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Research Productivity and Economic Growth: A Policy Lesson Learnt from Across the Globe

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Abstract

The relationship between research productivity and economic growth is the subject of information science which deals in this study to examine the impact of number of publications, research & development (R&D) expenditures and researchers involved in R&D activities on economic growth in the World's largest regions for the period of 1980–2011. The study further expanded the research-growth nexus in the context of top twenty nations in terms of research output for the field of science and social sciences. The results confirmed the long-run relationship between research output and economic growth; while there is bidirectional causality between real economic growth and number of publication, in United States, Italy, Spain, Australia, India, Netherlands, Brazil, Switzerland, Taiwan, and Poland. Similarly, there is two-way causal relationship between real economic growth and R&D expenditures in USA, China, UK, Japan, India, Switzerland, Taiwan, Sweden, and Turkey. Finally, there is evident of feedback hypothesis between real economic growth and researchers involved in R&D activities in the USA, UK, Japan, South Korea, and Taiwan. The direction of causality is crucial because it has significantly policy implications for economic development.

Keywords: Research Output, Economic Growth, Time Series Analysis, Granger Causality, World's Region.
JEL Classification: I23, O30.

1. Introduction

The relationship between research output and economic growth

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supports largely in causality framework, therefore, this study used time series econometric technique to evaluate long-run and causal relationship between the variables. The study gathered the data from different regions of the world including East Asia & Pacific (Australia, China, Japan, and Malaysia), Euro Area (Austria, Belgium, Cyprus, Ireland, and Italy), Europe & Central Asia (Poland, Russia, Turkey, and Tajikistan), European Union (Czech Republic, Denmark, and Estonia), and High income OECD (UK and the USA) countries. In addition, top twenty nations in terms of research output-and world share for the sciences and social sciences are also empirically estimated using secondary data from 1980 to 2011.

There are number of promising literature available on the topic, however, this study is different in many perspectives, i.e., it's covered the five largest regions of the world and evaluated top 20 nations in terms of research output share across the globe. There is no doubt about that research output increases economic growth and economic growth increases research output, however, there is necessary to formulate the long-term policy to stabilize economic growth by research productivity across the globe. Lee et al (2011) marked the joint causality between research and economic growth in Asia. The results concluded that causality in the Western countries is mixed and unclear. Inglesi-Lotz and Pouris (2013) concluded that underdeveloped nations need to coin the methods of utilizing their academic investment and the policies of industry for prosperity in future. It is difficult to answer the question of causality because the causation occurs in both directions, each including a time lag without which it is not possible to establish causality due to invalid results (Vinkler, 2008).

The relationship between productivity growth and R&D expenditure for 170 firms in UK are examined by Wakelin (2001). The study finds that the firm's own R&D expenditure plays a remarkably positive role in influencing productivity growth. The firms located in the innovation sector display a high rate of return on R&D that is influenced by the innovation history of the firm and the sector both. Jin (2010) examined the effects of research productivity on Japan's economic growth, through counting the number of pages published in 60 quality economics journals, finding it effective. It is indicated by the impulse responsiveness that the research output are promoted through the

economic growth. Cheng and Zhang (2013) compared scientific production in the field of rheumatology between countries and estimate the publication trend and citations worldwide in 39 rheumatology journals for fifteen years data i.e., 1996 to 2010. The results show that about 52.4% research produced by Western Europe and 23.1% by North America. The USA holds first position in terms of number of articles publications, followed by the UK and Germany. Ireland, Denmark and Netherlands had the (48.33), (40.19) and the (39.86) citations per article.

Cassia et al. (2013) explored the research performance of 46 centers globally and confirmed that centers facilitate a ‘‘compound Matthew-effect’’, according to which knowledge transfers to external stakeholders. The research performance is fostered and enriched after controlling the research orientation of the center. Moscone et al. (2013) examined the effect of scientific research on health care output in a sample of OECD countries from 1960 to 2008. The results advocate the important role of the medical research in elucidating health care productivity, though diverse paces in espousing scientific knowledge depict different countries. Another important result is that countries regarded by a faster immersion of academic science, such as the US, have on average a minor impact of scientific research on health productivity, as compared to the countries with slower immersion. The results conclude that countries absorbing more scientific research bear higher health costs.

The causal relationship between R&D and economic growth in the context of developed and developing countries has remained an interesting research area, as the major consideration on a casual relationship between R&D and GDP is extensively argued. Hall et al. (2013) inspected the R&D and ICT venture at the level of firm in an effort to evaluate their comparative prominence. Further the studies to what extent they are accompaniments or alternates by using data on a large uneven panel data sample of Italian manufacturing firms. The results show that R&D and ICT are both intensely related with invention and product, where R&D supports innovation and ICT supports productivity. The rates of return to both investments are so high for the median firm that they recommend extensive underinvestment in both these activities. Yang and Chen (2012)

examined the relationship between production and trades in Indonesian industrial firms. The results find that trading activity adds clearly to plants' R&D activity, while offshore company does not have a higher R&D tendency. The concurrent assessments on the interrelation of R&D, productivity, and export show that R&D has a positive impact on both productivity and exports.

The panel regression techniques were used to assess the policy determinants of private sector innovative activity across 19 OECD countries by Westmore (2013). Innovation-specific policies (i.e., R&D tax incentives, direct government support and patent rights) successfully encourage the inventive activities associated with advanced production growth. The relationship between R&D and firms' productivity differs from the R& D expenditures with state level, as first concept is related with micro analysis while the later analysis related with macro level. The micro perspective suggested the unit level analysis while the macro analysis considered for aggregate level. However, one thing is common in both the analysis i.e., R&D expenditures increases firms' productivity that ultimately amplified the economic growth of the country. There are number of studies confirmed that R & D expenditures increases firm level productivity, for example, Kumbhakar et al. (2012), and García-Manjón & Romero-Merino (2012) both confirmed this nexus in European firms, Hirschey et al. (2012) confirmed in U.S firms, Hall et al. (2013) confirmed in Italian firm etc. There are some other studies confirmed the positive association between R& D expenditures and economic growth, for example, Wang et al. (2013) confirmed this relationship in 23 OECD countries and Taiwan, Maskus et al. (2012) found in 22 manufacturing industries in 18 OECD countries and Guloglu and Tekin (2012) confirmed this relationship in the panel of high income OECD countries. These studies confirmed the strong linkage between research productivity and GDP in different regions of the World. Inglesi-Lotz et al. (2015) investigated the cause-effect relationship between research output and BRICs' economic growth and found the bidirectional causality in India, while in remaining four countries, the study holds neutrality hypothesis. In the similar lines, Ntuli et al. (2015) examined the causal relationship between OECD's economic growth and research output and finds research –led growth in the region.

The above discussions confirmed the long-run and causality association between the research productivity and economic growth across countries. The present study examined this relationship in the worlds' five largest regions in a panel setting and top twenty nations in science and social sciences publications as an individual country assessment for robust inferences.

2. Data Source and Methodological Framework

The publications data is collected from the National Sciences Indicators (NSI) database of Thomson Reuters. The data for R&D expenditures, researchers involved in R&D activities and economic growth are taken from *World Development Indicators*, which is published by World Bank (2012). In addition, this study brings the data of number of publications from National Science Indicators (ISI, 2012) of top twenty nations of the world for the sciences and social sciences. Forward and backward interpolation technique used where data values missing in the candidate variables. Table 1 shows the lists of the variables.

Table 1: List of Variables

Variables	Measurement	Symbol	Expected Signs	Data Source
Dependent Variable				
Real Gross Domestic Product	GDP/1+CPI (US $ million)	RGDP		World Bank (2012)
Independent Variables				
Number of Publications	Numbers	PUB	Positive	ISI (2012)
Research and Development Expenditures	Percentage of GDP	R&D	Positive	World Bank (2012)
Researchers in Research and development	Per million people	RESR&D	Positive	World Bank (2012)

Source: World Bank (2012) and ISI (2012). CPI stands for consumer price index.

Table 1 hypothesize that there is a positive association between research output and economic growth. The study used three indicators of research productivity, i.e., number of papers, R & D expenditures, and researchers involved in R & D activities, which served as independent variables. Real GDP served as a dependent variable of the

study, covering the time period of 1980-2011. The study estimated a simple non-linear research-growth model, which has been specified as follows:

$$\ln(RGDP) = \alpha_1 + \alpha_2 \ln(PUB) + \mu$$

$$\ln(RGDP) = \beta_1 + B_2 \ln(R \& D) + \mu$$

$$\log(RGDP) = \gamma_1 + \gamma_2 \ln(RESR \& D) + \mu \quad (1)$$

where:

i. RGDP represents Real Gross Domestic Product in US $ million,
ii. PUB represents number of publications in sciences and social sciences,
iii. R&D represents research and development expenditures as percentage of GDP,
iv. RESR&D represents researchers in R & D per million people and
v. Ln represents natural logarithm and μ represents stochastic term.

The smoothness of the data series is prerequisite to decompose the time series data in to the similar units of measurement, as GDP presented in current US $ million, while other variables are presented in either in total numbers, in million peoples or in as percentage of GDP. Therefore, the study converted the GDP data in to its real term and deflated it with the corresponding average price levels. In addition, the study used natural logarithm for all candidate variables that decreased the possibilities of distortions in the dynamic properties of annual data series. Natural log transformation method preferred in the regression equations that represented the coefficients values in the form of elasticities.

Universities or higher education institutes plays a vital role for formulating the policies to develop the nations worldwide. In order to energize educational systems, governments of the regions or state should have to amplify the research and development expenditures and involve researchers in R&D activities. Therefore, enhancement of human capital can be done through connection with R&D activities, their expenses and producing research production. The enhancement of the worth of human investment through productivity of research output can lead to an

enhancement of economic production in the developing as well as developed areas of the World (Inglesi-Lotz and Pouris, 2013).

Toda-Yamamoto-Dolado-Lutkephol (TDYL) approach is used in this study for examining the cointegration process by imposing restrictions on the coefficient in the VAR level model. TDYL approach used in this study by examining the causal relationship between the candidate variables, therefore, the study used Wald statistics with standard asymptotic chi-square distribution. As the study used natural logarithmic value of the candidate variables, therefore, there is not a prerequisite to use either dummy variable to minimize the sudden jumps in the data series. The study examined cause-effect relationship between the variables in the log-log model.

3. Results

Table 2 shows the estimates of Levin, Lin, and Chu panel unit root test and found that R&D expenditures are differenced stationary in 4 out of 5 worlds' regions, while Europe and Central Asia shows second differenced stationary. The researchers involved in R&D activities shows level stationary data in 4 out of 5 world regions except Europe and Central Asia which shows differenced stationary. The data for number of publications and real GDP exhibits the differenced stationary in 5 out of 5 regions.

Table 2: Summary of the Order of Integration between Research Output and Economic Growth in the Major Regions of the World

Selected World's Region	R & D Expenditures	Researchers in R & D	Number of Publications	Real GDP
East Asia & Pacific	I(1)	I(0)	I(1)	I(1)
Euro Area	I(1)	I(0)	I(1)	I(1)
Europe and Central Asia	I(2)	I(1)	I(1)	I(1)
European Union	I(1)	I(0)	I(1)	I(1)
High Income OECD	I(1)	I(0)	I(1)	I(1)

Note: I(0) shows non-stationary series at level; I(1) shows stationary series at first difference, and I(2) shows stationary series at second difference.

Table 3 shows the estimate of Fisher cointegration test and found the one cointegrating factor in East Asia and Pacific while Euro Area and High income OECD does not have any cointegration equations. Finally,

European Union confirmed the 2 cointegrating equations in the given model.

Table 3: Fisher Cointegration Test (Maximum Eigenvalue)

Selected World's Region	Hypothesized No. of CE(s)	Max-Eigen Test	Probability Value
East Asia & Pacific	None *	53.74	0.000
Euro Area	None	16.46	0.285
Europe and Central Asia	None	14.00	0.449
European Union	None *	29.90	0.007
	At most 1 *	32.75	0.003
High Income OECD	None	20.61	0.112

Note: * Indicates significant at 1% level.

Table 4 shows the estimate of Granger causality by using MWALD test. In the context of East Asia & Pacific and Europe and Central Asia, the bidirectional casualty exists between real economic growth and R&D expenditures, while for Euro Area and European Union, the causality running from economic growth to R&D expenditures but not vice versa. In the context of high income OECD, R&D expenditures Granger cause economic growth but not vice versa. There is a feedback relationship between researchers involved in R&D activities and economic growth in Europe and Central Asia, while economic growth Granger cause researchers involved in R&D activities in East Asia and Pacific and Euro area, while in case of European Union, causality running from researchers to economic growth but not vice versa.

Table 4: Granger Causality Results Using MWALD Test

Selected World's Region	R & D Expenditures → RGDP	RGDP → R & D Expenditures	Researchers → RGDP	RGDP → Researchers	Publications → RGDP	RGDP → Publications

East Asia & Pacific	✓	✓	≠	✓	✓	✓
Euro Area	≠	✓	≠	✓	✓	≠
Europe and Central Asia	✓	✓	✓	✓	✓	≠
European Union	≠	✓	✓	≠	✓	✓
High Income OECD	✓	≠	≠	≠	≠	✓

Note: ✓ causality exists and ≠ no causality.

The bidirectional causality exists between research publications and economic growth in East Asia and Pacific and European Union, while publications led growth hypothesis supported in Euro area and Europe and central Asia. In the context of high income OECD, causality running from economic growth to publications that support the growth led research publications in the region. The study further evaluates research-growth nexus in World's top twenty nations in terms of research output in sciences and social sciences.

The results in Table 5 confirm the long-run relationship between the variables. Except Italy and Netherland for RGDP; Australia, Switzerland, Taiwan and Sweden for publications; Germany, Russia and Netherlands for R&D expenditures; USA, China, Italy, Spain, Australia, Sweden, Turkey and Poland for researchers, remaining countries are differenced stationary. The long-run relationship holds between the RGDP and research factors in USA, China, Germany, Japan, France, Canada, Italy, Brazil, Switzerland and Poland. The Granger causality results for RGDP and publications; RGDP and R&D; and RGDP & researchers shows mixed results in different countries. There is eleven countries which shows bidirectional causality between RGDP and publications, six countries have a unidirectional causality running towards publications to RGDP; and four nations supports RGDP-led publications hypothesis. Similarly, in case of RGDP and R&D expenditures, nine countries have bidirectional causality between them. Four nations supports the RGDP-led R&D expenditures

hypothesis; four nations evident the R&D-led growth hypothesis and there is two nations i.e., Italy and South Korea, which do not show any causality between the variables. Finally, five countries which exhibits the feedback hypothesis between RGDP and researchers; eight nations supports the RGDP -led researchers hypothesis; Only Poland shows the unidirectional causality between researchers-led RGDP; and there is six countries which have no causal relationship between the RGDP and researchers.

Table 5: Granger Causality Test for Top 20 Nations in Research Output for the Sciences and Social Sciences

Selected World's Region	RGDP	Publications	R & D Expenditures	Researchers	Cointegration between RGDP and Research output	Causality between RGDP & Publications	Causality between RGDP and R & D Expenditures	Causality between RGDP and Researchers	Lag
United States	I(1)	I(1)	I(1)	I(2)	✓	⇔	⇔	⇔	4
China	I(1)	I(1)	I(1)	I(2)	✓	←	⇔	≠	7
United Kingdom	I(1)	I(1)	I(1)	I(1)	¥	←	⇔	⇔	5
Germany	I(1)	I(1)	I(0)	I(1)	✓	→	→	≠	4
Japan	I(1)	I(1)	I(1)	I(1)	✓	→	⇔	⇔	5
France	I(1)	I(1)	I(1)	I(1)	✓	→	←	→	1
Canada	I(1)	I(1)	I(1)	I(1)	✓	←	←	→	2
Italy	I(0)	I(1)	I(1)	I(2)	✓	⇔	≠	≠	4
Spain	I(1)	I(1)	I(1)	I(2)	¥	⇔	→	≠	4
Australia	I(1)	I(0)	I(1)	I(2)	¥	⇔	→	≠	4
India	I(1)	I(1)	I(1)	I(1)	¥	⇔	⇔	→	7
South Korea	I(1)	I(1)	I(1)	I(1)	¥	←	≠	⇔	7
Russia	I(1)	I(1)	I(2)	I(1)	✓	←	←	→	7

Selected World's Region	RGDP	Publications	R & D Expenditures	Researchers	Cointegration between RGDP and Research output	Causality between RGDP & Publications	Causality between RGDP and R & D Expenditures	Causality between RGDP and Researchers	Lag
Netherlands	I(2)	I(1)	I(2)	I(1)	¥	⇔	←	→	5
Brazil	I(1)	I(1)	I(1)	I(1)	✓	⇔	≠	→	5
Switzerland	I(1)	I(0)	I(1)	I(1)	✓	⇔	⇔	→	4
Taiwan	I(1)	I(0)	I(1)	I(1)	¥	⇔	⇔	⇔	4
Sweden	I(1)	I(0)	I(1)	I(0)	¥	→	⇔	→	5
Turkey	I(1)	I(1)	I(1)	I(0)	¥	←	⇔	≠	5
Poland	I(1)	I(1)	I(1)	I(0)	✓	⇔	→	←	7

Note: ⇔, →, and ← indicates bidirectional causality, causality running from RGDP to publications, R & D expenditures and researchers, causality running from publications, R & D expenditures and researchers to RGDP. ✓ indicates cointegration and ¥ indicates no cointegration exists between the variables.

This study has analyzed the productivity and visibility of research-growth nexus in five regions of the world and the world's top twenty nations with respect to research output in sciences and social sciences. The research findings outline the possible results for policy-makers and scholars by raising long term research activities in the region though this matter has not been treated in the literature of policy evaluation at length. Furthermore, this research implies that conventional short term, cross section, evaluation processes of these activities rendering narrow results do not help to establish guidelines for long run policy re-orientations on such issues. (Jimenez-Saez et al., 2013)

4. Conclusions

The Granger causality technique is applied to a time series aggregate data set on research factors (i.e., number of publications, R & D expenditures and researchers in R & D) and real economic growth (i.e.,

RGPD) from World's most promising regions, additionally top twenty countries in terms of research output also evaluated spanning 31 years from 1980-2011 to determine whether increases in research output/factors have driven economic growth or economic growth drive research productivity. The empirical results are mixed with fluctuate region to region and country to country, as this study confirms feedback hypothesis between research publications and economic growth in East Asia and Pacific region; European union; and OECD members; and bidirectional causality between R&D expenditures and RGDP in East Asia &Pacific and OECD members. There is further evidence on moderately support the conventional view that RGDP Granger causes publications; R&D expenditure and researchers in R&D in different regions of the World. Research output has significant long run casual effect on economic growth in top twenty nations of the World. The study find evident of feedback hypothesis, unidirectional causality; research-led growth hypothesis and no causal relations hip between the variables. This study is in better position to justify and generalize the results from the previous studies, as this study applied sophisticated econometrics technique on key variables of research i.e., number of publications, R&D expenditures and researchers involved in R&D activities which put forward to find the impact on economic growth of the World largest regions.

The scientometric analysis gains substantially through measurement and quantification in recent years still the ideal concept is under debate. The inclusion of papers published in journals ranked by the Social Science Citation Index (SSCI) often used next to the average impact of the respective journals, these measures are also debatable (Ketzler and Zimmermann, 2012). Thus, it can be safely concluded that Governments around the world emphasize substantially on investments in human capital through the provision of higher education.

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