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Research Article/Araştırma Makalesi

*ARDL Analysis for The Effects of R&D Expenditures on Economic Growth: The Case of Türkiye Between 1980-2020**

AR-GE Harcamalarının Ekonomik Büyüme Üzerindeki Etkilerinin ARDL Analizi ile 1980-2020 Yılları Arasında Değerlendirilmesi: Türkiye Örneği

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Abstract

Growth rates are one of the leading performance indicators of countries in global competition. Generally, growth leads to an increase in employment rates. Technological investments have a larger positive economic effect in in developed countries. The percentage of infrastructure investments in growth is higher in developing countries. Infrastructure investments, while stimulating the economy during the investment period, make a minimal contribution to the economy in the period after the investment is over. On the other hand, industrial investments contribute to continuous economic growth as they sell products to domestic and foreign markets, especially after the investment period. While growth rates follow a more stable course in economically developed countries, they follow a more volatile course in developing countries. When we examine this situation, the economic, social, political, democratic, legal, etc., of the developed countries have sufficient progress in these areas and appear as a safe haven in the global capital markets. This study investigated the effects of R&D expenditures, the number of researchers, and obtained patents on national income between 1980-2020 in Türkiye. As a method, ARDL and Granger Causality analysis were used to produce different econometric models. According to the results of the causality analysis, it has been determined that there is a one-way causality from economic growth to patent. When the ARDL analysis was examined, it was revealed that there was a positive relationship between R&D and economic growth in the short and long run.

Jel Codes: *030, F43, C22*
Keywords: *R&D Expenditures, Economic Growth, Time Series Analysis.*

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Öz

Büyüme oranları, ülkelerin küresel rekabetteki performans göstergelerinin başında gelmektedir. Genellikle büyüme beraberinde istihdam oranlarında artış sağlamaktadır. Gelişmiş ülkelerde büyümede teknolojik yatırımların payı daha büyük yer tutmaktadır. Gelişmekte olan ülkelerde ise alt yapı yatırımlarının büyümedeki payı daha yüksektir. Alt yapı yatırımları, yatırım döneminde ekonomiyi canlandırırken, yatırım bittikten sonraki dönemde ekonomiye çok sınırlı katkı yapmaktadır. Sanayi yatırımları ise özellikle yatırım dönemi sonrası imalat ile yurt içi ve yurt dışı pazara ürün satacağı için sürekli ekonomik büyümeye katkı sağlamaktadır. Büyüme oranları ekonomik gelişmiş ülkelerde daha istikrarlı bir seyir izlerken, gelişmekte olan ülkelerde ise daha oynak seyir izlemektedir. Bu durumun ana sebebi gelişmiş ülkelerin ekonomik, sosyal, politik, demokratik, hukuk vb. alanlarda yeterli ilerlemeye sahip olması ve küresel sermaye piyasalarınca güvenli liman olarak tanımlanmalarıdır. Yapılan çalışma ile Türkiye'de 1980 ile 2020 yılları sarasında AR-GE harcamaları, araştırmacı sayıları ve patentlerin milli gelir üzerindeki etkileri araştırılmıştır. Çalışmada farklı ekonometrik modeller üretilmiş ve ARDL ve Granger Nedensellik analizi kullanılmıştır. Nedensellik analizi sonucunda ekonomik büyümeden patente doğru tek yönlü nedenselliğin varlığı tespit edilmiştir. ARDL bulgularına göre ARGE harcamalarında meydana gelen %1'lik bir artış ekonomik büyümeyi %2.5 oranında arttırmaktadır. Uzun dönem analizlerinde ise AR-GE harcamaları ile ekonomik büyüme arasında anlamlı sonuçlar elde edilememiştir.

Jel Kodları: *030, F43, C22*
Anahtar Kelimeler: *ARGE Harcamaları, Ekonomik Büyüme, Zaman Serileri Analizi*

1. Introduction

When we take the Gregorian calendar as a basis, states that have been relatively regular for about two thousand years continue their existence. In this long historical process, many states have been established, and many of them have been destroyed. Until the Second World War, almost all countries were in a constant war atmosphere and were constantly trying to expand their borders or protect their existing ones. With the establishment of international institutions like the United Nations and NATO after the Second World War, the concern about global border security has almost disappeared, especially for developed countries.

When we look at world history, the fundamental economic elements that keep the states alive are seen as the cultivation of the soil, obtaining agricultural products, precious metals and trade. The population of the countries was of great importance for these labor-based processes. Until the Industrial Revolution, the economic process worked in this way. This process started in England in the second half of XVIII. century changed the political and economic order all over the world. The new processes, which first emerged in the textile and metal sector, have revealed manufacturing machines that primarily work with steam machines, with technological progress. Later, transportation vehicles such as steam-powered ships and trains emerged. These vehicles facilitated the rapid transportation of raw materials and products to national and international markets as well as transporting people. As a result of these developments, examples have emerged where a worker can complete a job in one year with a single machine in one day. In the past, people who had no alternative but to till the land or become soldiers, left their villages and started to work as workers in large factories. The concept of industrial cities was born and cities with very high populations emerged. The income of workers with regular income and the capital accumulation of companies have increased. As a result, they produce many goods in a short time and sell them to national and international markets. Increasing returns has become a priority for new technological advancements and the improvement of production processes.

By the beginning of the 20th century, besides precious metals and fertile lands, oil and its derivatives, also known as black gold, and increasing raw materials and workforce were becoming indispensable sources of prosperity for countries. With the development of societies, the demand for growing energy needs has been increasing. Another fundamental dynamic of the economy can be considered Technological Advances. Today, almost all of the countries that can move from a warlike, agricultural-based economic structure to an economic structure that has an important part of the total income from the manufacturing industry, attaches importance to technological progress, and has access to raw material resources and global markets, are called developed countries.

The concept of growth is of critical importance in today's economies. Especially in underdeveloped countries, economic growth is perceived as a combination of many main criteria, such as production, employment and total income. In developed countries, the situation is slightly different. Since the countries in this group already operate at high levels of their capacities, it does not seem reasonable for them to grow at high rates. When these are considered, the numbers after the decimal points have great importance for developed countries when setting economic growth targets.

Acemoğlu (2008) asks the following question in his work: Which countries are growing faster? People want to know this question in a cause and effect relationship, which features of states or the power of their policies casually affect economic growth? But what would be the effect on equilibrium growth, all else being equal, assuming that a particular feature of the country's economic characteristic is exogenously changed? It is quite challenging to answer these causal questions because it is difficult to isolate changes in endogenous variables that are not precisely driven by equilibrium dynamics or some other variables (Acemoğlu, 2008).

2. Literature Review

Ulku (2004)			
Independent variable	**Data set**	**Method**	**Conclusion**
Patents and R&D	Country: 20 OECD countries, Years: 1981-1997 Period: Annual Source: NBER U.S. Patent and Trademark Of.	Panel Data Analysis	While it shows a positive relationship between GDP per capita and innovation in both OECD and non-OECD countries, the impact of R&D stock on innovation is significant only in OECD countries with large markets.
Özer ve Çiftçi (2008)			
GERD: Ratio of R&D expenditures to GDP (%) RSRCH: Number of people working in the R&D sector per thousand people (in FTE) PATENT: Number of patents	Country: 21 OECD countries Years: 1990-2005 Period: Annual	Panel Data Analysis	It has been found that R&D expenditures, the number of researchers and the number of patents have a positive and high impact on GDP.
Altın ve Kaya (2009)			
R&D Expenditures	Country: Turkey Years: 1990-2005 Period: Annual Source: TURKSTAT	VEC (Vector Error Correction) model is selected. It has been analyzed in the context of causality.	As a result of the study, the relationship between R&D expenditures and economic growth in the short term could not be found in any direction. Still, it was concluded that R&D expenditures were the cause of economic growth in the long time.
Genç ve Atasoy (2010)			
R&D Expenditures	Country: 34 Countries Years: 1997-2008 Period: Annual Source: EuroStat, World Bank	Application of panel causality test	It reveals a one-way causality relationship between R&D expenditures and economic growth.
Korkmaz (2010)			

R&D Expenditures	Country: Turkey Years: 1990-2008 Period: Annual Source: IMF IFS, TURKSTAT	Johansen cointegration method	As a result of the Granger causality test, it was concluded that R&D expenditures affect GDP in the short run.
Yaylalı, Akan, Işık (2010)			
R&D Expenditures	Country: Turkey Years: 1990-2009 Period: Annual Source: TURKSTAT, TPI	ADF, cointegration and causality tests were used.	In the long run, a unidirectional relationship has been determined between R&D investment expenditures and economic growth.
Ağır ve Utlu (2011)			
Share of R&D Expenditures in GNP	Country: 17 OECD countries Years: 1981-2008 Period: Annual Source: WB WDI, OECD	Panel Cointegration and Panel Causality tests were used.	According to empirical findings, while R&D expenditures do not cause economic growth in the short run, they appear to cause economic growth in the long run.
Akçay (2011)			
Real total R&D investment, employment, real gross domestic investment (public + private) and real export revenues time series data	Country: USA Years: 1960-2007 Period: Annual Source: U.S. Department of Commerce, Bureau of Economic Analysis	Johansen - Juselius, Toda, Yamamoto (1995) Causality for Vector Autoregressive Cointegration	According to the cointegration test results, there is a long-term relationship between the variables. The causality test results found a two-way causality relationship between total R&D and economic growth.
Fernández, Martinez ve Sanchez (2012)			
Investment, Employment and R&D Expenditures	Country: 17 Spanish Regions Years: 1995-2008 Period: Annual Source: INE, OECD	Least Squares Dummy Variable Method, GMM Method.	The main results suggest that the overall R&D intensity positively affects growth. Public influence and University R&D activities are not significant.
Gülmez ve Yardımcıoğlu (2012)			
R&D expenditures per capita	Country: 21 OECD Countries Years: 1990-2010 Period: Annual Source: Eurostat	Pedroni and Kao cointegration tests, Pedroni DOLS and FMOLS tests	As a result, it can be stated that there is a mutually significant relationship between R&D expenditures and economic growth variables in the long run.
Taban Ve Şengür (2013)			

EVSt represents the share of R&D expenditures in GDP, and LTZEt represents the number of full-time equivalents (FTE) employees in R&D.	Country: TURKEY Years: 1990-2012 Period: Annual	Johansen cointegration and vector error correction model is used.	It has been shown that R&D expenditures and the number of full-time equivalent employees in R&D positively affect economic growth in the long run. In the short term, while the number of FTE employees in R&D had a significant positive effect on economic growth, it was seen that R&D expenditures did not have such an effect.
Bozkurt (2015)			
R&D expenditures	Country: Turkey Years: 1998 – 2013 Period: Annual Source: WDI, TURKSTAT	Johansen cointegration and vectorial error correction models.	The long-term coefficients for the R&D variable are statistically very significant and have a positive value. If R&D shares in GDP increase by 1%, the GDP growth rate will increase by 0.2630%.
Taş, Taşar, Açcı (2017)			
Industrial Production Index R&D expenditures the share of annual R&D expenditures in the gross domestic product (R&D).	Country: Turkey Years: 2005-2015 Period: Annual Source: IMF IFS, WDI, TURKSTAT	VAR model.	As a result of the study's empirical analysis, causality from R&D investments to economic growth in Turkey has been determined.
Sağlam, Egeli, Egeli (2017)			
The share of R&D expenditures in GDP, representing technological change	Country: 26 Countries Years: 1996 – 2014 Period: Annual Source: Eurostat	The dynamic panel is analyzed in the context of data analysis.	The findings indicate a unidirectional causality relationship between R&D expenditures and economic growth in the long run.
Türedi (2016)			
R&D Expenditures Ratio of Total R&D Expenditures to GDP (% of GDP). It is used in pure values (without calculating the logarithm). Patent Application Total Number of Patent Applications (resident and non-resident). It is used in logarithmic values.	Country: 23 OECD countries Years: 1996-2011 Period: Annual Source: NBER Patent WB WDI	The Wald test was used with the GMM (Generalized Moments Method) approach developed by Arellano-Bond (1991)..	Panel causality estimation results revealed the existence of a positive bidirectional causality relationship between R&D expenditures and economic growth and a unidirectional and positive causality relationship from patent applications to economic growth.
Algan, Manga ve Tekeoğlu (2017)			
High-tech product exports, the number of patent applications and the share of R&D expenditures in GDP are used to represent technological development indicators.	Country: Turkey Years: 1996-2015 Period: Annual Source: TURKSTAT, TPI	ADF and PP tests Granger causality test.	In the long run, it has been concluded that GDP per capita is positively affected by R&D expenditures and the number of patent applications and negatively by high-tech product exports.

Köse ve Şentürk (2017)			
R&D and patent expenditures	Country: Turkey Years: 1989-2012 Period: Annual Source: OECD	Regression Analysis with the least squares method was applied.	There is a two-way positive relationship between R&D expenditures and economic growth. It has also been determined that there is a significant relationship between technological development and economic growth. However, no significant relationship was found between economic growth and patent expenditures.

Explanation: In the studies, economic growth data was used as the Dependent Variable.

3. The Relationship between R&D Expenditures and Economic Growth

One of the main purposes of the analysis of economic data is to predict the future values of economic variables. An econometric model is created to explain the behaviors of the variable under the consideration of the model equation. (Tari, 2005). Econometric techniques estimate unknown parameters, and these parameters are used for the desired purpose. Time series estimation method aims to examine changes in the variable discussed are tried to be explained with the developments in the historical values of the variable. (Sevüktekin et al., 2005).

In the study, four technology variables were handled one by one, and the relationship between these variables and economic growth was studied. These variables are the ratio of R&D spending to GDP (GERD), the number of people working in the R&D sector per thousand people (in full-time equivalent) (RSRCH), Number of patent applications (Domestic applications only) (PATENT). The data for the variables included in the analysis were obtained for the period 1980-2020.

First, the ADF unit root test was implemented to determine the stationarity degrees of the series used. In the next step, the Johansen cointegration test was applied to test the existence of a cointegration relationship between the series. In the third stage, diagnostic tests were applied and the models' autocorrelation, homoskedasticity and model specification problems were tested. Afterwards, ARDL analysis was performed to estimate the long- and short-term coefficients. In the last stage, the Granger causality test was used for the causality relationships between the series.

4. The Data Set and Econometric Model

Data from 1980-2020 were used in the study, were gathered from the Turkish Statistical Institute, World Bank World Advanced Index database, Turkish Patent Institute data and Thomson Reuters-InCites (TÜBİTAK ULAKBİM) data.

The study is constructed with the Cobb-Douglass production formula as technological progress is used as an endogenous variable in the model.

Cobb-Douglass production formula: Y = F (K, L)

Production function for technology: ΔA=F (L_A, K_A, A)

Based on the production function, four different Econometric Models were created:

Model 1: $GDP_t = \alpha_t + K_t + L_t + \beta_t GERD_t + e_t$

Model 2: $GDP_t = \alpha_t + K_t + L_t + \beta_t RSRCH_t + e_t$

Model 3: $GDP_t = \alpha_t + K_t + L_t + \beta_t PATENT_t + e_t$

Models were established to investigate the impact of R&D expenditures, the number of researchers, and patents on GDP. Data were obtained from the World Bank Development Indicators (WDI) database at an annual frequency.

5. Methodology and Empirical Findings

In this section, the statistical analysis and the results will be explained. First, a unit root test will be performed for the four models created. Afterwards, the existence of cointegration will be tested. The existence of cointegration in the series will be investigated. After the diagnostic tests, short- and long-term coefficients will be estimated by ARDL analysis. Finally, for each model, the Granger causality test will be investigated to test the existence of a causal relationship between the variables.

5.1. Unit Root Analysis

The most essential prerequisite for performing time series analysis is that the series in question is stationary. Time series analysis is performed on the assumption that the series is stationary. Stationarity is explained by the fact that the series is stationary in meaning and variance. If the Mean and Variance consists of a fixed stochastic process in the period in question, it can be said that this series is stationary. A spurious regression trouble could occur in non-stationary time series, and this result does not reflect the proper relationship between the variables. For these reasons, the Augmented Dickey Fuller (ADF) test was used for the four models established within the scope of the study, and it was examined whether the series were stationary with unit root tests.

When the presence of unit root was investigated for the stationarity analysis of the series, the hypothesis was formed as follows:

H_0 : γ=0 The series is not stationary.

H_1 : $\gamma \neq$0 The series is stationary.

The formulation of the ADF test is as follows:

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=1}^{m} \beta_{it} \Delta y_{t-i} + e_t$$

Table 2: Augmented Dickey Fuller (ADF) Unit Root Test Results

	Constant		Constant and Trend	
Variables	**t-statistics**	**Probability**	**t-statistics**	**Probability**
LOG_GERD	-3.547	0.012**	-1.114	0.123
LOG_K	-3.636	0.041**	-2.023	0.237
LOG_L	0.703	0.854	-1.102	0.252
LOG_PATENT	-0.456	0.963	-2.450	0.474
LOG_RSRCH	-4.967	0.011***	-3.013	0.254
LOG_Y	-3.785	0.001**	-1.507	0.780
D(LOG_GERD)	-1.256	0.426	-6.149	0.011***
D(LOG_K)	-4.145	0.007***	-4.739	0.036**
D(LOG_L)	-1.214	0.743	-2.971	0.004*
D(LOG_PATENT)	-4.145	0.017***	-2.124	0.000*
D(LOG_RSRCH)	-2.783	0.267	-4.885	0.022**
D(LOG_Y)	-2.152	0.349	-4.670	0.001**

***, ** and * denote statistical significance levels of 1%, 5% and 10%, respectively. The maximum delay length is determined as 3 according to AIC.

Table A shows the results of the ADF unit root test and application for each model. The variables were tested for both as the constant term, constant term and trend. As a result of the analysis, it has been determined that the series are not stationary at the level but are stationary at the first difference.

5.2. Cointegration Analysis

In time series analysis, the existence of a long-term relationship between variables can only be explained if these variables are cointegrated. With the proof of cointegration, the regression with the level values of these variables is significant.

Within the scope of the study, the Johansen cointegration test was applied for cointegration test applications. The hypothesis to investigate the existence of cointegration is formed as follows:

H_0: δ=0 No cointegration between the variables.
H_1 : δ≠0 Cointegration between the variables.

The formulation of the Johansen cointegration test is as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 y_{t-1} + e_t$$

Table 3: Johansen Cointegration Test Results

Model	Number of Consolidated Vectors	Eigenvalue	Trace Statistics	*Probability Values	Max. Eigen Statistics**	Probability Values
1	none	0.9752	92.1256	0.0000	48.2315	0.0000
	up to 1	0.8236	45.8025	0.0000	27.6571	0.0378
	up to 2	0.7837	22.3456	0.0021	19.2347	0.0147
	up to 3	0.2142	4.4178	0.0273	5.2214	0.0463
2	none	0.8963	105.2145	0.0000	49.2256	0.0000
	up to 1	0.8547	59.3247	0.0000	41.8893	0.0004
	up to 2	0.7254	29.3214	0.0027	17.8896	0.0124
	up to 3	0.3647	7.2145	0.0156	7.6687	0.0247
3	none	0.9968	124.2321	0.0000	89.3325	0.0000
	up to 1	0.7964	45.2389	0.0017	25.3324	0.0524
	up to 2	0.5897	19.3256	0.0271	15.2264	0.0941
	up to 3	0.4217	9.3256	0.0361	6.3325	0.0247

The cointegration test results for each model are shown in Table 3. According to the findings, the null hypothesis that "no cointegration between the variables" was rejected. On the other hand, the existence of cointegration for each variable was revealed. By revealing the cointegration of the variables in the models with intercept, the long-term effects arising from these variables can be analyzed.

5.3. Diagnostic Tests

a. Serial correlation, Breusch-Godfrey Serial Correlation LM Test

Table 4: Breusch-Godfrey Serial Correlation LM Test Results

	Model 1	Model 2	Model 3
F-statistics	13.8644	0.1790	0.3215
Probability	0.2278	0.6345	0.6911

Until lag 1.

H_0: No serial correlation until Lag 1.

H_1: Serial correlation up to Lag 1.

As can be seen in the table, the Breusch-Godfrey test results show that there is no autocorrelation problem. Since the probability value is greater than 1%, this model has no serial correlation.

b. Heteroscedasticity, Breusch-Pagan-Godfrey Test

Table 5: Breusch-Pagan-Godfrey Test Results

	Model 1	Model 2	Model 3	Model 4
F-statistics	0.3780	0.5478	0.3647	0.8954
Probability	0.9825	0.6386	0.9233	0.6324

H_0 : There is no heteroscedasticity.
H_1 : There is heteroscedasticity.
As seen in the table, there is no homoskedasticity problem in the Breusch-Pagan-Godfrey test, as the probability value is greater than 1%.

c. Model Specification, Ramsey Reset Test

Table 6: Ramsey Reset Test Results

	Model 1	Model 2	Model 3	Model 4
F-statistics	0.8741	0.0112	0.8967	0.7123
Probability	0.3869	0.3258	0.8931	0.5473

H_0: The model specification is correct.
H_1: The model specification is not correct.
It tests the model building error with the 1st and 2nd lag lengths, it is seen that the probability value is greater than 1%, and there is no error in the constructed model.

d. Estimation of Short- and Long-Run Coefficients (ARDL Analysis)

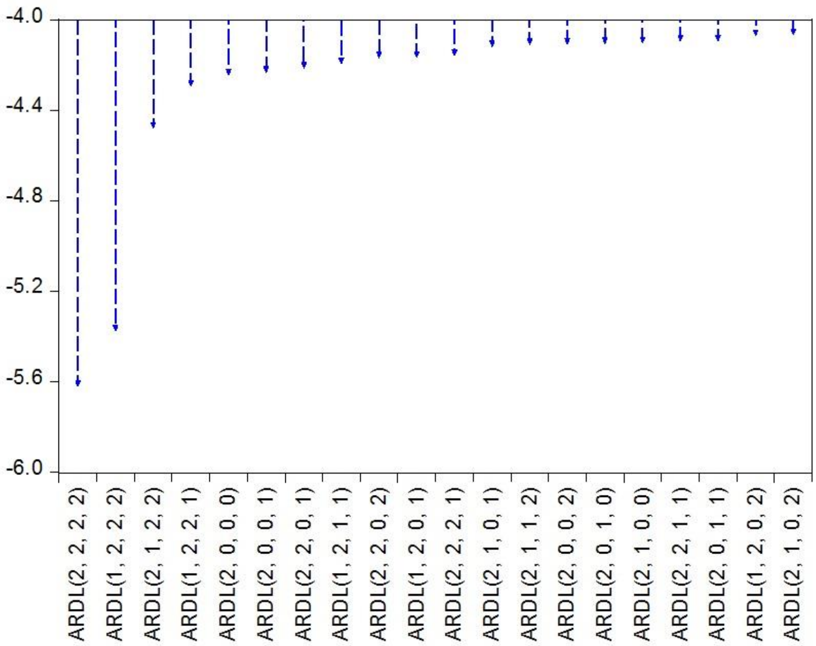
The ARDL Model (Autoregressive Distributed Autoregressive Model) is implemented with the boundary test developed by Pesaran (2001). The biggest advantages of ARDL over other tests are not accepting stationarity as a prerequisite, therefore short and long term estimations can be made.

The formulation of the ARDL Bounds Test is as follows:

$$\Delta Y_t = \beta_{0Y} + \sum_{i=1}^{m} \beta_{1Y}\Delta Y_{t-i} + \sum_{i=1}^{m} \beta_{2Y}\Delta X_{1\,t-i} + \cdots + \sum_{i=1}^{m} \beta_{KY}\Delta X_{K\,t-i} + \Omega_{1Y}Y_{t-i}$$
$$+ \Omega_{2Y}X_{1\,t-i} + \ldots + \Omega_{KY}X_{K\,t-i} + e_{1t}$$

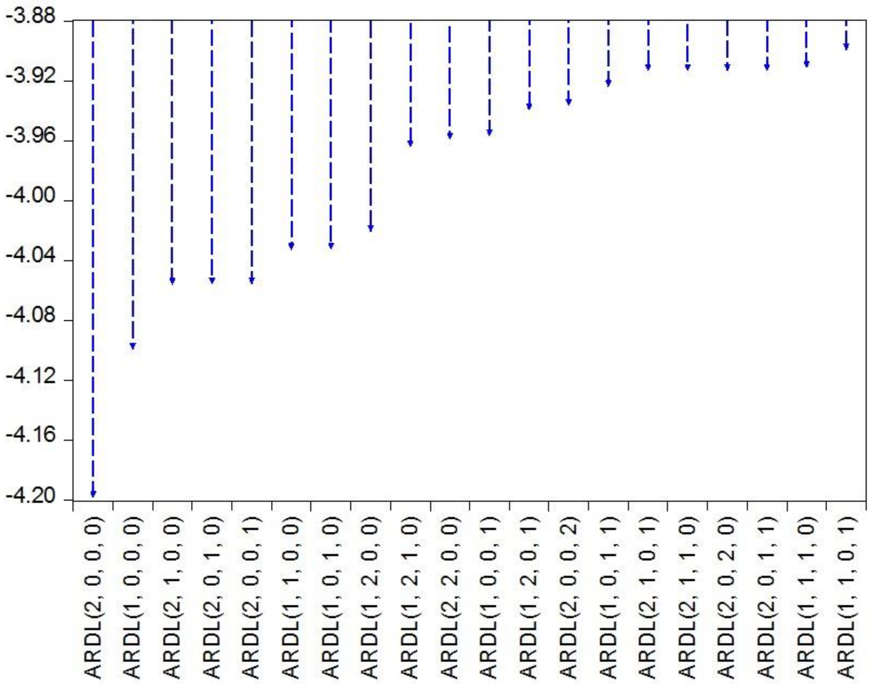
In order to analyze the models with ARDL method, first of all, the lowest values according to the Akaike Information Criteria (AIC) should be determined. So, models with lag length should be determined.

Figure 1: Akaike Information Criteria Results for Model One



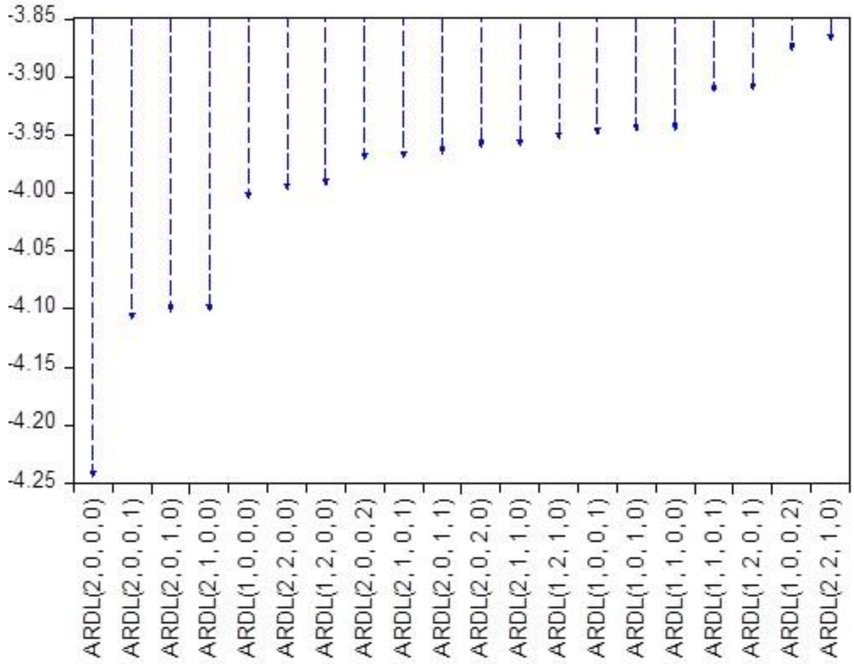
According to the AIC results, the ARDL (2,2,2,2) model was chosen for the first model.

Figure 2: Akaike Information Criteria Results for Model Two



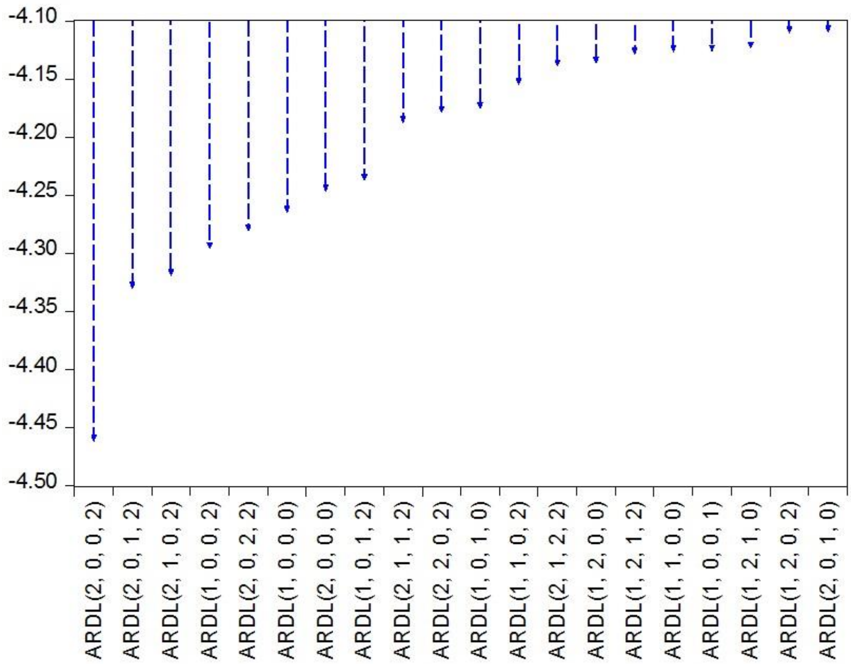
According to the AIC results, the ARDL (2,0,0,0) model was chosen for the second model.

Figure 3: Akaike Information Criteria Results for Model Three



According to the AIC results, ARDL (2,0,0,0) was chosen for the third model.

Figure 4: Akaike Information Criteria Results for Model Four



According to the AIC results, the ARDL (2,0,0,2) model was chosen for the fourth model.

Table 7: Estimation Results of Short-Run Coefficients (ARDL)

Model	Variables	Coefficient	t-statistic	Probability value
1	GERD	1.058	5.647	0.000
2	RSRCH	0.146	3.549	0.001
3	PATENT	0.547	6.322	0.005

Short-term coefficient estimates show that the effects of research and development expenditures, the number of researchers and the number of patents on GDP are positive, and that the 1% unit increase affects 1.058%, 0.146% and 0.547%, respectively.

Table 8: Estimation Results of Long-Term Coefficients (ARDL)

Model	Variables	Coefficient	t-statistic	Probability value
1	GERD	0.225	4.217	0.000
2	RSRCH	0.456	3.257	0.004
3	PATENT	0.247	3.986	0.007

Long-term coefficient estimates show that the effects of research and development expenditures, the number of researchers and the number of patents on GDP are positive and statistically significant and that the 1% unit increase affects 0.225%, 0.456% and 0.247%, respectively.

e. Causality Analysis

Cause and effect relationship, in other words, causality is an important and complex issue in studying economic concepts and events. The significance of the studies depends on the determination of the causality between the variables. While developing econometric models, variables are interdependent. However, every dependency does not mean that there is an absolute causal relationship between the variables. While there is a time-delayed relationship between the variables, the direction of causality needs to be estimated. The first study on this subject was done by Granger (1969). Granger causality analysis is based on time series analysis. Within the scope of the study, Granger Causality Test was applied to all models. When the test results are examined:

-For the first model, a bidirectional causality is observed from R&D spending to labor.

-In the second model, there is a unidirectional relationship between human resources and labor working in R&D.

-In the third model, a unidirectional causality is observed from economic growth to the patents' applications.

6. Conclusion

Technology is one of the most important and indispensable concepts of the 21st century. The expectation of using technology and developing existing technologies in daily life, the manufacturing industry, education, space studies, the defense industry and almost every field that comes to our mind continues to increase in almost every corner of the world. Increasing income, consumption habits and competition among companies accelerate this technology race. So, can a developing country, for example, produce a new mobile phone or a vehicle and find a place in the global market?

The concept of R&D remains more abstract compared to other factors affecting growth. One of the essential features of R&D is that stock is a variable. If we open this concept a little more, it may take decades for the R&D culture to emerge at the country level and for the substantial effects of R&D studies on economic growth to occur. Silicon Valley, established in the USA in the 1950s, can be an example of this event. Today, companies such as Microsoft, Apple, Oracle, Intel, Google and HP, established in Silicon Valley in America, the world's leading country in R&D, continued their R&D studies for years and eventually became the world leader in their sectors.

If we reconsider the production of a new technological product in the first paragraph and its presence in the global market in order to compete with Apple, which was founded in 1976, and Samsung, which was founded in 1938:

- Having more technology experience,

-The fact that these companies employ tens of thousands of engineers currently working in R&D departments,

-Accessing turnovers of billions of dollars,

-Acquiring billions of dollars in investment capital by being traded on stock exchanges,

-Having high profitability ratios,

-Owning thousands of patents,

-Establishing a global chain in manufacturing and sales

is necessary. Returning to our subject again, a new company needs to have access to the knowledge stocked over the years to enter the markets.

In the study, the relationship between economic growth and some Technology variables (GERD, RSRCH, PATENT) was investigated using the Econometric method (ARDL) for Turkey between 1980-2020. Analysis was carried out with empirical research and econometric modelling. For Turkey, four different models were developed to determine the relationship between four basic technological variables and growth.

ARDL test results revealed that the effects of both short and long run coefficients are positive and statistically significant., According to the results of Granger Causality Analysis, it is revealed that there is a two-way causality from R&D spending to labor, a unidirectional relationship between human resources working in R&D and labor, one-way causality from economic growth to the patent applications, and finally, in the fourth model, there is a causality from the number of international scientific publications to labor.

References

Acemoğlu, D. (2008). *Introduction to Modern Economic Growth.* USA: Princeton University Press.

Aghion, P., Howitt, P. (1992). A Model of Growth through Creative Destruction, *Econometrica*, *60*, 323-351.

Aghion, P, Howitt, P. (1998). Endogenous Growth Theory. Cambridge: The MIT Press.

Ağır, H., Utlu, S. (2011). Ar-Ge Harcamaları İle Ekonomik Büyüme Arasındaki Nedensellik İlişkileri: OECD Ülkeleri örneği, Uluslararası 9. Bilgi, Ekonomi ve Yönetim Kongresi Bildirileri, Saraybosna-Bosna Hersek.

Akçay, S. (2011). Toplam Ar-Ge Yatırımları ile Ekonomik Büyüme Arasında Nedensellik İlişkisi: Amerika Birleşik Devletlerinden Kanıt, *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *16*(1), 79-92.

Algan, N., Manga, M., Tekeoğlu, M. (2017). Teknolojik Gelişme Göstergeleri ile Ekonomik Büyüme Arasındaki Nedensellik İlişkisi: Türkiye Örneği, International Conference on Eurasian Economies, 332-338.

Altın, O., Kaya, A. (2009). Türkiye'de Ar-Ge Harcamaları ve Ekonomik Büyüme Arasındaki Nedensel İlişkinin Analizi. Ege Akademik Bakış, *9*(1), 251-259.

Arrow. K. J. (1962). The Economic Implications of Learning by Doing. *Rev. Econ. Studies 29*, 155-73.

Aslan, A. (2012). The Relationship Between Military Spending and Black-Market Premium in Greece an ARDL Approach, *Transition Studies Review*, *2*(19).

Aslan, A. (2013). Causality Between Electricity Consumption and Economic Growth in Turkey An ARDL Bounds Testing Approach, *Energy Sources Part B Economics Planning and Policy*, *1*(9)

Ateş, S. (1998). *Yeni İçsel Büyüme Teorileri Ve Türkiye Ekonomisinin Büyüme, Dinamiklerinin Analizi*,(Doktora Tezi), Adana: Çukurova Üniversitesi Sosyal Bilimler Enstitüsü.

Bahmani-Oskooee, M., Chi, Wing, Ng, R. (2002). Long-Run Demand for Money in Hong Kong: An Application of The ARDL Model, *International Journal of Business and Economics*, *1*(2), 147-155.

Bozkurt, C. (2015). R&D Expenditures and Economic Growth Relationship in Turkey. *International Journal of Economics and Financial Issues*, *5*(1), 188-198.

Fernandez, N., Martinez, V., Sanchez-Robles, B. (2015). R&D and Growth in the Spanish Regions: An Empirical Approximation. *International Journal of Business and Social Science*, *3*(10).

Genç, M. C., Atasoy, Y. (2010). Ar&Ge Harcamaları ve Ekonomik Büyüme ilişkisi: Panel Veri Analizi, *Bilgi Ekonomisi ve Yönetimi*, *5*(2), 27-34.

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. Econometrica, *37*: 424–438.

Gülmez, A., Yardımcıoğlu, F. (2012). OECD Ülkelerinde Ar-Ge Harcamaları ve Ekonomik Büyüme İlişkisi: Panel Eşbütünleşme ve Panel Nedensellik Analizi (1990-2010), Maliye Dergisi, *163*, 335-353.

Korkmaz, S. (2010). Türkiye'de Ar-Ge Yatırımları ve Ekonomik Büyüme Arasındaki ilişkinin VAR Modeli ile Analizi, *Journal of Yasar University*, *5*, 3320-3330.

Köse, Z., Şentürk, M. (2017). Ar-Ge - Patent Harcamaları Ve Teknolojik İlerlemenin Ekonomik Büyüme Üzerindeki Etkisi: Ampirik Bir Uygulama. Akademik Araştırmalar Ve Çalışmalar Dergisi (Akad), *9*(17), 215-221.

Nkoro, E., Uko, K. A. (2016). Autoregressive Distributed Lag (ARDL) Cointegration Technique: Application and Interpretation, *Journal of Statistical and Econometric Methods*, *5*(4), 63-91

Özer, M., Çiftçi, N. (2008). Ar-Ge Tabanlı İçsel Büyüme Modelleri ve Ar-Ge Harcamalarının Ekonomik Büyüme Üzerine Etkisi: OECD Ülkeleri Panel Veri Analizi, *SÜ Sosyal ve Ekonomik Araştırmalar Dergisi, 10*(16), 219-239.

Pesaran, M. H., Shin, Y., Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, *16*, 289- 326.

Sağlam, Y., Egeli, H., Egeli, P. (2017). The Relationship between R&D Expenditures and Economic Growth for Some Developed and Developing Countries: A Panel Data Analysis. *Sosyoekonomi*, *25*(31), 149-166.

Sevüktekin, M., Nargeleçekenler, M. (2005). *Zaman Serileri Analizi*. Ankara: Nobel Yayın Dağıtım.

Taban, S., Şengür, M. (2013). Türkiye'de Ar-Ge ve Ekonomik Büyüme. *AİBÜ Sosyal Bilimler Enstitüsü Dergisi*, *14*(1), 355-376.

Tarı, R. (2005). Ekonometri, İzmit: Kocaeli Üniversitesi Yayınları.

Taş, Ş., Taşar İ. ve Acci, Y. (2017). Ar-Ge Harcamaları ve Ekonomik Büyüme Arasındaki İlişki: Türkiye Örneği. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 10*(2), 197-206.

Türedi, S. (2016). The Relationship between R&D Expenditures, Patent Applications and Growth: A Dynamic Panel Causality Analysis for OECD Countries. *Anadolu University Journal of Social Sciences*, *16*(1), 39 - 48.

Ülkü, H. (2004). *R&D, Innovation, and Economic Growth: An Empirical Analysis*. IMF Working Paper, No.04/185.

Yaylalı, M., Akan, Y., Işık, C. (2010). Türkiye'de Ar&Ge Yatırım Harcamaları ve Ekonomik Büyüme Arasındaki Eş Bütünleşme ve Nedensellik İlişkisi: 1990–2009", *Bilgi Ekonomisi ve Yönetimi Dergisi*, *5* (2).

Etik Beyanı: Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazarlar beyan eder. Aksi bir durumun tespiti halinde Fiscaoeconomia Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarlarına aittir.

Ethics Statement: The authors declare that ethical rules are followed in all preparation processes of this study. In case of detection of a contrary situation, Fiscaoeconomia has no responsibility and all responsibility belongs to the authors of the study.