Higher education and economic growth: the importance of innovation

Mabrouka Bouhajeb [*]

Haifa Mefteh [**]

Rania Ben Ammar [***]

[*] PhD student, Faculty of Economics and Management, University of Sfax, Tunisia. Email:bouhajebm@yahoo.fr

[**] Doctor (PhD), Faculty of Economics and Management, Universityof Sfax, Tunisia.Email :haifamefteh@yahoo.fr

[***] PhD student, Faculty of Economics and Management, University of Sfax, Tunisia. Email: Rania.ba@outlook.com

Abstract

Higher education is considered as an engine for development and growth in the knowledge society, because of its benefits to boost research, knowledge and technological innovation. This paper examines the relation between innovation, higher education and economic growth during the 1996-2014 period in the case of developed and developing countries. The cointegration relationship between series was examined by using panel cointegration test developed by Pedroni (1999, 2004) and Kao (1999). As a result of the empirical analysis, cointegration relationship between the series was determined. The results provide also evidence of a positive effect of innovation in tertiary education on economic growth.

Resumen

La educación superior está considerada como un motor de desarrollo y crecimiento en la sociedad del conocimiento, debido a sus beneficios para impulsar la investigación, el conocimiento y la innovación tecnológica. Este documento examina la relación entre la innovación, la educación superior y el crecimiento económico durante el período 1996-2014 en el caso de los países desarrollados y en desarrollo. La relación de cointegración entre series se examinó mediante el uso de la prueba de cointegración de panel desarrollada por Pedroni (1999, 2004) y Kao (1999). Como resultado del análisis empírico, se determinó la relación de cointegración entre las series. Los resultados también proporcionan evidencia de un efecto positivo de la innovación en la educación terciaria sobre el crecimiento económico.

Keywords: Economic growth, Higher education, Innovation, R&D, Panel cointegration, DOLS.

JEL Classification: O31, I23, O40, C23

1. Introduction

Education is one of the most important factors of economic growth. Therefore, the relationship between higher education and economic growth has been a central subject of research in economics. In fact, human capital accumulation has become importance due to the emergence of endogenous growth theory given by Lucas (1988), Romer (1989, 1990) and Mankiw et al. (1992) who firstly used human capital in production function.

In fact, human capital theory, which was primarily developed by Schultz (1961), Becker (1962), Denison (1962) and Mincer (1974), is about the role of human capital in the production process and about the incentives to invest in skills, including the forms of schooling and training.

There is a solid theoretical framework of the economic growth and its relationship with education (Greiner et. al, 2005; Mankiw et al. 1992; Barro & Sala-i-Martin, 2004; Romer, 1989). Most of these previous studies generally confirmed the existence of a positive correlation between human capital and economic growth.

Nowadays, it is known that investment in human capital and knowledge economics are significant contributors to economic growth.

In this context, Benhabib & Spiegel (1994) showed that human capital is a determinant of production using a function type of Cob Douglas. However, the significant affect between human capital and gross domestic product (GDP per capita) is visible in this aspect, which influences the internal rate of innovation (Romer, 1989).

Indeed, innovation, as a pattern of investment in education, strengthens competitiveness as well as progress and, through them, a sustainable economic growth.

However, innovation in education is a difficult concept to define since it is a multidimensional notion which appears in difficult areas. Consequently, the conception of innovation was discussed, defined and developed from the perspective of several disciplines: sociology, psychology, economics, linguistics, management, cognitive science, philosophy, etc. (Popescu & Crenicean, 2012).

In order to identify the innovation variable, several studies, especially in the past, used research and development (R&D) as a measure of innovative activities (Schmookler, 1966). Recently, counts of the number of patents have been used as a proxy for innovation (Ahuja & Katila, 2001). In addition to the pervious indicator, some others have focused on information and communication technologies (ICT) to describe innovation (Charles & Issifu, 2015; Buabeng-Andoh & Yidana, 2015).

Various studies have focused on different countries, time periods, modeling techniques and different proxy variables which have been utilized to examine the relation between education and economic growth (Giziene et al., 2012; Simanaviciene et al., 2015; Dragoescu, 2015); innovation and economic growth (Genç & Atasoy, 2010; Falch & Mang, 2015); innovation and education (Tezci, 2011; Kubiatko & Halakova, 2009; Charles & Issifu, 2015).

Our study thus contributes to this existing literature by giving the first integrated approach to examine the three way linkages between higher education, innovation and economic growth in 42 heterogeneous countries over the 1996-2014 period.

That is to say that, education, and mainly higher education, can influence economic growth in various ways: education is converted to increased labor productivity by accumulating knowledge and skills by facilitating technological progress and innovation.

This hypothesis is tested using a sample of 42 countries divided into two groups according to their income level. Such a classification is based on the World Bank calculated using the World Bank Atlas method, in 2016[1]. They are developing countries (all countries with incomes below $ 12,236 per capita), which include Argentina, Belarus, Bulgaria, Cuba, India, Iran, Kyrgyz Republic, Madagascar, Malaysia, Mexico, Morocco, South Africa, Thailand, Tunisia, Turkey, Ukraine and developed countries (all countries with incomes of $ 12,236 per capita or more), including Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, United Kingdom, United States, Uruguay. The econometric analysis of this heterogeneous panel includes:

First unit root tests to verify the order of integration of the variables. Second, cointegration tests to examine the presence of long term relationship and finally, a Dynamic Ordinary Least Squares (DOLS) panel model to estimate the impact of innovation and higher education variables on economic growth.

This paper proceeds as follows: section 2 briefly reviews the related literature, followed by section 3 that presents the data and the methodology. Section 4 depicts the empirical findings and section 5 concludes.

2. Literature review

Several existing studies on the nexus between innovation, education and economic growth are carried out on a piecemeal basis without a comprehensive model in mind while ignoring the potential interaction between the series. Therefore, this paper reviews the literature under three subsections, e.g. (a) Education and economic growth; (b) innovation and economic and growth finally, (c) innovation and education. We discuss them in turn below.

[1] World Bank databases, July 2016, Country Classification, Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

2.1. Education and economic growth

Barro & Sala-i-Martin (2004) tested the junction between education quality measured by education expenditures in % of GDP and economic growth. Their research proves that there is a positive relation between the series. Some research found a linear relationship between education and growth, Uzawa (1965), Lucas (1988) and Rebelo (1991) who relied on the importance of the investment in human capital as a crucial factor influencing the spectacular growth recorded modern economics. However, others, such as Romer (1990), Grossman & Helpman (1991) and Aghion & Howitt (1992) state that innovative technical changes are a determinant of economic development.

Simanaviciene et al. (2015) envisaged the importance of investment in higher sector since it allows quality training by preparing a worker who is better educated and trained and able to produce and realize profit.

Furthermore, Dragoescu (2015) investigated the causality relationship between education, especially higher education and economic growth in Romania for the 1980-2013 period by using a vector correction model. Given the importance of education on economic growth, Cooray (2009) examined the effect of both the quantity and quality of education.

In this respect, Glewwe et al. (2014) examined the impact of education on economic growth. Their results showed that the effect of education on economic growth in sub-Saharan Africa is lower than that in other countries due to lower school quality.

In such a way, showing the effect of government expenditure on economic growth is largely indirect through its impact on improved education quality.

2.2. Innovation and economic growth

The economic growth theory confirmed that innovation is a primary source of productivity growth. In fact, the literature on economic growth identified a technical change as the major contributor to productivity growth (Solow, 1957). Thus, innovation, which is defined as the creation of new and improved products and new production methods that increase efficiency, is the driving force of economic growth (Falch & Mang, 2015).

On his part, Schumpeter dealt with the concept of creative destruction according to which innovation replaces old products and technologies having a positive impact on the turnover evolution. Therefore, the competition in the market caused by the entry of new innovations and the exclusion of old technologies comes to support the strength of economic growth (Aghion et al. 2010).

Ulku (2004) investigated the relationship between economic growth, research and development expenditure by using a panel model for the period 1981-1997. His result showed that research and development expenditure increases the level of innovation and leads to permanent growth of GDP per capita. Following this seminal study, Tiryakioğlu (2006) examined the relation between research and development expenditure and economic growth in the Organisation for Economic Co-operation and Development (OECD) countries by using causality tests. The findings obtained from this study demonstrate that there exists causality relationship between series. The same result was found by Genç and Atasoy (2010) for the case of 34 heterogeneous countries during the 1997-2008 period.

Gülmez & Yardımcıoğlu (2012) showed that there is a strong cointegration relationship between research and development expenditure and economic growth in the long run by using the Pedroni and Kao panel cointegration for the period between 1990 and 2010.

Recently, Westmore (2013) has investigated the determinants of research and development expenditure and patents in order to identify the link between innovation and economic growth. He used a panel of 19 OECD countries, during the 1980-2008 period. The empirical results provide evidence that public support for research and development and for patent rights encourages innovation activities. More recently, the results of Özcan & Arı (2014) have indicated that research and development positively affect economic growth.

Recently, Adak (2015) has examined the influence of technological progress and innovation on the Turkish economy. Their results showed a significant effect of technological progress and innovation on economic growth through ordinary least squares (OLS) method.

Consequently, innovation is an essential element to generate standardized economic growth. However, we cannot talk about innovation without a high level of education or a high standard of living.

2.3. Innovation and education

It is known that currency to achieve a high standard of living, a developed nation showed focus on education, research and innovation. For this reason, some studies, such as that of Popescu & Crenicean (2012) stated that existing innovation activities and changes in education for the case of Romania have an impact on economic growth. The research focuses on various educational institutions and modern forms of teaching and learning which promote creativity and strengthen entrepreneurial skills.

According to Tezci (2011) and Kubiatko & Halakova (2009), Information Communication Technology (ICT) has challenged the conventional teaching methods, transformed instructional practices and contributed to the emergence new instructional methods. Following this seminal study, Teles & Joiozo (2011) evaluate the contribution of human capital to technological innovation applying a panel data from 27 countries for the period 1960 to 2000. Their results significantly revealed that there is a clear long run relationship between human capital stock and the quantity of innovation. This relationship reflects the cointegration between the number of patents and the public spending in tertiary education.

Recent studies, which have examined the relation between innovation and education are, as follows Charles & Issifu (2015). In their study, the authors used a total of 3380 students from 24 public and private schools from four regions in Ghana. Research finding from ICT usage may have important implications for administrators, students and employers and may enhance educational delivery to students, students' learning experience in secondary schools and student's application of knowledge and skills in the real world of work.

The work of Kruss et al. (2015) shows how South African higher education institutions contribute to economic development by drawing on evolutionary economic and the national innovation system approach through two case studies from astronomy and automotives. Therefore, there are counter arguments that point out to limit interactions between the key variables of higher education expansion, growth, productivity and technological change. Moreover, Vitola & Erina (2015) compared higher education performance indicators and their relation with research and development expenditure in the Baltic States. The authors concluded that research and development expenditure in higher education sector is partially related to performance indicators in Latvia and Lithuania, contrary performance indicators are more related to expenditure in Estonia.

In addition, Iacopetta (2010) analyzed the transitional dynamics of a growth model utilizing time series data in which both human capital and innovation drive income expansion. This generates a trajectory showing that human capital formation is a first step toward the emergence of a modern economy.

Innovation will play a critical role in economic growth. Some of the most innovative discoveries have their origins in research conducted at universities. Countries with high levels of innovation also tend to have, on average, higher proportions of graduates in their populations and a stronger track record of investment in higher education.

As a consequence, innovation in education system allows several countries to attract new talents and improve the citizen's competences. Besides, it promotes science and research and, in this way, stimulates innovation, productivity, employment and growth.

3. Data and Methodology

3.1. Data analysis

The data set consists of cross-country observations, for 42 countries over the 1996–2014 period, obtained from the data base of World Development Indicators (http://data.worldbank.org/indicator). In this study, we employ data on 42 countries (developing and developed) in the world. Countries are chosen according to the availability of their data. The variables are per capita GDP which measures the economic growth, RD as a proxy of research and development expenditure, PAT as proxy of number of patent applications and EDU is the proxy of expenditure on tertiary education.

3.2. Methodology

In this study, the model is estimated using panel data for 42 countries. The panel data analysis allows the implication of data for N cross-sections (e.g. countries) and T time periods. The combined panel data consist of a time series for each cross-sectional member in the data set and offer a variety of estimation methods (Asteriou & Hall, 2007).

To examine the three-way linkages between higher education, innovation and economic growth in heterogeneous countries, we used a Cobb–Douglas production function where the gross domestic product (GDP) depends on human capital and innovation.

By taking log, the linearized model can be given as follows:

$$In\ GDP_t = \alpha_1 + \alpha_2 RD_t + \alpha_3 PAT_t + \alpha_4 EDU_{\ t} + \varepsilon_t \qquad (1)$$

The model is then:

$$lnGDP_{it} = \alpha_1 + \alpha_2 lnRD_{it} + \alpha_3 lnPAT_{it} + \alpha_4 lnEDU_{it} + \varepsilon_t \qquad (2)$$

Where the subscript i=1,….., N denotes the country (in our study, we have 42 countries) and t = 1, ……, T denotes the time period (our time frame is 1996–2014), lnGDP is real output, lnRD is the indicator of research and development expenditure, lnPAT is the number of patent applications, lnEDU is the expenditure on tertiary education (% of government expenditure on education) and ε is the error term.

3.3. Panel unit root tests

In order to understand whether there is a long run relationship between all the variables, applying cointegration test, should check nether all the variables are stationary at level or not. If these series are not stationary at level, it should be preceded by first difference to get stationary positions. When all the series become stationary at first difference level, we can use co-integration test (Dickey & Fuller, 1981; Phillips & Perron, 1988).

Therefore, we begin our work by performing the panel unit root test proposed by Levin et al. (LLC) (2002) and Im et al. (IPS) (2003). Both tests are based on the Augmented Dickey- Fuller principle.

Levin et al. (2002) considered the following basic Augmented Dickey–Fuller model:

$$\Delta X_{i,t} = \alpha i + \beta_i X_{i,t-1} + \sum_{j=1}^{P_i} \mu_{i,j}\, \Delta X_{i,t-j} + \varepsilon_{i,t} \qquad (3)$$

Where Δ is the first difference operator, $X_{i,t}$ is the dependent variable i over period t, and $\varepsilon_{i,t}$ is a white-noise disturbance with a variance of σ_i^2.

Both β_i and the lag order μ in this equation are permitted to vary across sections (countries). Hence, it is assumed that:

$$\begin{cases} H_0: \beta_i = 0 \\ H_1: \beta_i < 0 \end{cases}$$

According to LLC test, compared with the single-equation Augmented Dickey-Fuller test, the panel method sensibly raises power in finite samples. The proposed model is as follows:

$$\Delta X_{i,t} = \alpha i + \beta X_{i,t-1} + \sum_{j=1}^{P_i} \mu_{i,j}\, \Delta X_{i,t-j} + \varepsilon_{i,t} \qquad (4)$$

It is also assumed that:

$$\begin{cases} H_0: \beta_1 = \beta_2 = \cdots = \beta = 0 \\ H_1: \beta_1 = \beta_2 = \cdots \beta < 0 \end{cases}$$

where the statistics of the test is $t_\beta = \frac{\beta}{\sigma(\beta)}$; β is the OLS estimate of β in Eq. (4) and σ(β) is its standard error.

Im et al. (2003) proposed a testing procedure based on the mean group approach and also on the Augmented Dickey-Fuller regression presented by Eq.(3). By contrast, the null and alternative hypotheses are not similar to the LLC test, where the rejection of the null hypothesis indicates that all the series are stationary.

Now, we have: H_0: $\beta_1 = \beta_2 = \ldots\ldots = \beta_N = 0$ vs. H1: Some but not necessarily all $\beta_i \prec 0$

The IPS test is calculated as the average of the t-statistic with and without trend. Alternative t-bar statistics for testing the null hypothesis of the unit root for all individuals ($\beta_i = 0$) is as follows:

$$\bar{t} = \frac{\sum_{i=1}^{N} t\beta_i}{N} \qquad (5)$$

Where t is the estimated Augmented Dickey-Fuller statistics from individual panel members; N is the number of individuals. Using the Monte Carlo simulations, this test shows that the t-bar ($\bar{t}$) is normally distributed under the null hypothesis. Accordingly, the estimates of its mean and variance is used to convert t-bar ($\bar{t}$) into a standard normal z-bar ($\bar{z}$) statistic which is given by:

$$\bar{z} = \frac{\sqrt{N}(\bar{t} - E[\bar{t} \backslash \beta_i = 0])}{\sqrt{var[\bar{t} \backslash \beta_i = 0]}} \to N(0,1) \qquad (6)$$

Where E [$\bar{t}$ / $\beta_i = 0$] and var [$\bar{t}$ / $\beta_i = 0$] are the mean and variance of t_{it}.

Moreover, the IPS study shows that the standardized statistic converges weakly to the standard normal distribution, which allows the comparison with critical values of the distribution N (0,1).

3.4. Panel cointegration

The concept of cointegration introduced by Granger (1969) is relevant to the problem of determining long-run relationships between variables. The basic idea that supports cointegration is simple. If the difference between two non stationary series is itself stationary, then the two series are cointegrated. If two or more series are cointegrated, it is possible to interpret the variables in these series as being in a long-run equilibrium relationship (Engle & Granger, 1987). By contrast, a lack of cointegration suggests that the variables have no long-run relationship-thus, in principle, the postulated variables can arbitrarily move far away from one another. Therefore, Panel cointegration test is used to investigate the long-run equilibrium relation between the dependent variable and all the independent variables as a group in the model.

In fact, there are numerous cointegration tests such as those of Engle & Granger (1987), Johansen (1991) and Philips & Ouliaris (1990), which documented in the time series literature. However, these tests fail to take advantage of information across countries, which lead to the loss of efficiency in estimation. Recently, several authors, such as Pedroni (2004), Kao & Chiang (2000) and Kao (1999) have developed cointegration tests with panel data. In this article, we employ the Panel cointegration tests proposed by Pedroni (2004) and Kao (1999) to test whether a cointegration exists in the estimated equations.

To test the null hypothesis of non cointegration, Pedroni (1999, 2004) proposed seven cointegration tests of two types: Four within the model and three between models. This study employs the Augmented Dickey–Fuller (ADF) statistic and the ADF statistic for groups since Pedroni (1999) showed that the ADF tests work better than others when applied to small samples, such as the present panel. Following Pedroni (1999), the heterogeneous panel and group of the mean panel cointegration statistics are calculated as follows (Lee, 2005)

Panel ADF-statistics:

$$\tilde{Z}_t^* = \left(\hat{S}^{*2}\right) \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\hat{L}_{11i}^{-2}\, \hat{e}_{it-1}^{*2}\right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(\hat{L}_{11i}^{-2}\, \hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*}\right) \qquad (7)$$

Group ADF-statistics:

$$\tilde{Z}_t^* = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{S}_i^2 \hat{e}_{it-1}^{*2}\right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*}\right) \qquad (8)$$

Where e_{it} is the estimated residual from Eq. (1) and L^2_{11i} is the estimated long run covariance matrix for $\widehat{\Delta e_{it}}$ Likewise, $\hat{\sigma}_i^2$and $\hat{S}_i^2$ $(\hat{S}^{*2})$ are, respectively, the long run and contemporaneous variances for individual i. The other terms are appropriately defined by Pedroni (1999) with the property lag length determined by the Newey-West method. Despite the fact that co-integrated test was already proposed more than one decade ago, it is use is still very much used. The reasons are that the principles at the basis of the survey, the design of the seven cointegration tests in their two types, between and within the models, entail a certain strength in their results, due to the fact that they combine time series and cross sectional data obtaining more degrees of freedom, which improves properties of the estimators and corrects non observer heterogeneities (Robledo & Olivares, 2013). The panel Cointegration technique is still active and used in several studies as the main method (Cetin et al. 2014) or in a complementary way (Adhikari & Chen, 2012; Jebli & Youssef, 2015).

However, Kao offered two types of tests to examine panel cointegration, which are the Dickey Fuller (DF) and the augmented Dickey Fuller (ADF) tests. Besides, others used the Fisher type test to aggregate the p values of the individual Johansen maximum likelihood cointegration test statistics. Because the Ordinary least squares (OLS), which is used to estimate the panel cointegration vectors, are a biased and inconsistent estimator, hence, the Panel Dynamic Ordinary Least Squares (DOLS) estimator was introduced by Pedroni (2000); Phillips and Moon (1999) and developed by Kao and Chiang (2000) which is allowed to take serial correlation and endogeneity of the regressors into the conventional OLS estimator.

Additionally, we used the DOLS technique developed by Kao and Chiang (2000) to estimate the long-run panel cointegrated model. DOLS builds upon the time series analysis of Stock (Stock & Watson, 1993; Saikkonen, 1991). Kao and Chiang's (2000) Monte Carlo simulations showed that DOLS outperforms both the OLS and Fully Modified OLS (FMOLS) estimators on all counts. The estimated coefficients of the DOLS converge to the same coefficients as the FMOLS estimation. Mark & Sul (2003) evaluated the panel DOLS estimator by Monte Carlo simulation. They concluded that panel DOLS provides much more precise estimates and has standard asymptotic distributions that provide reasonably close approximations to the exact sampling distributions in small samples.

The model of the DOLS is as follows:

$$Y_{it} = \alpha_i + X_{it}\beta_i + u_{it}^* \qquad (9)$$

$$X_{it} = X_{it-1} + V_{it} \qquad (10)$$

With the regressors Y_{it} a real output, X_{it} is the indicator of research and development expenditure, number of patent applications, expenditure on tertiary education at time t, and being integrated of order 1, then cointegrated with slopes β_i.

4. Empirical results

4.1. Results of panel unit root tests

To investigate the stationarity of the series used, we applied the unit root tests on panel data (LLC, IPS) .The results of these tests are presented in table 1.

Table 1: Results for panel unit root tests (Level and First Differences)

Variables	LLC test				IPS test			
	Level		First difference		Level		First difference	
	T-Statistics	p-value	T-Statistics	p-value	T-Statistics	p-value	T-Statistics	p-value
GDP	-0.60942	0.2711	-8.69634	0.0000	3.84376	0.9999	-6.26461	0.0000
RD	0.23738	0.5938	-8.90663	0.0000	-0.34380	0.3655	-11.9905	0.0000
PAT	-1.19452	0.1161	-5.55852	0.0000	-1.50875	0.0657	-12.5167	0.0000
EDU	-4.92059	0.0000	-15.6323	0.0000	-6.09474	0.0000	-17.7521	0.0000

Source: Author' estimations

From the results of the unit root tests performed for the seven panels of the study, we can draw the following conclusions: All the statistics are not significant at 1% level for all the variables except for EDU. After differentiation into first degree data, we noticed a significant way that all data are stationary for all the variables. Thus, all the series are integrated of order one I (1).These results led us to a logical way to test for the presence or absence of a long-term relationship between them by applying Co-integration.

4.2. Results of cointegration tests

According to the results of Table 1, we confirm that all the variables are I (1), then we start the long-run analysis, that is to use panel cointegration tests examining the relationship between the four variables. Besides, considering the analysis of sensitivity and robustness, we employed two kinds of panel cointegration tests, those of Pedroni and Kao panel cointegration tests.

4.2.1. Pedorni's residual cointegration test results

Cointegration requires that all the variables are integrated of the same order.

The results of panel unit root test indicate that our variables are first order integrated I(1). Then, we proceed to test cointegration panel, by relying on Pedroni's Residual-Based Panel Cointegration Tests (1999, 2004), which refer to seven different statistics for this test. The results are presented in table 2.

Table 2: Results for Pedroni's panel cointegration tests

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob	Weighted Statistic	Prob
Panel v-Statistic	-1.724254	0.9577	-2.157136	0.9845
Panel rho-Statistic	-1.233770	0.1086	-0.789497	0.2149
Panel PP-Statistic	-6.730716	0.0000	-6.503468	0.0000
Panel ADF-Statistic	-5.887024	0.0000	-6.663201	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)				

	Statistic	Prob.
Group rho-Statistic	0.652806	0.7431
Group PP-Statistic	-9.478929	0.0000
Group ADF-Statistic	-7.002707	0.0000

Source: Author' estimations

From table 2, out of the total seven statistics, four statistics that include Panel PP-statistics, Panel ADF-statistics, Group PP and Group ADF- statistics are significant at 1% level, which indicates the rejection of the null hypothesis of no cointegration. Generally, evaluating according to the results of these four tests, it can be reported that Pedroni's cointegration test results show a cointegration relationship between the analyzed variables.

4.2.2. kao's residual cointegration test results

Table 3: Results for Kao panel cointegration tests

	t-Statistic	Prob
ADF	-2.188078	0.0143
Residual variance	15.68392	
HAC variance	3.022426	

Source: Author' estimations

Table 3 provides results for the Kao (1999) panel cointegration test, which rejects the null hypothesis of no cointegration for the economic growth and other variables at 1% significance level, therefore there is existence of cointegration.

It is clear that in all the panel data sets, there is a long run relationship between economic growth, RD, patent applications and tertiary education expenditure for our panel of continents. Since there is cointegration between economic growth and the other variables of our model, the equation model is estimated through the Dynamic Ordinary Least Square (DOLS) method.

In fact, the DOLS method has a feature of resolving deviations in the static regression (particularly problems arising from endogeneity), including dynamics elements to the model (Kök et al., 2010).

4.3. The DOLS estimation

After confirming the existence of a Co-integration relationship between the series, we have to move to the estimation of the long term relationship.

There are different available estimators to estimate a vector Co-integration panel data, including with and between groups such as OLS estimates, fully modified OLS (FMOLS) estimators and estimators dynamic OLS (DOLS).

In this part of the study, the long run individual cointegration coefficients will be estimated using the DOLS which was developed by Kao and Chiang (2000).

The DOLS estimations and the results are presented in Table 4.

Table 4: Results for Panel DOLS

Dependent Variable: GDP

Method: Dynamic Least Squares (DOLS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RD	0.853904	0.111645	7.648400	0.0000
PAT	0.075824	0.036781	2.061477	0.0396
EDU	2.862252	0.076898	37.22154	0.0000
R-squared	0.411785	Mean dependent var		9.244808
Adjusted R-squared	0.403479	S.D. dependent var		1.362883
S.E. of regression	1.052619	Sum squared resid		863.1374
Durbin-Watson stat	0.151675	Long-run variance		6.547267

Source: Author' estimations

From table 4, the elasticity of RD across the panels was calculated as 0.853. This means that a 1% increase in RD expenditure in the 42 countries generates approximately 0.854% increase of economic growth in the long-run. On the other hand, a 1% increase in public education expenditure in our panel countries causes approximately 2.862 % increases of economic growth in the long-run. Elastic coefficients of patent application are calculated as 0.075%. Therefore, an increase of 1% in patent application constitutes a positive effect on economic growth at the rate of approximately 0.075%.

According to the test results of the DOLS estimation, RD, innovation and tertiary education expenditure in the long-run affect economic growth significantly both in a positive and statistical way as expected. Furthermore, the findings support a strong and positive relationship between the quality of human capital and economic growth.

The above sections analyze the feedback effect between innovations, economic growth and higher education by considering certain factors that could drive these three elements of the economy. Our model organizes and estimates such effects, and the analysis shows that innovations and higher education share positive relationships with economic growth.

5. Conclusion and discussions

Nowadays, to achieve a competitive economy, the focus should be on some key factors, such as human capital, knowledge and innovation. In this context of the knowledge economy, education is the only way to develop skills and competences which increase competitiveness and long term state development.

This study investigated the link between higher education, innovation and economic growth in 42 countries over the 1996-2014 period while applying the DOLS method.

The existing literature provides inconclusive results about the link between innovation, the development of high educational performance and economic growth. What is clearly demonstrated by our results is that there is a long-run relationship between them, a point that has gone unrecognized in the existing literature. Our long-run results, naturally of greater interest to policy makers, provide evidence that economic growth is positively influenced by the following factors: innovations (quantified by research and development expenditure and the number of patent applications), and expenditure on tertiary education. In short, a 1% increase in RD, PAT and EDU affects GDP by 0.854%, 2.862 % and 0.075% successively in the long run.

In other words, the development of high education quality affects economic growth mainly by focusing on innovation activities. We have thus affirmed an important interaction effect suggesting to policy makers that the application of innovation into higher education system leads to a better economic growth performance. Evidently, among the considered macroeconomic variables, education appears to have the most statistically significant link with the other macroeconomic variables as well as a significant link with economic growth. Indeed for both the developing and developed groups, quality of higher education is an important factor that influences economic growth.

As a consequence, more resource allocations on education, especially on higher education which will have important contributions to the economic growth process, will have positive effects on the performance of country's economy by increasing the transfer of knowledge production opportunities and sharing and manufacturing process of universities.

That's why we insist on the role of higher education in training the next generation of leaders, managers, professionals and technical personnel.

We can suggest that tertiary educational level enhances innovation by promoting capacity for the well educated and qualified labor keeping pace with the rapid changes in the manufacturing process and producing high technology. The improvements in educational level affect the economic growth positively by increasing both the labor productivity and the capacity of knowledge production. The performance of a country in the development process is closely related to the effectiveness of educational system. Besides, its several positive contributions in social, cultural and political areas, an effective education system increases the competitiveness and contributes to the economic growth by training the qualified labor and productivity increase in economical aspects.

It is crucial to build bridges between innovation, technology and higher institutions in order to stimulate economic growth and productivity.

Thus in our view, the economies should invest relatively more in research and innovation processes in universities and improve university-industry interaction and collaboration .This will help the economies to narrow the enrolment gap, and achieve faster growth.

The policy implications of these results are straightforward. If policymakers wish to promote long-run economic growth, more attention must be paid to the development of innovation activities, mainly in higher institutions. In this regard, policy makers should primarily centre the mission of training qualified and productive labor to the fundamentals of the educational system. Making polices to increase the expenses on education from the primary to the higher level can be another choice.

In order to enhance the performance in higher institutions, it's necessary to strengthen the participation of students on research and development activities.

Finally, innovation has become an important component of educational reform and an integral part of the school curriculum.

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