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COMPARATIVE ANALYSIS OF THE RELATIONSHIP BETWEEN R&D INDICATORS AND ECONOMIC GROWTH IN THE PROCESS OF TÜRKİYE'S FULL MEMBERSHIP TO THE EUROPEAN UNION[1]

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ABSTRACT

The main purpose of this study is to comparatively analyze the existence, direction and size of the possible relationship between R&D indicators and growth as a result of innovation and R&D policies in Türkiye's EU full membership negotiation process and to test the hypothesis that there is a positive relationship between innovative R&D policies and economic growth. For this purpose, annual data for the period 2005-2021 on growth and five R&D indicators (R&D expenditures, number of researchers, number of patents, high technology exports, number of scientific publications) for Türkiye and the general average of 27 EU countries were compiled from the World Bank and Eurostat databases and their course was interpreted through figures. In addition, in accordance with the trend in applied studies, in this study, firstly, stationarity (KPSS unit root test) and cointegration (ARDL bounds test) analyses from time series analyses were performed for the variables and then the relationship between R&D indicators and growth was estimated with a multiple regression model. According to the findings, it was determined that all series for the EU and Türkiye (except $LnGSYH_t$ for Türkiye) comply with the I(1) process and there are no long-term relationships between them.

Key Words: *Türkiye, European Union, Innovation, Research and Development (R&D), Economic Growth, Stationarity Test, Cointegration Test.*

JEL Codes: *O30, O32, O40, O57.*

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1. INTRODUCTION

Innovation, which constitutes the competitive environment within the economic structure and is accepted as an important factor that determines the competitiveness of countries and enterprises, emerges as a result of R&D activities. R&D activities are the activities carried out by countries to encourage and increase innovation and technological progress, and have become an important necessity to ensure technological progress and to follow developments.

Indicators such as the number of researchers, the share of national income allocated to R&D, the number of patents, utility models and designs, high-tech exports, and the number of scientific publications are among the R&D indicators widely used in the literature. These indicators, which are used to identify and measure R&D activities, contribute to the evaluation of the innovation capacity, performance and impact of R&D activities of both countries and enterprises, and help to guide the structural decisions of countries and enterprises. In short, R&D, which constitutes the driving force of innovation and thus technological development, is considered to be one of the most important factors affecting economic growth.

Although classical economists generally treat technological developments and innovation as exogenous factors (Solow, 1956), the endogenous growth theories developed under the leadership of Schumpeter emphasized that R&D activities and technological advances, which are the fruits of these efforts, have a significant impact on economic growth (Kantarcı and Yıldırım, 2018: 668).

In the late 1980s and early 1990s, developments in the world economy and increased competition increased the interest in technological innovations. In this period, the endogenous growth model based on R&D, which is considered as the driving force of growth, was first put forward by Romer (1990). This approach was further advanced with the models developed by Grosman and Helpman and Aghion and Howitt (Taban and Şengür, 2014: 357).

On the other hand, Türkiye's accession process to the EU is a long and difficult one, spanning more than half a century. The Ankara Agreement of 1963, which entered into force with the acceptance of Türkiye's application for full membership to the European Union (then known as the European Economic Community), followed by the Türkiye-EU Customs Union Agreement of January 1, 1996 have been important milestones in this process, which has followed a bumpy course. The most important progress that brought Türkiye closer to full membership was the opening of full membership negotiations on October 3, 2005. Since then, intensive efforts have been made to harmonize Türkiye's legislation with that of the EU. Although full membership negotiations, which have been suspended from time to time, are perceived negatively for Türkiye's EU accession adventure, the reforms brought about by the negotiation process continue to be the main argument shaping domestic and foreign policy, especially economic policies.

The main objective of this study is to comparatively analyze the existence, direction and magnitude of the possible relationship between R&D indicators and growth as a result of innovation and R&D policies in Türkiye's EU integration process. In line with this objective, it is useful to present the scope and limitations of this study in terms of period, method, indicator, country, etc.

First of all, the subject of this study is the relationship between R&D indicators and economic growth. As in almost all of the studies in the literature, the dependent variable economic growth is represented by GDP. As independent variables, five of the R&D indicators (R&D expenditures as a share of GDP, number of researchers, number of scientific publications, number of patents and high technology exports) are included in the study.

On the other hand, the issue is analyzed for Türkiye and the overall 27 EU countries[2]. Each of the 27 EU member countries is not analyzed separately, but as a single country by taking into account the total values of the 27 countries for the variables in question. As a period, the years 2005-2021, from 2005, when the accession negotiations started, to 2021, have been analyzed.

As for the methodological scope of the study, in addition to interpreting trends of the annual data of the variables in question compiled from the World Bank and Eurostat databases through graphs, in this study, in line with the tradition in applied studies, firstly, stationarity (KPSS unit root test) and cointegration (ARDL bounds test) analyses from time series analyses were performed for the variables and the relationship between R&D indicators and growth was estimated with the multiple regression model.

By providing indicators that compare Türkiye's R&D performance with that of the EU, this study can provide a data-based approach to progress and monitoring processes, as well as enabling the testing of endogenous growth models. Such an analysis can both guide Türkiye's economic development policies and provide a solid basis of argument in the negotiation process with the EU.

The study consists of six main chapters. Following the introductory section where the purpose and scope of the study are stated, some of the prominent case studies in the literature are introduced and the R&D and growth structure of the EU and Türkiye in the analyzed period are presented comparatively with tables and graphs. In the applied part of the study, the methodology of the study is presented, the main findings of the empirical analyses are reported and the study is concluded with a general evaluation and recommendations.

2. LITERATURE REVIEW

Before moving on to the applied part of the study, it is understood that the studies can be evaluated from different perspectives as a result of the literature review on the subject. It has been found that some studies, whether under the name of innovation or research and development, aim to measure

[2] The United Kingdom (UK) officially left the European Union on January 31, 2020 (Brexit).

performance by sector, province, region or country (e.g. Albayrak (2015), Arlıer (2016), Bakkaloğlu (2015), Belgin and Avşar (2019), Bulut (2020), Cenikli (2021), Demir and Geyik (2014), Duman (2014), Ekinci (2021), Ersöz (2009a and 2009b), Gezer, Uzgören and Elevli (2015), Girgin and Arıoğlu (2001), Güler and Veysikarani (2018), Kavak (2009), Öner (2022), Özbek and Atik (2013), Özkan and Alancıoğlu (2017), Tahtasakal (2021), Türk (2011), Ünal and Seçilmiş (2013), Yaşar (2020), Zerenler, Türker and Şahin (2007), Zuhal and Seyhan (2021), Yiğit (2021)), while some studies examine the economic effects of R&D expenditures (such as growth, development, employment, competitiveness, relationship with tax incentives) by a single country or country groups (EU, OECD, G-7, etc.) (e.g. Çakal (2022), Çelik (2020), Eker (2011), Erdil and Pamukçu (2015), Işık and Kılınç (2011), Kardaş (2009), Kaya (2021), Seçilmiş and Konu (2019), Sezgin (2017)), and some micro-based studies analyze the effects of R&D expenditures on characteristics such as profitability and financial performance of firms (e.g. Aydıner (2014), Çıtak and İltaş (2017), Çiçekli (2019), Dedeoğlu (2018), Doğan and Yıldız (2016), Ezanoğlu (2021), Kılıç (2020), Kocamış and Güngör (2014), Ordu and Yücel (2022), Wakelin (2001), Yücel and Ahmetoğulları (2015)). On the other hand, considering the method of analysis used, it was determined that some studies applied time series analysis (e.g. Demirci (2017), Korkmaz (2010)) while others applied panel data analysis (e.g. Aytekin and Özçalık (2018), Çütçü and Bozan (2019), Kurtulmuş (2019)).

Table 1 summarizes the studies, especially the applied ones, in terms of their methodologies, which were reached as a result of the literature review conducted in line with the purpose of the study, but only some of which can be briefly introduced for the scope of the study.

Table 1. Literature Review

Study	Period	Country	Method	Relationship between R&D and Growth
Adıyaman and Hayaloğlu (2020)	1995-2018	30 developing countries	Panel data analysis	+
Ballı (2017)	1999-2014	Upper and upper-middle income countries	Panel FMOLS and panel causality test	+ R&D↔Growth
Sağlam, Egeli and Egeli (2017)	1996-2014	26 developed and developing countries	Panel data analysis	R&D→Growth
Samimi and Alerasoul (2009)	2000-2006	30 developing countries	Panel data analysis	No
Yıldırım and Kantarcı (2018)	1998-2013	15 developing countries	Panel data analysis	No
Goel and Ram (1994)	1960-1985	18 developed and 34 less developed countries	Multiple regression analysis	+
Akarsu, Alacahan and Atakişi (2020)	1996-2017	Selected 14 countries	Panel data analysis	+
Altın and Kaya (2009)	1990-2005	Türkiye	VEC model	+
Pece, Simona and Salisteanu (2015)	2000-2013	3 Central and Eastern European countries	Regression analysis	+

Kacprzyk and Doryń (2017)	1993-2011	Former EU-15 and new EU-13 countries	GMM	No
Bayraktutan and Kethudaoğlu (2017)	1996-2015	29 OECD countries	Panel data analysis	+
Börü and Çelik (2019)	2004-2016	Türkiye	Time series analysis	+
Canbay (2020a)	1990-2016	Türkiye	ARDL Bounds Test	+
Canbay (2020b)	1990-2017	Türkiye	ARDL Bounds Test	+
Çütçü and Bozan (2019)	1981-2016	G-7 countries	Panel data analysis	-
Dam and Yıldız (2016)	2000-2012	BRICS-TM countries	Panel data analysis	+
Demirgil (2021)	1990-2019	Türkiye	ARDL Bounds Test	+
Dereli and Salğar (2019)	1990-2015	Türkiye	Cointegration Analysis	R&D↔Growth
Erdemli and Çelik (2017)	1996-2014	G-7 countries and Türkiye	Panel data analysis	+
Genç and Atasoy (2010)	1997-2008	34 countries	Panel causality test	R&D→Growth
Mudronja, Jugović and Škalamera-Alilović (2019)	2005-2015	EU countries	GMM	+
Gülmez and Akpolat (2014)	2000-2010	15 EU countries and Türkiye	GMM	+
Gülmez and Yardımcıoğlu (2012)	1990-2010	21 OECD countries	Panel FMOLS and panel causality test	+ R&D↔Growth
Güneş (2019)	2000-2014	32 OECD countries	Panel causality test	R&D←Growth
İğdeli (2019)	1990-2016	Türkiye	ARDL Bounds Test	+ R&D→Growth
Tuna, Kayacan and Bektaş (2015)	1990-2013	Türkiye	Time series analysis	No
Kesikoğlu and Saraç (2017)	2010-2014	Türkiye	Time series analysis	+
Kılıç, Bayar and Özekicioğlu (2014)	1996-2011	G-8 countries	Panel data analysis	+
Korkmaz (2010)	1990-2008	Türkiye	Time series analysis	+
Külünk (2018)	1996-2016	Türkiye	Multiple regression analysis	No
Özbay, Arıcan and Oğuztürk (2021)	1986-2018	China	Cointegration Analysis	R&D↔Growth
Özcan and Arı (2014)	1990-2011	15 OECD countries	Panel data analysis	+
Özer and Çiftçi (2009)	1990-2005	OECD countries	Panel data analysis	+
Ülger and Durgun (2017)	1996-2015	4 OECD countries	VAR analysis	R&D←Growth
Pakdemirli (2020)	2003-2017	Türkiye	Granger causality test	R&D↔Growth
Maradana et al. (2017)	1989-2014	19 European countries	Granger causality test	Different from one country to another
Sarıdoğan (2019)	1995-2016	28 EU countries	Panel data analysis	+
Sungur, Aydın and Eren (2016)	1990-2013	Türkiye	Hatemi-J asymmetric causality test	R&D→Growth
Szarowská (2017)	1995-2013	20 EU countries	GMM	R&D→Growth
Türkmen, Ağır and Günay (2019)	1991-2016	20 OECD countries	Panel data analysis	+
Uçak, Kuvat and Aytekin (2018)	1990-2016	Türkiye	ARDL Bounds Test	+

In conclusion, innovation, which is the most important way to create difference and value in the globalized competitive environment, is shown as a factor that is the driving force of growth by creating added value in the economy. R&D is defined as a set of systematic studies that play an important role in the emergence of these innovations. In short, R&D activities are accepted as the cause of innovation and innovation as the cause of economic growth. When the domestic and foreign literature is evaluated in general, a significant positive causality relationship from R&D activities to economic growth has been found as a common finding of applied studies, but some studies (e.g. Samimi and Alerasoul (2009), Yıldırım and Kantarcı (2018), Kacprzyk and Doryń (2017)), albeit few in number, have found it insignificant contrary to expectations.

This study, which analyzes the possible relationship between R&D indicators and economic growth in Türkiye and the EU during the full membership negotiation process, differs from its counterparts in the literature both in terms of the period and country/country groups examined and the variables and analysis methodology used. The subject was analyzed for Turkey and the overall 27 EU countries by performing KPSS unit root test and ARDL bounds test with the data set related to the six variables for the period of 2005-2021 in the study.

3. COMPARATIVE STRUCTURAL ANALYSIS

The data on GDP and R&D indicators of Türkiye and the EU for the 2005-2021 period are presented in Table 2 and Graph 1.

Table 2. GDP and R&D Indicators of Türkiye and the EU (2005-2021)

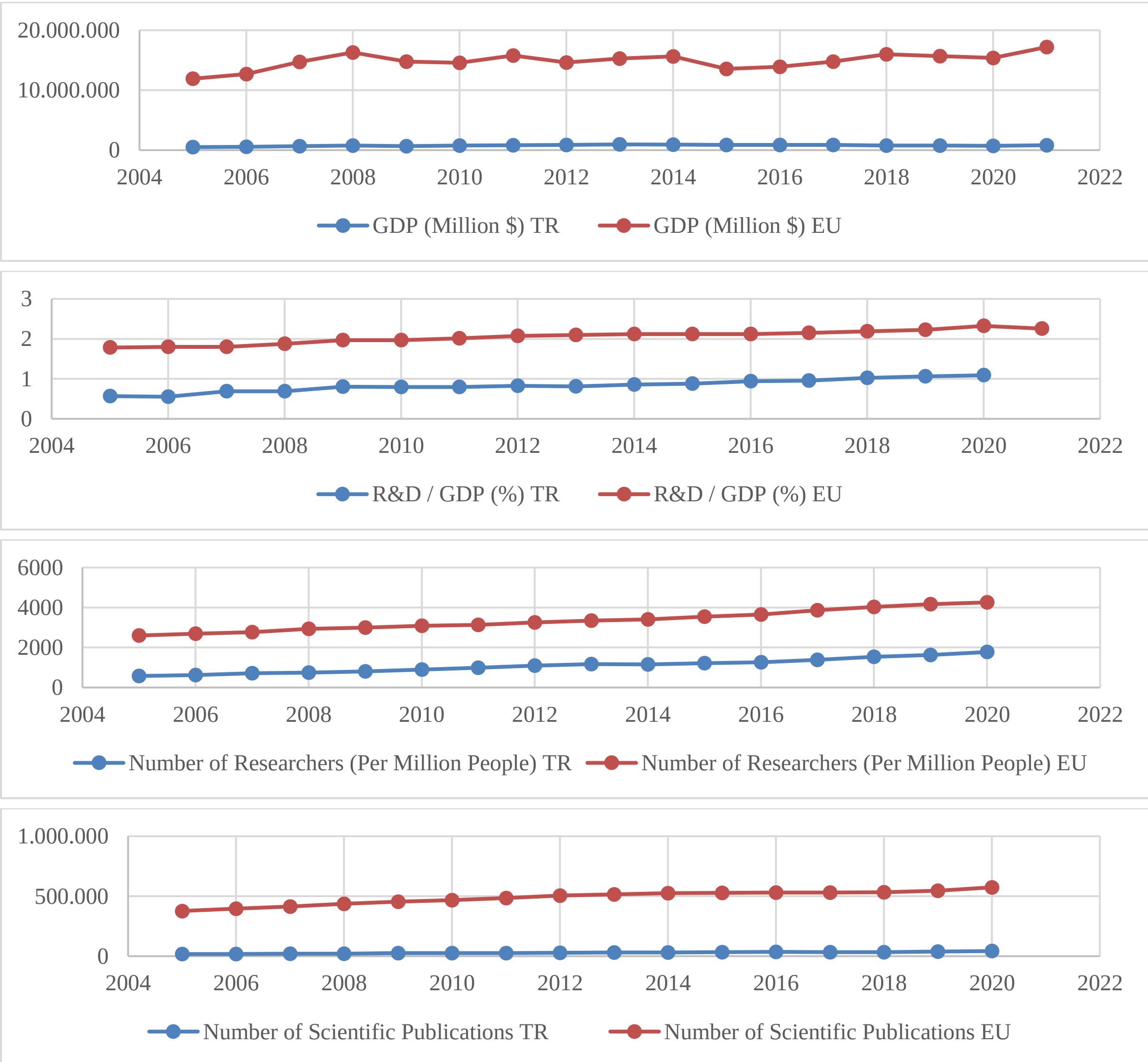
Year	GDP (Million $)		R&D / GDP (%)		Number of Researchers (Per Million People)		Number of Scientific Publications		Number of Patents (Per Million People)		High Technology Exports (Million $)	
	TR	EU	TR	EU	TR	EU	TR	EU	TR	EU	TR	EU
2005	506.315	11.910.060	0,564	1,782	576	2.601	17.795	376.954	14	124	-	-
2006	557.076	12.712.565	0,553	1,803	620	2.691	19.561	396.083	15	126	-	-
2007	681.321	14.727.376	0,686	1,797	714	2.769	21.637	414.092	26	131	1.856	561.531
2008	770.449	16.295.205	0,687	1,874	750	2.935	22.022	436.177	31	137	1.910	602.956
2009	649.289	14.762.589	0,804	1,968	810	2.991	25.022	454.295	35	130	1.569	521.112
2010	776.967	14.555.973	0,794	1,969	890	3.092	26.424	466.990	43	139	1.943	569.387
2011	838.786	15.764.817	0,794	2,016	982	3.130	27.180	485.889	52	135	2.202	639.339
2012	880.556	14.641.967	0,826	2,077	1.100	3.252	28.322	505.013	59	137	2.327	619.596
2013	957.799	15.294.848	0,812	2,097	1.173	3.346	30.326	514.498	57	138	3.782	642.204
2014	938.934	15.650.589	0,856	2,118	1.161	3.404	31.005	525.830	61	141	4.293	666.708
2015	864.314	13.553.055	0,877	2,118	1.212	3.546	32.969	529.285	67	141	3.872	607.990
2016	869.683	13.889.039	0,938	2,117	1.255	3.653	35.163	530.558	77	139	3.422	631.850
2017	858.989	14.764.669	0,953	2,153	1.379	3.858	33.240	531.716	100	143	4.069	631.089
2018	778.477	15.979.882	1,025	2,185	1.533	4.024	33.686	533.924	86	148	3.736	682.653

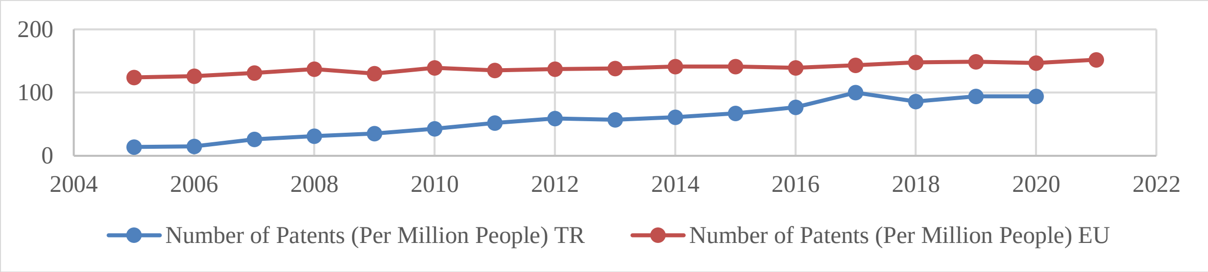
2019	759.935	15.692.625	1,064	2,224	1.624	4.171	37.430	546.474	94	149	4.280	692.283
2020	720.289	15.370.461	1,089	2,324	1.775	4.258	42.623	573.765	94	147	4.173	642.559
2021	819.034	17.187.870	-	2,260	-	-	-	-	-	152	5.715	700.717

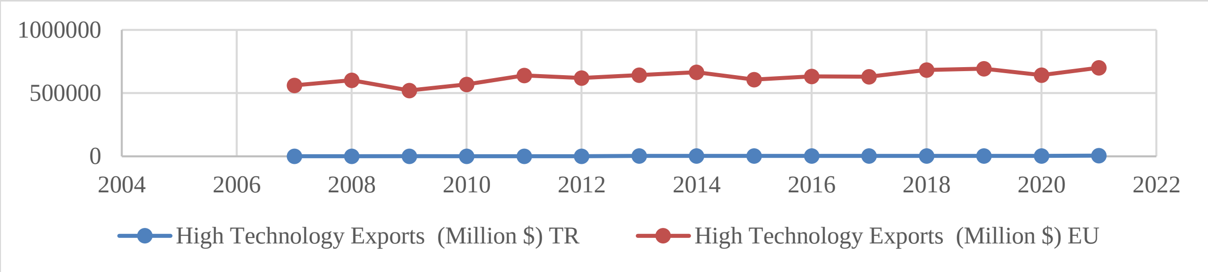
Source: World Bank and Eurostat databases.

Türkiye's GDP values show an overall increase from 2005 to 2021. However, in 2020, there seems to have been an economic contraction due to the global COVID-19 pandemic. This decline may reflect the economic effects of the pandemic. The GDP data of the EU is generally higher than that of Türkiye. There is also a decline in the EU's GDP in 2020, but this downward trend is milder than in Türkiye. In addition, the EU has a larger economic volume. The difference in GDP values between Türkiye and the EU is significant in terms of economic size.

Graph 1. R&D Indicators of Türkiye and the EU (2005-2021)







Although the EU's share of R&D expenditures in GDP is considerably higher than Türkiye's, the graph shows that the difference between them has remained almost constant over the years. In fact, in the period analyzed, the EU's share of R&D expenditures in GDP increased from 1.782% to 2.260%, while this share increased from 0.564% to 1.089% for Türkiye. While the share of R&D expenditures in GDP increased by 0.478 in the EU, it increased by 0.525 in Türkiye. This result shows that the gap is decreasing and Türkiye is giving more importance to R&D every day.

The EU has an overall higher number of researchers. This indicates that the EU has invested more in scientific research and development activities and has a great science and technology potential. When we look at Türkiye, it can be stated that the number of researchers has followed an upward trend over time. From this point of view, it can be stated that investments in science and technology are intended to be increased day by day and studies are being carried out on this situation. Considering the increase in the number of researchers in Türkiye and the EU in 2020, it can be said that the global COVID-19 pandemic has led to an increase in scientific research, especially in the fields of medicine and health.

The number of scientific publications in Türkiye and the EU has increased over time. Especially since the mid-2010s, upward trends are more evident. The increase seen in both regions in 2020 may indicate intensive work in health and science-related research during the pandemic period. In addition, the EU is advancing its scientific productivity with a continuous and sustained increase in the number of scientific publications, demonstrating that it is an important actor on a global scale. We can say that the increase in 2020 may reflect the intensity in research and studies in the field of health due to the pandemic. Between these periods, Türkiye shows that it has started to contribute more in the scientific field with an upward trend in the number of scientific publications and has the potential for the upward trend to continue. However, these increases have not reached the EU level.

The EU has a higher number of patents overall. This shows that the EU invests more in technological innovation and obtains more patents in this field. Türkiye, on the other hand, has increased its patent numbers over time. Especially by 2017, Türkiye's number of patents rose dramatically, rapidly approaching the EU's number of patents. This can be considered as a consequence of the importance attached to R&D and innovation in Türkiye and hence the increase in the share of R&D expenditures in GDP.

High-tech exports are an important indicator of a country or region's ability to sell more advanced and value-added products to other countries. In general, the EU has a significant advantage in high-tech exports. This shows that EU countries are able to sell more value-added and innovative products to world markets. In Türkiye, on the other hand, the economy has focused on more value-added and technology-intensive products and as a result, high-tech exports have increased over time. An analysis of the data in the graph shows that Türkiye's high-tech exports are well below those of the EU. However, Türkiye's improved performance in this area can be considered as an indicator of the country's economic transformation and innovation efforts.

4. METHODOLOGY

4.1. Variables, Data Set and Model

In the literature, while investigating the relationship between R&D (or innovation) and growth, it is observed that growth is represented by GDP and R&D is commonly represented by indicators such as research and development expenditures, number of researchers, number of scientific publications, number of patents, high technology exports, etc.

In this study, which aims to conduct a comparative analysis of the relationship between R&D and economic growth in the EU and Türkiye in the process of Türkiye's full membership to the EU, the gross domestic product (GDP) variable in current US dollars is used to represent growth, while research and development expenditures as a percentage of GDP, number of researchers per million people, number of scientific publications, number of patents per million people and high-tech exports variables in current US dollars are used to represent R&D. The symbols used for these variables, their expansions, units of measurement and the sources of data are presented in Table 3.

Table 3. Variables Used in the Model

Symbol	Explanation	Unit	Source
GDP	Gross Domestic Product	Current USD	World Bank
RDE	Research and Development Expenditure	% of GDP	Eurostat
NR	Number of Researchers	Per Million People	World Bank
NSP	Number of Scientific Publications	Number	World Bank
NP	Number of Patents	Per Million People	World Bank
HTE	High Technology Exports	Current USD	World Bank

As the theory suggests, improvements in R&D indicators will trigger innovation, which in turn will lead countries to outperform each other by increasing competitiveness and hence economic growth. In short, a positive relationship is expected between R&D indicators and growth.

In this study covering Türkiye's EU full membership process, the data of the variables for the period 2005-2021 are obtained from the World Bank and Eurostat databases.

As in studies that conduct time series analysis, in this study, in order to protect the series against possible heteroscedasticity and partly autocollinearity, the series are logarithmically transformed and the double logarithmic model in equation (1) is constructed.

$$LnGDP_t = \beta_0 + \beta_1 \ln RDE_t + \beta_2 \ln NR_t + \beta_3 \ln NSP_t + \beta_4 \ln NP_t + \beta_5 \ln HTE_t + \varepsilon_t \quad (1)$$

The model (where β_0 denotes the constant term of the model, the other β's denote the coefficients of the variables and ε_t denotes the error term) is estimated separately for the EU and Türkiye using EViews software.

4.2. Stationarity Analysis (Unit Root Test)

Most economic models, by their very nature, are based on time series data. The characteristics of the series of variables in these models should be known and taken into account. In order to obtain meaningful relationships between variables, the analyzed series should be stationary. Otherwise, the relationship found may be spurious (misleading) rather than reflecting the reality and the predictions made based on it may lose their validity (Tarı, 2018: 374).

In this study, before estimating the model, the stationarity of the variables in the model is tested with the Kwiatkowski, Phillips, Schmidt, Shin (KPSS) unit root test, which is one of the traditional unit root tests.

The KPSS test proposes to test the null hypothesis that an observable series is stationary around a deterministic trend (Kwiatkowski et al. 1992). Schwert (1989) argues that the power of ADF tests is weak and sensitive to the choice of lag length. According to Schwert (1989), the most important feature of the KPSS test is that unlike ADF, its power does not decrease in series with one or more moving average (MA) structures.

Unlike other conventional unit root tests, the hypotheses in the KPSS unit root test are in the form.

H_0: The series is stationary

H_1: The series is not stationary

In the second stage of the test, the KPSS test statistic ($\hat{\eta}_\mu$) is calculated as follows.

$$\hat{\eta}_\mu = T^{-2} \sum_{t=1}^{T} S_t^2 / s^2(l) \qquad t=1,\dots,T \quad (2)$$

Here $S_t = \sum_{t=1}^{T} \varepsilon_t$. The test statistic in question is also called the LM statistic because it is obtained by using the consistent estimator $(s^2(l))$ instead of $\hat{\sigma}_\varepsilon^2$ and taking into account the number of observations (T) in order to account for the possibility that the residuals (ε_i) in the Lagrange Multiplier test statistic formula ($LM = \sum_{t=1}^{T} S_t^2 / s^2(l)$) may be autocorrelated.

By comparing the critical values produced by KPSS (1992) with the test statistic value calculated from equation (2), it is decided whether the series is stationary or not. If the calculated test statistic value is greater than the critical value, the null hypothesis of 'The series does not contain a unit root, i.e. it is stationary' is rejected at the specified significance level and it is decided that the analyzed series is non-stationary.

4.3. Cointegration Analysis (ARDL Bounds Test)

One of the ways to avoid spurious regression is to use the stationarized versions of non-stationary variables by taking one or higher order differences. However, the differencing process destroys the long-run relationship between the series while stationarizing them. Therefore, in cases where the long-run relationship between non-stationary variables is analyzed, it would be more appropriate to resort to cointegration analysis (Sevüktekin and Çınar, 2014: 560).

Cointegration analysis, which suggests that even if the series of economic variables are non-stationary, a stationary linear combination of these series may exist and if so, it can be determined, is an approach that prevents the loss of information and insolubility caused by taking differences in long-run series (Tarı, 2018: 415).

These tests, which imply that there can be a stationary combination of two variables that are non-stationary at their levels, require the variables to be integrated of the same degree. This constraint, which poses an important problem in practice, is removed by the ARDL approach proposed by Peseran, Shin and Smith (2001), which allows the relationship between variables integrated of different degrees to be revealed. One of the advantages of the ARDL bounds test is that the fact that the variables to be used in the model are stationary at level I(0) or stationary at first difference I(1) does not prevent the application of the bounds test. Another advantage of this test is that it can provide statistically more reliable results than classical cointegration tests since it uses the error correction model. The most important feature of the error correction model is that it contains information about the short and long run relationship between variables (Akel and Gazel, 2014: 23-41).

The ARDL (m1,...,m6) model adapted to this study to analyze the existence of a cointegrating relationship between the variables in equation (1) with the ARDL bounds test can be written as follows.

$$\Delta LnGDP_t = \alpha_0 + \sum_{i=1}^{m1} \beta_{1i}\, \Delta LnGDP_{t-i} + \sum_{i=0}^{m2} \alpha\beta_{2i}\, \Delta LnRDE_{t-i} + \sum_{i=0}^{m3} \beta_{3i}\, \Delta LnNR_{t-i} + \sum_{i=0}^{m4} \beta_{4i}\, \Delta LnNSP_{t-i} + \sum_{i=0}^{m5} \beta_{5i}\, \Delta LnNP_{t-i} + \sum_{i=0}^{m6} \beta_{6i}\, \Delta LnHTE_{t-i} + \delta_1 LnGDP_{t-1} + \delta_2 LnRDE_{t-1} + \delta_3 LnNR_{t-1} + \delta_4 LnNSP_{t-1} + \delta_5 LnNP_{t-1} + \delta_6 LnHTE_{t-1} + \varepsilon_t \quad (3)$$

Where α_0 is the constant term, $\beta_{1i},\ldots,\beta_{6i}$ are the short-run coefficients, $\delta_1,\ldots,\delta_6$ are the long-run coefficients, $m_1,\ldots,m_6$ are the appropriate lag length for each variable, Δ is the difference operator and ε_t is the error term.

For the ARDL method, the null hypothesis that there is no cointegration relationship between the variables is H_0: $\delta_1 = \ldots = \delta_6 = 0$, while the alternative hypothesis that there is a cointegration relationship is H_1: $\delta_1 \neq \ldots \neq \delta_6 \neq 0$.

Peseran, Shin and Smith (2001) calculated the F test statistic to test the null hypothesis of 'no cointegration', but since this statistic does not fit the standard F distribution, the critical (table) values, where all variables are assumed to be stationary at level and considered as the lower bound, and the critical (table) values, where all variables are assumed to be stationary at first difference and considered as the upper bound, are generated for various significance levels (1%, 5% and 10%) as the number of observations goes to infinity. If the test statistic calculated according to this approach, known as the F-bounds test, is less than the critical lower bound value, the null hypothesis cannot be rejected and it is concluded that there is no cointegration relationship between the series. If the F test statistic is greater than the critical upper bound value, the null hypothesis is rejected and it is concluded that there is a cointegration relationship between the series. Finally, if the F test statistic is between the critical lower and upper bound values, no decision can be made on whether there is a cointegration relationship between the series (Mert and Çağlar, 2019: 282). The decision model summarizing these three cases is summarized in Table 4.

Table 4. ARDL Bounds Test Decision Model

Criterion	**Decision**	**Conclusion**
F-stat. > F-criticalupperbound	H_0 is rejected	There is cointegration
F-stat. < F-criticallowerbound	H_0 cannot be rejected	There is no cointegration
F-criticallowerbound < F-stat. < F-criticalupperbound	Indecision	?

Narayan (2005) reproduced for small samples the critical lower and upper bound values for the F-bound test produced by Peseran, Shin and Smith (2001) for large observations. Therefore, the critical values produced by Narayan are used in applications when the number of observations of the series is not very large (Mert and Çağlar, 2019: 282).

If the null hypothesis cannot be rejected, the ARDL bounds test is terminated by concluding that there is no cointegration (long-run relationship) between the variables. In case of indecision, suggestions such as using error terms for cointegration, using a different form of error correction model, changing lag lengths, applying other cointegration tests according to the stationarity degrees of the variables can be taken into consideration. If the null hypothesis of 'no cointegration' is rejected at the specified significance level and a long-run relationship between the variables is detected, the next step is to estimate the long-run coefficients.

The long-run ARDL model constructed to estimate the long-run coefficients is as follows.

$$LnGDP_t = \alpha_0 + \sum_{i=1}^{m1} \delta_{1i}\, LnGDP_{t-i} + \sum_{i=0}^{m2} \delta_{2i}\, LnRDE_{t-i} + \sum_{i=0}^{m3} \delta_{3i}\, LnNR_{t-i} + \sum_{i=0}^{m4} \delta_{4i}\, LnNSP_{t-i} + \sum_{i=0}^{m5} \delta_{5i}\, LnNP_{t-i} + \sum_{i=0}^{m6} \delta_{6i}\, LnHTE_{t-i} + \varepsilon_t \quad (4)$$

After estimating the coefficients that give the long-run relationship between the variables, the diagnostic tests of the model are examined and it is decided whether the model is appropriate or not. In addition, CUSUM and CUSUMSQ graphs can be used to analyze the stability of the variables in the model.

The error correction model in equation (5) based on ARDL can be used to determine the short-run relationships between variables.

$$\Delta LnGDP_t = \alpha_0 + \sum_{i=1}^{m1} \beta_{1i}\, \Delta LnGDP_{t-i} + \sum_{i=0}^{m2} \beta_{2i}\, \Delta LnRDE_{t-i} + \sum_{i=0}^{m3} \beta_{3i}\, \Delta LnNR_{t-i} + \sum_{i=0}^{m4} \beta_{4i}\, \Delta LnNSP_{t-i} + \sum_{i=0}^{m5} \beta_{5i}\, \Delta LnNP_{t-i} + \sum_{i=0}^{m6} \beta_{6i}\, \Delta LnHTE_{t-i} + \beta_7 ECT_{t-1} + \varepsilon_t \quad (5)$$

Here ECT_{t-1} is the error correction term and it is the one lagged value of the residuals of the model in which the long-run relationship between the variables is obtained. For this model to work, the coefficient of the error correction term, which indicates how long it takes for the shocks (disequilibrium) caused by the independent variables in the short run to stabilize in the long run, must be negative and statistically significant.

In light of all these explanations, the steps to be taken when applying the ARDL bounds test can be summarized as follows (Mert and Çağlar, 2019: 282). However, it should be noted that if the desired conditions are not met in each step and the result is not obtained, the process is not continued and alternatives such as trying different lag lengths, using different error correction models, etc. are evaluated.

- First, the null and alternative hypotheses,

H_0: There is no cointegration

H_1: There is cointegration

are established in the format.

- Appropriate unit root tests are used to determine whether the variables are *I(0)* or *I(1)* but not *I(2)* (i.e. not integrated to a degree higher than first order).

- The optimal lag length that minimizes the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) and satisfies the condition of no autocorrelation (Prob-Chi Square>α for LM) is determined.

- The F statistic value found by using the appropriate lag lengths is compared with the critical lower and upper bound values to decide whether there is a cointegration relationship.

- If there is no cointegration relationship, the analysis ends. If the null hypothesis H_0 is rejected and cointegration is concluded, the ARDL long-run model (4) and the short-run and error correction model (5) are estimated and interpreted at the last stage, thus completing the testing process.

5. EMPIRICAL FINDINGS

5.1. Descriptive Statistics

Descriptive statistics of the variables in the model for the EU and Türkiye are presented in tables.

Table 5. Descriptive Statistics of the Variables (EU)

	RDE	NR	NSP	GDP	NP	HTE
Mean	2.051783	3357.419	488846.4	1.49E+13	138.7229	6.27E+11
Median	2.096702	3298.926	509755.5	1.48E+13	138.8400	6.32E+11
Maximum	2.323580	4257.559	573765.2	1.72E+13	151.7500	7.01E+11
Minimum	1.781860	2601.231	376954.2	1.19E+13	123.5200	5.21E+11
Standard Deviation	0.165345	522.8736	58441.83	1.31E+12	7.950410	4.99E+10
Skewness	-0.285451	0.305129	-0.562318	-0.584799	-0.233575	-0.479770
Kurtosis	2.062092	1.965590	2.133474	3.117433	2.330379	2.680094
Jarque-Bera Stat.	0.853966	0.961614	1.343783	0.978740	0.472191	0.639410
Probability	0.652475	0.618284	0.510741	0.613012	0.789705	0.726363
Total	34.88031	53718.71	7821542.	2.53E+14	2358.290	9.41E+12
Observations	17	16	16	17	17	15

As can be seen from Table 5, the share of R&D expenditures in GDP in the EU during the period analyzed was 2.05% on average, with a maximum of 2.32% and a minimum of 1.78%. Looking at the mean values of the variables in the analyzed period, it is seen that the number of researchers is approximately 3,357, the number of scientific publications is 488,846, GDP is 14.9 trillion USD, the number of patents is 139 and high technology exports is 627 billion USD. Considering the distribution of the series by taking into account the Jarque-Bera statistic, it is understood that all series are normally distributed since the probability values of this statistic are greater than 0.05 significance level for all variables and therefore the null hypothesis stated as 'H_0: The series is normally distributed' cannot be rejected.

Table 6. Descriptive Statistics of the Variables (Türkiye)

	RDE	NR	NSP	GDP	NP	HTE
Mean	0.850124	1097.180	29025.37	7.78E+11	57.04477	3.28E+09
Median	0.825950	1130.504	29324.32	7.78E+11	58.12840	3.74E+09
Maximum	1.130000	1775.347	42623.31	9.58E+11	99.58603	5.72E+09
Minimum	0.552920	576.3915	17794.68	5.06E+11	13.50708	1.57E+09
Standard Deviation	0.170496	361.5095	6830.647	1.25E+11	28.17987	1.22E+09
Skewness	-0.083921	0.273840	0.105249	-0.693442	-0.005627	0.135919
Kurtosis	2.245631	2.091123	2.328259	2.808798	1.835136	2.064418
Jarque-Bera Stat.	0.423048	0.750674	0.330363	1.388337	0.904690	0.593256
Probability	0.809350	0.687058	0.847740	0.499490	0.636135	0.743321
Total	14.45211	17554.88	464405.9	1.32E+13	912.7164	4.91E+10
Observations	17	16	16	17	16	15

Similarly, Table 6 shows that while the share of R&D expenditures in GDP in Türkiye was 0.85% on average in the analyzed period, it was realized as maximum 1.13% and minimum 0.55%. Looking at the mean values of the variables in the analyzed period, it is seen that the number of researchers is approximately 1097, the number of scientific publications is 29,025, GDP is 778 billion USD, the number of patents is 57 and high technology exports is 3.28 billion USD. When the distribution of the series is analyzed by considering the Jarque-Bera statistic, it is understood that all series are normally distributed since the probability values of this statistic are greater than 0.05 significance level for all variables and therefore the null hypothesis stated as 'H_0: The series is normally distributed' cannot be rejected.

5.2. KPSS Unit Root Test Result

KPSS Unit Root Test is applied to test the stationarity of the EU and Türkiye series and the results are presented in Table 7.

Table 7. KPSS Unit Root Test Result

Variable	EU		Türkiye	
	LM Statistic	5% Critical Value	LM Statistic	5% Critical Value
LnRDE	0.528963	0.463000	0.653410	0.463000
ΔLnRDE	0.277738	0.463000*	0.140677	0.463000*
LnNR	0.638714	0.463000	0.639083	0.463000
ΔLnNR	0.101336	0.463000*	0.167529	0.463000*
LnNSP	0.612828	0.463000	0.645110	0.463000
ΔLnNSP	0.352958	0.463000*	0.170768	0.463000*
LnGDP	0.510124	0.463000	0.363339	0.463000*
ΔLnGDP	0.269225	0.463000*	0.343477	0.463000*

LnNP	0.667065	0.463000	0.608212	0.463000
ΔLnNP	0.196252	0.463000*	0.452838	0.463000*
LnHTE	0.519267	0.463000	0.544680	0.463000
ΔLnHTE	0.372505	0.463000*	0.093574	0.463000*

Note: Δ denotes difference operator, * denotes significance at 5% significance level.

As can be observed from the table, according to the unit root test results, all series of the EU have *I(1)* process, while most of the series of Türkiye are stationary at first difference, but the $LnGDP_t$ series is stationary at level *I(0)* at 0.05 level of significance. Considering the fact that the series taken as the basis of the study generally have *I(1)* process, but the $LnGDP_t$ series of Türkiye is stationary at level, it is seen that the basic condition of traditional tests such as Engle-Granger and Johansen cointegration tests, which is that the series are stationary at least at first difference and of the same order, is violated, and the ARDL Bounds Test, which can be applied regardless of whether the series are stationary at level or at first difference, is preferred to determine the cointegration relations between the variables.

5.3. ARDL Bounds Test Result

The estimation results of the unconstrained error correction model (3) are presented in Table 8 and the findings are evaluated.

Table 8. ARDL Bounds Test Result

	EU		Türkiye	
F-stat. Value	**2.861**		**0.530**	
Optimal lag length	(1,0,1,1,0,1)		(1,0,1,0,1,1)	
Significance Level	Critical Values		Critical Values	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
10%	2.26	3.35	2.26	3.35
5%	2.62	3.79	2.62	3.79
1%	3.41	4.68	2.96	4.18
Diagnostic Tests	Statistic (Prob)		Statistic (Prob)	
BG-LM Test	12.266 (0.0022)		12.705 (0.0017)	
White Test	10.461 (0.3144)		7.848 (0.5495)	
JB Test	0.452 (0.7976)		1.214 (0.5448)	

According to Table 8, which presents the results of the ARDL bounds test, it is observed that the F statistic value (2.861) calculated for the EU does not exceed the critical upper bound values at three different significance levels, but exceeds the critical lower bound values at 0.05 and 0.10 significance levels. Therefore, the null hypothesis stating that there is no long-run relationship (cointegration) between economic growth and R&D indicators cannot be rejected, and since the calculated F value is between the lower bound and upper bound values, it is not possible to comment on whether there is a cointegration relationship.

For Türkiye, the main hypothesis claiming that there is no co-integration relationship between economic growth and R&D variables for the period 2005-2021 cannot be rejected, as the calculated F statistic value does not exceed the critical upper bound values at the significance levels and is smaller than the lower bound values.

According to Table 8, which presents information on the cointegration relationships between economic growth and R&D variables, in the ARDL models for both the EU and Türkiye, the null hypothesis stating that there is no autocorrelation problem is rejected according to the BG-LM test result, the null hypothesis stating that there is no heteroskedasticity problem according to the White Test result and the null hypothesis stating that the errors are normally distributed according to the Jarque-Bera Test cannot be rejected. According to the results of the ARDL model estimated for the EU and Türkiye, no long-run relationship was found between these variables and therefore, we could not proceed to the next stages of the Bounds Test. Since we cannot proceed to the next stages of the test, the interpretation of the partial effects of R&D indicators on economic growth for the EU and Türkiye is based on the findings obtained from the estimation of model (1) with the Ordinary Least Squares (OLS) method.

5.4. Model Estimation Result

The results obtained from the estimation of the double logarithmic model (1), which was created to analyze the relationship between economic growth and R&D indicators, separately for the EU and Türkiye by using the OLS method in the EViews program are presented in Table 9.

Table 9. Model Estimation Result

Variables	**EU**				**Türkiye**			
	Coefficient	**St. Error**	**t-stat.**	**Prob**	**Coefficient**	**St. Error**	**t-stat.**	**Prob**
Constant	42.6613	4.9004	8.7056	0.0000	19.4307	2.9426	6.6033	0.0002
LnRDE	3.6911	0.6608	5.5854	0.0005	-1.9204	0.5094	-3.7699	0.0055
LnNR	-0.3599	0.2019	-1.7829	0.1125	-0.0243	0.3649	-0.0666	0.9485
LnNSP	-2.8319	0.4309	-6.5727	0.0002	0.3403	0.3611	0.9422	0.3737
LnNP	0.2512	0.4567	0.5501	0.5973	0.4975	0.1400	3.5533	0.0075
LnHTE	0.8785	0.1540	5.7043	0.0005	0.1075	0.1117	0.9619	0.3642
Test Statistics								
R^2		0.8975				0.8611		
Adjusted R^2		0.8334				0.7742		
St Error of the Estimate		0.0216				0.0548		
Sum Squared Residuals		0.0037				0.0240		
F-stat.		14.0041				9.9169		
Prob (F-stat.)		0.0009				0.0028		

When we look at the p-values of the coefficients of the variables in the model estimated with the OLS method for EU, it is understood that the p-values of the coefficients of all variables except lnNR and lnNP are less than 0.05, thus they are statistically significant at the 5% significance level. On the other hand, the p-value of the F statistic value less than α (0.001<0.05) indicates that the coefficients are jointly significant (the model in general) at the 5% significance level, while the very high R^2 value (0.897) indicates that 89.7% of the possible change in the growth rate is explained by the change in the independent variables in the model.

When the signs of the coefficients are analyzed to determine the direction of the relationship between the dependent variable and the independent variables, it is observed that the direction of the relationship between the dependent variable and all variables except lnNR and lnNSP are in line with the theoretical expectations.

If the model estimation results are to be interpreted by taking into account the coefficient sizes, it should be remembered that the coefficients in the double logarithmic model used indicate elasticities. In other words, it expresses the percentage change that a 1% change in the relevant independent variable will cause in the dependent variable. Accordingly, the elasticity of the GDP variable with respect to the R&D variable is 3.691. In other words, a 1% increase in the share of R&D expenditures in GDP will lead to a 3.691% increase in economic growth. Similarly, to interpret the other coefficients, a 1% increase in the Number of Researchers and Number of Scientific Publications variables will lead to a 0.360% and 2.832% decrease in GDP, respectively, while a 1% increase in the Number of Patents and High Technology Exports variables will lead to a 0.251% and 0.879% increase in GDP, respectively.

When we look at the p-values in the model estimated with the OLS method for Türkiye, it is understood that the p-values of the coefficients of the variables other than lnNR, lnNSP and lnHTE variables are less than 0.05, thus they are statistically significant at the 5% significance level. On the other hand, the p-value of the F statistic less than α (0.003<0.05) indicates that the coefficients are jointly significant at the 5% significance level, while the very high R^2 value (0.861) indicates that 86.1% of the possible change in the growth rate is explained by the change in the independent variables in the model.

When the signs of the coefficients are analyzed to determine the direction of the relationship between the dependent variable and the independent variables, it is observed that the direction of the relationship between the dependent variable and all variables except lnRDE and lnNR are in line with the theoretical expectations.

If the model estimation results are to be interpreted by taking into account the coefficient sizes, the elasticity of the GDP variable with respect to the R&D variable is -1.920. In other words, a 1% increase in the share of R&D expenditures in GDP will lead to a 1.920% decrease in economic growth. Similarly, to interpret the other coefficients; a 1% increase in the Number of Researchers variable will lead to a 0.024% decrease in GDP, while a 1% increase in the Number of Scientific Publications, Number of Patents and High Technology Exports variables will lead to 0.340%, 0.497% and 0.107% increase in GDP, respectively.

When the model estimation results are evaluated in general, it is expected that each of the R&D indicators included as independent variables in the model will have a positive effect on economic growth by contributing positively to innovation, technological development and thus competitiveness. However, the fact that these variables are also closely related to each other may negatively affect the results in technical terms. The fact that some results do not conform to the theoretical expectations is not unique to this study. It is possible to find similar studies in the literature such as Bozan (2019) and Özcan and Arı (2014), whose results are consistent with the results of this study.

Bozan (2019) analyzes the relationship between innovation, represented by R&D expenditures and patent applications, and economic growth in G-7 countries and finds a negative relationship between economic growth and R&D. Among many possible reasons, it is evaluated that the negative relationship between R&D and economic growth may be due to the fact that some countries are less effective in transforming R&D outputs into products compared to other countries, or that their marketing capabilities are less effective compared to other countries, or that growth is lower than in other years even if R&D expenditures are increased during crisis periods.

Analyzing the role of R&D expenditures in the economic growth process for 15 selected OECD countries, Özcan and Arı (2014) finds that R&D has a positive effect on growth for seven of these countries, while an increase in R&D expenditures unexpectedly affects growth negatively in Germany, the Netherlands, Spain and the UK.

In conclusion, the fact that the results of this and similar studies, albeit few in number, do not conform to the theoretical expectations in terms of some variables is thought to be based on reasons such as, in addition to the reasons stated above, breaks in the course of the data due to extraordinary events in the world and Türkiye during the period examined (global financial crisis, Covid-19 pandemic, Russia-Ukraine war, internal and external threats against Türkiye, etc.), differences in the methods used and the periods examined, and the possible close relationship between R&D indicators in the period examined.

6. CONCLUSION AND RECOMMENDATIONS

In this study, in a global economic system where R&D, which constitutes the driving force of innovation and technological development, is one of the most important factors affecting economic growth, the existence, direction and magnitude of the possible relationship between R&D indicators and growth in Türkiye's EU accession negotiation process are comparatively analyzed.

The literature can be evaluated from different perspectives. In fact, it has been determined that some studies aim to measure performance by sector, province, region or country, while some others examine the economic effects of R&D expenditures (such as growth, development, employment, competitiveness, relationship with tax incentives) for a single country or country groups (EU, OECD, G-7, etc.), and some micro-based studies analyze the effects of R&D expenditures on characteristics such as profitability and financial performance of firms. On the other hand, when the method of analysis used is taken into account, it is determined that some studies apply time series analysis while others apply panel data analysis.

In addition to compiling annual data on the variables analyzed from the World Bank and Eurostat databases and interpreting their trends through figures, this study, in line with the tradition in applied studies, firstly analyzes stationarity (KPSS unit root test) and cointegration (ARDL bounds test) from time series analyses for the variables and estimates the relationship between R&D indicators and growth separately for the EU and Türkiye with the double logarithmic multiple regression model.

According to the results of the KPSS unit root test, all the series of the EU have *I(1)* process and most of the series of Türkiye are stationary at first difference, while the $LnGDP_t$ series is stationary at level *I(0)* at 5% significance level. In this case, ARDL Bounds Test, which can be applied regardless of whether the series are stationary at level or at first difference, was preferred to determine the cointegration relations between the variables.

According to the results of the ARDL model estimated for the EU and Türkiye, the other stages of the Boundary Test could not be proceeded since no long-run relationship was found between these variables, and the interpretation of the partial effects of R&D indicators on economic growth was made according to the findings obtained from the estimation of the model given in equation (1) with the OLS method.

When the model estimation results are evaluated in general, it is determined that some results do not meet the theoretical expectations. The fact that the results of this and similar studies, albeit few in number, do not conform to the theoretical expectations in terms of some variables may be attributed to many technical reasons, as well as the breaks in the course of the data due to extraordinary events in the world and in Türkiye (global financial crisis, Covid-19 pandemic, Russia-Ukraine war, internal and external threats against Türkiye, etc.), the differences in the methods used and the periods examined, and the possible close relationship between R&D indicators in the period examined.

In order to analyze the possible relationship between R&D indicators and economic growth, new studies can be conducted by changing the period and country/country groups examined as well as the variables and analysis method used. Based on the findings of this study, a few suggestions can be made to shed light on future studies.

In this study, the ARDL bounds test process conducted based on the results of the KPSS unit root test was terminated on the grounds that no cointegration relationship was found according to the results of the ARDL model constructed based on the selected lag lengths. However, instead of terminating the process, alternative methods such as using a different form of the error correction model or changing the lag lengths can be used. Moreover, different unit root tests can be tried and different cointegration tests can be performed depending on the results. However, these suggestions, which cannot be implemented due to the time, volume, etc. constraints of this study, can be taken into consideration in future studies.

Again, in this study, time series analysis was conducted as if it were a single country by taking into account all 27 EU member countries. Panel data analyses can be applied by evaluating each EU country separately. On the other hand, instead of the five R&D indicators used in this study, the relationship between R&D and economic growth can be analyzed by using different numbers and different types of indicators.

Finally, the period analyzed can be extended by going back further, thus increasing the number of observations. As a result, the analysis results may be more reliable. However, in this case, it is highly probable that structural breaks may occur within the period. Accordingly, the analysis methods to be used will also differ, and test and estimation methods that take structural breaks into account will need to be used.

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Fikir veya Kavram / *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak / *Form the research hypothesis or idea*	İbrahim ÖZER Asst. Prof. Ceran Zeynep ZAFİR BAHÇEKAPILI (Ph.D.)
Tasarım / *Design*	Yöntemi, ölçeği ve deseni tasarlamak / *Designing method, scale and pattern*	İbrahim ÖZER Asst. Prof. Ceran Zeynep ZAFİR BAHÇEKAPILI (Ph.D.)
Veri Toplama ve İşleme / *Data Collecting and Processing*	Verileri toplamak, düzenlenmek ve raporlamak / *Collecting, organizing and reporting data*	İbrahim ÖZER Asst. Prof. Ceran Zeynep ZAFİR BAHÇEKAPILI (Ph.D.)
Tartışma ve Yorum / *Discussion and Interpretation*	Bulguların değerlendirilmesinde ve sonuçlandırılmasında sorumluluk almak / *Taking responsibility in evaluating and finalizing the findings*	İbrahim ÖZER Asst. Prof. Ceran Zeynep ZAFİR BAHÇEKAPILI (Ph.D.)
Literatür Taraması / *Literature Review*	Çalışma için gerekli literatürü taramak / *Review the literature required for the study*	İbrahim ÖZER Asst. Prof. Ceran Zeynep ZAFİR BAHÇEKAPILI (Ph.D.)

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