HIGHER EDUCATION AND ECONOMIC GROWTH: A COMPARISON BETWEEN THE CZECH REPUBLIC AND ROMANIA

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Abstract

Although there is a strong theoretical framework for the economic growth and its relationship with education, the empirical evidence of this relationship is rather scarce. In this paper we investigated the causality and the long-run relationship between economic growth and higher education in the Czech Republic and Romania, using data series for 1980–2013 period. We used a VECM to analyse the long-run relationship between higher education and economic growth and Granger methodology to test the causality between variables. The results showed that higher education has an important positive effect on economic growth, although the impact level of the higher education on economic growth is different in the two countries. We also showed that there is a causality relationship that goes from higher education to economic growth for both countries.

Keywords: higher education, economic growth, cointegration, ADF, unit roots

JEL Classification: I21, I23, C32

1. Introduction

In the new era of the knowledge society, education in general and particularly higher education is one of the most important determinants of the economic growth. The investigation of the relationship between education and economic growth started in early 1960s, initiated by the human capital school (Schultz, 1961), and has become one the central themes of research in economics in the last decades.

The theory of economic growth is based on asset accumulation, including human capital, on the return of these assets and the efficiency with which they are used. Lucas (1988) developed an endogenous growth model that considered the human capital as one of the main determinants of the economic growth. Education was considered a proxy for the human capital accumulation in this model. Most of the present economic growth models build on the endogenous growth model proposed by Lucas emphasizing the role of human capital in technological progress. Romer (1990) also showed that human capital development results in technological progress that influences the accumulation of physical capital and in the end leads to economic growth. Mankiw *et al*. (1992) showed that the human capital has a significant role in the economic growth. The authors used a Solow-Swan type model and introduced the human capital measured through education as a new variable in the model, showing the importance of the investment in education as a determinant of the economic growth. Greiner *et al.* (1995) build on the Uzawa-Lucas

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model of economic growth and explicitly introduce the education in the model showing that there are linear effects of the education effort on the economic growth. Barro and Sala-i-Martin (1995) review the most important economic growth models emphasizing the role of education in the formation of the human capital.

Although there is a solid theoretical framework for the economic growth and its relationship with education, the empirical evidence of this relationship is scarce. Recently, the analysis of the relationship between higher education and economic growth has shifted from a pure theoretical approach to an empirical testing. In the following we mention few of the empirical econometric models that describe the relationship between education and economic growth.

Starting from a panel of 146 countries with data from 1950 to 2010, Barro and Lee (2010) used a form of the Cobb-Douglas production function with inputs given by the physical capital and human capital measured by an exponential function of the years of education, and derived the following equation using a fixed effect model:

$$\log\left(\frac{Y_i}{w_i}\right) = 0.121 S_i + 0.544 \log\left(\frac{K_i}{w_i}\right) \qquad (1)$$

Where Y_i is the output, S_i is the average schooling years, K_i is the stock of the physical capital *per capita*, and w_i is the working age population in country i. In a loose interpretation, the coefficient of S_i in the regression equation can be seen as a return to investment in one additional year of education (Mincer, 1974; Patrinos and Psacharapoulos, 2011). This model shows that the rate of return to education is 12.1%. If the estimation is restricted to European and Central Asiatic countries this rate is around 8%.

Patrinos and Psacharapoulos (2011) used a data set that covers 1950–2010 period to estimate the effect of the education on the economic growth starting from a Mincerian equation:

$$\log Y_{it} = \mathrm{a} + \mathrm{b} S_{it} \qquad (2)$$

Where S_i is the average schooling years, log Y_i is the logarithm of the GDP *per capita* in country i. The result of the estimation at the global level is:

$$\log Y_i = 6.645 + 0.258\, S_i \qquad (3)$$

which means that the rate of return to education is 25.8%. If the estimations are restricted to Europe and Central Asia the value is 22.8%, for East Asia and Pacific 34.3% and for the developed countries 20.2%.

In our analysis we will investigate whether there is a causality and long-run relationship between economic growth and higher education for two countries that passed through a transition period, the Czech Republic and Romania. For our purpose we used data series that cover 1980–2013 period.

The evolution of the higher education system in the Czech Republic and Romania after the political changes at the end of 1989 is analysed in several papers. A detailed description of the Czech higher education system after 1989 can be found in (Ministry of Education, Youth and Sport, 2001), while Strielkowski (2010) provides a breakdown of the organization of studies emphasizing the distinction between public and private higher education institutions. Matějů and Simonová (2003) analyse the development of the Czech higher education sector after November 1989, showing that although the number of students increased by approximately 60% between 1989 and 2001, the offer of the higher education institutions was too low to meet the demand for higher education. The differences between the development of the higher education in the Czech Republic and Romania are analysed in Dobbins (2011) who concludes that despite similar external conditions, Romania rapidly converged to the market oriented model while the Czech Republic stuck to its historical model of higher education.

Andrei *et al.* (2010a) present an evolution of the some important statistical indicators used to characterize higher education sector in Romania during 1990–2006 period, emphasizing a weak correlation between the number of students, the demographic phenomena and the high schools enrolments. They concluded that on a long and medium term the expansion of the higher education system cannot be sustained. In another paper, Andrei *et al.* (2010b) describe the developments registered in the higher education field in Romania, comparing the results with those obtained for other two countries, Bulgaria and Hungary. The authors highlight a series of common features, namely the important increase in the number of students after 1990, which was not accompanied by a proportional increase in the academic staff. The authors also show that, for Romania, there is no causal relationship between the education expenditure and the number of students. In another paper, Drăgoescu (2013) presents an overview of the transformations occurred in the higher education sector in Romania after 1990, emphasizing that the law and economic fields of study have recorded an impressive development while technical education experienced a major decrease in the number of students.

Despite many descriptive analyses of the higher education sector, we found only a few papers that deal with the long-run relationship between higher education and economic growth for the Czech Republic and Romania. Dănăcică and Belasku (2008) explored the causal relationship between higher education and economic growth in Romania and found a direct causality running from GDP to the number of students enrolled in higher education. In another work, Dănăcică (2011) found a unidirectional causality between school education measured by enrolment ratio in secondary and higher education and economic growth in Romania, showing that the education has a positive effect on the economic growth. Ochrana *et al.* (2010) and Hamerníková and Maaytová (2012) analysed education funding, highlighting the importance of education for general economic development in the Czech Republic. Vourvachaki *et al.* (2014) analysed the role of human capital in an endogenous growth model and showed that the gradual decentralization of the Czech educational system implied a declining share of specific human capital that can be associated with a lower rate of long-run growth. Chudárková and Verner (2012) investigated the relationship between higher education and economic growth in Austria and the Czech Republic and found that while in Austria higher education has a positive influence on the GDP *per capita* in the Czech Republic this relationship cannot be confirmed.

The causality relationship between economic growth and education is analysed in Barro, 2002 and, 2013) who found that education significantly influences economic growth using a cross section of 100 countries. He showed that there is a direct causality relationship running from education measured by schooling rates to the economic growth and education has a positive effect on economic growth.

Agiomirgianakis *et al.* (2002) studied the causality relationship between human capital measured through primary, secondary and tertiary education enrollment rates and economic growth for the case of Greece. Their results showed that there is a direct causality between primary and secondary education and economic growth and a reverse causality for tertiary education. In another study, Kui (2006) analysed the economic growth and its relationship with education in China during 1978–2004 and obtained an interesting result. The economic growth in China is determined by the primary education and represents a direct cause for higher education, which is somehow similar to the results obtained by Agiomirgianakis *et al.* (2002).

The long-run relationship between economic growth and higher education in China is also investigated in Huang *et al.* (2009) who found that there is a long-run relationship between enrollment in higher education and economic growth. Katircioglu (2009) found a long-run equilibrium relationship between higher education and economic growth and a direct causality relationship from higher education to economic growth in North Cyprus. The role of the higher education as a determinant of the economic growth in Taiwan is analysed in Lin (2004) for the 1965–2000 period. The author shows that higher education provided a positive and significant effect on Taiwan's economic development. Ljungberg (2009) showed that the human capital was an important factor of the economic growth in Sweden using data series from 1870 to 2000.

A number of studies showed that there is a direct causality running from economic growth to education. Bils and Klenow (2000), using the Barro Lee data set, confirm the relationship between education and economic growth but with a reverse causality, from economic growth to education. The authors justify their results by noticing that the countries with high participation rates in education in the 1960s did not register a rapid increase of the human capital and in the end this contributed to a lesser extent to the economic growth. Diebolt *et al.* (2003), using a data set for Germany and France, showed that there is a direct causality from economic growth to education. The authors noticed that there are some methodological problems in estimating this relationship because of the difficulty of measuring the education. The results of their study come into contradiction with the theory of the endogenous economic growth: the return of the human capital is decreasing and the knowledge transfer generated by the education cannot cause economic growth.

In our analysis we will test the existence of a direct causality relationship between higher education and economic growth and the direction of this causality, if such a relationship exist. We will also test whether there is a long-run relationship between higher education and economic growth for the Czech Republic and Romania. The results of this study are important for building strategies and public policies in the long term in the area of higher education.

The rest of the paper is organized as follows: in Section 2, we present the data that we have used in our analysis, in Section 3, the methodological approach is presented and in Section 4 we discuss the results. Our paper ends with a section of conclusions.

2. Data Series

Current studies measure higher education by different proxy variables such as participation rate, the number of students, expenditures on education. In our study, higher education was measured through the number of the students (ISCED97 levels 5 and 6) *per* 100,000 inhabitants. We choose this variable because the number of students in the two countries alone is not directly comparable, depending on the population of each country. We also used the public education expenditures for all levels of education because the public education expenditures only for higher education are available only for a very limited period of time. In both countries the expenditures on education come mainly from public sources, the private expenditures on education recording only 0.1% of GDP in Romania and 0.6% of GDP in the Czech Republic in 2011. As a measure of the economic growth we used the GDP *per capita*. Throughout the paper, we used annual data series covering 1980–2013 period of time for both countries.

While the data for Romania poses no problems, the data for the Czech Republic between 1980 and 1992 must have been adapted, because at this period only data for the whole Czechoslovakia were known. Like in the division of federation, we used the same key 2:1 (the Czech Republic : Slovakia). Deployment and stratification of universities throughout Czechoslovakia was approximately equal, so the analysed data are as accurate as possible.

The data series used in our analysis were retrieved from different sources. GDP *per capita* (in constant LCU) was obtained from the World Bank (2014), EconStats (2015), Czech Statistical Office (2015) and Romanian National Statistics Institute (2015). The public expenditure on education was retrieved from the Eurostat database (Eurostat, 2014) and (European Commission, 2013). The number of students enrolled in higher education was retrieved from the UNESCO Institute for Statistics database (2015) and Romanian National Statistics Institute (2015). All the data series are transformed using the natural logarithm.

Throughout the rest of the paper we will use the following notations for our variables:

LGDP_PER_CAPITA is the natural logarithm of the GDP for *capita,*

DLGDP_PER_CAPITA is the first difference of LGDP_PER_CAPITA,

LHE_STUD is the natural logarithm of the number of students enrolled in higher education *per* 100,000 inhabitants,

DLHE_STUD is the first difference of LHE_STUD,

LEDU_EXP is the natural logarithm of the public education expenditures,

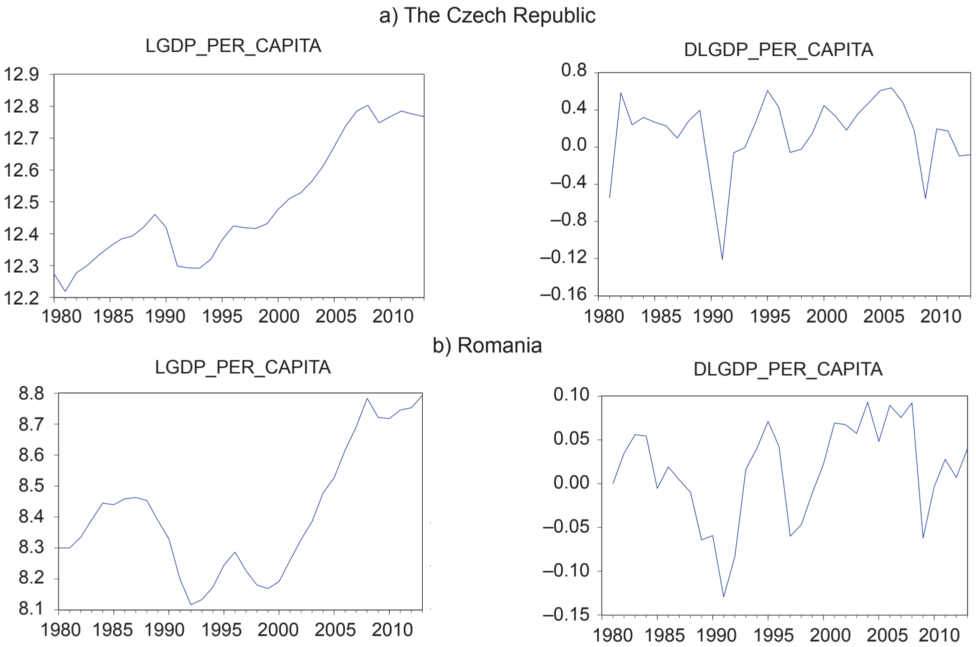
DLEDU_EXP is the first difference of the LEDU_EXP.

Figures 1 to 3 show the evolution of these variables between 1980 and 2013 for the Czech Republic and Romania.

One can notice that the GDP *per capita* recorded a similar evolution in both countries. While there was a slow increase in the GDP *per capita* between 1980 and 1990, we recorded a decreasing trend in both countries immediately after 1990. Starting with 1992–1993, the GDP *per capita* increased constantly in the Czech Republic and Romania with a temporary drop from 1997 to 1999. Since 1999, it had increased until 2008 when the economic crisis affected both countries. As an effect of the economic crisis, GDP *per capita* decreased and the level reached in 2008 was recovered only in 2013 in Romania. In the Czech Republic the maximum value of the GDP *per capita* reached in 2008 was not recovered until 2013.

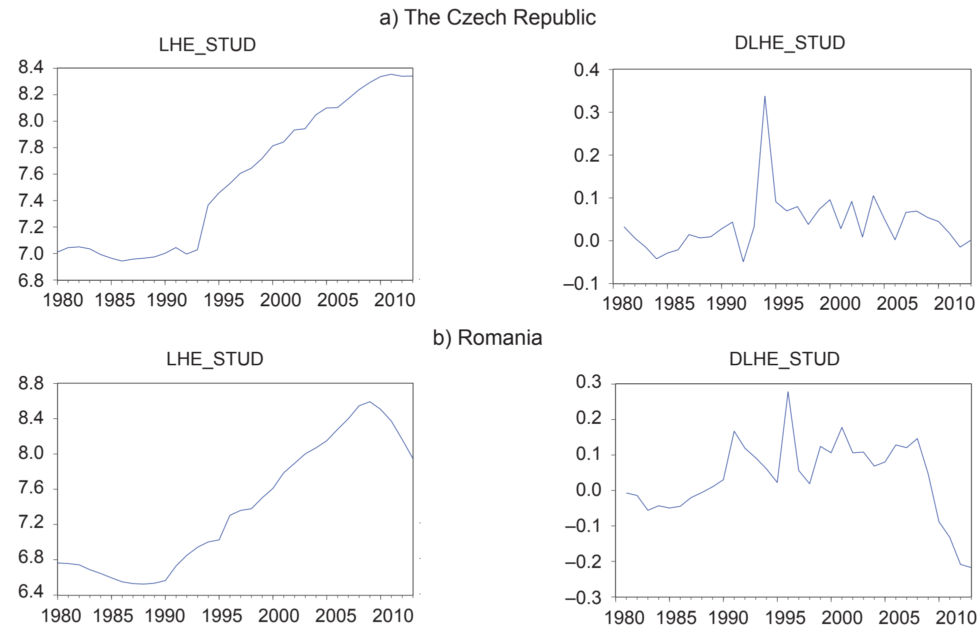
After the collapse of the communist regime at the end of 1989, most of the Eastern European countries have witnessed important changes in their educational systems in general, and within their higher education systems in particular. At the outset of the transition period, the first private universities appeared, the number of public universities increased, and there was a spectacular increase in the number of in most cases. Thus, in the last 20–25 years we assisted at the massification of the higher education not only in the Eastern Europe but throughout the world.

Figure 1 | The Logarithm of the GDP *per capita* and the Same Time Series in First Difference



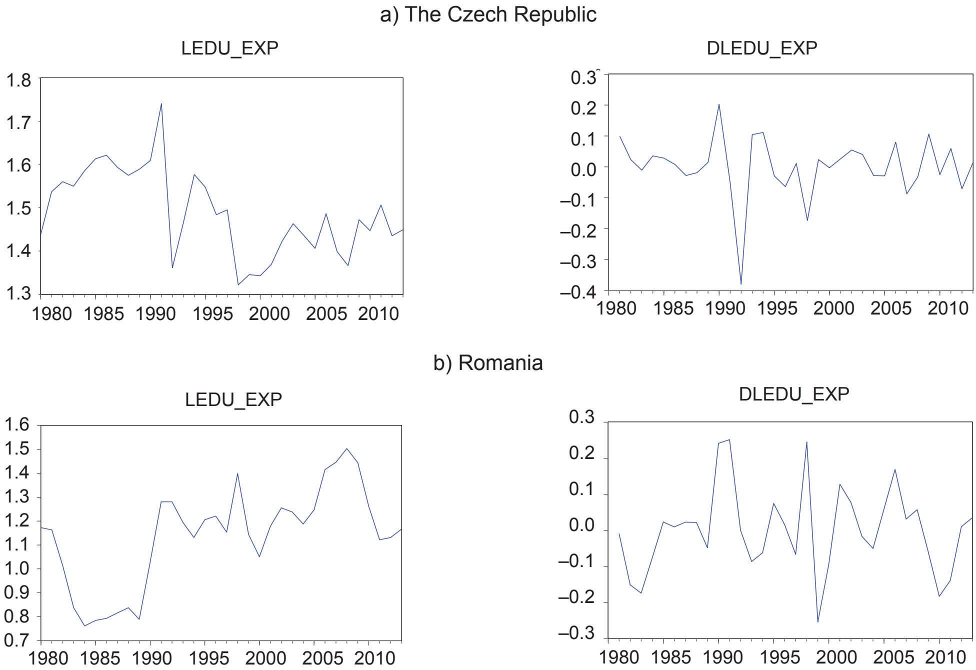
Source: Romanian National Statistics Institute, Czech Statistical Office, World Bank, and Econstats.

Figure 2 | The Logarithm of the Number of Students in Higher Education *per* 100,000 Inhabitants and the Same Time Series in First Difference



Source: Romanian National Statistics Institute and UNESCO Institute for Statistics.

Figure 3 | The Logarithm of the Public Education Expenditures and the Same Time Series in First Difference



Source: Eurostat Database and European Commission

The number of students enrolled in higher education in Romania was more or less constant between 1980 and 1990 under the communist regime when the access to higher education was restricted, but after the political changes in December 1989, there was an impressive growth in the number of students: there were 164,507 students in 1990 and this number increased to 1,098,188 in 2009 (a 6.67 times increase). After 2009, Romania experienced a decrease in population due to natural causes and international migration. These demographic changes together with the economic crisis caused the constant decrease in the number of students until 2013 when there were only 564,384 students, approximately the same number as in 2001. This decrease was very sharp and significant: in 2013, the number of students reached 51% of its level in 2009.

Table 1 shows the average annual increase rate of the number of students in Romania for three distinct periods: 1980–1989, 1990–2009 and 2009–2013. Until 1989 the number of students increased with an average yearly rate of 0.61%, between 1990 and 2009 the average increase rate was 10.5% (one of the largest in Europe) and after 2009, there was an average yearly decrease rate of 14.8%.

The number of Romanian universities increased from 56 universities with 186 faculties in 1990 to 103 universities with 590 faculties in 2013. This evolution is due to the emergence of the private universities and the increased number of public universities.

The evolution of the number of students enrolled in higher education in the Czech Republic was evolution. Between 1980 and 1990, the number of students was approximately constant, but after 1989, it increased from 113,417 students in 1990 to 441,247 in 2013

(3.9 times increase). The analysis of the evolution of the number of students must take into account the demographic trends in the Czech Republic. While the population in the Czech Republic is still about over 10,000,000, the number of people aged from 19 to 24 decreased from 975,000 in 1990 to 797,000 in 2013, so is just 82% of the value 23 years ago. Table 2 shows the annual average increase rate of the number of students in the Czech Republic.

Table 1 | Annual Average Increase Rate of the Number of Students in Romania

Period	Annual average increase rate
1980–1989	0.61%
1990–2009	10.50%
2009–2013	–14.80%

Source: Authors own computations using Romanian NSI data

Table 2 | Annual Average Increase Rate of the Number of Students in the Czech Republic

Period	Annual average increase rate
1980–1989	0.99%
1990–2013	4.50%

Source: Authors own computations using UNESCO Institute for Statistics data

Starting with 2011, there was a decrease in the number of students, but this decrease is very low in comparison with Romania: in 2013, the number of students was approximately 98% in comparison with the number of students in 2011.

Private universities in the Czech Republic started to appear in 1999. There are 44 private universities now with more than 50,000 students (about 12% of all university students) but there was not such a big increase in the number of public universities: there were 24 universities in 1990 and 27 in 2013. Nevertheless, a greater increase occurred in the number of faculties and individual study programs of public universities.

These figures show that the evolution of higher education was different: while it followed a steady and sustainable development process in the Czech Republic, there was an explosive increase in the number of students, totally uncorrelated with other variables such as the number of professors or the technical endowment of the higher education institutions which caused a massive drop in the number of students when the economic factors have changed.

The public expenditure on education in Romania has recorded an oscillating evolution with an increasing trend starting from 1990. Nevertheless, the public education expenditure has always been one of the lowest in the EU with a maximum value of 4.5% in 2008, showing that in Romania, the education is constantly underfinanced. In the Czech Republic there was also an oscillating evolution of public expenditure on education but at a higher level: 4.51% in 2011 compared to only 3.07% in Romania. Table 3 summarizes a descriptive statistics of the data series.

Table 3 | Descriptive Statistics of the Data Series

	GDP (constant LCU) *per capita*	Number of students per 100,000 inhabitants	Public expenditures on education as % of GDP
The Czech Republic			
Average	270,175.70	2,215.85	4.45
Median	248,318.70	1,934.00	4.38
Max. value	363,436.30	4,251.00	5.70
Min. value	202,487.10	1,036.00	3.75
Std. deviation	52,301.48	1,173.95	0.44
Romania			
Average	4,600.46	2,092.08	3.18
Median	4,389.39	1,529.00	3.22
Max. value	6,587.35	5,392.00	4.50
Min. value	3,349.10	681.00	2.14
Std. deviation	1,000.19	1,514.37	0.63

Source: Own computations using Romanian National Statistics Institute, Czech Statistical Office, World Bank, Econstat, UNESCO Institute for Statistics and Eurostat data.

Figures 1–3 show that the data series under analysis do not seem to be stationary in level but their first difference seem to mender around 0. In order to avoid the spurious regression problem, we will check if the data series used in our study have unit roots.

3. Methodology

The first step in our methodological approach was to test the stationarity of the data series using ADF and Phillips-Perron tests and determine the order of integration of each data series. According to Enders (1994), the ADF unit root test estimate the following equation:

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \tag{4}$$

If $\gamma = 0$ the above equation is entirely in first differences and has a unit root. The ADF and Phillips-Perron tests can be applied even if the error term is not a white noise. The number of lags p is determined by using an information criterion: Akaike, Schwarz or Hannan Quinn.

In the second step, we performed the Granger causality test that shows the capability of predicting future values of a data series using past values of other data series. If we consider two data series, X and Y, X is a Granger cause for Y if the past values of X can be successfully used to predict the future values of Y. The following regression model has to be estimated in order to test if X is a Granger cause for Y:

$$Y_t = b_1 + \sum_{j=1}^{p} a_{11}^j Y_{t-j} + \sum_{j=1}^{p} a_{12}^j X_{t-j} + \varepsilon_t \tag{5}$$

where the number of lags p is chosen such that the errors are white noise. The null and alternative hypotheses are:

$H_0 : a_{12}^1 = a_{12}^2 = \ldots = a_{12}^p = 0$, X is not a Granger cause for Y

$H_1 : \exists a_{12}^i \neq 0$

The null hypothesis can be tested using Fisher-Snedecor statistics:

$$F = \frac{\frac{(SSR_r - SSR_u)}{p}}{\frac{SSR_u}{(T-2p-1)}} = \frac{\frac{(R_u^2 - R_r^2)}{p}}{\frac{(1-R_u^2)}{(T-2p-1)}} \in F(p, T-2p-1) \tag{6}$$

where $SSR_u = \sum_{t=1}^{T} \varepsilon_{1t}^2$, R_u^2 is the determination coefficient in the unrestricted equation, SSR_r and R_r^2 have the same meaning but for the equation with the restrictions imposed by the null hypothesis, $a_{12}^1 = a_{12}^2 = \ldots = a_{12}^p = 0$.

Next, we proceeded to estimate the possible long-run relationship between data series. We employed a VAR model that has become a standard approach in time series modelling, mainly because it makes no assumptions of what variables are exogenous, considering that all variables are endogenous. In order to specify the VAR model we first had to decide how many lags should we include. For this purpose, we used information criteria (SBIC, AIC, HQ and FPE) as well as misspecification tests.

We used the Johansen-Juselius approach to test the cointegration between variables. Since we found out that our data series are I(1), we proceeded with a VEC model. If the general form of a VAR(p) model is given by:

$$Y_t = B + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \varepsilon_t \tag{7}$$

and all variables from the vector $Y_t = (Y_{1t}, Y_{2t}, \ldots, Y_{kt})'$ are I(1), the VAR representation can be put in an equivalent form called VECM (Vector Error Correction Model):

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \ldots + \Gamma_{p-1} \Delta Y_{t+1-p} + B + \varepsilon_t \tag{8}$$

where Π is a matrix that contains information regarding the long-run effect and Γi are matrices that measures the short-term impact:

$$\Pi = \sum_{j=1}^{p} A_j - I_k , \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j \tag{9}$$

One can conclude that $rank\ (\Pi) = r < k$ because $\Delta Y_{t-1}, \ldots, \Delta Y_{t+1-p}$ are stationary and ΠY_{t-1} should be stationary too, *i.e.* the determinant of the matrix Π should be zero. A matrix Π (k, k) with $rank\ (\Pi) = r < k$ can be decomposed as a product of two matrices $\Pi = \alpha \beta'$, where both matrices α and β have dimensions ($k \times r$). Matrix β contains r cointegration vectors while matrix α contains the adjustment coefficients. We can therefore write the VEC model as:

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \ldots + \Gamma_{p-1} \Delta Y_{t+1-p} + B + \varepsilon_t \tag{10}$$

where $\alpha\beta' Y_{t-1} = \mu_{t-1}$ is the stationary residual vector. The number of the cointegration equations between variables in vector Y_t is given by the rank of Π. The procedure of estimating the cointegration between variables is based on the maximum likelihood and it can be described shortly as follows. The estimated eigenvalues of Π are sorted $\hat{\lambda}_1 \geq \hat{\lambda}_2 \geq \ldots \geq \hat{\lambda}_k$. $\hat{\beta}$ is the matrix of the eigenvectors corresponding to the r greatest eigenvalues $\hat{\lambda}_i$, $i = 1, 2, \ldots, r : \hat{\beta} = (v_1, v_2, \ldots, v_r)$. The rest of the k-r eigenvalues $\hat{\lambda}_i$, $i = r+1, r+2 \ldots, k$ indicate the number of unit roots, providing nonstationary linear combinations. Two kinds of likelihood ratio may be used for testing whether the last k-r eigenvalues do not significantly differ from zero. First, the trace test has the following null and alternative hypotheses:

H_0: $\lambda_i = 0$, $i = r + 1, \ldots, n$
H_1: $rank\ \Pi > r$

and the statistics:

$$LR_{trace}(r) = -T \sum_{i=r+1}^{k} \log(1 - \hat{\lambda}_i) \ , \ \text{for } r = 0, 1, \ldots, k-1 \tag{11}$$

In order to reject the null hypothesis, the calculated value of the statistics should be greater than the critical value. The test is applied successively for $r = 0, 1, ..., k - 1$, until the first value of r that cannot reject H_0 is found, this value being the number of cointegration relationships, $rank\ (\Pi) = r$.

The null hypothesis of the second test tests the existence of r cointegration vectors against the alternative hypothesis of $r + 1$ cointegration vectors:

H_0: $rank\ \Pi = r$
H_1: $rank\ \Pi = r + 1$, $\quad r = 0, 1, ..., k-1$

The test statistics is:

$$LR_{max}(r, r+1) = -T \log\left(1 - \hat{\lambda}_{r+1}\right) r = 0, 1, ..., k-1 \tag{12}$$

The testing procedure is again sequential. We start with $r = 0$ ($rank\ \Pi = 0$, no cointegration) and test against the alternative $r = 1$ ($rank\ \Pi = 1$, one cointegration equation). If, for example, the calculated test statistics is greater than the critical value we can reject the null hypothesis and conclude that there is one cointegration equation (Enders, 1994, p. 392). Before stopping the procedure we should test $r = 1$ against the alternative hypothesis $r = 2$. If the test statistics is less than the critical value we cannot reject H_0 meaning that there is one cointegration equation.

4. The Results

We applied the ADF test for all variables in level and tested 3 models: M1 with intercept, M2 with intercept and trend, and M3 without intercept or trend. The results for M3 are shown in Table 4, the results of the other two models are similar. It can be observed that all variables have a unit root, which means that all variables are non-stationary. The same results have been obtained using the Phillips-Perron test.

Table 4 | The ADF and Phillips-Perron Tests for the Variables in Level

Variable	The Czech Republic		Romania	
ADF	**Test statistics**	**Prob.**	**Test statistics**	**Prob.**
LGDP_PER_CAPITA	1.74	0.98	0.80	0.88
LHE_STUD	3.47	0.99	0.08	0.70
LEDU_EXP	–0.28	0.57	–0.29	0.57
Phillips-Perron	**Test statistics**	**Prob.**	**Test statistics**	**Prob.**
LGDP_PER_CAPITA	2.20	0.99	1.03	0.92
LHE_STUD	2.83	0.99	1.08	0.92
LEDU_EXP	0.01	0.68	–0.30	0.56

Note: 5% critical value for ADF and Phillips Perron tests is –1.95.

Source: Own computations.

Table 5 | The ADF and Phillips-Perron Tests for the Variables in First Difference

Variable	The Czech Republic		Romania	
ADF	**Test statistics**	**Prob.**	**Test statistics**	**Prob.**
LGDP_PER_CAPITA	–3.62*	0.00	–2.61*	0.01
LHE_STUD	–3.41*	0.00	–1.70***	0.08
LEDU_EXP	–6.81	0.00	–4.68	0.00
Phillips-Perron	**Test statistics**	**Prob.**	**Test statistics**	**Prob.**
LGDP_PER_CAPITA	–3.61*	0.00	–2.63*	0.01
LHE_STUD	–3.43*	0.00	–1.70***	0.08
LEDU_EXP	–11.74*	0.00	–4.60*	0.00

Note: *, ** and *** denote significance at 1%, 5% and 10%
* 1% critical value for ADF and Phillips Perron tests is –2.64, 5% critical value is –1.95 and 10% critical value is –1.61.

Source: Own computations.

We applied the same tests but took the first difference of the data series into consideration. The results presented in Table 5 show that all data series are stationary in first difference and we can conclude that our variables are I(1). A causal relationship between the variables can be analysed using the Granger methodology. Table 6 shows the causal relationships found between the variables after applying the Granger test with 2 lags.

These results show a direct causality running from the number of students to the GDP *per capita* for both countries which means that the number of students enrolled in tertiary education is helpful for predicting the economic growth. Similar results were obtained when running the Granger causality test with 3 or 4 lags. A bidirectional causality has been found between the number of students and the public expenditures on education for the Czech Republic but for Romania this relationship goes only from the number of students to public education expenditures. The causality relationships should be considered with precaution since the variables are non-stationary. Granger causality is valid only if these variables are cointegrated (Enders, 1994).

Table 6 | The Causal Relationships between Variables

The Czech Republic			
Causal relationship	LHE_STUD → LGDP_PER_CAPITA	LHE_STUD → LEDU_EXP	LEDU_EXP→ LHE_STUD
F statistic	4.56**	4.14**	5.27**
Romania			
Causal relationship	LHE_STUD → LGDP_PER_CAPITA	LHE_STUD → LEDU_EXP	
F statistic	6.67*	3.43**	

Note: * and ** denote significance for 1% and 5%.

Source: Own computations.

Since the data series are integrated of the same order, the next step was to estimate the VAR model and decide how many lags should be included in the model. The number of lags was chosen by using the information criteria: Akaike (AIC), Schwarz (SC), Hannan-Quinn (HQ), Final Prediction Error (FPE), modified sequential LR. These criteria indicate 2 lags for Romania and 1, 2 or 3 lags for the Czech Republic. For the Czech Republic, we chose 3 lags based on specification criteria of the VAR model. Table 7 shows the values of the information criteria used to determine the number of lags.

Table 7 | Information Criteria for Selecting the Number of Lags for the VAR Model

Lag	LogL	LR	FPE	AIC	SC	HQ
The Czech Republic						
0	46.93	NA	1.07e−05	−2.93	−2.79	−2.88
1	140.08	161.47	3.95e−08	−8.54	−7.98*	−8.36
2	153.12	19.99*	3.08e−08	−8.81	−7.83	−8.49*
3	163.95	14.44	2.88e−08*	−8.93*	−7.53	−8.48
4	168.75	5.42	4.23e−08	−8.67	−6.83	−8.06
Romania						
0	−0.68	NA	2.55e−04	0.24	0.37	0.28
1	115.31	202.04	2.57e−07	−6.66	−6.11	−6.48
2	134.03	28.98*	1.40e−07*	−7.29*	−6.32*	−6.97*
3	138.95	6.67	1.91e−07	−7.03	−5.64	−6.57

Source: Own computations.

We tested the existence of a cointegration relationship between variables using the Johansen-Juselius method. The results of the Johansen Juselius cointegration test shown in Table 8 indicate that there are no cointegration relationships between these three variables for Romania.

We eliminated the public expenditure on education from the model and tested the existence of a cointegration relationship between GPD *per capita* and the number of students for Romania again. We redefined the VAR model only with the two variables and used the LR, FPE, AIC, SC and HQ information criteria to determine the number of lags which indicated 2 lags (the results are shown in Table 8).

Table 8 | Information Criteria Used to Select the Number of Lags for the 2 Variable VAR Model for Romania

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−22.43	NA	0.02	1.57	1.67	1.61
1	80.97	186.79	2.72e−05	−4.84	−4.56	−4.75
2	97.47	27.67*	1.22e−05*	−5.64*	−5.18*	−5.49*
3	98.15	1.04	1.53e−05	−5.43	−4.78	−5.22

Source: Own computations.

The results of the Johansen test for the model with 2 variables and 2 lags are presented in Table 9. AIC indicates that the most appropriate model is M2 with one cointegration equation between variables.

Table 9 | Johansen Cointegration Test for LGDP_PER_CAPITA and LHE_STUD for Romania

Model	M1	M2	M3	M4	M5
Data trend	None	None	Linear	Linear	Quadratic
Test type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	1	2	1	2
Max-Eig	0	1	2	0	0
Rank/ No. of cointegrating equations	**AIC**				
0	−5.42	−5.42	−5.33	−5.33	−5.27
1	−5.37	−5.61*	−5.54	−5.56	−5.55
2	−5.13	−5.45	−5.45	−5.53	−5.53

Source: Own computations.

For the Czech Republic we tested the existence of a cointegration relationship between the three variables and the results indicate that there is such a relationship. We estimated the VEC model but this was invalidated by the specification tests (normality and autocorrelation of the errors). As in the case of Romania, we eliminated the public expenditure on education from the model and tested the existence of a cointegration relationship between GPD *per capita* and the number of students again. We could not find any cointegration relationship between these two variables and we restricted the time period to 1990-2013 after we tested that the variables under analysis are I(1) for the new time period. We redefined the VAR model and using the information criteria, we found that the optimum number of lags is 4. The results of the Johansen Juselius tests are presented in Table 10 which indicates that there is one cointegration equation.

Table 10 | Johansen Cointegration Test for LGDP_PER_CAPITA and LHE_STUD for the Czech Republic

Model	M1	M2	M3	M4	M5
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	2	1	0	0
Max-Eig	1	0	0	0	0

Rank/ No. of cointegrating equations			AIC		
0	−5.67	−5.67	−5.90	−5.90	−5.95
1	−5.93	−5.91	−6.12*	−6.06	−6.11
2	−5.71	−5.90	−5.90	−5.89	−5.89
			SIC		
0	−5.08	−5.08	−5.21	−5.21	−5.17
1	−5.14	−5.07	−5.24*	−5.13	−5.12
2	−4.72	−4.82	−4.82	−4.72	−4.72

Source: Own computations.

Both AIC and SIC indicate that model M3 with one cointegrating equation is the most appropriate one.

The existence of a cointegrating equation for both countries indicates that there is a long-run relationship between the variables and a VEC model will capture this relationship. The long-term relationship between variables is very important to validate the Granger causality tests presented earlier in this section. We estimated the VEC model for Romania and the Czech Republic and we obtained the cointegration vector β presented in Table 11 and the adjustment parameters α presented in Table 12. The linear combination $\beta' Y_t$ with $Y_t = (LGDP\_PER\_CAPITA_t, LHE\_STUD_t)$ is a stationary combination.

Table 11 | Cointegration Parameters (t statistics in [])

The Czech Republic	
LGDP_PER_CAPITA(−1)	1.00
LHE_STUD(−1)	−0.42 [−8.41]
C	−9.29
Romania	
LGDP_PER_CAPITA(−1)	1.00
LHE_STUD(−1)	−0.20 [−4.48]
C	−6.92

Source: Own computations.

Table 12 | The Adjustment Parameters α

D(LGDP_PER_CAPITA)	D(LHE_STUD)
The Czech Republic	
−0.31	−0.03
Romania	
−0.20	−0.15

Source: Own computations.

The cointegration equations can be written as:

The Czech Republic: $$LGDP\_PER\_CAPITA_t = 9.30 + 0.42 \cdot LHE\_STUD_t \tag{13}$$

Romania: $$LGDP\_PER\_CAPITA_t = 6.90 + 0.20 \cdot LHE\_STUD_t \tag{14}$$

The cointegration equations shows that a 1% increase in the number of students enrolled in higher education leads to a 0.42% increase in GDP *per capita* for the Czech Republic and 0.20% for Romania meaning that higher education has a significant positive effect on economic growth in both countries but the effect is twice greater for the Czech Republic than for Romania. This result indicates that the investment in higher education leads to economic growth and is consistent with other studies (Barro, 1995, 2010 and 2013; Ljundberg and Nilsson, 2009; Lin, 2004).

The negative sign of the adjustment coefficients α indicates that the GDP *per capita* is an endogenous variable which corresponds to the theoretical framework and the model is dynamically stable. The negative sign also shows that there is direct causality running from the number of students to the GDP *per capita*.

The error correction equations are:

The Czech Republic:

$$\begin{aligned}\Delta LGDP\_PER\_CAPITA &= -0.31\mu_{t-1} + 0.42\Delta LGDP\_PER\_CAPITA_{t-1} \\ &-0.17\Delta LGDP\_PER\_CAPITA_{t-2} - 0.035\Delta LGDP\_PER\_CAPITA_{t-3} \\ &+0.04\Delta LHE\_STUD_{t-1} - 0.04\Delta LHE\_STUD_{t-2} - 0.04\Delta LHE\_STUD_{t-3}\end{aligned}$$

$$R^2 = 0.63 \qquad (15)$$

$$\Delta LHE\_STUD_t = -0.03\mu_{t-1} + 0.06\Delta LGDP\_PER\_CAPITA_{t-1} + 0.52\Delta LGDP\_PER\_CAPITA_{t-2} - 1.15\Delta LGDP\_PER\_CAPITA_{t-3} + 0.07\Delta LHE\_STUD_{t-1} - 0.11\Delta LHE\_STUD_{t-2} + 0.07\Delta LHE\_STUD_{t-3}$$

$$R^2 = 0.42 \qquad (16)$$

Romania:

$$\Delta LGDP\_PER\_CAPITA_t = -0.2\mu_{t-1} + 0.66\Delta LGDP\_PER\_CAPITA_{t-1} - 0.25\Delta LHE\_STUD_{t-1}$$

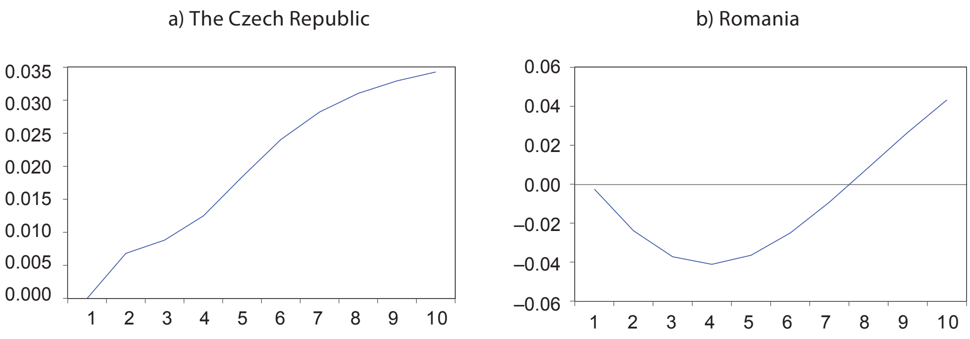
$$R^2 = 0.57 \qquad (17)$$

$$\Delta LHE\_STUD_t = -0.15\mu_{t-1} + 0.08\Delta LGDP\_PER\_CAPITA_{t-1} + 0.56\Delta LHE\_STUD_{t-1}$$

$$R^2 = 0.51 \qquad (18)$$

Figure 4 shows the impulse-response function of the GDP *per capita* to a shock in the number of students. For the Czech Republic the impulse-response function shows that an impulse in the number of students leads to an increase in the GDP *per capita* and this effect is permanent while for Romania it causes a drop in the GDP *per capita* in the first 4 years followed by an increase in the GDP in the long term.

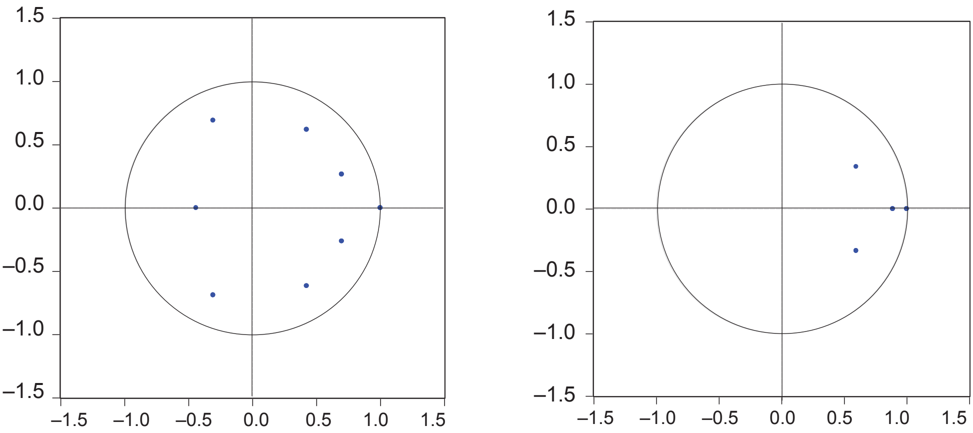
Figure 4 | The Impulse Response Function



Source: Own computations.

We have made a series of tests to verify the stability of the models and the correctness of the specification. Jarque Berra test indicates that the residuals are normally distributed and the LM test for detection of the residuals' autocorrelation indicates that the null hypothesis cannot be rejected which means that there is no autocorrelation. We have also computed the inverse roots of the AR characteristic polynomials: excepting one unit root imposed by the VEC model, the rest of the roots are inside the unit circle, which means that the models are stable.

Figure 5 | The Inverse Roots of the AR Characteristic Polynomial



Source: Own computations.

5. Conclusions

The relationship between education and economic growth is a central theme in economic research. In the introduction we briefly presented some empirical models on education-economic growth relationship developed in recent years. Next, we examined the long-run relationship between economic growth and higher education in the Czech Republic and Romania. For this purpose we used data series for GDP *per capita*, the number of students enrolled in higher education *per* 100,000 inhabitants and the public education expenditure as a share of GDP. We tested the data series for unit roots in level and in first difference and found that they are I(1). Using the Johansen-Juselius method, we tested whether there is a cointegration relationship between GDP *per capita*, public education expenditure and the number of students enrolled in higher education. The test showed that there is a cointegration equation only between GDP *per capita* and the number of students for both countries. This means that there is a long-term relationship between higher education and economic growth. We estimated a VEC model for both countries and we showed that the number of students in higher education has a significant positive effect on economic growth. For the Czech Republic, an increase with 1% in the number of students leads to a 0.42% increase in GDP *per capita* while in Romania it leads to 0.2% increase. We also showed that the causal relationship goes from higher education to economic growth. Our results are in line with other studies (Barro, 1995; 2010; 2013; Ljundberg and Nilsson, 2009;

Lin, 2004) that highlighted a causal relationship from education to economic growth and contradicts other studies mentioned in the introduction that advocate a reverse relationship, from economic growth to education.

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