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S. M. HUSEYNOV, PhD student

IMPACT OF R&D AND INNOVATION ON ECONOMIC DEVELOPMENT: AN EMPIRICAL ANALYSIS ON AZERBAIJAN

Abstract. *The purpose of the study is to investigate the impact of Research and Development (R&D) and innovation on the economic development of the Republic of Azerbaijan. For this purpose, time series analysis was applied with the help of the "EViews 12.0" application, taking R&D expenditure, the number of researchers in the country, the number of patent applications, and finally the Gross Domestic Product (GDP) data as an indicator of economic development. In addition, causality from both the number of patent applications and the number of researchers to economic growth has not been determined. In addition, causality from R&D expenditures, patent applications and researchers to economic growth in the long run has not been determined. Undetected causality hypotheses are highlighted in the article.*

Keywords: *Economic Growth, R&D, Innovation, VECM, Causality.*

INTRODUCTION

Today, the concepts of innovation and Research and Development (R&D) are among the concepts that individuals, companies and countries focus on the most. Innovation, which includes steps such as the emergence, implementation and commercialization of a new and creatively striking idea; It is formulated as "Innovation = Invention + + Commercialization". On the other hand, R&D can be expressed as systematic studies of great importance, such as the emergence of new products and production methods and opening up to new markets, in order to make a difference in the globalizing competitive environment [1].

Schumpeter is known as an economist who has worked extensively on innovation. Schumpeter; In his work titled "Capitalism, Socialism and Democracy" published in 1942, he explained his views on innovation by talking about the assumption of "creative destruction". According to Schumpeter, innovation is defined as introducing new output to the market, using new production methods, creating new markets, finding new sources of raw materials and exploring new industrial areas [2]. In addition, Schumpeter argued that it will become much more important in the future to be able to create a new product or service through entrepreneurs in order for countries to have a strategic advantage. Especially he argued that developed countries would tend to use technological innovation, which is considered a new stage, for a new product or service [3].

A new product can change people and the environment, create natural and social effects, both in the production process and after production. Therefore, innovation is valuable not only in measuring input and output values, but also in all stages that lead companies to success. It is also of great importance for those who want to change the direction of economic progress and improve the quality of life [4].

According to Sati, R&D is defined as the studies that cover the operation and application of the findings proven to be economical as a result of these studies, including the stages such as discussing, examining and interpreting all company functions in economic and scientific terms. In short, it is explained as creative and systematic studies aimed at revealing new products and production stages of companies [5].

The idea that the state can also provide the economic and social development stage with innovation increases the effects of the state on R&D formations [6]. In addition, the state provides the necessary support to R&D activities for the production and export of these technology-containing products, making it easier to achieve the long-term growth rate target [7].

R&D has become a necessary condition for companies to continue their activities profitably by providing a competitive advantage. To obtain the said science and technology or to produce new materials, products and tools with existing knowledge; It is possible to create new systems, processes and services to cover software production or to improve existing ones, with regular R&D activities [8].

In the new assumptions put forward in economics, factors such as R&D, innovation and

qualified human capital lead to the positive effects of technology on growth. The measure of development for a country is closely related to the importance given to science and technology. Recently, it is seen that developed countries act with an innovative perspective and intensify the infrastructure and R&D activities necessary for innovation. At this point, the share allocated to Research and Development (R&D) expenditures in Gross Domestic Product (GDP) is of great importance. As a matter of fact, the fact that this rate is more than 2 % in the literature is accepted as an important measure of the development of the country. For this reason, R&D and its origin science have been a direct productive force in recent years. Countries that realize the essence of R&D studies early and produce policies for this purpose are in the position of countries with high competitiveness and innovation power today.

LITERATURE REVIEW

Many studies have been made on technological innovation, R&D and economic growth from Marx and Schumpeter to the present. In some of these studies, technology is considered as an internal variable and in others as an external variable. In both cases, the general opinion is that technological innovation and R&D have positive contributions to economic growth. Some studies on this subject are summarized below.

Schumpeter has conducted a study that considers the causality between financial development, economic growth and R&D expenditures. This study suggests that a well-functioning financial system will trigger technological innovation by identifying, selecting and financing entrepreneurs who are expected to successfully implement their products and productive processes [9].

Hyukjoon Kim and Yongtae Park have discussed in their studies the concept of open innovation, which emerged with the implementation of all kinds of new ideas, methods, workforce and technology with external resources as well as their own internal resources. In their study to demonstrate the suitability of open innovation for SMEs, they analyze the impact of open innovation-related external activities on innovation output with a logistic regression and compare the results with those of large enterprises. In the empirical analysis to evaluate the relative impact of external activities with the Bayesian network method, they found that all open innovation activities of SMEs do not positively affect their innovation output [10].

Jae-Pyo Hong examined the Granger causality between R&D investment and economic growth for Korea's IT industry. Two-way Granger causality analysis has been studied between R&D investment and economic growth, and according to the result, a bidirectional relationship has been observed that R&D investment is caused by economic growth and vice versa. When R&D investments were graded to the public and private sectors, it showed that private R&D investment was more strongly associated with economic growth than public R&D investment. This means that private R&D investments are more effective than public R&D investments in economic growth and investment increases resulting from economic growth. In addition, two-way causality was observed between public R&D investments and private R&D investments in the results. Establishing bidirectional Granger causality between the public and private sectors indicates that a positive cycle has occurred [11].

Wu and Zhou tested the relationship between R&D expenditures and economic growth in China between 1953 and 2004 by using co-integration and causality analysis. As a result of the study, co-integration and causality relationship was determined between R&D and GDP in the long run. This result means that an increase in R&D expenditures may lead to the continuation of economic growth. It also means that an R&D-intensive planning policy may be appropriate to stimulate China's economic growth in the long run, and a sustainable development strategy with a higher level of R&D investment is possible [12].

Falk examined the effect of research and development expenditures on long-term growth in OECD countries in the 1970–2004 period using dynamic panel data analysis. As a result of the study, it is stated that Per Capita Income will increase as well as the R&D investment shares of advanced technology sectors in GDP [13].

Wang et al. examined the effects of R&D expenditures on economic growth in high-tech sectors for 23 OECD countries and Taiwan between 1991 and 2006. As a result of the study, it was determined that high industry research and development expenditures have a strong and positive effect on real income per capita [14].

EMPIRICAL ANALYSIS

In this section, the effect of R&D and innovation on economic growth is tested with an econometric method. The aim of this study is to investigate the effects of R&D and innovation on the economic growth of Azerbaijan. For this purpose, empirical analysis was made for the period of 2000–2020 by considering the R&D expenditures and the number of researchers in the country, the patent application numbers of the country representing innovation, and finally the GDP data representing economic growth.

Table 1

Explanations of Variables

Abbreviation	Variable Name	Source
GDP	Gross Domestic Product (Azerbaijan)	The World Bank
NR	Researchers in R&D (per million people) — Azerbaijan	
PA	Patent applications in Azerbaijan	
R&D	Azerbaijan research and development expenditures	The State Statistical Committee of the Republic of Azerbaijan

Source: Own elaboration.

Table 2

ADF unit root test results

ADF Test Results: For level values of series				
	ADF test statistic	**ADF critical value 1 %**	**ADF critical value 5 %**	**Prob. value**
GDP	–1.798291	–3.831511	–3.029970	0.3698
RD	–2.289786	–4.498304	–3.658446	0.4200
NA	–1.748845	–4.498307	–3.658446	0.6808
PA	–1.012417	–3.857386	–3.040391	0.7253
ADF Test Results: For the first differences of the series				
	ADF test statistic	**ADF critical value 1 %**	**ADF critical value 5 %**	**Prob. value**
GDP	–2.607220	–2.692358	–1.960171	0.0122
RD	–4.950322	–2.692358	–1.960171	0.0050
NA	–3.662269	–4.571559	–3.690814	0.0110
PA	–4.815787	–4.667883	–3.733200	0.0077

Source: the author's own development based on the analysis via eviews 12.0 application.

DATASET AND APPLICATION

In the analysis, four variables consisting of GDP, R&D expenditure, Number of Researchers, Patent Application data were used. The relevant information on these variables is given in **Table 1**.

UNIT ROOT TEST RESULTS

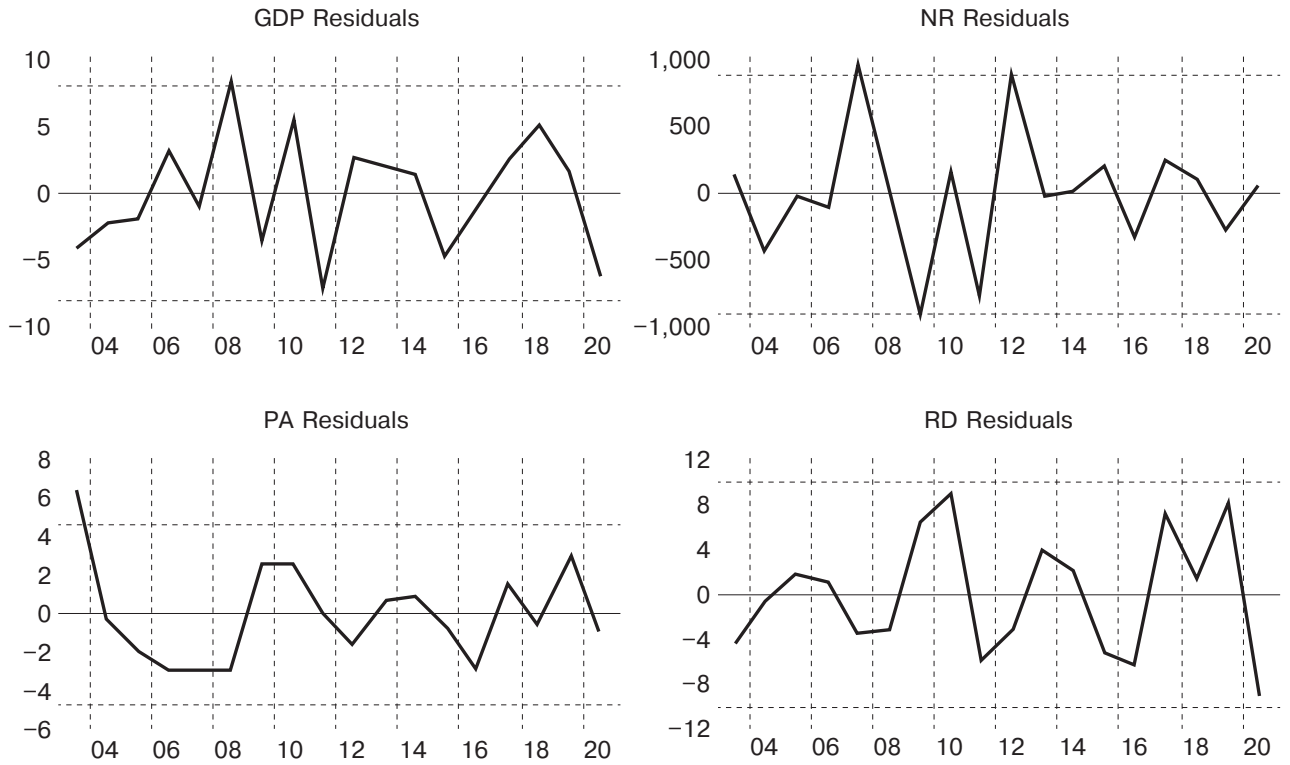
In the study, ADF unit root test was applied to test the stationarity of the variables. According to the test results, all of the variables contain a unit root in the level value, and therefore it is understood that the variables are not stationary. Differentiation was applied to make the series stationary. All series become stationary at first difference (**Table 2**).

The charts below show the graphs of the static models of the VAR residuals of the variables in the database (GDP, RD, NA and PA). When the goal of bringing the variables in the mentioned database to a fixed shape graph is a fixed path graph, it will be revealed whether there is a relationship between the variables (**Graph 1**; **Table 3**).

VECTOR ERROR CORRECTION MODEL (VECM)

VAR models (Vector Autoregressive Models) are used for multivariate time series. The structure is that each variable is a linear function of past lags of itself and past lags of the other variables[1]. After examining the long-term, an error correction model in which GDP is the dependent variable was estimated in order to evaluate the short-term dynamics among the variables. One of the advantages of using the error correction model is that it reveals short- and long-term causality and enables the imbalance between variables to be determined and corrected. With the error recovery model, the existence of divergences from the long-term equilibrium and how the deviations from the averages approach the average in each period are investigated.

[1] https://online.stat.psu.edu/stat510/lesson/11/11.2



Graph 1. Vector Autoregression (VAR) Residuals

Source: Results of the VAR analyses via Eviews application by the author.

Table 4 illustrates that there is no relationship between the research expenses, the gross domestic product and the number of researchers, with patent applications as the dependent variable. The main reason for this is that the t-statistic value is greater than 0.05, as can be seen from the table above. In the Vector Error Correction Model, when the coefficient values take values between -1 and 1, it indicates the accuracy of the Vector Error Correction Model. This gives the basis for the Granger causality test to be formulated. Four interdependent equations have been created. After the VAR Model is formed, the Granger Causality Test is performed to determine whether there is a dependency between which variables.

The table above shows the results of Granger causality tests between the four variables. Based on the dependent variable R&D in the first formula, since the statistical value is less than 0.05 and it falls into the rejection region. H_0 is rejected and H_a is accepted. (0.038587 < 0.05). It means that R&D is the cause of Patent Application. Since the statistical values in the other formulas are each greater than 0.05 and it falls into the non-rejection region. Therefore the hypotheses H_0 are accepted and the hypotheses H_a are rejected. This meaans

Table 3

Vector Autoregression (VAR) Estimates

Vector Autoregression Estimates
Date: 08/28/22 Time: 14:30
Sample (adjusted): 2002 2020
Included observations: 19 after adjustments
Standart errors in () & t-statistics in []

	PA	R&D	NR	GDP
PATENT_APPLICATION (−1)	−0.466646	0.262623	22.28762	0.813230
	(0.29692)	(0.73472)	(70.7059)	(0.65302)
	[−1.57162]	[0.35744]	[0.31522]	[1.24534]

End of table 3

	PA	R&D	NR	GDP
PATENT_APPLICATION (–2)	–0.299893	0.339632	73.44904	0.462231
	(0.26508)	(0.65592)	(63.1224)	(0.58298)
	[–1.13135]	[0.51779]	[1.16360]	[0.79288]
R_D_EXPENDITURE (–1)	0.143891	0.473643	–42.12101	0.122082
	(0.144993)	(0.35864)	(34.5133)	(0.31875)
	[0.99280]	[1.32068]	[–1.22043]	[0.38300]
R_D_EXPENDITURE (–2)	0.053898	0.318386	33.15122	–0.130790
	(0.11626)	(0.28767)	(27.6840)	(0.25568)
	[0.46362]	[1.10659]	[1.19749]	[–0.51154]
NUMBER_OF_RESEARCHERS (–1)	–0.000746	0.003776	0.716224	–0.000344
	(0.00117)	(0.00289)	(0.27808)	(0.00257)
	[–0.63858]	[1.30673]	[2.57557]	[–0.13389]
NUMBER_OF_RESEARCHERS (–2)	–0.000344	–0.000145	0.115503	–0.002890
	(0.00131)	(0.00323)	(0.31109)	(0.00287)
	[–0.26298]	[–0.04486]	[0.37128]	[–1.00570]
GDP (–1)	–0.248940	–0.300454	56.15843	1.113818
	(0.15999)	(0.39588)	(38.0975)	(0.35186)
	[–1.55601]	[–0.75895]	[1.47407]	[3.16555]
GDP (–2)	0.344905	0.172217	–31.39783	–0.153705
	(0.19629)	(0.48571)	(46.7422)	(0.43170)
	[1.75714]	[0.35457]	[–0.67172]	[–0.35605]
C	15.31060	–20.71850	1199.624	26.66139
	(10.3119)	(25.5164)	(2455.56)	(22.6788)
	[1.48476]	[–0.81197]	[0.48853]	[1.17561]
R-squared	0.671688	0.954305	0.922393	0.919514
Adj. R-squared	0.409038	0.917748	0.860308	0.855126
Sum sq. resids	146.3581	896.1549	8299369.	707.9164
S.E. equation	3.825627	9.466546	911.0087	8.413777
F-statistics	2.557353	26.10509	14.85689	14.28074
Log likelihood	–46.35519	–63.56974	–150.3387	–61.32976
Akaike AIC	5.826863	7.638920	16.77250	7.403132
Schwars SC	6.274228	8.086286	17.21986	7.850498
Mean dependent	13.89474	104.8916	12928.53	41.59684
S. D. Dependet	4.976553	33.00801	2437.458	22.10527
Determinanat resid covariance (dofadj.)		4.17E+10		
Determinanat resid covariance		3.20E+09		
Log likelihood		–315.7626		
Akaike information criterion		37.02765		
Schwarz criterion		38.91711		
Number of coefficiets		36		

Source: The author's own development based on the analysis via Eviews 12.0 application.

Table 4

Vector Error Correction Model (VECM)

Dependent Variable: PATENT_APPLICATION
Method: Least Squares
Date: 08/28/22 Time: 14:03
Sample: 2000-2020
Included observations: 21

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R_D_EXPENDETURE	0.095914	0.038838	2.469617	0.0244
GDP	–0.013287	0.049549	–0.268164	0.7918
NUMBER_OF RESEARCHERS	0.000207	0.000649	0.319232	0.7534
C	1.732509	5.195638	0.333455	0.7429
R-squared	0.521502	Mean dependent var		13.47619
Adjusted R-squared	0.437061	S.D. dependent var		4.905294
S.E. of regression	3.680406	Akaike info criterion		5.613566
Sum squared resid	230.2716	Schwarz criterion		5.812523
Log likelihood	–54.94245	Hannan-Quinn criter.		5.656745
F-statistic	6.175941	Dubrin-Waston stat		2.314753
Prob(F-statistic)	0.004931			

Source: The author`s own development based on the analysis via Eviews 12.0 application.

Table 5

VAR Granger Causality tests results

VAR Granger Causality / Block Exo geneity Wald Tests
Date: 08/28/22 Time: 14:08
Sample : 2002 2020
Included observations: 19
Dependent variable: PATENT_APPLICATION

Dependent variable: PATENT_APPLICATION			
Excluded	**Chi-sq**	**df**	**Prob.**
R_D_EXPENDITURE	6.50963282...	2	0.03858790...
NUMBER_OF_RESEARCHERS	0.82706517...	2	0.66130998...
GDP	3.14530122...	2	0.20749446...
All	15.2790092...	6	0.001819419...
Dependent variable: R_D_EXPENDITURE			
Excluded	**Chi-sq**	**df**	**Prob.**
PATENT_APPLICATION	0.35977044...	2	0.83536608...
NUMBER_OF_RESEARCHERS	2.14454555...	2	0.34222982...
GDP	1.56500814...	2	0.45725956...
All	7.41010982...	6	0.28457865...
Dependent variable: NUMBER_OF_RESEARCHERS			
Excluded	**Chi-sq**	**df**	**Prob.**
PATENT_APPLICATION	1.38982558...	2	0.49911797...
R_D_EXPENDITURE	1.59447517....	2	0.45057191...
GDP	6.08949583...	2	0.04760831...
All	11.2297042...	6	0.08153133...

End of table 5

Dependent variable: GDP			
Excluded	**Chi-sq**	**df**	**Prob.**
PATENT_APPLICATION	1.98773042...	2	0.37014323...
R_D_EXPENDITURE	0.26813270...	2	0.87453203...
NUMBER_OF_RESEARCHERS	1.50225905...	2	0.47183330...
All	4.80051970...	6	0.56964085...

Source: The author`s own development based on the analysis via Eviews 12.0 application.

that there is no causality based on the values used in the analysis between 2000 and 2020.

CONCLUSION

The aim of this study is to investigate the effects of R&D and innovation on the economic growth of Azerbaijan. For this purpose, time series analyzes were applied for the period 2000–2020 by considering R&D expenditures and the number of researchers in the country to represent research and development, the number of patent applications of the country representing innovation, and finally the GDP data representing economic growth.

The applied time series analysis consists of unit root test, error correction analysis, VAR Model and Granger causality test. The data that were non-stationary in the level states were made stationary by taking the first difference with the ADF unit root test. The error correction model was applied to analyze the short-term deviations in the variables that act together in the long-term and to determine the short-term dynamics of the variables. As a result of the analysis, the error term coefficient was found to be negative and statistically significant as expected. This shows that the error correction mechanism is working in our model and the deviations are approaching the equilibrium.

Finally, according to the Granger causality test results, 4 equations were created. The causality relationships between the equations were negative.

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Сафар Мазахір ГУСЕЙНОВ, аспірант

ВПЛИВ НДДКР ТА ІННОВАЦІЙ НА ЕКОНОМІЧНИЙ РОЗВИТОК: ЕМПІРИЧНИЙ АНАЛІЗ АЗЕРБАЙДЖАНУ

Резюме. *Метою дослідження є вивчення впливу НДДКР та інновацій на економічний розвиток Азербайджанської Республіки. Для цього було застосовано аналіз часових рядів за допомогою програми «EViews 12.0», враховуючи витрати на НДДКР, кількість дослідників у країні, патентних заявок, а також дані про ВВП як індикатор економічного розвитку. Причиново-наслідковий зв'язок між кількістю патентних*

заявок і кількістю дослідників та економічним зростанням не встановлений. Причиново-наслідковий зв'язок між витратами на НДДКР, патентними заявками та дослідженнями й економічним зростанням у довгостроковій перспективі не був визначений. Невиявлені гіпотези причиново-наслідкового зв'язку були виокремлені в статті.

Ключові слова: *економічне зростання, НДДКР, інновації, VECM, причино-наслідковий зв'язок.*

INFORMATION ABOUT THE AUTHOR

Huseynov Safar Mazahir — PhD student in Economy of Technological Innovation, Economic Scientific Research Institute under The Ministry of Economy of Azerbaijan Republic, AZ1122,196 Hasan bay Zardabi, Yasamal, Baku, Azerbaijan, +994554330050, safarguseynov96@mail.ru, ORCID: 0000-0002-9531-5632

ІНФОРМАЦІЯ ПРО АВТОРА

Гусейнов Сафар Мазахір — аспірант (спец. «Економіка технологічних інновацій»), Науково-дослідний економічний інститут при Міністерстві економіки Азербайджанської Республіки, AZ1122,196 Hasan bay Zardabi, Ясамал, Баку, Азербайджан, +994554330050, safarguseynov96@mail.ru, ORCID: 0000-0002-9531-5632