Journal of Informetrics 8 (2014) 349–361

Contents lists available at ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

Relationship between educational indicators and research outcomes in a panel of top twenty nations: Windows of opportunity

Ghulam Akhmat[a,1], Khalid Zaman[b,*], Tan Shukui[a,**], Yasir Javed[b], Muhammad Mushtaq Khan[c]

[a] College of Public Administration, Huazhong University of Science and Technology (HUST), 1037, Luoyu Road, Wuhan, PR China
[b] Department of Management Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan
[c] Department of Humanities, COMSATS Institute of Information Technology, Abbottabad, Pakistan

ARTICLE INFO

Article history:
Received 17 October 2013
Received in revised form 10 January 2014
Accepted 13 January 2014
Available online 7 February 2014

Keywords:
Higher education
Research outputs
R&D expenditures
Panel cointegration

ABSTRACT

The objective of the study is to examine the empirical relationship between educational indicators and research outcomes in top twenty nations of the World in terms of number of publications, citations and patents. The literature on higher education is useful in expressing the general and visible characteristics of a research domain, but cannot reveal the possible interaction between educational reforms and research outcomes. In order to overcome this limitation, the current study employed a panel cointegration technique to evaluate the long-run relationship between educational indicators and research productivity over a period of 1980–2011. The results reveal that educational indicators act as an important driver to increase research productivity in the panel of selected countries. The most promising educational factors i.e., higher education enrolment increases GDP and number of publications by 0.898% and 1.425%, respectively. Similarly, higher education expenditures per student increases research and development (R&D) expenditures, number of citations and number of patents by 1.128%, 0.968% and 0.714%, respectively. Finally, increasing school-life expectancy contributed to researchers in R&D by 0.401%. The study concludes that there is a window of opportunity to equip the youth with necessary skills to ensure a sustainable future for the nations. Higher education empowers and enables students to compete in a highly competitive and interconnected world through research and innovations, which are the drivers of new ideas, businesses and economic growth.

1. Introduction

Bibliometric indicators used to measure research performance are mainly based on two central elements i.e., number of publications and citation count. The statistics based on the number of publications primarily reflect the quantitative output of research activity. In contrast, there is little agreement on what the figures based on citations exactly measure, as the reasons for citing a paper may be highly disparate (Diem & Wolter, 2013). Education is an important discipline, but receives

* Corresponding author. Tel.: +92 334 8982744; fax: +92 992 383441.
** Corresponding author. Tel.: +86 2787559342; fax: +86 27 87543047.
E-mail addresses: ahmad_choudary@hotmail.com (G. Akhmat), khalidzaman@ciit.net.pk (K. Zaman), tansk@126.com (T. Shukui), yjaved@ciit.net.pk (Y. Javed), khanmm@ciit.net.pk (M.M. Khan).
1 Tel.: +86 15827481835; fax: +86 27 87543047.

1751-1577/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.joi.2014.01.007

Table 1
Listed by papers.

Rank	Country	Papers	Citations	Cites per paper
1	USA	3,049,662	48,862,100	16.02
2	PR China	836,255	5,191,358	6.21
3	Germany	784,316	10,518,133	13.41
4	Japan	771,548	8,084,145	10.48
5	England	697,763	10,508,202	15.06
6	France	557,322	7,007,693	12.57
7	Canada	451,588	6,019,195	13.33
8	Italy	429,301	5,151,675	12.00
9	Spain	339,164	3,588,655	10.58
10	Australia	304,160	3,681,695	12.10
11	India	293,049	1,727,973	5.90
12	South Korea	282,328	2,024,609	7.17
13	Russia	265,721	1,282,281	4.83
14	Netherlands	252,242	3,974,719	15.76
15	Brazil	212,243	1,360,097	6.41
16	Switzerland	181,636	3,070,458	16.9
17	Sweden	179,126	2,686,304	15.00
18	Taiwan	177,929	1,273,682	7.16
19	Turkey	155,276	819,071	5.27
20	Poland	154,016	1,036,062	6.73

Source: Essential Science Indicators (ESI, 2012) from Thomson Reuters, time period: 2001–August 31, 2011 (fourth bimonthly period of 2011).

little attention in related evaluation projects (Tseng, Chang, Tutwiler, Lin, & Barufaldi, 2013). Knowledge has become a key driver of growth and development. Countries with higher skill levels are better equipped to face new challenges and master technological discoveries (Akhmat et al., 2013). Education brings significant benefits to society, not only through higher employment opportunities and income but also via enhanced research skills, improved social status and access to networks. By fully recognizing the power of education, policy makers could better address diverse societal challenges (OECD, 2013).

There are a number of reasons why some countries publish more than others but it is no real surprise that the USA produces the most scientific papers. The facts indicate that during the period of 1999–2009, there were 2.9 million scientific papers published in the USA according to Essential Science Indicators at Thomson Reuters. This is considerably more than the next two countries in the top 20 list, Japan and Germany, who each produced a respectable 0.8 million scientific papers (Young, 2011). Out of the 147 countries in the Essential Science Indicators database (ESI, 2012), 60 published at least 10,000 papers during the period. Countries are listed by three separate measures in the Table 1 based on number of citations, total papers, and cites per paper.

According to Lips et al. (2008, p. 1),

> "Debates about how to improve public education in America often focus on whether government should spend more on education. Federal and state policy makers proposing new education programs often base their arguments on the need to provide more resources to schools to improve opportunities for students".

In an educational effectiveness research, it frequently has proven difficult to make credible inferences about cause and effect relations. With the use of data from top twenty countries in terms of number of publications, citations and patents; this study investigates the long-run relationship between educational indicators and research outcomes. This study contributes in the academic arena by two means i.e., at once, this study examine the dynamic relationship between educational indicators and research outcomes through economic growth in a panel of top twenty nations of the World. Secondly, this study used sophisticated econometric modeling to energize the results in a conclusive manner.

The study divided into following sections: after introduction which is presented in Section 1 above, review of literature is presented in Section 2. Data source and methodological framework are presented in Section 3. Results are discussed in Section 4. Section 5 concludes the study.

2. Literature review

Academic researchers have sought to answer the question of whether education indicators are correlated with research outcomes. Policy-makers are ever more demanding of production efficiency in research activities and this in turn has required and stimulated much analysis of the research production function (Abramo, Cicero, & D'Angelo, 2012). According to Bochove (2013, p. 799),

> "The core of scientometrics consists of indicators of scientific output: publications and citations. They can be detailed by authors and their attributes as well as by attributes of the publications. Output data form a rich source of information on the global research enterprise. However, to compare the efficiency of institutions and nations and to analyze science and research policy, a link is needed with data on inputs: research cost and research labor".

Table 2
Lists of variables.

Variables	Measurement	Symbol	Expected signs	Data source
Endogenous variables – economic growth and research productivity				
Gross domestic product	Current US $	GDP		World Bank (2012)
Publications	Numbers	PUB		ESI (2012)
Citations	Numbers	CITE		ESI (2012)
Patents	Numbers	PAT		ESI (2012)
Research and development expenditures	Percentage of GDP	R&D		World Bank (2012)
Researchers in R&D	Per million people	RES		World Bank (2012)
Independent variables – educational Indicators				
Education expenditures	Percentage of GDP	EDUC	Positive	World Bank (2012)
Higher education enrolment	Numbers	HEENROL	Positive	World Bank (2012)
Higher education expenditures per student	Percentage of GDP per capita	HEEXP	Positive	World Bank (2012)
School-life expectancy	Total Years	SLEXPECT	Positive	World Bank (2012)
Pupil–teacher ratio	Percentage	PTECH	Positive	World Bank (2012)

Eash (1983) investigates educational research productivity in U.S higher education institutions based on contributions to AERA annual meetings and 14 leading educational research journals over a period of 1975–1981. The results reveal that total volume productivity has an impact on the field regardless of faculty size; faculty productivity emphasizes the strengths of institutional research activity. Leslie, Slaughter, Taylor, & Zhang (2012) employed panel technique on Integrated Postsecondary Education Data on the 96 U.S. Research Extensive Institutions during the period of 1985–2008 to identify revenue–expenditure relationships. Results suggest a strong relationship between some revenue and expenditure categories for some institutions. For public universities, these relationships tend to follow expected paths. Eid (2012) examine the impact of higher education R&D and its impact on productivity growth in 17 high-income OECD countries using country level data over the period 1981–2006. The results suggest that lagged R&D performed by higher education is positively affecting productivity growth in all specifications. The long-run propensity of productivity growth to R&D performed by the higher education sector is also found to be positive and significant while it is found be insignificant to business R&D.

Diem and Wolter (2013) investigate the fitness-for-purpose and soundness of bibliometric parameters for measuring and elucidating the research performance of individual researchers in the field of education sciences in Switzerland. The results indicate that Google Scholar is so inclusive that it impedes a meaningful interpretation of the data. However, the Web of Science inclusion policy for journals is also associated with certain shortcomings that put some researchers at an unjustified disadvantage. Hallinger and Bryant (2012) efforts to map the terrain of knowledge production in educational leadership and management in East Asia since the year 2000. Authors identified a body of literature, comprised of all articles published about or from East Asia between 2000 and 2011 in eight core educational leadership and management journals. The results reveal that the volume of knowledge production from East Asia between 2000 and 2011 consisted of less than 6 percent of total output in the relevant journals. A substantial majority of the publications not only came from a few societies, but from a small number of universities. Citation analyses were highly consistent with all of the above trends, and reinforced a picture of limited impact. Wang, Yub, & Liub (2013) explore the marginal effect of R&D expenditures in the high-tech sector across different quantiles of the conditional GDP distribution for 23 OECD countries and Taiwan during 1991–2006. The results indicate that the impacts of R&D expenditures in the high-tech sector are heterogeneous across levels of per capita income. High-tech industrial R&D spending has a strong positive effect on GDP per capita at the highest quantile of the distribution. However, all sectors' R&D spending relative to GDP is subject to significant negative returns only when considering the middle-income countries.

Delgado, Henderson, & Parmeter (2013) use a non-parametric local-linear regression estimator and a non-parametric variable relevance test to conduct a rigorous and systematic search for significance of mean years of schooling by examining five of the most comprehensive schooling databases. The results suggest that mean years of schooling is not a statistically relevant variable in growth regressions. However, within a cross-sectional framework, educational achievement provides a reliable measure of human capital than mean years of schooling. Jung (2013) examines the publications of 38 specialized journals on higher education in Asia over the past three decades. The findings indicate a growing number of higher education research publications but the proportion of Asian publications in relation to the total world publications in higher education research remains stationary. Roy and Goswami (2013) conduct a scientometric analysis of 71 research papers during 1995–2010 published in international peer-reviewed journals, university publications, reports of development organizations and conference publications on the performance management of the microfinance institutions. Based on results, author proposed model that focus on the overall performance of the microfinance institutions. The study turn the attention of microfinance researchers, microfinance practitioners, and various rating agencies to the various dimensions affecting the overall assessment of microfinance institutions.

Agasisti and Bonomi (2013) empirical analysis the teaching efficiency scores of the different schools belonging to 12 universities within one Italian region. The results show how the 'ranking' of efficient universities varies when they are analyzed according to the different sub-units that compose them; moreover, the average efficiency scores seem to be greatly affected by the subject mix. Anninos (2013) critically assess some standard bibliometric indicators commonly used based on publication and citation counts to evaluate academic units, and examine whether there are factors not taken into account that

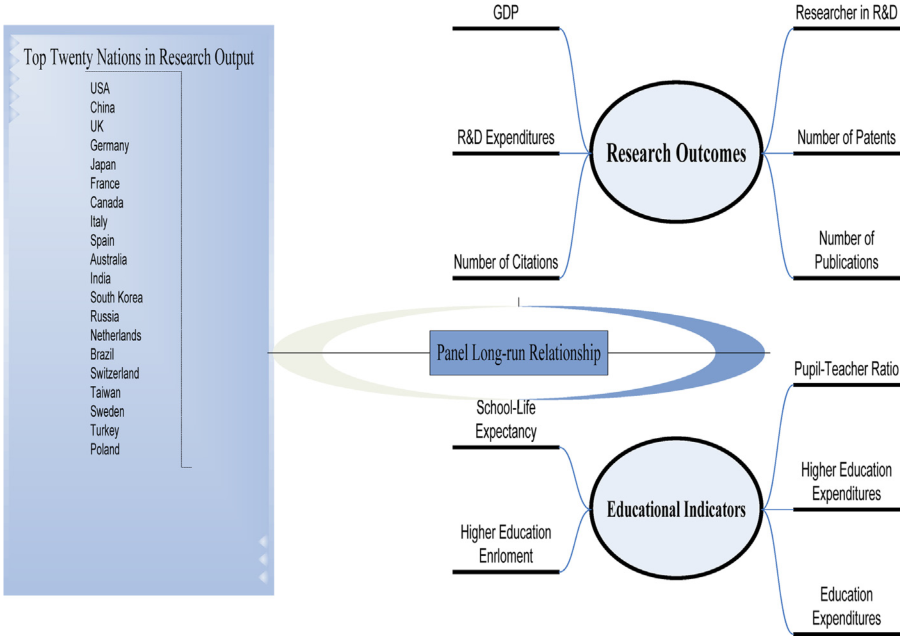

Fig. 1. Educational Indicators and Research Outcomes. *Source*: Self-extract.

influence evaluation results. The results suggest that the dissimilarity of academic units regarding their scientific orientation and size in terms of staff number, if not taken into consideration may lead to incorrect evaluation results. Akhmat et al. (2013) develop a model for internationalization of universities with the transformation of some promising macroeconomic variables i.e., educational reforms and economic growth in the seven largest regions of the world analyzed by panel fixed effect regression from the period of 1990–2011. The results show the dynamic linkages between educational indicators and economic factors in the selected regions of the World. The results conclude that educational indicators improve the economic gains, which ultimately reap out the benefit of internationalization.

The results confirm the strong correlation between education and research output. This study takes an initiative to explore the panel long-run relationship between educational indicators and research output in top twenty nations of the World during the period of 1980–2011.

3. Data source and methodological framework

The data of number of publications, number of citations and number of patents[3] extracted from the National Sciences Indicators database of Thomson Reuters (ESI, 2012). The data of other indices for research output (i.e., Research & Development Expenditures[4] and Researchers in Research & Development) taken from *World Development Indicators*, which is published by World Bank (2012). Educational indicators include public expenditures on education, enrolment in higher education, higher education expenditures per student, school-life expectancy and Pupil–Teacher ratio taken from World Bank (2012). GDP in current US $ also taken from the World Bank (2012) to access the overall development in the panel of top twenty nations of the World in research output. Econometric model has been estimated through the software EViews 6. Table 2 shows the lists of the variables and their expected signs.The study hypothesize that educational indicators increases research outcomes, therefore, education reform efforts should focus on improving resource allocation. Fig. 1 shows the conjunction of educational indicators and research outcomes in the panel of top twenty nations in research output.

3.1. Analytical framework

The Solow model is the starting point for almost all analysis of growth. The Solow model (which is sometimes known as Solow–Swan model) was developed by Robert Solow (Solow, 1956) and Swan (1956). The Solow model focuses on four

[3] Patent-based data must be interpreted with caution. Year-to-year changes in the data may reflect changes in USPTO processing times (so-called “patent pendency” rates). Likewise, industries and companies have different tactics and strategies for pursuing patents, and these may also change over time.

[4] The R&D/GDP ratio is a convenient indicator of how much of a nation’s economic activity is devoted to innovation through R&D.

variables i.e., output (Y), capital (K), Labor (L) and knowledge or the effectiveness of labor (A). The production function takes the form:

$$Y(t) = F[K(t), A(t)L(t)] \tag{1}$$

where 't' denotes time and 'AL' is referred to as "effective labor", and technological progress that enters in this fashion is known as "labor-augmenting or Harrod-neutral".

This study extended the "labor-augmenting" concept in terms of research productivity which would desirable for healthy economic growth, therefore, state should focus on educational reforms in a country (Akhmat et al., 2013). In addition, this study segregates educational indicators in terms of educational expenditures, higher education enrolment higher education expenditures per student, school-life expectancy and pupil–teacher ratio; while research factors contains number of publications, citations, patents, R&D expenditures, researchers in R&D and overall GDP. Thus, the study believes that these considerations in labor–augmenting function are necessary for long-run economic growth. To keep the analysis manageable, we start with the case of Cobb–Douglas production. Thus, the production function (1), becomes

$$Y(t) = K(t)^{\alpha} E(t)^{\beta} P(t)^{\gamma} [A(t)L(t)]^{1-\alpha-\beta-\gamma} \tag{2}$$

where 'E' denotes educational indicators and 'P' denotes research productivity.

The new assumption concern with educational indicators and research productivity i.e.,

$$E(t) > 0$$

Similarly, the facts that research factors increase production i.e.,

$$P(t) = b(P(t); \quad b > 0$$

The presence of 'E' and 'P' in the production function means that 'K/AL' no longer converges top same value. As a result, we cannot use previous approach of focusing on 'K/AL' to analyze the behavior of this economy. This study employed panel econometric technique for analyzing educational indicators and research productivity in a manageable form of equations.

3.2. Panel econometric model

There are a few studies using panel cointegration to access long-run relationship between education and research outcomes, this study takes an initiative to explore this relationship in the panel of top twenty nations of the world in terms of research output. For this purpose, this study employed panel cointegration technique to test multiple factors that affects educational indicators over a period of 1980–2011. The model used to test the relationship between educational indicators and research factors are as follows:

$$\ln(\text{RESEARCH}) = f \ln(\text{EDUC, HEENROL, HEEXP, SLEXPECT, PTECH})$$

The general representation of the equation mentioned above is as follows:

$$\begin{aligned}\text{Ln}(\text{RESEARCH}_t) = {} & \beta_0 + \beta_{1t}\text{Ln}(\text{EDUC}_{1t}) + \beta_{2t}\text{Ln}(\text{HEENROL}_{2t}) + \beta_{3t}\text{Ln}(\text{HEEXP}_{3t}) + \beta_{4t}\text{Ln}(\text{SLEXPECT}_{4t}) \\ & + \beta_{5t}\text{Ln}(\text{PTECH}_{5t}) + \varepsilon_{it}\end{aligned} \tag{3}$$

where RESEARCH = Research factors include GDP, PUB, R&D, RES, CITE and PAT. All factors are taken as an endogenous variable; β_0 = intercept; β_1 = slope of the independent variables; T = 1, 2,. . ., 31 periods; i = 1, 2,. . ., 20 countries; ε_t = error term.

Three different panel unit roots tests, i.e., Levin-Lin-Chu (LLC) test, Im-Pesaran-Shin (IPS) test, Breitung and Hadri test have used in this study.

3.3. Panel unit root tests

Panel unit root tests could be considered as an extension of the univariate unit root test. The LLC test is based on the pooled panel data as follows (Levin & Lin, 1992):

$$\Delta y_{it} = \rho y_{it-1} + \alpha_0 + \sigma_t + \sigma_i + \theta_t + \varepsilon_{it} \tag{4}$$

where ρ, α_0, σ are coefficients, α_i is individual specific effect, θ_t is time specific effect.

According to Levin and Lin (1992), the LLC test could be conducted by the following steps. In step1, subtract the cross-section average from data:

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_{it} \tag{5}$$

In step 2, an ADF test is applied to each individual series and normalizes the disturbance. The ADF model could be expressed as:

$$\Delta y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{P_i} \delta_{ij} \Delta y_{i,t-j} + \alpha_i + \varepsilon_{it} \quad (6)$$

Maddala and Wu (1999) argued that this is equivalent to perform two auxiliary regressions of Δy_{it} and $y_{i,t-1}$ on the remaining variable n Eq. (3). Let the residuals from these two regression be $\hat{e}_{i,t}$ and $\hat{V}_{i,t-1}$ respectively. The, regress $\hat{e}_{i,t}$ on $\hat{V}_{i,t-1}$.

$$\hat{e}_{i,t} = \rho_i \hat{V}_{i,t-1} + \varepsilon_{it} \quad (7)$$

Levin and Lin (1992) suggest the following normalization to control the Heteroscedasticity in error.

$$\hat{\sigma}_{ei}^2 = \frac{1}{T - P_i - 1} \sum_{t=p+2} (\hat{e}_{i,t} - \hat{\rho}_i - \hat{V}_{i,t-1})^2$$

$$\tilde{e} = \frac{\hat{e}_{i,t}}{\hat{\sigma}_{ei}}$$

$$\tilde{v}_{i,t-1} = \frac{\tilde{v}_{i,t-1}}{\hat{\sigma}_{ei}}$$

In the next step, the LLC test statistic could be obtained from the following regression:

$$\tilde{e}_{i,t} = \rho \tilde{v}_{i,t-1} + \tilde{\varepsilon}_{i,t}$$

The t-statistic for testing $\tilde{o} = 0$ is given by

$$t_\delta = \frac{\hat{\delta}}{STD(\hat{\delta})}$$

where

$$\hat{\delta} = \frac{\sum_{i=1}^{N} \sum_{t=2+p}^{T} \hat{v}_{t-1} \hat{e}_{it}}{\sum_{i=1}^{N} \sum_{t=2+p} \hat{v}_{it-1}^2}$$

Next, the paper also employs the IPS test which is based on the mean value of individual ADF statistics or t-bar (Im, Pesaran, & Shin, 2003). The IPS test provides separate estimation for each i section, allowing different specifications of the parametric values, the residual variance and the lag lengths. Their model is given by:

$$\Delta Y_{i,t} = \alpha_i + \rho_i Y_{i,t-1} + \sum_{k=1}^{n} \phi_k \Delta Y_{i,t-k} + \delta_i t + u_{it} \quad (8)$$

The null hypothesis and the alternative hypothesis are formulated as:

$$H_0 : \rho_i = 0$$
$$H_A : \rho_i < 0$$

for at least one i

Thus, the null hypothesis of this test is that all series are non-stationary process under the alternative that fraction of the series in the panel are assumed to be stationary. IPS also suggested a group mean Lagrange multiplier test for testing panel unit roots.

Breitung (2000) and Hadri (2000) attempted to improve to the same degree the drawbacks of all previous tests by proposing a model that could also be estimated with unbalanced panels. Basically, Breitung (2000) and Hadri (2000) are in line with the assumptions that a heterogeneous alternative is preferable, but they disagree with the use of the average ADF statistics by arguing that it is not the most effective way of evaluating stationary.

3.4. Panel cointegration tests

This study employs Pedroni's (1999, 2004) panel cointegration method in order to examine the long-run relationship between educational indicators and research outcomes. If the independent and dependent variables are co-integrated or have a long-run relationship, the residual e_{it} will be integrated of order zero, denoted $I(0)$. Pedroni used two types of panel Cointegration tests. The first is the "panel statistic" that is equivalent to a unit root statistic against the homogenous alternative; the second is the "group mean statistic" that is analogous to the panel unit root test against the heterogeneous alternative. Pedroni (2004) argued that the "panel statistic" can be constructed by taking the ratio of the sum of the numerators and the sum of the denominators of the analogous conventional time series statistics. The "group mean statistic" can be constructed by first computing the ratio corresponding to the conventional time series statistics, and then computing the standardized sum of the entire ratio over the N dimension of the panel. This study uses panel co-integration tests as suggested by Pedroni (1999, 2004), namely the "panel ADF statistic". The versions of the ADF statistics could be defined as:

$$\text{Panel}\,Z_t = \left(\tilde{s}_{NT}^2 \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{e}_{i,t-1}^2\right)^{-1/2} \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{e}_{i,t-1}\Delta\hat{e}_{I,T} \tag{9}$$

where $\hat{e}_{i,t}$ represents the residuals from the ADF estimation, $\tilde{s}_{NT}$ is the contemporaneous panel variance estimator, and $\tilde{s}_i$ is the standard contemporaneous variance of the residuals from the ADF regression. The asymptotic distribution of panel and group mean statistics can be expressed in:

$$\frac{K_{N,T} - \mu\sqrt{N}}{\sqrt{\upsilon}} \Rightarrow N(0, 1)$$

where $K_{N,T}$ is appropriately standardized form for each statistics and μm ADF regression is the mean term, and v is the variance adjustment term. Pedroni provides Monte Carlo estimates of μ and υ (Pedroni, 1999)].

The null hypothesis tested is conducted to see whether η_i unity is. The finite sample distribution for the test statistics have been tabulated in Pedroni (2004) using Monte Carlo simulations, if the test statistic exceeds the critical values in Pedroni (2004), the null hypothesis of no Cointegration is rejected, implying that the variables are cointegrated. In addition, the Kao and McCoskey (1998) LM test for the null of Cointegration is applied. The long run is estimated by efficient methods carried out separately for the panel members. Then, the Cointegration residuals are pooled, and the test statistic is asymptotically Gaussian with a right hand side rejection area.

3.5. Panel long-run relationship

It is important to note that the panel cointegration tests do not provide an estimate of the long run relationship. More or less, the cointegration vector should be common for the panel members, as fundamental economic principles are involved. Also, hypothesis testing is a critical issue. In fact, the asymptotic distribution of the OLS estimator depends on nuisance parameters. In a panel environment, this problem seems to be more serious, as the bias can accumulate with the size of the cross section. To overcome these deficits, efficient methods like fully modified (FMOLS) and dynamic OLS (DOLS) are required. As these techniques control for potential endogeneity of the repressors and serial correlation, asymptotically unbiased estimates of the long run can be obtained. The methods are asymptotically equivalent (Banerjee, 1999). Hence, their relative merits boil down to a comparison in finite samples. In the FMOLS case, nonparametric techniques are used to transform the residuals from the Cointegration regression and get rid of nuisance parameters (Phillips, 1995; Pedroni, 2001). In the time series model

$$\begin{aligned} y_{it} &= \alpha_i + \beta_i x_{it} + u_{it} \\ x_{it} &= x_{it-1} + \varepsilon_{it}, = (u_{it}, \varepsilon_{it})' \end{aligned} \tag{10}$$

The asymptotic distribution of the OLS estimator is conditioned to the long run covariance matrix of the joint residual process. The FMOLS estimator for the ith panel member is given by

$$\beta^{\wedge *} = (Xi'Xi)^{-1}(Xi'y_i^* - T\delta^{\wedge}) \tag{11}$$

where y^* is the transformed endogenous variable and δ a parameter for autocorrelation adjustment. Appropriate correction factors are based on certain sub matrices of the joint long run covariance matrix.

In the DOLS framework, the long run regression is augmented by lead and lagged differences of the explanatory variables to control for endogenous feedback (Saikkonen, 1991). Lead and lagged differences of the dependent variable can be included to account for serial correlation (see Stock & Watson, 1993). In particular, the equation

$$y_{it} = \alpha_i + \beta_i x_{it} + \sum_{j=p-1}^{p2}\delta_j \Delta y_{it} + \sum_{j=q-1}^{q2}\lambda_j \Delta x_{it-j} + u_{it} \tag{12}$$

is run for the ith panel member, where the appropriate choice of leads and lags is based on data dependent criteria (Westerlund, 2003). Standard errors are computed using the long run variance of the Cointegration residuals. In a panel setting, the Cointegration relationship is homogeneous. Heterogeneity is limited to fixed effects, time trends and short run dynamics. The panel FMOLS estimator is the average of the individual parameters (see Pedroni, 2001).

Table 3
Panel unit root test.

Levels				
	LLC	Breitung	IPS	Hadri
EDUC	$I(0)$	$I(0)$	$I(0)$	$I(0)$
HEENROL	$I(0)$	$I(0)$	$I(0)$	$I(0)$
HEEXP	$I(0)$	$I(0)$	$I(0)$	$I(1)$
SLEXPECT	$I(0)$	$I(0)$	$I(0)$	$I(1)$
PTECH	$I(0)$	$I(0)$	$I(0)$	$I(0)$
GDP	$I(1)$	$I(0)$	$I(0)$	$I(1)$
PUB	$I(0)$	$I(1)$	$I(0)$	$I(1)$
R&D	$I(0)$	$I(0)$	$I(0)$	$I(0)$
RES	$I(0)$	$I(0)$	$I(0)$	$I(0)$
CITE	$I(0)$	$I(0)$	$I(0)$	$I(0)$
PAT	$I(1)$	$I(0)$	$I(0)$	$I(1)$
First difference				
	LLC	Breitung	IPS	Hadri
EDUC	$I(1)$	$I(1)$	$I(1)$	$I(1)$
HEENROL	$I(1)$	$I(1)$	$I(1)$	$I(1)$
HEEXP	$I(1)$	$I(1)$	$I(1)$	$I(1)$
SLEXPECT	$I(1)$	$I(1)$	$I(1)$	$I(1)$
PTECH	$I(1)$	$I(1)$	$I(1)$	$I(1)$
GDP	$I(1)$	$I(1)$	$I(1)$	$I(1)$
PUB	$I(1)$	$I(1)$	$I(1)$	$I(1)$
R&D	$I(1)$	$I(1)$	$I(1)$	$I(1)$
RES	$I(1)$	$I(1)$	$I(1)$	$I(1)$
CITE	$I(1)$	$I(1)$	$I(1)$	$I(1)$
PAT	$I(1)$	$I(1)$	$I(1)$	$I(1)$

Note: $I(0)$ indicates non-stationary at level while $I(1)$ indicates stationary at their first difference. LLC = Levin et al. (2002); IPS = Im et al. (2003). The other statistics are described in detail in Breitung (2000) and Hadri (2000). The statistics are asymptotically distributed as standard normal with a left hand side rejection area, except of the Hadri test, which is right sided.

4. Results

In this study, four types of panel unit root test are employed for evaluating stationarity series between the variables. This study tests whether each of the variable series contain a panel unit root, which were proposed by Levin, Lin, & Chu (2002), Im et al. (2003), Breitung (2000) and Hadri (2000) in the literature. The results reported in Table 3, where it is divided into four panels. Panel A consists of results from the Levin and Lin (1993); panel B consists of the results from the Im et al. (2003) test and panel C consists of results from the Breitung (2000) and panel four Hadri (2000) test. The results from all four tests, with or without linear trends; suggest that educational indicators and research factors contain a panel unit root, indicate from at least one test.

The results indicate that except GDP and PAT, all variables are non-stationary at level; however, after taking first difference, it would become stationary in LLC test. Similarly, in case of Bruiting test, except PUB all variables contain unit root. IPS test indicates that all variables have contained a non-stationarity series. Finally, Hadri tests shows mixed results, as some variables contain $I(0)$ property while some have $I(1)$, however, in a nut shell, one may conclude that, all variables have a unit root problem. It is good justification to step forward toward panel cointegration test. The panel cointegration tests point to the existence of a long run relationship between educational indicators and research factors, as shown in Table 4.

Table 4 shows that there is a long run relationship between the variables for the panel of top twenty nations of the World in research output, which are followed by the different tests i.e., Pedroni's (2004), panel Phillips and Perron (1988) and type rho-statistic. In Table 3, panel rho-statistic is significant in relation with GDP for all educational indicators in Rho statistics except PTECH; however, this PTECH is significant at PP statistics. In case of PUB, education expenditures are significant at Rho and PP statistics; higher education enrolment significant at all panel statistics; higher education enrolment significant at ADF statistics only; school-life expectancy significant in PP statistics and finally, PTECH is significant in PP statistics and ADF statistics. The remaining endogenous variables i.e., R&D; RES; CITE and PAT in relation with different educational indicators are at least significant at one Panel statistics, which indicates the long-run relationship exists between the variables. In addition, Table 5 shows the Kao and McCoskey (1998) – FMOLS and DOLS residual tests.

Table 5 shows the long-run estimate by using FMOLS and DOLS residual tests. The results indicate that Kao and McCoskey (1998) test that do not reject the null of cointegration and all variables are cointegrated at 5 percent level of significance. These results further support the estimates of panel cointegration test by Pedroni (1999). The long-run results displayed in Table 6.

The results reveal that public spending on education increases economic growth of selected top twenty countries of the World in terms of number of publications, citations and patents, as coefficient value indicates 0.725% in FMOLS and

Table 4
Panel cointegration tests.

Models including	EDUC	HEENROL	HEEXP	SLEXPECT	PTECH
Pedroni (1999) – panel statistics [GDP]					
Variance ratio	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Rho statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$
PP statistics	$p > 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$
Pedroni (1999) – panel statistics [PUB]					
Variance Ratio	$p > 0$	$p < 05$	$p > 0.05$	$p > 05$	$p > 0.05$
Rho Statistics	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
PP Statistics	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p > 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$
Pedroni (1999) – panel statistics [R&D]					
Variance Ratio	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Rho Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$
PP Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$
Pedroni (1999) – panel statistics [RES]					
Variance Ratio	$p < 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Rho Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
PP Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Pedroni (1999) – panel statistics [CITE]					
Variance Ratio	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Rho Statistics	$p > 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$
PP Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Pedroni (1999) – panel statistics [PAT]					
Variance Ratio	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Rho Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
PP Statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
ADF statistics	$p > 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p > 0.05$

Note: Models contain different indicators of education and research. Endogenous variables include GDP, PUB, R&D, RES, CITE and PAT. Statistics are asymptotically distributed as standard normal. The Pedroni statistics are described in detail in Pedroni (1999). $p < 0.05$ indicates 5% probability level of significance, while $p > 0.05$ indicates insignificant probability.

0.685% in DOLS which indicates that education expenditures have a less elastic relationship with the economic growth. The results imply that relatively high percentage of expenditures devoted to a specific level of education indicates the priority given to that level in national educational policy and resource allocation (Musila & Belassi, 2004). Spending on education is generally regarded as productive spending with a comprehensive role in the economy. Returns from such spending are often accounted for in terms of appreciable progress in education constrains (Maitra & Mukhopadhyay, 2012). Similarly, other educational indicators i.e., higher education enrolment, higher education expenditures and school-life expectancy increases economic growth while pupil–teacher ratio decreases economic growth in the panel of top twenty countries. The results infer that higher school life expectancy indicates greater probability for children to spend more years in education and higher overall retention within the education system (Todose, 2000). The result supports the view that higher levels of educational attainment are linked to higher incomes, less unemployment, less poverty, and less reliance on public assistance (United Way, 2009). Improving human capital through schooling has an implication for economic development on large scale. Number of theoretic work confirms that there is a link between human capital formation and economic development. Romer (1986, 1990); Lucas (1988) and Stokey (1991) confirm the positive association between human capital stocks and economic growth. The results of pupil–teacher ratio indicates that a high share of per capita income being spent on each pupil/student in a specified level of education which represents a measure of the financial cost per pupil/student in relation to average per capita income. A high teacher pupil–ratio suggests that each teacher has to be responsible for a large number of pupils. In other words, the higher the pupil/teacher ratio, the lower is the relative access of pupils to teachers. It is generally assumed that a low pupil–teacher ratio signifies smaller classes, which enables the teacher to pay more attention to individual students, which may in the long-run result in a better performance of the pupils (UNESCO, 2009).

In Table 6, panel 11, indicates that educational indicators overall improves number of publications in a top twenty nations of the World. The major contribution from educational indicators is higher education enrolment and public spending on higher education, which increase publications by 1.425% and 1.012%, respectively. The results infer that as knowledge can be created, absorbed, and applied only by the educated mind, schools, in general, and universities in particular, played increasingly important roles as our societies enter this new age. In a sense, knowledge is the medium of the universities. Through the activities of discovery, shaping, achieving, transmitting, and applying knowledge, the universities serves society in a myriad of ways i.e., educating the young, preserving our cultural heritage, providing the basic research so essential to our

Table 5
Kao and McCoskey (1998) panel residual test.

Models including	EDUC	HEENROL	HEEXP	SLEXPECT	PTECH
Kao and McCoskey (1998) – FMOLS residual [GDP]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – FMOLS residual [PUB]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – FMOLS residual [R&D]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – FMOLS residual [RES]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – FMOLS residual [CITE]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – FMOLS residual [PAT]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [GDP]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [PUB]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [R&D]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [RES]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [CITE]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Kao and McCoskey (1998) – DOLS residual [PAT]					
LM statistics	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$

Note: Minimum significant value of LM-statistics at $p < 0.05$ is −3.988 while maximum value is −5.968.

Table 6
Panel estimation of the cointegration vector.

Method	EDUC	HEENROL	HEEXP	SLEXPECT	PTECH
I. GDP and educational indicators					
FMOLS (Pedroni, 1999)	0.725*	0.898*	0.025	0.301***	−0.045**
DOLS (Mark & Sul, 2002)	0.685*	0.521*	0.128**	0.102	−0.125
II. Number of publications and educational indicators					
FMOLS (Pedroni, 1999)	1.012*	1.425*	0.042	0.120	−0.125***
DOLS (Mark & Sul, 2002)	0.889*	1.102*	0.101	0.252**	0.142***
III. Research and development expenditures and educational indicators					
FMOLS (Pedroni, 1999)	0.989*	0.772*	1.128*	0.998*	−0.253
DOLS (Mark & Sul, 2002)	0.885*	0.625*	0.895*	0.452**	−0.302***
IV. Researchers in R&D and educational indicators					
FMOLS (Pedroni, 1999)	0.025	0.325**	0.201**	0.401*	0.202**
DOLS (Mark & Sul, 2002)	0.109	0.125	0.129***	0.325**	−0.128***
V. Number of citations and educational indicators					
FMOLS (Pedroni, 1999)	0.556*	0.528*	0.968*	0.025	0.152
DOLS (Mark & Sul, 2002)	0.449*	0.362**	0.725*	0.256**	−0.185
VI. Number of patents and educational indicators					
FMOLS (Pedroni, 1999)	0.332**	0.252**	0.714*	0.169***	−0.128
DOLS (Mark & Sul, 2002)	0.223**	0.199***	0.623*	0.102	−0.100

Note: Endogenous variables are GDP; number of publications; R&D expenditures; researchers in R&D; number of citations and number of patents. All variables are in natural logarithm form, therefore, the results are discussed in elasticities.

* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.

security and well-being, training our professionals and certifying their competence, challenging our society and stimulating social change. However, the age of knowledge substantially broaden the roles of higher education (Duderstadt, 2012). Panel 111 indicates that educational factors increases research and development expenditures, as academic scientists and engineers conduct the bulk of the nation's basic research and are especially important as a source of the new knowledge that basic research produces. For this purpose, R&D expenditures are required for educational reforms in countries (NSF, 2012). Panel IV shows that higher education enrolment provides the best human capital to produce knowledge base literature for academic and industry linkages, as coefficient value indicates that if there is one percent increase in higher education enrolment, researchers increase in R&D around 0.325%. EUROPA (2003) concludes that a knowledge society needs 'researchers' in all areas and at all levels. This statement shows the importance of researchers in R&D activities. According to Inglesi and Pouris (2013, p. 129),

> "An increasing number of researchers have recently shown interest in the relationship between economic growth of a country and its research output, measured in scientometric indicators. The answer is not only of theoretical interest but it can also influence the specific policies aimed at the improvement of a country's research performance".

Panel V shows that higher education expenditures per student, education expenditures and higher education enrollment increases number of citations by 0.968%, 0.556% and 0.528%, respectively. The main incentive for researchers is to publish work that is recognized as high quality by peers and becomes highly cited by the international academic community (Corbyn, 2008). Finally, in Table 6, panel VI indicate that educational reforms plays a significant role to increase number of patents, as investment in R&D encourages innovation, which in turn spurs economic growth (Prodan, 2005).

Universities, and higher education systems worldwide, are being transformed by new or changing practices, programs, policies, and agendas. From notions of 'global competency' and the 'global engineer,' through to ever more common perceptions that international collaborative research is a desirable objective, through to the phenomena of bibliometrics, rankings and benchmarking that work at a global scale, contexts are changing (Old & Robertson, 2013).

This study provided new evidence of ways in which educational indicators acts as a strong contributor to increase economic growth and research productivity. Yet, the study is not without its limitations. First, research diffusion occurs in many ways other than how it was measured in this study. For example, co-authorship in a research was not investigated, a clear means by which multiple authors have some optimal impact on research outcomes. A second limitation was the academic-industry R&D collaboration which was not account for in this study. Finally, this study is focused only on top twenty nations, the future research in this area may be conducted, with reference to research outcomes in a panel of developed and developing countries.

5. Conclusion

In today's knowledge and practice-oriented market only those institutions of higher learning that offer practical courses and are sensitive to the current needs of the society are competitive and desirable (Xhaferri & Iqbal, 2013). The present study examine the long-run relationship between educational indicators (i.e., education expenditures, higher education enrolment, higher education expenditures per student, school-life expectancy and pupil–teacher ratio) and research factors (i.e., number of publications, number of citations, number of patents, R&D expenditures, researchers in R&D and GDP) in a panel of top twenty nations of the World over a period of 1980–2011. The results indicate some promising facts i.e.,

(i) Public spending on education, higher education enrolment and school-life expectancy increases GDP by 0.725%, 0.898% and 0.301%, respectively.
(ii) Education expenditures and number of publications are 1-to-1 relationship between them.
(iii) Higher education enrolment is more elastic with the number of publications.
(iv) Education expenditures, higher education enrolment, higher education expenditures per student and school-life expectancy increases R&D expenditures by 0.989%, 0.772%, 1.128% and 0.998%, respectively.
(v) Increasing school-life expectancy lead to researchers in R&D by 0.401%.
(vi) One percent increases in higher education expenditures per student, education expenditures and higher education enrolment increases number of citations around 0.968%, 0.556% and 0.528%, respectively.
(vii) Educational reforms play a significant role to increase number of patents, as investment in R&D encourages innovation, which in turn spurs economic growth.

The following conclusion has emerged with this exercise i.e.,

- More education is good for individuals who stay in school to earn their high school degree or who enter and graduate college, but it is also good for all of us, paying big dividends in the form of increased civic engagement, greater neighborhood safety, and a healthy, vibrant democracy (United Way, 2009).
- Academic R&D relies on funding support from a variety of sources, including the federal government, universities' and colleges' own institutional funds, state and local government, industry, nonprofits, and other organizations. Nevertheless, the federal government has consistently provided the majority of funding (NSF, 2012).

- Self-review and appraisals can help with career planning while open provision of information from a range of sources on the realities of academic career options, use of mentoring schemes and access to impartial careers advice and guidance, could help researchers to make realistic plans (Gibney, 2013).
- There is a broad, research-based consensus amongst academic researchers, policymakers and pundits that the key to economic growth lies in improving productivity. There is wide agreement that productivity increases come through innovation (Toivanen & Väänänen, 2013).
- Higher education empowers and enables students to compete in a highly competitive and interconnected world through research and innovations, which are the drivers of new ideas, businesses and economic growth (Xhaferri & Iqbal, 2013).

For the school years, three kinds of policies were enacted. First, there were reforms to the nature of education: curriculum, assessment and the types of schools available. Second, there were policies to improve system performance across the board, such as inspection, training, central guidance on pedagogy, investments in school buildings and equipment, and accountability through targets. Third, there were specific targeted initiatives and programs to address the needs of children from low income homes, those needing particular or complex support, and/or those at risk of or already disengaged from learning (Lupton & Obolenskaya, 2013). Given the significant increase in resources allocated to public education, policymakers should consider whether government-spending increases have led to improved student outcomes (Lips, Watkins, & Fleming, 2008). Higher education needs to value its basic research activities, for they are important in knowledge societies. It also has to commit to producing knowledge that is socially, economically and culturally significant: to producing what some call 'applied knowledge'. Knowledge societies should know how to use knowledge, how to turn the inert knowledge on the bookshelf into the active knowledge that creates better practices (EUROPA, 2003).

Acknowledgements

This work was financially supported by the National 985 Project of Non-traditional Security at Huazhong University of Science and Technology, PR China. Authors are thankful to the anonymous reviewers for their comments and suggestions. Any remaining errors are the authors own responsibility.

References

Abramo, G., Cicero, T., & D'Angelo, C. A. (2012). Revisiting size effects in higher education research productivity. *Higher Education*, *63*, 701–717.

Agasisti, T., & Bonomi, F. (2013). Benchmarking universities' efficiency indicators in the presence of internal heterogeneity. *Studies in Higher Education*, http://dx.doi.org/10.1080/03075079.2013.801423

Akhmat, G., Zaman, K., Shukui, T., & Ahmad, T. (2013). Educational reforms and internationalization of universities: evidence from major regions of the world. *Scientometrics*, http://dx.doi.org/10.1007/s11192-013-1130-5

Anninos, L. N. (2013). Research performance evaluation: Some critical thoughts on standard bibliometric indicators. *Studies in Higher Education*, http://dx.doi.org/10.1080/03075079. 2013.801429

Banerjee, A. (1999). Panel data unit roots and cointegration: An overview. *Oxford Bulletin of Economics and Statistics*, *S1*(61), 607–629.

Bochove, C. A. (2013). Economic statistics and scientometrics. *Scientometrics*, *96*, 799–818.

Breitung, J. (2000). The local power of some unit root tests for panel data;. In B. Baltagi (Ed.), *Advances in Econometrics 15. Non-stationary panels, panel cointegration, and dynamic panels* (pp. 161–178). Amsterdam: JAI Press.

Corbyn, Z. (2008). Senior academics predict a boom in manipulation of citations under new system. *Times Higher Education News*,. Online available at: http://www.timeshighereducation.co.uk/400516.article (accessed on 21.09.13)

Delgado, M. S., Henderson, D. J., & Parmeter, C. F. (2013). Does education matter for economic growth? *Oxford Bulletin of Economics and Statistics*, 0305–9049. http://dx.doi.org/10.1111/obes.12025

Diem, A., & Wolter, S. C. (2013). The use of bibliometrics to measure research performance in education sciences. *Research in Higher Education*, *54*, 86–114.

Duderstadt, J. J. (2012). The future of higher education in the knowledge-driven. In *Global economy of the 21st century*. Toronto, Canada: The University of Michigan.

Eash, M. (1983). Educational research productivity of institutions of higher education. *American Educational Research Journal*, *20*(1), 5–12.

Eid, A. (2012). Higher education R&D and productivity growth: An empirical study on high-income OECD countries. *Education Economics*, *20*(1), 53–68.

ESI. (2012). *Essential sciences indicators*. Thomson Reuters. Online available at: http://thomsonreuters.com/essential-science-indicators/ (accessed 01.01.13)

EUROPA. (2003). *Measures to improve Higher Education/Research Relations in order to strengthen the strategic basis of the ERA. Report of an independent High Level Expert Group set up by the European Commission, November 2003*. Luxembourg, Belgium: Office for Official Publications of the European Communities.

Gibney, E. (2013). Researchers' 'unrealistic' hopes of academic careers. *Times Higher Education*,. Available at: http://www.timeshighereducation.co.uk/news/researchers-unrealistic-hopes-of-academic-careers/2007247.article (accessed 26.09.13)

Hadri, K. (2000). Testing for stationarity in heterogeneous panel data. *Econometric Journal*, *3*(2), 148–161.

Hallinger, P., & Bryant, T. (2012). Mapping the terrain of educational leadership and management in East Asia. *Journal of Educational Administration*, *51*(5), 618–637.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74.

Inglesi-Lotz, R., & Pouris, A. (2013). The influence of scientific research output of academicson economic growth in South Africa: An autoregressive distributed lag (ARDL) application. *Scientometrics*, *95*, 129–139.

Jung, J. (2013). Higher education research in Asia: A publication and co-publication analysis. *Higher Education Quarterly*, 0951–5224. http://dx.doi.org/10.1111/hequ.12015

Kao, C., & McCoskey, S. (1998). A residual-based test of the null of cointegration in panel data. *Econometric Reviews*, *17*(1), 57–84.

Leslie, L. L., Slaughter, S., Taylor, B. J., & Zhang, L. (2012). How do revenue variations affect expenditures within U.S. research universities? *Research in Higher Education*, *53*, 614–639.

Levin, A., & Lin, C. F. (1992). Unit root tests in panel data: Asymptotic and finite-sample integrated systems. *Econometrica*, *61*(4), 783–820.

Levin, A., & Lin, C.-F. (1993). *Unit root tests in panel data: New results*. Department of Economics: University of California.

Levin, A., Lin, C. F., & Chu, C. S. (2002). Unit root tests in panel data: Asymptotic and finite -sample properties. *Journal of Econometrics*, *108*(1), 1–24.

Lips, D., Watkins, S. J., & Fleming, J. (2008). Does spending more on education improve academic achievement? *Backgrounder*, *2179*, 1–20.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3–42.

Lupton, R., & Obolenskaya, P. (2013). *Labour's record on education: Policy, spending and outcomes 1997–2010. Social policy in a cold climate, working paper 3*. UK: The London School of Economics and Political Science. Available at: http://sticerd.lse.ac.uk/dps/case/spcc/wp03.pdf (accessed 25.09.13)

Maddala, G., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics & Statistics*, *61*, 631–652.

Maitra, B., & Mukhopadhyay, C. K. (2012). Public spending on education, health care and economic growth in selected countries of Asia and the Pacific. *Asia Pacific Development Journal*, *19*(2), 19–48.

Mark, N. C., & Sul, D. (2002). Cointegration vector estimation by panel DOLS and long-run money demand. In *NBER Technical Working Paper 287*.

Musila, J., & Belassi, W. (2004). The impact of education expenditures on economic growth in Uganda: Evidence from time series data. *The Journal of Developing Areas*, *38*(1), 123–133.

NSF. (2012). *Chapter 5: Academic Research and Development*. Available at: http://www.nsf.gov/statistics/seind12/pdf/c05.pdf (accessed 13.08.13)

Old, K., & Robertson, S. L. (2013). *Globalizing higher education and research for the 'knowledge economy'*. UK: University of Bristol.

OECD. (2013). *Education indicators in focus*. Available at: http://www.oecd.org/edu/skills-beyond-school/EDIF%202013–N%C2%B010%20%28eng%29–v9%20FINAL%20bis.pdf (accessed 09.12.13)

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, *61*, 653–670.

Pedroni, P. (2001). Fully modified OLS for heterogeneous cointegrated panel. *Advances in Econometrics*, *15*, 93–130.

Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory*, *20*, 597–625.

Phillips, P. C. B. (1995). Fully modified least squares and vector autoregression. *Econometrica*, *63*, 1023–1078.

Phillips, P. C. B., & Perron, P. (1988). Testing for unit roots in time series regression. *Biometrika*, *75*, 335–346.

Prodan, I. (2005). Influence of research and development expenditures on number of patent applications: Selected case studies in OECD countries and central Europe, 1981–2001. *Applied Econometrics and International Development*, *5*(4), 5–22.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(5), 1002–1037.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5), 71–102.

Roy, A., & Goswami, C. (2013). A scientometric analysis of literature on performance assessment of microfinance institutions (1995–2010). *International Journal of Commerce and Management*, *23*(2), 148–174.

Saikkonen, P. (1991). Asymptotically efficient estimation of cointegration regressions. *Econometric Theory*, *7*, 1–21.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*, 65–94.

Stock, J., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica*, *61*(4), 783–820.

Stokey, N. L. (1991). Human capital, product quality, and growth. *The Quarterly Journal of Economics*, *106*(2), 587–616.

Swan, T. W. (1956). Economic growth and capital accumulation. *Economic Record*, *32*, 334–361.

Todose, D. (2000). Education management in knowledge based society. *Współczesna Ekonomia*, *3*(7), 109–117.

Toivanen, O., & Väänänen, L. (2013). *Does education lead to more innovation?* Available at: http://www.voxeu.org/article/does-education-lead-more-innovation-0 (accessed 26.09.13)

Tseng, Y., Chang, C., Tutwiler, M. S., Lin, M., & Barufaldi, J. P. (2013). A scientometric analysis of the effectiveness of Taiwan's educational research projects. *Scientometrics*, *95*, 1141–1166.

UNESCO. (2009). *Education indicators technical guidelines*. Available at: http://www.uis.unesco.org/Library/Documents/eiguide09-en.pdf (15.02.13)

United Way. (2009). *Goals for the common good: Exploring the impact of education. A joint publication of Measure of America and United Way*. Available at: http://www.measureofamerica.org/file/common_good_forecaster_full_report.pdf (accessed 16.12.12)

Wang, D. H., Yub, T. H., & Liub, H. (2013). Heterogeneous effect of high-tech industrial R&D spending on economic growth. *Journal of Business Research*, *66*(10), 1990–1993.

Westerlund, J. (2003). *A panel data test of the bank lending channel in Sweden. Working Papers 2003:16*. Department of Economics, Lund University.

World Bank. (2012). *World development indicator data base*. Washington, DC: World Bank.

Xhaferri, R., & Iqbal, K. (2013). *Windows of opportunity: Putting our brains into business*. Dawn News.

Young, J. (2011). *The top 20 countries for scientific output*. Available at: http://www.openaccessweek.org/profiles/blogs/the-top-20-countries-for-scientific-output (accessed 27.09.13)