et al.: *Alternative progress indicators to Gross Domestic Product (GDP) as a means towards sustainable development*. [online]. European Parliament, 2007. Available from WWW: https://www.europarl.europa.eu/thinktank/en/document/IPOL-ENVI_ET(2007)385672

[17] HANUSHEK, E. A.: Publicly Provided Education. In: Auerbach, A. J.; Feldstein, M. (eds.), *Handbook of Public Economics*. [online]. Amsterdam, North-Holland, 2002, pp. 2045–2141. Available from WWW: http://hanushek.stanford.edu/publications/publicly-provided-education

[18] HANUSHEK, E. A.: Will more higher education improve economic growth? *Oxford Review of Economic Policy*. 2016, Vol. 32, Issue 4, pp. 538–552. DOI: 10.1093/oxrep/grw025

[19] HANUSHEK, E. A.; WOESSMANN, L.: The Role of Cognitive Skills in Economic Development. *Journal of Economic Literature*. 2008, Vol. 46, Issue 3, pp. 607–668. DOI: 10.1257/jel.46.3.607

[20] HUGGINS, R.; JOHNSTON, A.: The Economic and Innovation Contribution of Universities: A Regional Perspective. *Environment and Planning C: Politics and Space*. 2009, Vol. 27, Issue 6, pp. 1088-1106. DOI: 10.1068/c08125b

[21] LUCAS, R. E. Jr.: On the mechanics of economic development. *Journal of Monetary Economics*. 1988, Vol. 22, Issue 1, pp. 3-42. DOI: 10.1016/0304-3932(88)90168-7

[22] MARQUEZ-RAMOS, L.; MOURELLE, E.: Education and economic growth: an empirical analysis of nonlinearities. *Applied Economic Analysis*. 2019, Vol. 27, Issue 79, pp. 21–45. DOI: 10.1108/aea-06-2019-0005

[23] RUBEN, B. D.: *Toward A Balanced Scorecard for Higher Education: Rethinking the College and University Excellence Indicators Framework*. [online]. The Hunter Group, USA, 1999. [accessed 2022-08-20]. Available from WWW: www.academia.edu/49628056/Balanced_Scorecard_in_Higher_Education_1

[24] SADLAK, J.: Efficiency in higher education — Concepts and problems. *Higher Education*. 1978, Vol. 7, pp. 213–220. DOI: 10.1007/bf00129419

[25] SECOLSKY, Ch.; DENISON, D. B.: *Handbook on Measurement, Assessment, and Evaluation in Higher Education*. 2nd ed. Routledge, 2017. ISBN 9781138892156.

[26] SHATTOCK, M.: *Managing successful universities*. 2nd ed. McGraw Hill, Maidenhead, England, 2010. ISBN-10 0335237436. ISBN-13 978-0335237432.

[27] UNESCO: *Leading SDG 4 - Education 2030*. [online]. 2022. [accessed 2022-08-20]. Available from WWW: https://en.unesco.org/themes/education2030-sdg4

[28] WOOLDRIDGE, J. M.: Fixed-Effects and Related Estimators for Correlated Random-Coefficient and Treatment-Effect Panel Data Models. *The Review of Economics and Statistics*. [online]. 2005, Vol. 87, Issue 2, pp. 385–390. [accessed 2022-01-30]. Available from WWW: http://www.jstor.org/stable/40042911

[29] SIMON, H. A.; LEVY, F. K.: A Note on the Cobb-Douglas Function. *The Review of Economic Studies*. 1963, Vol. 30, Issue 2, pp. 93–104. DOI: 10.2307/2295806

[30] ROMER, P. M.: Crazy Explanations for the Productivity Slowdown. Discussion. *NBER Macroeconomics Annual*. 1987, Vol. 2, pp. 208–210. DOI: 10.1086/ma.2.4623718

[31] GRILICHES, Z.; MAIRESSE, J.: Production Functions: The Search for Identification. In: *Econometrics and Economic Theory in the 20th Century*. Cambridge University Press, Cambridge, 1995, pp. 169–203. DOI: 10.1017/CCOL521633230.006

[32] LEAMER, E. E.: Let's Take the Con Out of Econometrics. *The American Economic Review*. 1983, Vol. 73, Issue 1, pp. 31–43.

[33] LEAMER, E. E.: A Class of Informative Priors and Distributed Lag Analysis. *Econometrica*. 1972, Vol. 40, Issue 6, pp. 1059–1081. DOI: 10.2307/1913855

[34] LEVINE, R.; RENELT, D.: A Sensitivity Analysis of Cross-Country Growth Regressions. *The American Economic Review*. 1992, Vol. 82, Issue 4, pp. 942–963.

[35] SALA-I-MARTIN, X.; DOPPELHOFER, G.; MILLER, R. I.: Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach. *American Economic Review*. 2004, Vol. 94, Issue 4, pp. 813–835. DOI: 10.1257/0002828042002570

[36] STIGLITZ, J. E.; SEN, A.; FITTTOUSI, J.-P.: *Report by the Commission on the Measurement of Economic Performance and Social Progress*. [online]. 2009. Available from WWW: https://ec.europa.eu/eurostat/documents/8131721/8131772/Stiglitz-Sen-Fitoussi-Commission-report.pdf

[37] SCHEPELMANN, P.; GOOSSENS, Y.; MAKIPAA, A.: *Towards Sustainable Development: Alternatives to GDP for measuring progress*. Wuppertal Institute for Climate, Environment and Energy, 2010. ISBN 978-3-929944-81-5. Available from WWW: https://epub.wupperinst.org/frontdoor/deliver/index/docId/3486/file/WS42.pdf

[38] EUROPEAN COMMISSION: *Commission presents European Skills Agenda for sustainable competitiveness, social fairness and resilience*. [online]. 2020. [accessed 2022-08-20]. Available from WWW: https://ec.europa.eu/social/main.jsp?langId=en&catId=89&furtherNews=yes&newsId=9723

[39] EUROPEAN COMMISSION: *The Knowledge Future: Intelligent policy choices for Europe 2050*. [online]. 2015. [accessed 2022-08-20]. Available from WWW: https://ec.europa.eu/futurium/en/content/knowledge-future-intelligent-policy-choices-europe-2050.html

JAK UNIVERZITY URČUJÍ EKONOMICKÝ ROZVOJ VE 27 ČLENSKÝCH STÁTECH EU

Mnoho evropských zemí se v současnosti společně zaměřuje na spojení nejmodernějších technologií a nejchytřejších myslí, aby se vypořádaly se sociálními, ekonomickými a ekologickými záležitostmi a nalezly udržitelnou rovnováhu. Univerzity mohou pomoci vytvářet vhodné znalosti pro takové výzvy a podporovat hospodářské a sociální inovace. Tento článek shrnuje důkazy existujících vazeb mezi terciárním vzděláváním a ekonomickým růstem měřeným v HDP na hlavu a poskytuje kvantitativní hodnocení těchto závislostí pomocí nyní široce kritizované Cobb-Douglasovy produkční funkce pro vytváření obyčejných nejmenších čtverců (OLS) a Bayesiánského průměrování klasických odhadů (BACE) ekonometrických modelů. Výsledky získané v tomto výzkumu ukázaly, že výdaje na terciární vzdělávání a počty převážně absolventů - mužů BA a MA (v technologiích, vědách a medicíně) robustně a částečně korelují s ekonomickým růstem. Dobře rozložené investice do rozvoje terciárního vzdělávání STEM mohou potenciálně posílit pozitivní dopad univerzit na udržitelný hospodářský růst.

WIE DIE UNIVERSITÄTEN DIE ÖKONOMISCHE ENTWICKLUNG IN DEN 27 MITGLIEDSSTAATEN DER EU BESTIMMEN

Viele europäische Staaten konzentrieren sich derzeit auf die Verbindung der modernsten Technologien und der klügsten Geister, damit diese sich mit sozialen, ökonomischen und ökologischen Angelegenheiten auseinandersetzen und ein nachhaltiges Gleichgewicht finden. Die Universitäten können bei der Schaffung geeigneter Kenntnisse für solche Herausforderungen helfen und wirtschaftliche und soziale Innovationen unterstützen. Dieser Artikel fasst die Beweise existierender Bindungen zwischen der tertiären Bildung und dem im HDP pro Kopf gemessenen ökonomischen Wachstum zusammen und liefert eine quantitative Bewertung dieser Abhängigkeiten mit Hilfe der zurzeit kritisierten Cobb-Douglas'schen Produktionsfunktion für die Bildung gewöhnlicher kleinster Quadrate (OLS) und der Bayes'schen Berechnung des Durchschnitts klassischer Schätzungen (BACE) ökonometrischer Modelle. Die in dieser Untersuchung gewonnenen Ergebnisse haben gezeigt, dass die Ausgaben für die tertiäre Bildung und die Anzahl der Absolventen (Männer mit BA- und MA-Abschluss in Technologien, Wissenschaften Medizin) robust und teilweise mit dem ökonomischen Wachstum korrelieren. Gut verteilte Investitionen in die Entwicklung der tertiären Bildung STEM können die positive Auswirkung der Universitäten auf das nachhaltige ökonomische Wachstum stärken.

W JAKI SPOSÓB UNIWERSYTETY DETERMINUJĄ ROZWÓJ GOSPODARCZY W 27 PAŃSTWACH CZŁONKOWSKICH UE

Wiele krajów europejskich skupia się obecnie wspólnie na łączeniu najnowocześniejszych technologii i najzdolniejszych umysłów w celu rozwiązania problemów społecznych, gospodarczych i ekologicznych oraz znalezienia trwałej równowagi. Uniwersytety mogą pomóc w generowaniu odpowiedniej wiedzy dla takich wyzwań i wspierać innowacje gospodarcze i społeczne. Niniejszy artykuł podsumowuje dowody na istniejące powiązania między szkolnictwem wyższym a wzrostem gospodarczym mierzonym w PKB per capita i przedstawia ilościową ocenę tych zależności, wykorzystując obecnie szeroko krytykowaną funkcję Cobba-Douglasa do tworzenia zwykłych najmniejszych kwadratów (OLS) i Bayesowskiego uśredniania klasycznych oszacowań (BACE) modeli ekonometrycznych. Wyniki uzyskane w ramach przeprowadzonych badań pokazały, że wydatki na szkolnictwo wyższe oraz liczba absolwentów, przeważnie płci męskiej, studiów licencjackich i magisterskich (w zakresie technologii, nauk i medycyny) są mocno i częściowo skorelowane ze wzrostem gospodarczym. Dobrze rozłożone inwestycje w rozwój kształcenia wyższego na kierunkach STEM mogą potencjalnie zwiększyć pozytywny wpływ uniwersytetów na zrównoważony wzrost gospodarczy.