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Assessing the impact of science and education on GDP: Evidence from Armenia

Yuri Suvaryan[1], Meri Manucharyan[2,3*], Liana Khachatryan[2,4], Manush Minasyan[2], Yevgenya Hakobyan[2]

[1]*National Academy of Sciences of the Republic of Armenia, 24 Marshal Baghramyam Ave, Yerevan 0019, Armenia.*
[2]*The Institute of Economics after M. Kotanyan of the National Academy of Sciences of the Republic of Armenia, 15 Grigor Lusavorich Str., Yerevan 0015, Armenia.*
[3]*Armenian National Agrarian University, Faculty of Agribusiness and Economics, 74 Teryan Str.,Yerevan 0009, Armenia.*
[4]*Armenian State University of Economics, Chair of Theory of Economics, 128 Nalbandyan Str., Yerevan 0025, Armenia.*

Corresponding author: Meri Manucharyan (*Email: meri.g.manucharyan@gmail.com*)

Abstract

This study aims to assess the methodological challenges and quantify the impact of scientific research and education on the volume and growth rates of GDP, with a specific focus on the case of Armenia. The analysis employs correlation and regression models to explore the relationships between GDP, scientific research expenditures, and educational services. Drawing on monthly macroeconomic data from Armenia for the period 1995–2023, the methodological framework includes trend analysis, Pearson correlation, and Granger causality tests to determine both the strength and the direction of predictive relationships between these variables. The results reveal strong positive correlations: between GDP and science (0.97), GDP and education (0.99), and between science and education (0.98). Regression analyses indicate that a one-unit increase in scientific output raises GDP by 564.3 billion drams, while a one-unit increase in educational output contributes 28.9 billion drams. Critically, Granger causality tests show that education and science outputs are significant predictors of future GDP growth, whereas GDP growth does not have a statistically significant predictive effect on future outputs in education or science. The study concludes that science and education are fundamental drivers of economic growth in Armenia, demonstrating a consistent and direct relationship with GDP despite geopolitical fluctuations. The findings suggest a unidirectional causality where investments in these sectors stimulate economic expansion, not vice versa. For policymakers in resource-limited economies like Armenia, the study underscores the critical importance of strategic, sustained investment in science and education as a primary engine for sustainable development. The methodological insights highlight the need for nuanced, long-term approaches to effectively capture the full economic return of investments in human capital and innovation.

Keywords: Analyses, Economic development, GDP, Granger Causality, Growth rate, Science and education.

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1. Introduction

In the modern world, science and education play a key role in shaping the economic potential of countries. Their impact on the volume and growth rates of gross domestic product (GDP) is becoming increasingly significant in the context of globalization and the transition to a knowledge-based economy [1]. Science and education systems contribute to innovative development, increased productivity, and the creation of new technologies, which ultimately affect economic growth. However, despite the obvious connection between these factors, the mechanisms of their impact on GDP remain insufficiently studied. The relevance of this topic is due to the need to develop effective strategies for sustainable economic development based on scientific and technological progress and quality education.

The aim of the study is to assess the impact of science and education on the volume and growth rates of GDP, as well as to identify the main mechanisms of this impact.

2. Literature Review

The study of the impact of science and education on economic growth has a long history. One of the first theorists to draw attention to this relationship was Solow [2], who identified technological progress as a key factor in long-term GDP growth in his model of economic growth [2]. Later, Romer [3] and Lucas [4] developed this idea by including human capital and innovation in endogenous growth models [3, 4]. Modern research confirms that investments in education and science contribute to increasing labor productivity and innovative activity [5]. For example, research by Hanushek and Woessmann [6] showed that the quality of education directly affects economic growth rates [6]. Similar conclusions were made in the works of Aghion and Howitt [7] who emphasized the role of scientific research in creating new technologies and increasing the competitiveness of the economy [7].

A significant number of authors justify the effectiveness of investments in science and technology. Thus, Ma et al. [8] in their work emphasize the importance of scientific and technical activities, noting that the rapid changes currently taking place in the world are mainly due to the progress of science and technology, which in turn is due to scientific and technical activities (STA) [8]. As part of the research, they assessed STA in the countries of the world and in Ukraine, as well as analyzed the impact of STA on sustainable economic growth. The authors calculated the ISTA of the countries of the world with their subsequent rating. The impact of ISTA (an indicator of scientific and technical activities) on the economic growth of the countries of the world was assessed, as well as the relationship between the global innovation index (GII) and the human development index (HDI). The importance of environmentally friendly technologies and innovations in ensuring the economic growth of the countries of the world was also assessed and analyzed. The analysis and results obtained allowed the authors to conclude that, in order for a country to take a leading position in terms of STA, it is important to harmoniously combine efforts to support and develop the country's scientific potential, as well as to create principles for the implementation of scientific achievements in innovative activities to ensure economic growth and improve the living standards of the population. They also confirmed the importance of STA in ensuring the economic growth of countries around the world by a significant correlation between ISTA and GDP per capita (R = 0.84). However, they concluded that countries with high GDP per capita have more opportunities to develop STA, while countries with low GDP per capita lack sufficient resources for this development. The importance of R&D and innovation for sustainable economic growth is clearly evident in the EU's "Europe 2020" agenda, where "smart, sustainable, and inclusive growth" has become the EU's new strategic objective. Member states were expected to ensure a 3% share of R&D spending in GDP. The EU argues that R&D support should help member states maintain sustainable economic growth while reducing unemployment, increasing competitiveness, and reducing regional disparities [9].

Other authors, Mallick et al. [10] attempted to identify the relationship between education spending and economic growth in 14 Asian countries between 1973 and 2012. The analysis concluded that there is a long-term correlation between education expenses and economic growth in all selected countries. To achieve economic development, a nation's policies must prioritize improving various institutions. Countries must pursue policies that can promote high-quality education for all, and this will only be successful when governments increase their country's expenditure on education.

Brautzsch et al. [11] conclude that R&D support in Germany was very successful during the economic crisis of 2008 and 2009, generating a significant leverage effect and counteracting a 0.5% decline in GDP in 2009 [11].

The results of a study by Rehman et al. [12] indicate a high intensity of university and private research and development in European countries, which also documented the existence of close research ties between universities and industry. Based on empirical research, they found that to effectively withstand the economic crisis, special government-funded R&D (Research and Development) programs, such as tax breaks, R&D grants, and subsidies, will stimulate technological innovation in the private sector. Based on this analysis of European and Asian countries, the authors concluded that if public support programs (tax incentives) are invested in research and development, this will stimulate technological innovation in the private sector.

Andrés et al. [13] used meta-analysis methods from 37 studies published between 2004 and 2011 in their study. The results showed that the effects of public investment on research and development are mostly positive and significant, as public funds are not crowding out but rather incentivizing companies to invest in research and development.

Target 9.5 of the UN Sustainable Development Goals (SDGs) [14] is defined as “Enhance research and modernize industrial technologies,” which implies strengthening R&D, modernizing technological capacities of all countries, in particular developing sectors, including by 2030 taking measures to encourage innovation and increase the number of researchers, as well as R&D expenditure. Thus, the SDGs also emphasize the need to increase the potential of STA and improve its results.

Many other authors also discuss the prospects for the development of science; in particular, Schneider et al. [15] analyzed how science can support the 2030 Agenda for Sustainable Development. The authors, analyzing the impact of scientific research and development on sustainable economic growth, emphasize the need to activate scientific activity in the face of global challenges and to create conditions for economic growth in all countries of the world.

Falk [16] studied the impact of scientific analyses and developments on the development of the monetary sector in OECD countries, using data from 1970-2004. Based on the results obtained, they found that both the ratio of R&D expenditures of commercial organizations to GDP and the share of R&D investment in the high-tech sector have a significant positive impact on GDP per capita and GDP per hour worked in the long run [16].

Sadraoui et al. [17] **b**roke down the causality between Research and Development coordinated effort and financial development by dissecting the connection between Research and Development expenditures and monetary development for China. It was concluded that GDP will increase by approximately 0.92% if there is a 1% increase in Research and Development expenditures.

However, despite a significant amount of research, questions remain regarding the measurement of the contribution of science and education to economic growth, especially in different institutional and economic contexts [18, 19]. This determines the need for further study of this issue.

3. Background

Undeniably, in the 20th century, currently, and in the future, economic development is largely based on innovations, especially advanced technological solutions. In this context, assessing the economic consequences of knowledge and education is an extremely important and topical scientific issue. The latter, being a relatively new direction of study, nevertheless originated in the works of the classics of economics [20, 21].

The conceptual issues of innovative development have been considered especially in the works of Schumpeter [22]. Qualitative and quantitative assessments of the impacts of the scientific and educational system are highly valued among the issues of economic development and are the focus of attention of many researchers. Numerous applied studies, based on the examples of different countries, have been devoted to these issues and have been carried out in a number of directions. In particular, the issue of the effectiveness of investments in the scientific and educational system has been studied [23]. These investments are one of the most important components of the economic policy of a given country, and approaches to this issue differ greatly in different countries. The principles for assessing the interrelationships between the scientific and educational system and economic development are also unique. Spending on science is particularly significant in South Korea and Sweden, accounting for more than 4% and 3% of their GDP, respectively, and $1,200-1,300 per capita. In absolute terms, spending on science is high in the United States and China. It is interesting to note that a number of countries with low levels of economic development, such as Estonia, Slovenia, and Iceland, are not lagging behind the above-mentioned countries in this regard, and are also making significant investments in the field of science, expecting its future high economic efficiency [24].

Of interest are studies conducted in various countries that have revealed the so-called economic efficiency of education and science. These studies reveal useful experiences in developing the system in a given country. There are numerous studies on the effects of education on the economy. The latter have been evaluated from various perspectives. For example, the impact of education on both the dynamics of individual incomes and the macroeconomic indicators of countries has been calculated. In terms of revealing the economic effectiveness of science, the experience of South Korea is noteworthy, where over the past few decades, structural changes in GDP in favor of science spending led to an unprecedented 5-6-fold increase in per capita GDP [25].

The study of the issue is especially important for countries that are on the path of reforming their scientific and educational systems to ensure sustainable economic growth. The Republic of Armenia is among such countries. The future economic development of Armenia also depends significantly on investments in science and education. The Republic of Armenia does not have rich natural resources and a geopolitical position conducive to economic progress [26, 27]. For this reason, economic development can be primarily based on new scientific, technical, informational, and technological solutions.

During the period of independent statehood, the scientific and educational system of Armenia has undergone certain tests and is currently on the path of reforms. In order to develop a strategy for the further development of the scientific and educational system of the Republic of Armenia, it is especially important to assess the interrelationships between the system and the economy for the period of our modern history.

4. Materials and Methods

The methodology for assessing the impact of science and education on development and economic growth is based on extensive international experience in researching this issue.

In order to assess the impact of science and education on the volume and growth rate of gross domestic product, the direct impact of changes in the volume of public (state, private, grant) scientific work and educational services in these sectors on the process of economic development was calculated, as well as the impact of scientific and technical progress and education on it as factors of economic development was observed.

Investments in innovation and research sectors, human capital, expansion of grant programs funded by international organizations, and investments in corporate innovative and scientific-design developments are essential for a direct impact on GDP growth. They directly increase the volume and growth rates of GDP as factors that expand the volume of educational, scientific, and technical services. The results of scientific and educational activities carried out at the expense of the state budget, with private financing, as well as with grant programs, are reflected in the country's GDP as scientific and educational services purchased by entities operating in the market (including the state). Accordingly, the contribution of the scientific and educational system (ΔP(S+E)) to the GDP growth rate (P) was calculated using the following formulas:

$$\Delta P_{(S+E)} = \frac{(S_t - S_{t-1}) + (E_t - E_{t-1})}{GDP_{(t-1)}} * 100 \quad (1)$$

$$\Delta P_{(S)} = \frac{S_t - S_{t-1}}{GDP_{(t-1)}} * 100 \quad (2)$$

$$\Delta P_{(E)} = \frac{E_t - E_{t-1}}{GDP_{(t-1)}} * 100 \quad (3)$$

Where S and E express the volume of scientific and technical and educational services in periods t and t-1, respectively.

The prospective impact on GDP growth is manifested in the long term through the creation and introduction of new technology and the training of high-quality specialists, as well as an increase in the country's competitiveness. To assess such an impact, economic and mathematical models accepted in international practice were used. Based on the above, the following dependent and independent variables were selected for the purpose of building the model:

Y1-GDP at current prices (billion drams),

X1-science output (billion drams),

X2-education output (billion drams).

The empirical analysis presented in this study utilizes monthly macroeconomic data spanning the period from January 1995 to December 2023, sourced from the RA Statistical Committee and the World Bank. The use of high-frequency data significantly enhances the analytical precision of the study, enabling a detailed investigation of both short-term and medium-term macroeconomic dynamics, including seasonal variations and lagged responses among key economic indicators. To ensure the accuracy of the calculations, data processing and cleaning procedures were applied. The methodological framework of the study follows these key steps:

- Conducting a trend analysis of the macroeconomic indicators.
- Implementing correlation analysis through the Pearson correlation matrix to examine initial relationships between selected indicators.
- Applying Granger Causality tests to assess predictive relationships between the identified indicators.

The availability of a large number of time-series observations substantially improves the statistical power and reliability of the econometric techniques employed. This level of temporal granularity allows for a more robust exploration of dynamic interactions among macroeconomic indicators, facilitating a deeper understanding of the timing and transmission of macroeconomic shocks, policy interventions, and structural shifts within the economy.

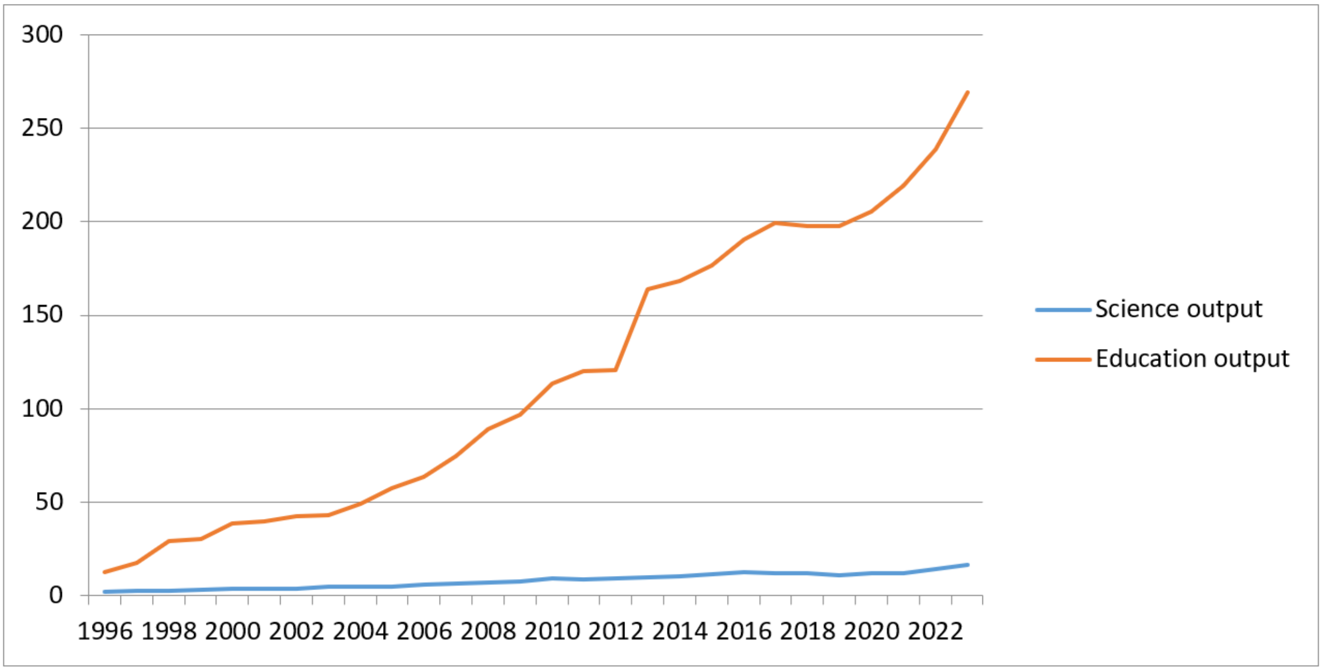

Figure 1.
Science and education output for 1995-2023, billion AMD drams.
Source: ARMSTAT [28].

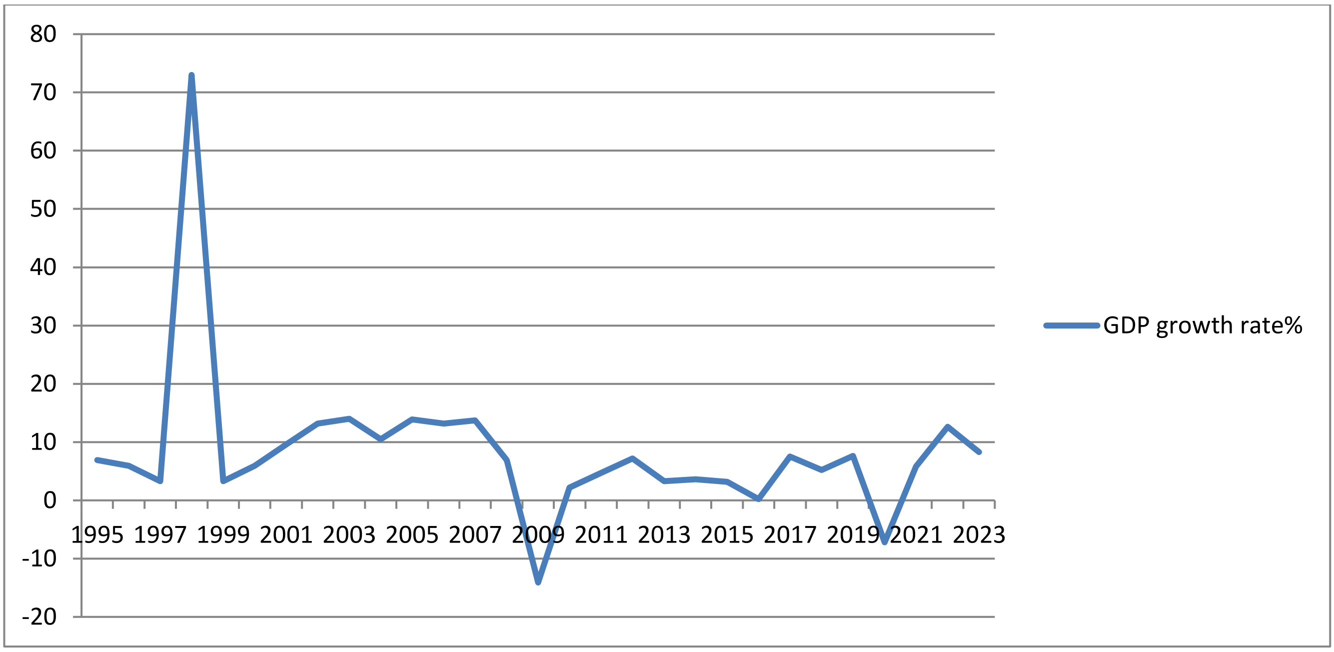

Figure 2.
GDP growth rate, %.
Source: ARMSTAT [28].

5. Results and Discussion

In order to identify the relationships between the selected variables, a matrix of Pearson's r linear correlation coefficients was constructed. Using the Pearson's r linear correlation coefficient, let's try to determine the strength and direction of the relationship between the variables. The correlation between two variables indicates that a certain value of one of the characteristics corresponds to values of the other characteristic that vary around the average value. The Pearson r linear correlation coefficient is calculated by dividing the covariance by the corresponding standard deviation:

$$r = \frac{\sum_{i=1}^{n}(X_1-\bar{X})(Y_1-\bar{Y})}{(n-1)*\sigma_x*\sigma_y} \quad (4)$$

Where σ_x and σ_y are the standard deviations of the data series

$$r = \frac{\sum_{i=1}^{n}(X_1-\bar{X})(Y_1-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_1-\bar{X})^2 \sum_{i=1}^{n}(Y_1-\bar{Y})^2}} \quad (5)$$

Y1- dependent variable (GDP)
X1 and X2 are the independent variables, respectively, the science output and the education output.
The regression analysis is represented by the following equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \mathcal{E} \ (6)$$

Where Y - is the dependent variable
β_0 (Intercept) – is free member (constant)
β_(1),β_2 – are the coefficients of the independent variables X1 and X2
Ɛ - is the model error.
The table presents the results of the correlation analysis of the researched indicators, calculated using Excel.

Table 1.
Pearson correlation matrix between GDP (Y1), science output (X1) and education output (X2).

	Y1	***X1***	***X2***
Y1	1.00		
X1	0.97	1.00	
X2	0.99	0.98	1.00
Correlation	r Correlation coefficient		
r (Y1, X1)	0.97		
r (Y1,X2)	0.99		
r (X1,X2)	0.98		

There is a strong positive correlation (0.97) between GDP (Y1) and science output (X1); GDP growth leads to an increase in the funds allocated to science work and vice versa. There is also a nearly perfect positive correlation (0.99) between GDP and the amount spent on educational services. The independent variables, science and education, also interact with each other, with a strong positive correlation (0.98).

Correlation dependence justifies the symmetry of changes in numerical series of variables, their dependence. The analysis of the relationship between the variables is presented through regression analysis. The relationship between GDP and the volume of scientific research and educational services is presented by three regression analyses:

Y1 and X1: between GDP and science output

Y1 and X2: between GDP and education output

Y1 and X1, X2: between GDP and the volume of science output and education output.

First, let us show the regression analysis of the strong positive relationship between GDP and the volume of scientific research activities.

Table 2.
Model 1. Summary output.

Regression Statistics								
Multiple R	0.975							
R Square	0.95							
Adjusted R Square	0.948							
Standard Error	560.328							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	160540300.767	160540300.767	511.328	0.000			
Residual	27	8477121.168	313967.451					
Total	28	169017421.934						
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	-1038.434	232.246	-4.471	0.000	-1514.962	-561.905	-1514.962	-561.905
X1	564.271	24.954	22.613	0.000	513.069	615.472	513.069	615.472

The table presents the results of the regression analysis of the variables of GDP and the volume of scientific research activities, calculated using Excel. 29 years of data on dependent and independent variables were studied. The strength of the relationship between the independent and dependent variables under study is shown by the multiple R coefficient (0.98). The R2 coefficient of determination of the model is also high, which indicates a 95% proportion of the volume of scientific research works and the volume of GDP. The small difference between the adjusted R2 and the R2 coefficient of determination indicates that the model is not burdened with irrelevant variables and allows for a full analysis of the relationship between only these two variables. The standard error of the model represents the deviation of the mean of the dependent variables from the true values.

The significance of the overall model is evidenced by two main indicators of regression analysis: statistical F and significant F (<0.005). The magnitude of the squared deviation also indicates a good model: the model can explain 160,540,300.767 of the variability and cannot explain only 5.01% (8,477,121.168).

The regression coefficients are also interpreted using Excel. It is calculated that a one-point increase in the scientific research sector will lead to an increase in GDP of 564,271 drams. Both significance coefficients are less than 5%, indicating an interaction between GDP and science.

The results of the regression analysis of the model demonstrate that the presented data can be used for further predictions. The interaction between the independent variable GDP (Y1) and the dependent variable volume of educational services (X2) is also presented through the results of regression analysis in Excel.

Table 3.
Model 2. Summary output.

Regression Statistics								
Multiple R	0.989							
R Square	0.977							
Adjusted R Square	0.976							
Standard Error	378.191							
Observations	29							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	165155652.816	165155652.816	1154.705	0.000			
Residual	27	3861769.118	143028.486					
Total	28	169017421.934						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	95.412	126.157	0.756	0.456	-163.440	354.264	-163.440	354.264
X2	28.903	0.851	33.981	0.000	27.158	30.648	27.158	30.648

The coefficient of determination of the interaction between Y1 and X2 indicates that 97.7% of the change in the dependent variable is due to the presented model. The adjusted coefficient of determination is almost the same (0.976), which allows us to use the model in future predictions. The high significance of the model is evidenced by the significant F, which is close to 0.

Unlike the analysis of the volume of scientific research work, the deviation from the average for the volume of educational services is much smaller (560,328; 378,191). There is no 0 in the confidence interval of the dependent and independent variables in the model, which confirms the impact of the X2 factor on GDP (-163.440; 354.264 and 27.158; 30.648). The impact of an increase in the volume of one unit of educational work on GDP is low, an increase of only 28,903 AMD drams. Let us present the regression analysis of the interaction between GDP Y1 and the volume of scientific research X1, and the volume of educational services X2.

Table 4.
Model 3. Summary output.

Regression Statistics								
Multiple R	0.989							
R Square	0.977							
Adjusted R Square	0.976							
Standard Error	384.378							
Observations	29							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	2	165176010.456	82588005.228	558.984	0.000			
Residual	26	3841411.478	147746.595					
Total	28	169017421.934						
	Coefficients	**Standard Error**	**t Stat.**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	17.148	246.769	0.069	0.945	-490.093	524.388	-490.093	524.388
X1	35.605	95.920	0.371	0.713	-161.561	232.772	-161.561	232.772
X2	27.134	4.844	5.601	0.000	17.177	37.091	17.177	37.091

The multiple correlation coefficient indicates a strong linear relationship between actual and forecast GDP values. According to the calculated coefficient of determination, 97.7% of the change in GDP can be explained by the presented model. The small difference between the adjusted R^2 and R^2 coefficients justifies the correct choice of factors.

Compared to the first model discussed, the standard error rate in this model is also significantly lower (560.328; 384.378), but is slightly higher than the indicator in the second model (378.191; 384.378). The F statistic and F significance coefficients demonstrate that the model is overall significant, and at least one of the presented factors, X1 or X2, has a significant effect on Y. In the two-factor joint model, factors Y and X1 are not statistically significant, but X2 has an effect on Y.

If X1=0 and X2=0, then the predicted Y=17.148. If the volume of educational services does not change, each unit increase in the volume of scientific and research work will lead to an increase in GDP by 35.605 units, but this factor is not statistically significant. The volume of educational services is important, and if the volume of scientific research does not change, each unit increase in its value will lead to an increase in GDP by 27.134 units.

In the scope of the study, the following pairs of macroeconomic indicators were selected for the Granger causality analysis:

- GDP Growth and Education,
- GDP Growth and Science,

Taking into account those pairings, this study explores key interrelated hypotheses concerning the dynamics of economic growth.

Table 5.
The Granger Causality test results[1].

Null hypothesis	F-Statistic	Prob.
GDP Growth does not predict Education output	0.80037	0.4821
Education output does not predict GDP Growth	***5.92153***	***0.0264***
Science output does not predict GDP Growth	***2.97858***	***0.0107***
GDP Growth does not predict Science output	1.94956	0.0825

Analyzing the test results, we have come to the conclusion that:

- GDP Growth does not predict Education output

F-Statistic – 0.80037
p-value – 0.4821
Fail to reject the null hypothesis. GDP growth does not Granger-cause education output, indicating no statistically significant predictive relationship.

- Education output does predict GDP Growth

F-Statistic – 5.92153
p-value – 0.0264 (significant at the 5% level)
Reject the null hypothesis. Education output Granger-causes GDP growth, suggesting that improvements in education may lead to future economic growth.

- Science output does predict GDP Growth

F-Statistic – 2.97858
p-value – 0.0107 (significant at the 5% level)
Reject the null hypothesis. The scientific output indicates that Granger-causes GDP growth, implying that advancements in science contribute to future economic performance.

- GDP Growth does not predict Science output

F-Statistic – 1.94956
p-value – 0.0825

Fail to reject the null hypothesis at the 5% significance level (though marginal at 10%). GDP growth does not strongly Granger-cause science output.

6. Conclusions

The correlation and regression analysis conducted on the interaction between GDP, scientific research activities, and the volume of educational services shows a strong relationship between changes in the three presented factors, with high predictive significance. During the 29 years studied, numerous geopolitical changes have occurred in the Republic of Armenia, but as the results of the study show, the role of science and education has always been directly and strongly related to the main indicator characterizing economic growth, GDP. The presented models yielded high comparative indicators, especially in single-factor models, which is explained by the large number of indicators analyzed in the multifactor model. Also noteworthy is the calculated impact of the volume of scientific research on the size of GDP - 564.3, which can be used in the strategic planning process. Also, the Granger Causality test results reveal that while education and science outputs significantly predict future GDP growth, GDP growth itself does not have a statistically significant predictive effect on education or science outputs, suggesting that investments in education and science may drive economic expansion rather than the reverse.

[1] The table was composed by the authors using data from www.armstat.am.

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