RESEARCH ARTICLE

THE EFFECT OF HEALTH RESEARCH AND DEVELOPMENT EXPENDITURES ON ECONOMIC GROWTH [1]

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ABSTRACT

This study aims to determine the effect of health R&D (Research and Development) expenditures on economic growth at the level of 10 countries (Czech Republic, Hungary, Korea, Poland, Portugal, Slovakia, Turkey, Romania, Russia, and South Africa) by using data between 2004-2019. Gross Domestic Product (GDP) as representative of economic growth; as the representative of R&D Expenditures in health, Health R&D Expenditures were considered. In the analysis of the relationships between variables Least Square Test, Granger Causality Test, Cointegration Tests, FMOLS and DOLS tests were applied within the framework of Panel Data Analysis. The existence of a bidirectional Granger-type causality relationship between Health R&D Expenditures and GDP and the long-term cointegration relationship between them was determined. FMOLS and DOLS analysis results revealed the positive effect of Health R&D expenditures on economic growth. The results showed that health R&D activities play an important role in general R&D activities in the countries covered by the study and that health R&D expenditures/investments positively affect economic growth.

Keywords: *Economic Growth, Health Research and Development Expenditures, Granger Causality Test, Cointegration Test, Panel Data Analysis.*

ARTICLE INFO

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ARAŞTIRMA MAKALESİ

SAĞLIKTA ARAŞTIRMA VE GELİŞTİRME HARCAMALARININ EKONOMİK BÜYÜME ÜZERİNDEKİ ETKİSİ [1]

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ÖZ

Bu çalışma, sağlık alanında Araştırma ve Geliştirme (Ar-Ge) harcamalarının ekonomik büyüme üzerindeki etkisini belirlemek amacıyla 2004-2019 yılları arasında sağlık Ar-Ge harcamalarına ait düzenli verisi bulunan 10 ülke düzeyinde (Çek Cumhuriyeti, Macaristan, Kore, Polonya, Portekiz, Slovakya, Türkiye, Romanya, Rusya ve Güney Afrika) analizler yapılmıştır. Ekonomik büyümenin temsilcisi olarak Gayri Safi Yurtiçi Hasıla (GSYİH); Ar-Ge Harcamalarının sağlıktaki temsilcisi olarak Sağlık Ar-Ge Harcamaları araştırma değişkenleri olarak ele alınmıştır. Değişkenler arasındaki ilişkilerin analizinde Panel Veri Analizi çerçevesinde En Küçük Kareler Testi, Granger Nedensellik Testi, Eş bütünleşme Testleri, FMOLS ve DOLS testleri uygulanmıştır. Sağlık Ar-Ge Harcamaları ile GSYİH arasında çift yönlü Granger tipi nedensellik ilişkisinin varlığı ve aralarında uzun dönemli eşbütünleşme ilişkisi tespit edilmiştir. FMOLS ve DOLS tahmin yöntemlerinden elde edilen temel bulgular, sağlık alanında araştırma ve geliştirme harcamalarının ekonomik büyüme üzerinde pozitif yönde etkisi olduğunu ortaya koymuştur. Çalışma kapsamında değerlendirilen ülkelerde sağlık Ar-Ge harcamalarının/yatırımlarının ekonomik büyümeyi olumlu yönde etkilediği tespit edilmiştir.

Anahtar Kelimeler: *Ekonomik Büyüme, Sağlık Araştırma ve Geliştirme Harcamaları, Granger Nedensellik Testi, Eşbütünleşme Testi, Panel Veri Analizi.*

MAKALE HAKKINDA

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I. INTRODUCTION

Economic growth is the reflection of the efficiency in the use of factors of production, including labor, capital, natural resources, and technology, to per capita income. From an economic perspective, the effect of factors of production on income is explained by economic growth theories. In this context, the economic development periods of societies were explained by the limited growth, which includes the physiocracy period that prioritizes agricultural production and mercantilism in which precious metals were at the forefront, which was called the pre-classical economic growth period. In classical period economic growth theories, while the sources of growth were explained by Adam Smith's theory of absolute advantage; Ricardo put forward the theory of comparative advantage, Marx emphasized capital accumulation and surplus value of labor, Keynes focused on supply-demand balance, Harrod-Domar deal with investment and savings. In the classical period, the turning point of economic growth was shaped by the Solow-Swan growth model. In the Solow-Swan growth model, while technology was included in the traditional production factors as a fixed and exogenous factor, it was explained by the convergence hypothesis, which suggests that the economic growth differences between developing countries and developed countries would decrease within the framework of the assumption of diminishing returns on capital. However, as a result of the inadequacy of the factors of economic growth in the Solow-Swan growth model in explaining growth and the inability to support the convergence hypothesis with empirical findings, the Internal Growth Models pioneered by Romer took their place in the literature. In Intrinsic Growth Models; the emphasis on physical capital in previous models was found exaggerated and accepted that there were increasing returns to scale by including technological development, research and development activities and human capital in the model (Taş et al., 2017). Due to understanding the importance of the knowledge and skills of the workforce in terms of the economy; Modern Growth Theories based on information, Technology, Human capital, and Public expenditures had taken their place in the literature. While workforce and technology, which were sources of growth considered external factors in classical growth models, modern growth theories consider them as internal factors. Besides this, in the first three economic growth approaches the results of using production factors were identified as limited growth or trying to determine the equilibrium points of growth (balanced, unbalanced, unlimited, creative destruction). Modern growth theories, which considered R&D and knowledge as the source of growth, were evaluated as internal and stable growth models in the long run. Therefore, when we evaluate the sources of growth in terms of the sustainability of the results, we think that it is appropriate to classify economic growth theories as Statinory and Non-Statinory economic growth theories. Namely; while limited growth is observed in stationary economic growth models (static) (pre-classical, classical, and neo-classical periods), there is no long-term sustainability in balanced points. Non-stationary economic growth models (dynamic), on the other hand, internalize the sources of growth as Information, Technology, Human capital, Public expenditures, and predict sustainable growth in the long run (Table 1).

Table 1. Classification of Economic Growth Theories

THEORIES OF GROWTH		THE SOURCE OF GROWTH	CONCLUSION
Stationary Economic Growth Models (Static Models)	**1. PRE-CLASSIC GROWTH THEORIES**		
	Mercantilist Period Growth Theory	Precious Metals Colonial	Limited Growth
	Physiocratic Period Growth Theory	Agricultural Production law of diminishing returns	Limited Growth
	2. CLASSICAL GROWTH THEORIES (External Economic Growth Theories)		
	Adam Smith Growth Theory	Labor Force Capital Specialization	Limited Growth
	David Ricardo Growth Theory	Agricultural Production Declining yields Distribution	Limited Growth and Recession
	T.R. Malthusian Growth Theory	Population	Limited Growth
	Karl Marks Growth Theory	Capital accumulation Labor and surplus value Increasing rate of profit	Limited and unbalanced growth
	Joseph Alois Schumpeter Growth Theory	Innovation Competition	Creative Destruction
	Johnard Maynard Keynes	Supply-Demand	Balanced Growth
	Harrod-Domar Growth Theory	Investment and savings	Dynamic but unstable and stabbing growth in the long run
	3. NEO-CLASIC GROWTH THEORY (External Economic Growth Theories)		
	Solow-Swan Growth Theory	Extrinsic technological development	Ransient growth due to the absence of technological development
	Evolutionary Growth Theory (Neo-Schumperteryan)	Internal Technological Development	R&D and imitation-based growth
Non-Stationary Economic Growth Models (Dynamic Models)	**4.MODERN GROWTH THEORIES (Internal Growth Theories)**		
	AK Model (Robelo Model)	Information	Internal and stable growth in the long term
	R&D-Based Growth Model	R&D investments	Internal and stable growth in the long-term
	Growth Model Based on Human Capital	Human capital	Internal and stable growth in the long run
	Growth Model Based on Public Expenditures	Public expenditures	Internal and stable growth in the long run

Reference : Prepared by the authors according to economic growth literature.

Economic growth is the most important factor affecting the living standards and prosperity of individuals in a country. One of the determinants of economic growth is Research and Development (R&D) activities (Goel and Ram, 1994; Coe and Helpman, 1995; Freire-Serén, 2001). The rapid change based on R&D activities and the competition conditions created by this change force all economies in the world to invest in R&D. Investments in R&D activities, it affects economic growth in many ways such as efficiency, inventions, innovations, capital accumulation and capital development. Developments in the field of technology directly affect the health sector and the delivery of health services, at the same time this developments create a high level of positive effects with the effects on the diagnosis and treatment of the diseases, the health economics and the positive externality of the public healths' level. From this perspective, health R&D activities are the most important factor in economic growth and development, but their effectiveness depends on the development and accumulation of human capital in the field of health R&D.

Human capital is a concept that expresses all concepts such as knowledge, skills, abilities, current health status, cultural values and education level of the individual.

Health is the most important factor that contributes to the development of human capital and directly affects economic growth. A good level of well-being is a source of prosperity all over the world. Health is not only the absence of disease, but also the capacity to develop an individual's abilities and skills. Health reduces production losses due to diseases, reduces absenteeism, improves learning, and enables the use of financial resources allocated for treatment in different ways (Lusting, 2004). Because of the good quality of human capital in a healthy society, productivity increases and economic growth is positively affected (Karagül, 2002).

The tight relationship of health between technology and innovation, directly affecting human capital reveals the importance of health R&D activities. However, the literature reveals that the studies aimed at evaluating health R&D activities are performed by middle and upper income countries. In the literature; investments in health R&D; the studies showing that it leads to three broad areas of medical advances and savings; including direct savings, indirect savings and health gain. For example; the total economic value of the reduction of deaths from cardiovascular diseases for the United States is estimated to be around US $ 1.5 billion per year (Access Economics, 2003). Global R&D efforts in health; it has led to significant cancer treatments and interventions that provide health benefits equivalent to £124 billion for British patients between 1991-2010 through early diagnosis, disease prevention and treatment (The Academy Of Medical Science, 2014). Again, while vaccination programs provided a net economic benefit of 69 billion dollars for industrialized countries (USA), the 34 billion dollars cost of immunization programs in LMIC countries provided broader economic benefits of 1.53 trillion dollars besides to prevented the cost of illness 586 billion dollars (Ozawa et al., 2016; Orenstein and Ahmed, 2017).

The field of biotechnology in health has grown 10 times in the world since 2000. The number of diseases that can be applied to genetic testing is increased by 17 times from 1993 to 2008 and reach to 1700; the defined gene-drug relationships were negligible in 1990, it reached 510 in 2007 (Arslanhan, 2012). Such practices increase the life expectancy and quality of the patients, shorten the treatment and rehabilitation processes, reduce the costs of diagnosis and treatment, increase the efficiency of health services and contribute to the economy positively.

According to the World Bank (1993), health problems are an important obstacle to economic development. Chronic diseases are increasing in the world and cause the primary cause of death (Arslanhan, 2012). On the other hand, burden of disease related to communicable diseases; it still remains an important problem in less developed countries. Health R&D funding is allocated less than 1% to diseases such as malaria, tuberculosis, which are predominantly seen in developing countries about 12.5% of global disease burden (WHO, 2012; Rottingen et al., 2013; Kieny et al., 2016). The recent Ebola virus disease has dramatically demonstrated the lack of investment and approaches to products to prevent and minimize the effects of pathogens on epidemic potential (WHO, 2023). Although the disease caused by the Ebola virus remained at the level of endemic, the Covid-19 virus, which was seen in the following years, turned into a pandemic, infecting 687 million people for 3.2 years and causing the death of approximately 6.9 million people all over the world (Statista, 2023) Vaccines aimed at preventing the Covid-19 disease have been rapidly produced and the disease has been tried to be controlled. This is a current experience that reveals the importance of health R&D expenditures and investments in the fight against health-related uncertainties (Chinta et al., 2023).

World Health Organization (WHO), in recognition of the critical role of research in combating the determinants of excessive mortality and morbidity in low- and middle-eastern countries, has called for funding specific research into diseases affecting people in developing countries (WHO, 2012; Conalogue et al., 2017).

The United Kingdom International Development Department supports the importance of research investments as an important element of development and is the second largest government supporter of product development research (Conalogue et al., 2017; Policy Cures, 2017).

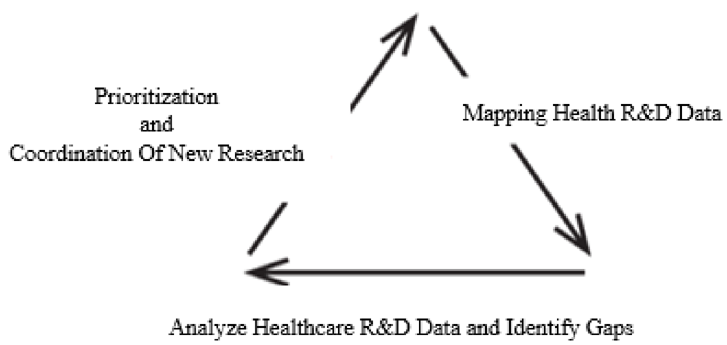
The USA International Development Agency (USAID) is working with the WHO on Global Health Research and Development Strategies to solve the world's most demanding health and development problems. However, the results demonsrated that the health R&D investments made in world-wide are not in line with the demands and needs of the global public health; at the same time have shown that the policies towards the development and monitoring of the Sustainable Development Goals (SDGs) on the world-wide cannot be sufficient on their own.

From this perspective, health R&D activities to harmonize with health needs, to ensure the efficiency of allocation in resources; the need to evaluate health R&D activities on a common platform; a Global Health Research and Development Observatory was established by WHO.

The Global Health R&D Observatory is a global-level initiative that aims to help identify Health R&D priorities according to public health needs and in WHA 66.22 decision; it aims to support the coordination, monitoring and analysis of health R&D requirements of developing countries and coordinated actions in health R&D based on existing data collection mechanisms (WHO, 2023).

In this context, SDGs related to health R&D were determined. The Global Health R&D Observatory identified two targets and two indicators, namely SDG Target 3.b and b2 and SDG Target 9.5, and described its function as below (Figure:1):

Figure 1. Public Needs Based Research-Development Cycle



Reference :www.who.int/research-observatory

The ultimate goal of the international and national regulations for the development of the health R&D field is to address the health R&D field with a holistic approach and to manage its activities in line with the needs in this area. At the same time WHO emphasizes the need for lack of literature to be developed in the health R&D activities (WHA, 2013). In the literature, however, the studies reveal the health R&D activities in the world, the investments made in this field with the economic growth, and the benefits provided to the country's economies are almost nonexistent worldwide.

Evaluation of R&D expenditures as total on a global scale, having insufficient analyzes in terms of R&D expenditures and studies of R&D Expenditures are especially being related to on education, energy and defense expenditures, otherwise this condition reveals the literature gaps' in health R&D activities and investments.

Health R&D field; when we evaluate health as the main activity that meets of the necessity of developed in integrity, to analyze the effect of health R&D expenditures on economic growth worldwide; we believe that the national/international regulations in this field will have a significant contribution to the health R&D literature and will be guided to development of plans and programs in this field.

II. METHODOLOGY

Health R&D activities have features that include information, technology, human capital, and public investments together, which are discussed under separate headings in modern and internal growth theories. So this study had being evaluated as an internal economic growth model within the framework of health R&D activities that reveal the importance of health and technology together. In this context, the impact of health R&D expenditures on economic growth was intended to be analyzed on a world scale. The main hypothesis of this study was defined as:

H_1: The impact of Health R&D expenditures on economic growth was positive.

In the analysis panel data method was used to determine the relationship between GDP and health R&D expenditures. The analyzes were done in four main stages. In the first stage, variables' descriptive information was given, then the econometric model significance was done by using the Least Squares Method. In the following stage, unit root tests were applied to the variables to determine the stationary degrees. In the third stage the length of the lag was determined and the Granger causality test was used to determine the causality relationship between the variables. In the fourth stage; co-integration and coefficients of the variables were analyzed by using co-integration tests, Dynamic Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) tests to determine the health R&D expenditures effect on PGDP.

2.1. Statistical Analysis

The econometric analysis was done by using Eviews 10 Statistics program (Eviews 10, IHS Global Inc., 4521 Campus Drive, #336, Irvine, CA 92612).

2.2. Ethical Approval

This study was an empirical analysis and the data of study were taken from Worldbank database and unesco.org; therefore, Ethics Committee Approval was not required in the study.

2.3. Panel data analysis

Econometric data are defined as time series, cross-sectional data and panel data. The difference of the panel data from the horizontal (M) and time series (T); the panel data are both horizontal (space) and time-sized data. If the unit referred to in a panel data set is equal to the same number of observations are named balanced panel, if not equal it is named unbalanced panel. If the number of time in the data is more than the number of horizontal sections (M>T) the panel is named Short Panel, if not (M<T) the panel is named the Long Panel. A series of econometric programs (Like Eviews, PcGive, Stata etc.) are used for estimating panel data. Gujarati and Porter (2009) stated that panel usage is becoming more widespread and they explain to this issue based on Baltagi (2005);

- It is possible to estimate the countries, households, companies, etc. which are accepted as individual over the years by keeping within the time dimensions
- Using horizontal section and time series together provides more informative, less multiple linearity, more variable, more degrees of freedom and efficiency in analyses
- In some work areas, these data are more appropriate to include change Dynamics
- Panel data produces and measures much more effects than horizontal sections and time series
- These series are suitable for studies on more complex behavior models in econometric theory
- It has the ability to use a lot of data together more easily (Gujarati and Porter, 2009).

2.4. Unit root test

Unit root testing is an analysis method used to determine the stability of time series. Series which varying mean and variance over time are named as non-stationary unit root series. If the series are not stationary; there could be seasonal effects, trend, conjunctival fluctuations. Unreliable results are obtained in the estimation of non-stationary series in Least Squares. For this reason, in order to be able to make an analysis with an accurate model, the difference of series are taken until the same degree is stationary. The point to be considered here is that while taking the difference process to stationary of the series, there may be a risk of losing the long term relationship in the model. Therefore, I (0) or I (1) levels are generally preferred in international studies (Baltagi, 2005).

In panel data analysis the unit root tests are used as individual and common unit root tests. In the first group, individual unit root tests are called Fisher-oriented tests (such as ADF and PP tests) and Im, Peseran, Shin (2003); common unit root tests are named Breitung (2000), Levin-Lin-Chu (2002) and Hadri (2000) unit root tests.

2.5. Granger causality test

Causality is the expression of a situation arising from the relationship between result and reason. Statistically, strong relationship between the two variables does not mean a causality. In statistically, the relationship is a expression of togetherness but causality is, above all, based on a theoretical explanation (Ertek, 1996).

Granger causality analysis; if there is a time-delayed relationship between the two variables, is one of the tests used to determine the direction of the causality relationship statistically. Granger causality analysis is based on the following assumptions;

- The future is not the cause of the past, but absolute causality is possible if the past causes the present or the future. The cause always occurs before the result, so between the cause and the result requires a time delay.
- Causality can be determined for a group of stochastic processes; It is not possible to know the causality between two deterministic processes (Işığıçok, 1994).

Granger causality analysis is one of many causality tests (Granger, 1969). Therefore, when interpreting results when using this test comments are made; "Granger type causality" or "Granger is the cause of". In addition, the Granger causality test between two variables (two variables in our example) is based on the assumption that these variables are in a time relationship. Thus, there can be four results:

- X is the Granger cause of Y (Unidirectional Causality)
- Y is the Granger cause of X (Unidirectional Causality)
- Both 1 and 2 occurrences (Bidirectional Causality)
- No causality.

2.6. Cointegration analysis

Cointegration analysis is a technique developed to reveal the long-term relationship between non-stationary series in the analysis of econometric data. In the analysis, it is subjected to serial unit root analysis of the error term estimated with the help of LS. That is, if two series I (0) are detected stationary; the series are interpreted to be cointegration and there is a long-run equilibrium relationship between them. There are a number of methods for panel cointegration testing. These are Pedroni (1999, 2004), Kao (1999) and Fisher Type (Maddala and Wu 1999) tests using Johansen's test methodology are used.

2.7. DOLS and FMOLS Tests

Panel FMOLS and Panel DOLS tests have been carried out including "within- and between-group FMOLS and DOLS" estimators. Among the panel estimators, the FMOLS and DOLS are the mostly used (Yorucu and Kırıkkaleli, 2017). After determining the cointegration relationship between GDP and PHRDE, FMOLS and DOLS tests were applied to determine the existence of a long-term equilibrium relationship. OLS estimates can give biased and inconsistent results in co-integrated panels. Therefore, Pedroni suggested DOLS and FMOLS, which include dynamic and interdimensional "group mean". These prediction tests provide greater flexibility in the presence of heterogeneity in the cointegrated vectors studied. According to Harris and Sorris (2003), While FMOLS tests are used as a non-parametric approach in correcting serial correlation, DOLS tests are considered as a parametric approach in which delayed first derivative series are estimated. In the DOLS estimator, the residuals are incremented by the lagged values, leading and simultaneous values of the regressors. The literature suggests that the between-group estimators are preferable to the within-group estimators for a number of reasons (Pedroni, 1999; Pedroni, 2001; Harris and Solis, 2003; Yorucu and Kırıkkaleli, 2017).

2.8. Defining variables

The variables used in the model description; with the GDP ratios of the countries covered by the study in 2004-2019, health R&D expenditures had been determined (Table: 2).

Table 2. Defining Variables

Variables	Description	Source	Abbreviation
GDP	in the country's t period GDP per capita	Worldbank	PGDP
Health R&D Expenditure	in the country's t period Per capita Health R&D Expenditure	Unesco	PHRDE

In the study, the Per Capita Gross Domestic Product (PGDP) values of the countries with health R&D expenditure data was used according to the PPP$ was used. Only 10 countries at 26 country had health R&D expenditures data between 2004-2019. These countries were Czech Republic, Hungary, Korea, Poland, Portugal, Slovakia, Turkey, Romania, Russia and South Africa. The data on Health R&D Expenditure was calculated according to the PPP$ for 2004-2019 was divided by the population of the countries between 2004-2019 and the Per capita health R&D Expenditure was calculated.

III. EMPIRICAL RESULTS

In the analysis, 10 countries and 2004-2019 years with regular data in the field of health R&D Expenditure was analyzed. PGDP mean was 14497.68 ± 6380.183 (min: 3494.95; max: 33436.92); PHRDE mean was 28.99 ± 28.78 (min: 2.56; max: 170.15).

The analyze method was Panel Data Analysis. The number of horizontal sections (M) in our panel analysis was 10 (ten). The time dimension (T) of our model was 15 (fifteen). As the subject units were equal to the same number of observations, our panel was defined as Balanced Panel Analysis. As our number of horizontal sections (countries) was less than the number of times' periods, our panel was evaluated as Long Panel. In the study, equation was defined as:

$$PGDP = f\,(PHRDE)$$

In our model, PGDP was considered dependent variable, PHRDE was considered as independent variables. In order to analyzed the significance and explanation power of the model, the relationship between the dependent variable PGDP with PHRDE was tested by Panel Least Square method. The econometric model equation' was established as follows:

$$PGDP = C(1)*PHRDE + C(2) + [CX=F]$$
$$PGDP = 72.7429*PHRDE + 12388.18 + [CX=F]$$

R-squared and Adjusted R-squared values are indicating the explanation power of the model. The closer the R-value to 1, the higher the explanation power of the model. The power of the model was high cause of R and R2 was 99 %. besides this results, the relationships between dependent variables and independent variable was significant in all series. Therefore, the model based on the study was significant according to the fixed effects model (Table: 3).

Table 3. Panel Least Square Test

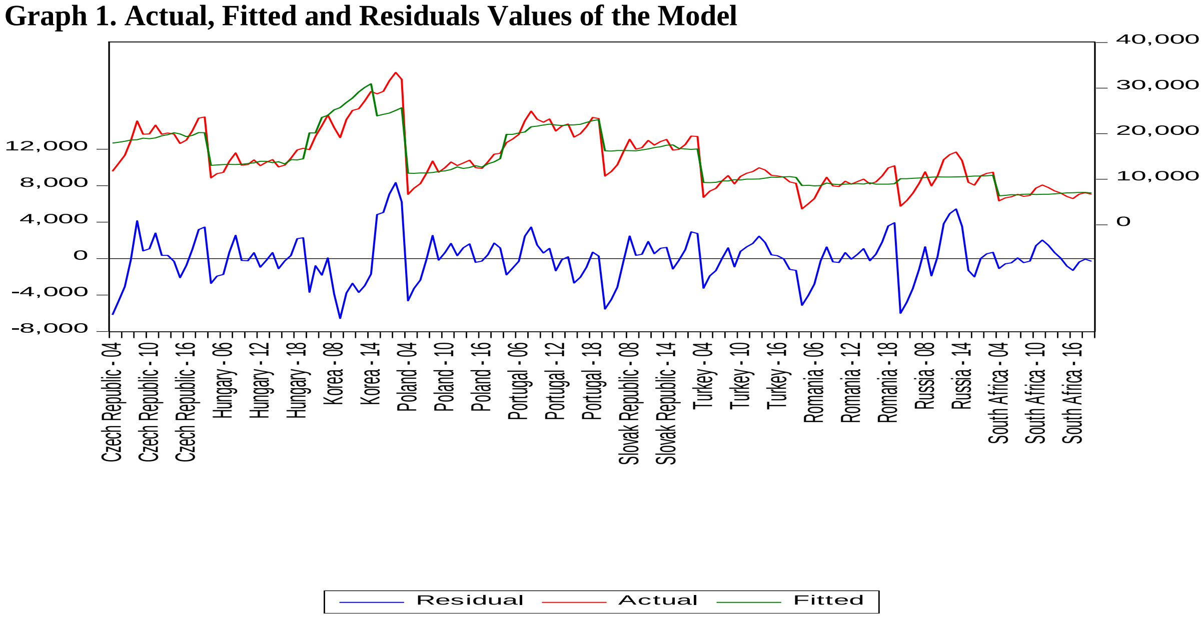
The dependent variable: PGDP				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
PHRDE	72.7429	3.2453	22.4082	0.0000*
C	12388.18	114.7521	107.9561	0.0000*
R-squared	0.9967	**Hausmann Test results**		0.0172**
Adjusted R-squared	0.9966	**Normality test results**		0.6192
F-statistic	4614.452	**Pesaran CD**		0.9943
Prob(F-statistic)	0.0000*	**Durbin-Watson stat**		1.6019

Numbers in parenthesis were probabilities; *,** significance at 1% and %5 level respectively; according to Hausmann test result; we estimated model in fixed effects model; GLS Weights Cross-section SUR; Coef Covariance method: Cross-section weights (PCSE).

Reference : Own calculations based on UNESCO and World Bank

The graphical view of the model established in the research is presented in Graph 1. According to Graph 1, the estimated values of the variables are shown in green, the actual values in red, and the residual values in blue. The closeness of the actual values (red) and the predicted values (green) showed that the model was also compatible.

Graph 1. Actual, Fitted and Residuals Values of the Model



The most important assumption of Granger causality analysis and cointegration tests; the series of variables must be stationary. To revealed the stationary of the variables, unit root tests were done. According to Table 4, five type unit root tests results were showed. These tests were IM, Pesaran and Shin W-stat. test, Levin, Lin ve Chu Test (LLC), Breitung t-stat, PP Fisher Chi-square, ADF Fisher Chi-square tests. According to findings, the stationarity of the GDP series was determined at Level value according to LLC, Im et al, PP Fisher Chi-square, ADF Fisher Chi-square tests. In 1. Difference

I(1) all the series were statinory at invidual effects, invidual effects trend and none model all the unit root test. In the analysis series I(1) was used in the causality and cointegration analysis (Table: 4).

The second assumption to be determined in causality and cointegration analysis is to determine the lag length. In order to determine the lag length of the variables in the research model, the VAR model was defined and the equations were estimated. The maximum length of the model was found to be 0,4,5,6 (Table 4).

Table 4: Results of the Unit Root and Lag Lenght Test

A. Unit Root Tests

			LLC	**Breitung t-stat**	**Im et al.**	**ADF**	**PP**
GDP	Level	İnvidual Effects	0.0002*	-	0.0192	0.0466**	0.0127*
		İnvidual Effects-Trends	0.0001*	0.2304	0.1241	0.1450	0.5404
		None	0.9621	-	-	0.9999	1.0000
	1.diff.	İnvidual Effects	0.0000*	-	0.0000*	0.0000*	0.0000*
		İnvidual Effects-Trends	0.0000*	0.0000*	0.0008*	0.0020*	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*
PHRDE	Level	İnvidual Effects	0.0632***	-	0.8299	0.7526	0.8582
		İnvidual Effects-Trends	0.4105	0.5298	0.7619	0.8275	0.8190
		None	0.9999	-	-	1.0000	1.0000
	1.diff.	Invidual Effects	0.0006*	-	0.0006*	0.0019*	0.0000*
		Invidual Effects-Trends	0.0156**	0.0430**	0.0371**	0.0418**	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*

* , **, *** significance at 1%, 5%, 10% level respectively.

B. Lag Length Criteria of VAR Model

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-1121.739	NA	2.40e+08	24.97199	25.02754*	24.99439
1	-1119.730	3.884493	2.51e+08	25.01622	25.18288	25.08343
2	-1113.126	12.47388	2.37e+08	24.95836	25.23612	25.07037
3	-1109.362	6.942989	2.38e+08	24.96360	25.35246	25.12041
4	-1096.222	23.65251	1.95e+08	24.76048	25.26045	24.96210*
5	-1090.481	10.07840*	1.87e+08	24.72180	25.33286	24.96821
6	-1085.101	9.206064	1.82e+08*	24.69113*	25.41329	24.98235

* indicates lag order selected by the criterion: *LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion; RootTest: 0.1949-0.5410.

Reference : Own calculations based on UNESCO and World Bank

After determining that all of the variables are I(1) by the unit root test, the long-term relationship was investigated by Johansen cointegration analysis. To test whether there is a long-term relationship between the variables, eigenvalue (max-eigen value) and trace statistics are used. While investigating the long-term relationship between the variables with the Johansen cointegration test, the 5th length was applied to determine the lag length of the VAR model. According to the results of Johansen (1988) cointegration tests; trace test statistic of H0 hypothesis (r=0), which states that there is no cointegration between PGDP and PHRDE, was found to be 44.18835. Since this value is greater than the critical value of 15.49471 at the 5% significance level, the null hypothesis was rejected and Trace test indicates 2 cointegrating eqn(s) at the 0.05 level (Table: 5).

In the next step, in Table 5 DOLS and FMOLS tests for cointegrated panels estimation results were given. According to the DOLS coefficient estimation results, Health R&D expenditures were effective on economic growth positively and 1 unit increase in health R&D expenditures at 5% significance level increases economic growth by 25.40 units. According to the FMOLS coefficient estimation results, Health R&D expenditures were effective on economic growth positively and 1 unit increase in health R&D expenditures at 1% significance level increases economic growth by 16.43 units. In summary, the main findings obtained from DOLS and FMOLS methods was confirmed the positive impact of Health R&D expenditures on economic growth.

Although the cointegration test results show that there is a long-term relationship between the variables, they do not provide information about the direction of causality. For this reason, Granger causality analysis was applied in the VAR model and it was determined that there was a bidirectional causality relationship between Health R&D expenditures and GDP. In addition, the diagnostic tests of the causality test results confirmed that the analysis was valid (Table 5).

Table 5: Cointegration and Casuality Tests

A . Cointegration Test

	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.**
None*	0.258126	44.18835	15.49471	0.0000
At Most 1*	0.175028	17.31655	3.841666	0.0000

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; unit root test: 0.640061- 0.816937.

B. DOLS and FMOLS Estimations Results

The Dependent variable: PGDP

	DOLS		**FMOLS**	
PHRDE	Coefficient	t-Statistic	Coefficient	t-Statistic
	25.40565	2.687610	16.43050	132.7036
	(0.0118)** R^2 ->79 %		(0.0000)* ; R^2 -> 0.036 %	

Note: Probability of the values were in parenthesis. In the DOLS estimation method, lead and lag were set as 4 HQ maxlags; Bartlett kernel, Newey-West fixed bandwidth; significance at *1% and **5%.

C. Granger Casuality/Block Exogeneity Wald Tests

Hipotesis	**Probability**	**Result**	**Decision**	**Interpretation Of The Result**
PHRDE ≠> PGDP	0.0001*	Rejected	PHRDE was the Granger cause of PGDP	Economic Growth ⟷ Health R&D Expenditures
PGDP ≠> PHRDE	0.0479**	Rejected	PGDP was the Granger cause of PHRDE	

Roots of Characteristic Polynomial: 0.6401-0.8169; Serial Correlation LM Tests: 0.0966; Normality Tests: 0.3240; Heteroskedasticity Tests: 0.0713; significance at *1% and **5%.

Reference : Own calculations based on UNESCO and World Bank

IV. CONCLUSION AND DISCUSSION

The relationship between technology and economic growth is related to income and R&D activities in high-income countries increase economic growth (Goel and Ram, 1994; Gittleman and Wolf, 1995;

Sylwester, 2001; Amaghouss and Ibourk, 2013; Gümüş and Çelikay, 2015; Aybarç and Selim, 2017). R&D activities of public, private and foreign sectors are also determinants of growth (Guellec and Potterie, 2004; Khan et al., 2010). Efficient use of R&D expenditures provides better economic growth performance to countries (Wang, 2007; Alene, 2010). At the same time, studies show that private R&D investments are more effective than public investments (Lichtenberg, 1992; Goel et al., 2008). Commercial activities in this area contribute to economic growth by spreading information (Guellec and Potterie, 2001; Luintel and Khan, 2005; Sadraouı et al., 2014; Tunalı and Erbelet, 2017).

This paper's aim was to analyze relationship between gross domestic product and its determiner as PHRDE using panel data for 10 countries over the period 2004-2019 within a multivariate framework. According to the basic findings obtained from the analysis; i) According to Granger causality analysis, the bidirectional causality between economic growth and PHRDE was determined. ii) The results of the panel cointegration tests confirmed the existence of a long-term relationship between economic growth and PHRDE. iii) The FMOLS coefficient estimation results indicated that PHRDE had positive effects on economic growth. iv) DOLS coefficient estimation results showed the positive effects of HRDE on economic growth.

Between the health R&D expenditures and GDP; a bidirectional causality relationship was determined. Besides this result was considered consistent with the two-way causality relationship between R&D expenditures and GDP determined in the literature (Gülmez and Yardımcıoğlu, 2012; Güloğlu and Tekin, 2012; Türedi, 2016; Zaman et al., 2018). At the same time Blanco et al. (2013) reported that there was a cointegration relationship between R&D and economic growth reported in the literature (Gülmez and Yardımcıoğlu, 2012; Blanco, 2013; Zaman et al., 2018). So this result was consistent with the results of this study.

Generally the relationship between Health R&D expenditures and GDP was found significant according to R&D expenditures and GDP related literature (Lichtenberg, 1992; Goel and Ram, 1994; Gittleman and Wolff, 1995; Guellec and Potterie, 2004; Luintel and Khan, 2005; Falk 2007; Wang, 2007; Genç and Atasoy, 2010; Khan et al., 2010; Horvath 2011; Gyekye et al., 2012; Özcan and Arı, 2014; Gümüş and Çelikay, 2015).

The findings of this study, which demonstrates the current state of health R&D activities in the world, support our economic growth hypothesis based on health R&D activities and therefore the main hypothesis of this study was that the impact of health R&D Expenditures' affects on Economic Growth Positively hypothesis was accepted.

Health R&D activities should be evaluated as a strategic sector in terms of extending the expected life span, increasing the quality of life, developing and producing high value added products, employing highly qualified employees and providing technological and scientific contributions in the medical field. As a result of policies pursued towards health promotion on a world scale, the years lost to disease in the world[‡] was a 44 % increase in non-communicable diseases from 1990 to 2019; besides this finding in communicable diseases and injuries, that decreased by 44 % and 7.8 %, respectively. Besides this, from the macroeconomic point of view, between 1990-2019 the world population and life expectancy at birth increased by 46.3 %, and 12.3 % respectively; and this can cause to increase in the burden of diseases following years. From this perspective, it is also clear that direct health expenditures, indirect labor losses, and early deaths will include significant burdens in the economies of countries.

In addition to the international success achieved in health performance indicators through SDGs on a world scale, it is predicted that developing health research activities to build a sustainable health economy to control the costs of the current burden of diseases and diagnostic-therapeutic health

[‡] https://vizhub.healthdata.org/gbd-results/ veri tabanında yer alan bilgilerden faydalanılarak yazarlar tarafından hesaplanmıştır.

services. For this reason, in developing countries it is important to plan health R&D activities sector-oriented with include all stakeholders to expand their health R&D investments and activities.

Health R&D activities have features that include information, technology, human capital, and public investments together, which are discussed under four separate headings in modern growth theories. From this perspective, evaluating the results obtained from Health R&D investments supporting economic growth could be received as an internal economic growth model based on Health R&D (the fifth heading in the modern growth theories) was thought to contribute to the economic literature.

In the development of technological innovations in the field of health, in the production of high value-added products and in the increase of their exports, in the reduction of the importation of medicines/medical devices and equipment, in the construction of the systems to control the disease burden of the nations on their own; to create a strong and sustainable health economy with using the direct and indirect effects of health R&D expenditure/investments on human capital, dealt with rationally and current analyzes health R&D indicators' that can be monitored together in the health R&D models' with economic growth; it is foreseen that this study which puts the importance of health R&D activities at the national and international level, will contribute to the literature, researchers, health politicians, academicians and all institutions/organizations operating in the health R&D field different specific suggestions.

Ethical Approval: This study was an empirical analysis and the data of study were taken from Worldbank database and unesco.org; therefore, Ethics Committee Approval was not required in the study.

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