# CHAPTER 3

# ANALYSIS OF THE RELATIONSHIP BETWEEN R&D EXPENDITURE AND ECONOMIC GROWTH: COMPARISON BETWEEN DEVELOPING AND DEVELOPED COUNTRIES

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**Abstract**

In the global competitive environment, where international borders have been abolished and multilateral liberalization processes and economic cycles are experienced, a number of changes have occurred in the determinants of growth. Research and development activity (R&D) as an impulsive force of economic growth plays a leading role in the economic structures of countries. The R&D sector contributes to economic growth by creating externality via increasing returns in endogenous growth models. This study aims to test if the predictions of the R&D models are valid for developing and developed countries by using the annual data for the period 2000-2019. This study showed that R&D expenditures and the number of patents positively affected growth for both groups of countries.

**Keywords:** R&D Expenditures, Economic Growth, Panel Regression Analysis.

## 1. Introduction

Advances in science and technology have caused countries to undergo many changes in economic and social spheres. Technological developments have clear positive effects on critical matters such as streamlining human life, real income increase, productivity, increasing living standards, growth, and development. Technological advances manifest themselves as inventions and innovations created as a result of the studies depending on research and scientific knowledge (Capello & Lenzi, 2014).

One of the major challenges facing all countries regardless of their level of development is achieving sustainable economic development. Even though the factors that determine the economic growth performance of countries are wide-ranging, R&D expenditures, which constitute the fundamentals of technological progress, are thought to be a crucial determiner in terms of economic growth. The technological knowledge that is generated as a result of R&D activities permeates the whole economy and consequently, economic growth is actualized (Zerenler et al., 2007).

Looking at developed countries, it is seen that they proceed with an innovative perspective and concentrate on the infrastructure and the R&D activities required for innovation. Therefore, it is possible to note that these factors create positive effects for the countries in attaining the status of being a developed country. In the statistical indicators of these countries, the share of R&D expenditures in GDP is observed to be high. This situation confirms the hypothesis that high R&D expenditures in developed countries will produce a growth-enhancing effect. In developing countries, the infrastructure and R&D activities required for innovation are at low levels; therefore the outputs are not on a grand scale. The way for developing countries to finally become "developed" is to create a difference in the global competitive environment by presenting new products and new production methods to new markets. Developing countries can create economic value only through R&D and innovation. It is the developing countries in particular, which need to put much more emphasis on R&D and innovation in order to solve their economic problems (Karakaş & Adak, 2014). Developing countries have always been in search of ways of increasing their welfare levels. However, the different approaches adopted in these searches have been reflected in their development levels. With globalization, innovation and R&D have become concepts that determine the development levels of societies.

This study aims to analyze the impact of R&D expenditure on growth in both developing and developed countries by using panel regression analysis with data obtained from the period 2000-2019 and make comparative comments.

## 2. The Importance Of R&D Expenditures For Countries

Innovation plays an important role in increasing the production, quantity, and quality of products and services, and in the emergence of new branches of industry and new business opportunities. It has a direct impact on the growth of the economy and increasing social welfare. It helps to increase the economic resources and quality of life of individuals. Therefore innovation is both economically and socially important. A novelty introduced by a company contributes to the development of new products and production processes by creating a stimulating effect first in the relevant industry and then in the whole economy. The innovation resulting from an investment in an invention creates a “technological multiplier” effect and helps other companies to accomplish a range of novelties. R&D studies are essential in terms of ensuring the efficient, planned, and rational use of the resources available in countries. Moreover, R&D studies contribute to finding solutions to the economic and social problems of countries and to investigating their causes (Uzun Kocamış & Güngör, 2014).

New companies play an effective role in realizing technology transfer between sectors by assisting the transformation of knowledge into technological products. Therefore, the increase in R&D studies and R&D return rates will create a positive effect on technology exports and dependence on foreign sources will be diminished (Atkinson & Ezell, 2012). The increase in R&D activities helps to increase and diversify economic efficiency by enabling regional and local restructuring of the economy. The development of R&D activities creates economic value and accelerates the emergence of innovative companies. Thus, it helps to groom new entrepreneurs and to increase employment areas. Moreover, the emergence of new employment areas assists in the prevention of brain drain as well. In this respect, R&D helps to increase the welfare levels of countries by facilitating the efficient use of economic resources. All these factors, which are targeted with R&D expenditures, play an active role in increasing the competitiveness levels of countries (Yaylalı et al., 2010).

Countries have different social, political, and economic characteristics and these will affect the capacity of R&D investments to contribute to innovation and growth. Thus there are some countries that can transfer most of their R&D expenditure to innovation and economic growth, while there are others that cannot manage to transfer R&D expenditure to innovation and growth to the same degree. Education level, unemployment, demographic characteristics, as well as investment volume, are factors affecting societies because science and technological knowledge require a good education, long-term experience, and talent. The economic conditions of the country, on the other hand, will reflect the number of resources allocated to R&D investments and the extent of sectoral development (Bilbao-Osorio & Rodriguez-Peso, 2004). R&D expenditures make positive contributions to economic growth by creating a set of advantages in economic activities. These advantages are:

1- **Competitive Advantage:** The most important factor which determines the competitiveness of a country in the international arena is technological developments, hence, R&D expenditures.

2- **Attracting Foreign Capital:** The technological prowess of a country is highly essential in attracting foreign direct investments to the country and for foreign companies to make technology-oriented investments in the country.

3- **Productivity Increase:** R&D expenditures are key factors in promoting economic development by increasing productivity at the micro and macro levels. For example, due to the knowledge or technology created as a result of R&D expenditures, problems will be solved in areas such as environment, health, and economy, resulting in positive contributions to humanity.

4- **Eliminating Technological Dependence:** R&D expenditures save countries from being dependent on other countries in terms of technology (Inekwe, 2015).

R&D activities make a substantial contribution not only to the increase in production and economic performance but also to the accomplishment of social objectives. Based on these aforementioned advantages and functions of R&D expenditures, it can be said that they are the most important factors to be considered when measuring the development level of a country. For developing countries to compete in the world market and maintain their industrial assets, they need to acquire competence in technological innovation and base their competence in their R&D. Although the science is international to a certain extent, developing technology and creating R&D awareness are national concepts. As a measure of the emphasis on science and technology and development level in a country, the share of resources allocated to R&D expenditures in GDP is taken into account. If any country's ratio of R&D expenditures in its GDP is more than 2 percent, those countries are considered to be developed countries. Although technological development has gained a global dimension, technological developments are monopolized by about a mere 15-20 developed countries. These countries account for 95 percent of the R&D expenditures in the world. On the other hand, developing countries, which constitute about 70% of the world's population, make only 5 percent of total R&D expenditures (Silaghi et al., 2014).Another R&D indicator is related to R&D financing. In developing countries, R&D financing is provided by the public sector, while in developed countries this funding is provided by the private sector. While 55-70% of R&D financing is provided by the private sector in developed countries, this rate is below 50% in developing countries. Another indicator of the comparison of international R&D structure is the R&D personnel employed in the R&D sector.

Unless underdeveloped and developing countries launch intensive efforts to develop or transfer technology, the divergence between countries will continue, and these countries will not be able to converge with developed countries. The differences of technology, cost, productivity, and competitive power between developed countries and underdeveloped or developing countries are caused by insufficiencies in technological development and innovation activities, human capital and infrastructure deficiencies, financing problems, institutional and structural problems, and macroeconomic instabilities (Kılıç et al., 2011).

Moreover, the European Union has decided to formulate a new strategy to cope with the problems arising due to recent crises, intense competition, and issues emerging accordingly, with a holistic approach on behalf of unity. Within the framework of this strategy, which was announced by the European Commission in 2010, the main priorities for the purpose of establishing high employment, productivity and social cohesion are defined as follows:

- **Smart Growth:** Developing the economy based on knowledge and innovation,
- **Sustainable Growth:** Promoting a greener and more competitive economy, where resources are used effectively,
- **Inclusive Growth:** Achieving high levels of employment to ensure social and regional cohesion. The objective is to achieve the goal of allocating 3% of the GDP to R&D, to improve conditions for the private sector to invest in R&D, and to create a new indicator for monitoring innovation (Akbaş & Apar, 2010).

Economic progress and development in an economy of free markets can only be possible by producing goods and services which can penetrate international markets. Companies that tend to overlook technology investments inherent to their industry will inevitably lose their competitiveness and have to withdraw from their market. Therefore, it is inevitable for companies to attach importance to R&D. According to OECD data, more than half of the recent growth in developed economies is driven by innovation. Nowadays, the comparative advantage based on capital and natural resources has now been replaced by superiority in information and technology (Göçer, 2013).

## 3. Literature Review

The intensity and direction of the relationship between R&D and economic growth vary according to the economic structure of a country. The literature on the relationship between R&D and economic growth is dominated by the view that R&D expenditures support economic growth. However, the scale at which R&D expenditures can support economic growth is significantly affected by the efficiency of expenditures and the internal dynamics of the national economy.

**Table 1.** The literature on the relationship between R&D expenditures and economic growth.

| | | |
|---|---|---|
| Sylwester (2001) | 20 OECD countries 1980-2000 | It was concluded that there is no relationship between R&D spending and economic growth and that there is a positive relationship between industrial R&D spending and growth in the G7 countries. |
| Bassanini & Scarpetta (2001) | 21 countries 1970-1980 and 1980-1990 | They determined that a 1% increase in R&D spending increased economic growth by 0.4%. |
| Guellec & Van Pottelsberghe (2004) | 16 OECD countries 1980-1998 | They found that R&D activities are a significant determinant of the increase in productivity in the long run. |
| Ülkü (2004) | 30 countries 1981-1997 | It was concluded that there is a positive relationship between the number of patents created by the R&D sector and GDP per capita. |
| Zachariadis (2004) | 10 OECD countries 1971-1995 | It was concluded that the increase in R&D expenditures positively affected the growth rate. |
| Falk (2007) | 15 OECD countries 1970-2004 | It was concluded that R&D expenditures and the increase in high technology R&D investments had a strong and positive effect on both GDP per capita and GDP per worker. |
| Wang (2007) | 30 countries 2000-2006 | They determined that countries that use R&D expenditures effectively will have better economic performance. |
| Özer & Çiftçi (2008) | OECD countries 1990-2005 | They determined that R&D expenditures have a positive and significant impact on GDP. |
| Saraç (2009) | 10 OECD countries 1983-2004 | It was determined that R&D expenditures have a positive impact on economic growth. |
| Samimi & Alerasoul (2009) | 30 countries 2000-2006 | They determined that R&D investments do not affect economic growth, as developing countries devote few resources to R&D activities. |
| Alene (2010) | 52 countries 1970-2004 | It determined that a 1% increase in agricultural R&D expenditures would increase total productivity by about 0.20%. |
| Genç & Atasoy (2010) | 34 countries 1997-2008 | They determined that there is a causality relationship between R&D expenditures and economic growth. |

| | | |
|---|---|---|
| Horvath (2011) | 72 countries<br>1960-1992 | It determined that R&D expenditures have a positive impact on long-term growth. |
| Güloğlu & Tekin (2012) | 13 countries<br>1991-2007 | They determined that there is bi-directional causation between technological innovation and economic growth. |
| Kirankabeş & Erçakar (2012) | 31 countries<br>1997-2007 | They determined that there was a significant positive relationship between R&D expenditures and patent number and growth. |
| Eid (2012) | 17 countries<br>1981-2006 | This study found that R&D expenditures had a significant and positive effect on the increase in productivity after the year in which they were made. |
| Gülmez &Yardımcıoğlu (2012) | 21 OECD countries<br>1990-2010 | They found that there is a long-term bi-directional causality relationship between R&D expenditures and economic growth and that a 1% increase in R&D expenditures increases economic growth by 0.77%. |
| Göçer (2013) | 11 countries<br>1996-2012 | The 1% increase in R&D expenditures supported exports of high-tech products by 6.5%, exports of information and communication technologies by 0.6% and economic growth by 0.43%. |
| Doruk & Söylemezoğlu (2014) | 22 developing country<br>2000-2007 | R&D expenditures have positive effects on economic growth. |
| Özcan & Arı (2014) | 15 OECD countries<br>1990-2011 | It was concluded that R&D expenditures have a positive impact on economic growth. |
| Bozkurt (2015) | Turkey<br>1998-2013 | There was a one-way causality from GDP to R&D expenditures, but no causality from R&D to GDP. |
| Bilas et al. (2016) | EU countries<br>2003-2013 | There is a causality relationship between R&D expenditure and economic growth. |
| Blanco et. al. (2016) | USA<br>1963-2007 | R&D investment has a positive effect on economic growth. |

## 4. Econometric Analysis

### 4.1. Data

In the study, 10 developed countries and 10 developing countries were analyzed for the period between 2000 and 2019. A panel regression model was analyzed to determine the relationship between the independent variable, i.e. the ratio of R&D expenditures to GDP (R&D) and the dependent variable, i.e. growth (GRW). In addition, the number of patents (PATS) was included in the model as the control variable. The data were obtained from www.worldbank.org. Developed countries composing the sample of the study are Norway, Germany, the United Kingdom, France, Belgium, Austria, Canada, Finland, Switzerland, and Denmark. Developing countries are Turkey, Bulgaria, Romania, Malaysia, Russia, Mexico, Brazil, South Africa, Poland, and India.

### 4.2. Testing Homogeneity and Cross-Sectional Dependence

First-generation unit root tests are categorized into two as homogeneous and heterogeneous models. Levin, Lin, & Chu (2002), Breitung (2005), and Hadri (2000) tests are based on the homogeneous model assumption, while Im, Pesaran, & Shin (2003), Maddala & Wu (1999), and Choi (2001) tests are based on the heterogeneous model assumption. In this study, relationships will be determined using regression analysis. However, cointegration analysis was not to be performed since the efficiency and reliability of the unit root test to be used would vary according to the presence of heterogeneity and cross-sectional dependence, but both homogeneity and cross-sectional dependence were tested to determine the suitable test.

**Table 2.** Paseran and Yamagata (2008) homogeneity test results.

| Developed countries | | | Developing countries | | |
|---|---|---|---|---|---|
| | **Test statistics** | **p** | | **Test statistics** | **p** |
| $\tilde{\Delta}$ | 9.463 | 0.000* | $\tilde{\Delta}$ | 11.890 | 0.000* |
| $\tilde{\Delta}_{adj}$ | 10.356 | 0.002* | $\tilde{\Delta}_{adj}$ | 10.342 | 0.006* |

* Significance at 0.05 level.

As the probability values of the tests calculated in Table 2 were less than 0.05 for both country groups, $H_0$ was rejected. It was decided that the slope coefficients were not homogeneous. The first-generation Im, Pesaran & Shin (2003), Maddala & Wu (1999) and Choi (2001) tests, which were based on the assumption of heterogeneity, were used in the study. First-generation unit root tests are based on the assumption that the cross-sectional units forming the panel are independent and that all the cross-sectional units are equally affected by a shock that occurs to one of the units forming the panel. However, it is a more realistic approach that a shock to a cross-sectional unit which constitutes the panel would affect other units at different levels. In order to overcome this deficiency, second-generation unit root tests were developed to analyze stationarity by taking into account the interdependence between the cross-sectional units.

When panel data is used to test for the presence of a unit root, the cross-sectional dependence must then be tested. If the cross-sectional dependence is rejected in the panel data set, then, 1st generation unit root tests can be used. However, if there is a cross-sectional dependence in the panel data, using 2nd generation unit root tests will provide a more consistent, effective and strong estimation.

The cross-sectional dependence between the series was determined using the LM CD test developed by Pesaran (2004) and the LM adj. test, of which the deviation was corrected by Pesaran et al. (2008), and test results are presented in Table 3. Since the probability values of the test results were less than 1% and 5%, the null hypothesis (no cross-sectional dependence) was rejected and cross-sectional dependence was determined to exist between the series.

**Table 3.** Cross-sectional dependence test results.

| Cross-sectional dependence test ($H_0$: no cross-sectional dependence) | | |
|---|---|---|
| **Developed countries** | | |
| **Test** | **Test statistics** | **p** |
| LM (Breusch and Pagan (1980) | 15.982 | 0.000* |
| LM $_{adj}$ (Pesaran et al. (2008) | 22.364 | 0.000* |
| LM CD (Pesaran (2004) | 19.622 | 0.003* |
| **Developing countries** | | |
| **Test** | **Test statistics** | **p** |
| LM (Breusch and Pagan (1980) | 10.731 | 0.000* |
| LM $_{adj}$ (Pesaran et al. (2008) | 11.099 | 0.000* |
| LM CD (Pesaran (2004) | 12.534 | 0.021* |
| * Significance at 0.05 level. | | |

Since the probability values of the test results were less than 1% and 5%, the null hypothesis (no cross-sectional dependence) was rejected and cross-sectional dependence was determined to exist between the series. In this case, there is cross-sectional dependence among the countries which constitute the panel. The shock to one country affects the others.

### 4.3. Unit Root Tests

#### 4.3.1. First-Generation Unit Root Tests Results

In Table 4, the t-value and probability values at the level and first-order differences resulting from the application of 1st-generation unit root tests to panel data as constant + trend are given separately.

**Table 4.** First-generation unit root tests

| Country group | Variables | | Im, Pesaran, & Shin (2003) | Maddala & Wu (1999) | Choi (2001) |
|---|---|---|---|---|---|
| **Developed countries** | R&D | Level | -1.109(0.172) | 5.966 (0.101) | -0.877(0.214) |
| | | ∇ | -6.933(0.001)* | 34.993(0.000)* | -6.990(0.000)* |
| | GRW | Level | -0.821(0.149) | 8.251(0.250) | -1.045(0.231) |
| | | ∇ | -7.886(0.001)* | 37.369(0.000)* | -11.903(0.000)* |
| | PATS | Level | -0.923(0.251) | 8.225(0.259) | -0.887(0.132) |
| | | ∇ | 8.451(0.000)* | 39.441(0.000)* | -9.561(0.001)* |
| **Developing countries** | R&D | Level | -0.863(0.138) | 7.611(0.150) | -0.913(0.149) |
| | | ∇ | -6.790(0.000)* | 39.903(0.000)* | -11.273(0.000)* |
| | GRW | Level | -0.822(0.173) | 8.405(0.281) | -1.142(0.237) |
| | | ∇ | -7.653(0.001)* | 39.044(0.001)* | -9.962(0.002)* |
| | PATS | Level | -1.055(0.178) | 8.463(0.205) | -0.901(0.124) |
| | | ∇ | -7.563(0.000)* | 38.559(0.000)* | -8.364(0.000)* |

**Note**: ∇ represents the first-order difference, *indicates the stationary state. The deterministic specification of the tests includes constant and trend. Probability values are indicated in parentheses. Tests were made for significance at 5% level. The zero hypothesis of the tests is that the unit has a root. The optimal lag length was determined using the Schwarz information criterion.

As seen in Table 4, all variables have unit roots in their level values. However, the first difference series do not contain a unit root. Therefore, it can be observed that all variables are I(1), in other words, they are stationary for the first-order difference.

### 4.3.2. Second Generation Unit Root Test Results

In this study, the stationarity of the series was tested with CADF, which is a second-generation unit root test, since cross-sectional dependence was determined between the countries that compose the panel. In the CADF test, it was assumed that the error term consists of two parts as common to all series and specific to each series. In this model, it was assumed that cross-sectional dependence was due to the presence of an unobservable common element. The hypotheses of the test are as follows;

$H_0$: Has a unit root

$H_{1:}$ Has no unit root

For this test, the CADF statistics for each country are calculated first. These calculated values are then compared with the table values calculated by Pesaran (2006) using the Monte Carlo simulation. To determine the presence of unit root throughout the panel, the arithmetic average of the CADF statistics found for each country are taken and CIPS statistics are calculated. The calculated CIPS statistics are compared with the table values in the study of Pesaran (2007). If the resulting CIPS value is less than the critical value of the table then $H_0$ is rejected. CIPS statistics were calculated, and the results obtained are presented in Table 5.

**Table 5.** CIPS test results.

| Country group | Variables | CIPS statistics |
|---|---|---|
| **Developed countries** | R&D | -7.452* |
| | GRW | -9.881* |
| | PATS | -8.471* |
| **Developing countries** | R&D | -8.809* |
| | GRW | -9.637* |
| | PATS | -9.334* |

*Stationary series for first-order difference
**Note:** For CIPS Pesaran (2007) p 281 In Table IIc, the critical value at 5% significance level = -2.922. The number of lag was determined according to the Schwarz Information Criteria. Trend + constant model was studied.

Since the calculated CIPS statistic was greater than the table critical value, $H_0$ was accepted, and it was concluded that there was no unit root when the first-order difference was taken in the series composing the panel. In this case, the series were not stationary in the level values; they were stationary when the first-order difference was taken. Since the series were not stationary in the level values, regression analysis was performed with the first-order differences.

### 4.4. Findings and Comments on the Panel Regression Analysis

Panel data methods are performed with pooled, fixed and random effects as stated in the study by Baltagi (2005). In this research, some statistical tests are performed in order to choose between two possible estimation models. Since all variables in the models can vary between countries and times, the basic question is whether to collect the data between countries and times (pool data). Table 6 shows the results of Chow and Breusch-Pagan (BP) tests that were applied to determine which panel regression model to choose. While the $H_0$ hypothesis for the Chow test was pooled regression and $H_1$ hypothesis was the fixed effects model (FEM), the Ho hypothesis in the BP test was considered as pooled regression and $H_1$ as a random-effects model (REM).

**Table 6.** Panel regression estimation method selection test results for country groups.

| **Developed countries** | | | | **Developing countries** | | |
|---|---|---|---|---|---|---|
| **Test** | **p** | **Decision** | | **Test** | **p** | **Decision** |
| **Chow(F test)** | 0.001 | $H_1$ accepted | | **Chow(F test)** | 0.001 | $H_1$ accepted |
| **BP($\chi^2$ test)** | 0.018 | $H_1$ accepted | | **BP($\chi^2$ test)** | 0.003 | $H_1$ accepted |
| **Hausman test** | **Cross-section random** | | 0.195 | **Cross-section random** | | 0.185 |
| | **Period random** | | 0.167 | **Period random** | | 0.171 |
| | **Cross-section and period random** | | 0.132 | **Cross-section and period random** | | 0.158 |

The other stage consists of using the Hausman test to test hypotheses of $H_0$: Random effect (REM) and $H_1$: Fixed effect (FEM). As can be seen from the test results, the $H_0$ hypothesis was accepted for both countries and the REM model was decided upon. Different algorithms were tried for the analysis. The model estimation results that were obtained for developing countries by the Cross-section SUR algorithm giving the smallest total error square and the results for developed countries by the White Cross-section method were analyzed by taking the first-order difference of the variables; the results are presented in Table 7.

**Table 7.** Results of panel regression estimation for country groups

| **Panel Regression Estimation Results for Developing Countries** | | | | |
|---|---|---|---|---|
| Dependent variable: **D(GRW)**<br>Method: Cross-Section SUR (PCSE) | | | | |
| | **Coefficient** | **Std. error** | **t-statistic** | **p** |
| **D(R&D)** | 0.057 | 0.014 | 4.071 | 0.000* |
| **D(PATS)** | 0.072 | 0.025 | 2.889 | 0.028* |
| **C** | 2.128 | 0.503 | 4.230 | 0.000* |
| $R^2$ = 0.561 $F_{statistic}$ = 27.31 F(p)= 0.000 DW=1.993<br>Wooldridge autocorrelation Test (p)=0.125<br>Greene Heteroscedasticity Test (p)=0.178 | | | | |
| **Panel Regression Estimation Results for Developed Countries** | | | | |
| Dependent variable: **D(GRW)**<br>Method: White Cross-Section | | | | |
| | **Coefficient** | **Std. Error** | **t-statistic** | **p** |
| **D(R&D)** | 0.115 | 0.012 | 9.583 | 0.000* |
| **D(PATS)** | 0.092 | 0.026 | 3.538 | 0.001* |
| **C** | 3.851 | 0.483 | 7.973 | 0.000* |
| $R^2$ = 0.602 $F_{statistic}$ = 29.66 F(p)= 0.000 DW=2.104<br>Wooldridge autocorrelation Test (p)=0.193<br>Greene Heteroscedasticity Test (p)=0.245<br>*Significant variable at 0.05 level | | | | |

When Table 7 is reviewed, it can be seen that R&D and PATS variables have significant positive effects on the GRW variable for developed and developing country groups. When the coefficient values were analyzed, it was determined that the effect of the R&D variable on GRW in developed countries is twice as high as in developing countries. This situation reveals a very important difference.As a result of the hypothesis tests of the model for both country groups, it was determined that there were no autocorrelation and heteroscedasticity problems. As a result of the F test, the models were found to be significant.

**5. Conclusion**

As a result of structural changes in their economies, countries consistently increase their production, as well as the utilization of information. Today, developed countries, that create big differences in science and technology and are at the forefront of competition, allocate the largest share in their GDPs to R&D and innovation. It is of great importance for developing countries to generate technological knowledge through R&D and innovation, to increase product quality and standards, to reduce production costs, and to make their economies competitive on an international level.

In this study, 10 developed countries and 10 developing countries were taken as examples for the period between 2000 and 2019. A panel regression model was analyzed to determine the relationship of the independent variable, i.e. the ratio of R&D expenditures to GDP (R&D) and the control variable, i.e. the number of patents (PATS) with the dependent variable, i.e. growth (GRW). As a result of the analysis, it was determined that R&D and PATS variables had a significant positive effect on the GRW variable for both country groups. The effect of these two variables is two times higher for developed countries than for developing countries. Significant differences were determined between the two country groups. This confirms the hypothesis that high R&D expenditures in developed countries will help to increase growth. In developing countries, the infrastructure and R&D activities required for innovation are at low levels; therefore, the outputs are not of a grand scale.

Developing countries need to increase their due growth performance to catch up with developed countries and opt for long-term R&D investments rather than short-term solutions in order to make this performance sustainable. It should be emphasized that they should allocate more shares to R&D expenditures from their national income and make educational arrangements for training a highly skilled labor force that will realize advanced technology production. Not only the government but also the private sector should attach importance to R&D investment in the long run in order to survive and grow in globalizing and ever-growing world markets.

As a result of the study, it can be affirmed that technological innovations and existing knowledge stock can be created through R&D activities and that technological knowledge will consistently increase the economic growth rate by providing new investment and an increase in employment opportunities. It should be kept in mind that innovations created with technological knowledge will enable the increase of both physical capital and human capital and will prevent decreasing yields, therefore sustaining economic growth. It would be beneficial for developing countries to determine reliable technological progress strategies, prepare necessary institutional and physical infrastructures for this purpose, allocate more of their national incomes to R&D activities, improve their human capitals and industrial infrastructures to produce high-tech products, and provide incentives to foreign investors who can transfer technology to their countries. In these countries, establishing R&D centers and building facilities for technology development and commercialization of these technologies will positively contribute to technological progress. It may be beneficial to provide R&D investments with tax exemptions and infrastructure support to enable the private sector to have a more active role in the technology development process. The cooperation, coordination, and mutual knowledge sharing between the public and private sectors in R&D activities should be ensured, and the share of the private sector in R&D activities should be increased as much as possible.

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