Proceedings of the 2023 International Conference on Management Research and Economic Development
DOI: 10.54254/2754-1169/21/20230267

The Impact of Scientific Research on Economic Growth: An Empirical Study Based on Data from 20 Countries in 2000-2018

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Abstract: This article aims to reveal the relationship between scientific and technological development and economic growth, which is essential in figuring out what ultimately decides economic development. This paper uses the empirical method and adopts data about the economy, technology, and education of the 20 most significant economic communities from 2000 to 2018 to analyze how science and technology creativity will influence economic growth. A meaningful finding may be that scientific research and high education are not always favorable to economic growth. Only after a country's research and education level reaches a point can they play a positive role in the economy.

Keywords: scientific, technological, education, economic growth, empirical

1. Introduction

Economists have long mentioned the importance of scientific and technological innovation and scientific research ability to economic progress. In endogenous growth theory, technology is put into the equation as a factor with a multiplier effect, which reflects that the approach attaches great importance to the positive impact of science and technology on economic growth[1]. Besides, other theories, like Schumpeter's long-wave theory, describe the cyclical nature of innovation and economic growth, which also explains the massive role of innovative development in economic growth[2]. It seems so natural and undoubted that science, technology, and education are essential in improving economic growth. But the precise relationship between science and economy is still to be explored. Moreover, if scientific research and technology development enhance GDP growth every time and space should not be so easy to conclude.

Many empirical studies have been based on fundamental theories about the relationship between innovation and economic growth. This paper will continue doing this work and try to get some fresh ideas about this issue.

2. Literature Review

Previous studies include some theoretical researches which used a mathematical model to derivate the relationship between education and economic growth, like what Bouzahzah Mohamed, Asongu Simplice A, and Jellal Mohamed did in 2016[3]. Other researches, which is also in this pattern, involve Chu Shan-Ying's articles, which described how Internet technology influences the

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economy[4], and Feng Yuan's study, which is empirical research about how the development of the Internet makes a contribution to the economy in China[5].

More articles focused on empirical studies to get more precise relations. For instance, Weng Lei, Song Wei, and Sheng Si-Bei empirically studied scientific and technical innovation and economic growth in Shanghai[6]. Zhang Lei, Song Wei, and He Jun did similar research in Beijing[7]. The most generalized one is the article from Wang Ying and Liu Shasha in 2016, who did empirical research about how education and human capital influence economic growth, using data on 55 countries and regions from 1960-2009[8]. Except for China, empirical studies about other countries are also abundant. Abdullah Almaraee and Mohammed explore the effects of higher education in Saudi its economic globalization[9]. Besides, a study from the U.S. described how a specific technic influences productivity growth in the transportation industry in the U.S.[10]. These articles all play good roles in this paper's research.

Though so much empirical research had been done, most focused on a country or a region. The topic of a few articles focusing on studying the macro situation of the entire world, like Wang Ying and Liu Shasha's in 2016, are also closer to the economic impact of education than scientific research. This paper will use panel data to do an empirical study and mainly focus on how the scientific research level of a country affects its economic growth.

3. Methodology

The article adopts data from World Development Indicator (WDI: https://datatopics.worldbank.org/), selecting annual GDP growth rate as the dependent variable and three different indicators that can state a country's scientific research and technological level as dependent variables to do some regressions. Specifically, this paper chooses data from 20 countries with the highest GDP in 2022 and the world as a whole, and the time of data is from 2000 to 2018. The reason for choosing these 20 countries is that they are the most significant economic communities in the world, and their developments are representative. Besides, here adds the globe as a whole to reflect the typical situation, which can help briefly on behalf of the status of all countries in the world. The 20 countries are the United States, China, Japan, German, the United Kingdom, India, France, Italy, Canada, Brazil, Russian Federation, South Korea, Australia, Mexico, Spain, Indonesia, Saudi Arabia, Switzerland, Turkiye, and the Netherlands.

Three independent variables are scientific and technical journal articles which is the number of a country's published scientific papers in a specific year; technicians in R&D (per million people), which shows a country's concentration of scientists and educational attainment-doctoral or equivalent; which tells them are how many doctors in a country. The variables can demonstrate a country's scientific and education level to a considerable degree and further show a country's technology innovation level. For instance, the number of scientific and technical journal articles can lead to a country's research strength. In contrast, the number of technicians in a country can demonstrate the technological innovation potential of a nation. Lastly, doctors are the ones who do or will do scientific research. The article sets quadratic terms for each dependent variable to consider that influences from independent to dependent variables are not all linear.

The regression model is set as follows:

$$GDPG_{it} = \beta_0 + \beta_1 STA_{it} + \beta_2 STA2_{it} + \beta_3 TRD_{it} + \beta_4 TRD2_{it} + \beta_5 EDU_{it} + \beta_6 EDU2_{it} \quad (1)$$

GDPG is GDP growth rate annually, STA means scientific and technical journal articles, TRD is technicians in R&D (per million people), and EDU means educational attainment-doctoral or equivalent. The footmarks in the lower right corner of each variable represent different countries and times. STA2 and similar variables are quadratic terms of each dependent variable. Moreover, because

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the dependent variable is a time series variable, the paper adds the phase I lag term and phase II lag term to prevent the influences of the value from the independent variable in the past. This article will use the fixed effect model to do the panel regressions.

4. Descriptive Statistics

It has been calculated that all variables don't correlate significantly with other variables. The table below shows the dataset.

Table 1: Descriptive statistics.

	count	mean	std	min	50%	max
Time	462	2010.5	6.351	2000	2010.5	2021
Country Name	462	10	6.062	0	10	20
GDPG	462	2.778	3.418	-11.325	2.704	14.231
SAT	462	156278.117	368148.898	326.740	56212.330	2554318.672
TRD	462	914.480	429.742	16.312	914.480	2935.196
EDU	462	0.931	0.296	0.032	0.931	2.974

The variables Time and Country Name describe the time and region in which time was set yearly. Adding the two variables into regression transforms the data into panel data. It has been told that the time was from 2000 to 2018, which was close to now, so it's representative. And there are 21 different space units which are 20 countries adding one unit named the world as a whole.

GDPG states a country's GDP growth rate at a specific year. It should be mentioned that GDPG should be a percentage variable, but here, the article pulls out the percent sign so that the GDPG in the data is just numeric (for example, 8.7% is shown as 8.7).

STA demonstrates how many scientific articles are published in a country in a specific year. Due to statistical caliber, STA can float. By observing the 50% value (about 56212) and mean value (about 156278) of STA, it can be found that there are some extreme outliers because the mean value is much larger than the 50% value. This is caused by the dataset adopting data from the world, where the number of published papers is the sum of all countries worldwide. Other reasons may come from some countries with many articles published each year, such as the United States, China, etc. Besides, it can be observed that the standard deviation and the gap between the minimum and maximum values are significant, which shows that the differences between countries should not be overlooked.

TRD is the number of technicians per million people in a country in a specific year. This factor measures the creativity and innovation ability of a nation. It can be observed in the table above that the difference in this index of different countries is significant. The minimum number is about 16, which states that one country has only 16 technicians per million people. While for those advanced countries in this aspect, they have near 3000 technicians per million people. The minimum and maximum value of TRD also display the gap between technologically advanced countries and those not.

EDU is the percent number of how many doctors (or equivalent) in a country. Doctors are the leading group who do scientific research, so this variable can also describe a nation's science and technology level. Though there is still a gap between the minimum and maximum values, the difference is smaller than the previous two. This is not only because the dimension of this variable is a percentage. Even those scientifically developed countries have a small percentage of people getting Ph.D. degrees, which can be found by observing the maximum value of EDU--the most significant number of EDU is 2.974, which shows the country with the highest percentage of PHDs just has 2.974% of doctors.

The original data has some missing values, especially for TRD and EDU. This paper adopts the method of filling the mean value of each variable into the table to solve the problems raised by missing values.

5. Regression Progress

Based on the methodology above, this paper now begins to do regressions. Four regressions are done. Firstly, the report regresses the dependent and three independent variables, such as GDPG to STA and STA2 only. After finishing three reversals, the paper will add all variables to do a regression, just like equation (1). The reason to do this is to separately observe the different influences that different variables cause on GDPG.

The results are shown below:

Table2: Regression results.

GDPG				
	(1)	(2)	(3)	(4)
L.GDP	0.191***	0.204***	0.209***	0.190***
	(0.051)	(0.052)	(0.0520)	(0.0520)
L2.GDP	-0.111**	-0.101**	-0.095**	-0.116**
	(0.050)	(0.050)	(0.050)	(0.050)
SAT	-1.27E-05***			-1.26E-05***
	(-4.05E-06)			(4.06E-6)
SAT2	3.32E-12***			3.3E-12***
	(1.15E-12)			(1.15E-12)
TRD		-0.002*		-0.002*
		(0.001)		(0.001)
TRD2		5.09E-07*		5.06E-07*
		(3.91E-07)		(3.88E-07)
EDU			-0.358	-0.404
			(1.121)	(1.107)
EDU2			0.154	0.180
			(0.369)	(0.365)
sigma_u	3.405	1.915	1.972	3.402
sigma_e	2.189	2.211	2.221	2.192
rho	0.708	0.429	0.441	0.707

Note:(1) *, **, and *** indicate 10%, 5%, and 1% confidence levels, respectively; (2) The corresponding standard deviation is in parentheses below each coefficient.

The regression results may differ from what many people thought before, and these results tell us some critical issues.

(1)As a country's published scientific papers increase, the GDP growth rate will decrease at first. After reaching the turning point at 1912651, the GDPG will increase as SAT increases. But this doesn't mean that common sense has been overturned. Actually, it's a natural idea that before scientific research articles accumulate to a specific level, they are not enough to make many contributions to economic growth. There may be various reasons. Firstly, not all the research results can be transferred into productivity immediately. It needs a significant amount of time, from publishing an issue to using it and then putting it into production. Without a large scale of articles, the positive effects will not be evident quickly. Secondly, scientific research consumes resources, which negatively affects the economy. When there is little scientific research, the consumption of resources may be larger than the products it releases. Only after scientific research reaches a scale level can it stimulate tremendous production momentum.

By watching the dataset, another finding will be clear no one country reaches the level at which the number of published articles arrives 1912651. The only unit that comes to this standard is the world as a whole. So, it might conclude that any country individually hasn't come to the research level that can improve GDP growth. Still, the world's economic growth has increased because of large amounts of scientific research.

(2)The results about technicians in a country are similar to those above. Before the number of technicians arrived in 1965(per million people), the increase of technicians harmed economic growth. If a country has more than 1965 technicians per million people, then they will contribute to economic growth. The possible reasons may also be similar to the above. Nurturing talent takes lots of resources, while the return of each technician individually may not be significant. Only after a large number of technicians in a country can it lead to qualitative change.

It should be mentioned that this variable is a little different from SAT because the world's TRD is not the sum of all countries, but a kind of mean value, which is because TRD is counted per million people but not the exact number. Though, few countries have more than 1965 technicians per million people. TRD and SAT both tell us that if a government wants to improve its GDP growth rate through science and technology, it should invest many resources. After the scientific research ability reach the standard, can it be beneficial?

(3)The third regression shows that the variable EDU and its square item are insignificant. There might be many reasons that the two variables are not significant. For example, different countries set different standards for getting a doctorate. Thus, the research abilities of doctors from each country vary a lot. Besides, getting a Ph.D. doesn't mean that this one will continue to research, which states that the number of doctors is irrelevant to the number of published scientific articles (the correlation of SAT and EDU can approve this argument). But actually, this conclusion should not be made too easy. Further discussions need to be done.

(4)The significance levels of the fourth regression are not different from the three regressions before. SAT and TRD are significant at different levels, and EDU is unimportant even at a 10% significance level. It should also be mentioned that the lag terms are all substantial in all four regressions.

6. Conclusion and Limitation

To sum up, this paper finds that the quantity of published scientific research articles and technicians in a country will significantly influence economic growth. But the impacts are not linear but are quadratic function type. As the quantity of published papers and technicians increases, the GDP growth rate will first decrease. After the number goes larger than a specific level, the GDP growth rate will increase as the two variables increase. This result suggests that all countries improve their scientific production to a high level. Besides, different countries may take different strategies for scientific research. Due to the small benefits and high cost of low scientific level, those countries with poor scientific basis are complex to hence their scientific level quickly, so they can appropriately spare their resources into other essential areas to decrease the waste. At the same time, those countries developed in science should continue to input relative industries to go over the turning point. As a result, scientific research will be beneficial to the economy.

The percentile of doctors (or equivalent) in a country has no significant influence on a country's economic growth. The reasons might be that the quantity of doctors is irrelevant to the number of

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published scientific articles, and doctors in different countries have different scientific research abilities.

This paper solved some questions about the influence of science and technology levels on economic growth. But some other questions are left. The limitation of this article is as follows:

(1) The turning point of SAT is too significant as no one country can reach this level.

In this case, the conclusion may not give practical advice to governments. The world became an extreme value in the paper, which may influence the results. The adjusted model should be used to find a better relationship between the number of published scientific articles and the GDP growth rate.

(2) The coefficient for the primary term of SAT and TRD is too small. By regarding each regression result as a quadratic function, this means the change of GDPG due to SAT and TRD is so tiny as not to be significant at a realistic level.

(3) The relationship between EDU and GDPG needs deeper mining.

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