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The Relationship Between R&D Expenditures and Economic Growth: Panel Data Analysis 1990-2013

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Abstract

In the world of globalization, economic growth is associated with the amount of innovation created. The expenditures on new product development thus R&D is the main factor for the economic growth of both developed and developing countries. R&D expenditures are in the center of new growth theories. The countries that produce technologically advanced products have the ability to compete internationally and show progress in production levels and qualities. The purpose of this study is to explore the relationship between R&D expenditures and economic growth using panel data analysis. As a result of the analysis, covering 15 OECD countries for the period between 1990 and 2013, a positive relationship has been determined between R&D expenditures and economic growth.

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

JEL classification: O10, O30, O40.

1. INTRODUCTION

Technological change and innovation activities are strong indicators of economic growth and productivity increase. Because of increasing competition worldwide, developing technological innovation and adapting to continuous change has become inevitable. Therefore, it's not possible for countries to realize sustainable economic growth unless they attach importance to R&D activities.

Models developed within the context of endogenous growth theory and based on R&D activities have led to a growth model that is based on human capital employed by the R&D sector, and its novel products. According to these models, continuous long term growth is based on the number of researchers assigned to this sector by the economy. It is claimed that the more economy has of these inputs, and the more it enables development of new products and technologies through the R&D sector; the higher the growth rate will be. R&D enables production of new knowledge and technologies. Novel technologies resulting from R&D activities increase productivity and contribute to economic growth. Consequently, there are many empirical studies on the significant role of technological advancement and therefore of R&D expenditures on economic growth.

The purpose of this study is to analyze the correlation between R&D expenditures and economic growth in 15 OECD countries in 1990-2013 through panel data analysis. The first section is about the theoretical framework whereby R&D expenditures and economic growth is correlated; the second section covers the development of R&D expenditures in the world and Turkey; the third section covers empirical studies about R&D expenditures and economic growth; and last section is about the empirical implementation of the study.

2. THEORETICAL LITERATURE

There is an increasing focus on innovation due to developments in the global economy and increasing competition. Within the framework of new growth models that emerged in the 1980's, endogenous growth models are based on technology and innovation created through companies' R&D efforts. In endogenous growth models based on R&D activities in particular, it has been accepted that the main driver of the continuity of growth is the R&D sector; and it's stated that inputs related to this sector should be supported. Schumpeter was the first economist underlining the positive impact on development of innovation and technological advancement, and his conceptual framework lies behind R&D activities. According to Schumpeter, innovation encompasses all kinds of changes such as manufacture of a new product, creation of a new production method, new sales methods and opening up of new markets, etc. Models based on R&D activities consist of three sectors: finished products sector, intermediate products sector, and the R&D sector. The R&D sector produces new ideas and designs by utilizing human capital. Furthermore, it also has a significant role in enabling sustainable economic growth (Schumpeter, 1970).

The neoclassical growth model deals with the relations between savings, capital accumulation and economic growth. According to the basic assumptions of the model developed by Solow (1956), the conclusion is that marginal capital productivity decreases, earnings to scale are fixed, technology is determined as an exogenous factor, and the long term or stationary state growth rate is "zero". In other words, it's accepted that the impact of government policies on long term economic growth is weak.

In the neoclassical growth model, the savings rate is directly proportional to stable capital-labor and income per capita values. In other words, a country that has relatively higher savings will be more capital intensive and richer in a stationary state compared to one with less savings. However, the increase in the savings rate does not impact the growth rate in a stationary state. As the model is expressed in decreasing productivity, when it becomes stable, the basic factor defining economic growth shall be the changes in technology and the rate of population increase. On the other hand, these two factors are not defined within the model, and are accepted to be extrinsic (Solow, 1956).

The model claims that in the long term, countries' national income levels shall converge, and the differences in development will thus spontaneously disappear. It's proposed that in this process, called the convergence hypothesis, there will be a flow of capital from rich (developed) counties to the poor (developing) countries where capital income is greater. According to this hypothesis, it's believed that in an economy where capital increases faster than labor, interest rates will fall when technology is exogenous and stable, and poor countries will grow faster than rich countries to catch up with them eventually. Here, development levels between various countries are expressed by the difference in factor endowments between countries and decreasing marginal productivity of capital.

However, studies on new growth models have shown that these hypotheses of neoclassicists together with the basic assumptions of the convergence hypothesis are not realistic, and the assumption that technology is exogenous and stable is invalid.

While neoclassical growth models accept decreasing capital returns, endogenous growth models assume that capital including human capital might have an increasing return, and this increasing return will not hinder growth in the long term (Sala-i -Martin, 1990). Contrary to the neoclassical model, if less developed countries do not take the necessary measures, the gap between them and developed countries will get even wider, and this refutes the hypothesis that countries' income levels will spontaneously converge. Technology is internalized in new growth models, and public policy mechanisms that influence economic growth are emphasized.

Endogenous growth models are developed as an alternative to the neoclassical model, and are based on the work of Romer (1986) and Lucas (1988). In Romer's model the endogenous growth theory explains technological development as intrinsic in the economic model; and explains that a side-product of investments is to increase technological knowledge, which is used as a kind of free input in other manufacturing processes, and which eventually expands all over the sector as a result of spillover. Therefore investments have a lower cost compared to neoclassical models, and their returns are higher.

In fact, Romer's study uses a concept called 'learning-by-doing' by Arrow (1962). Arrow noticed that in certain sectors as time passes production costs decrease, quality increases, and production is faster. He attributed this to accumulation of knowledge, and called it 'learning-by-doing'. Arrow claims that the contribution of the increase in production to the economy as a whole through spillover and learning-by-doing is greater than the companies' own attainments.

In endogenous growth models based on R&D activities, it's underlined that the R&D sector has a role in enabling the continuity of growth, and that inputs regarding this sector need to be supported. Although there are many studies on the subject, these models are essentially based on Paul Romer's model (1990), Grossman and Helpman's model (1991), and Aghion and Howitt's model (1992).

R&D activities have an important place in Romer's model, and human capital employed by the R&D sector as well as novel products or manufacturing techniques produced by the same industry constitute its basis. It is underlined that the economy may have not only a level effect, but also a continuous growth effect in the long term, and stated that the way to realize this is to increase R&D expenditures as well as the number of researchers (scientists, engineers, technical staff, etc.) in the country. Therefore, it's claimed that the more an economy enables development of new products and technologies, the higher its growth rate will be. New ideas based on profit-seeking R&D investments and ensuing accumulation of knowledge play an important role in such endogenous growth theories (Romer, 1990).

Another important contribution concerning growth models based on technological innovation is Grossman and Helpman's work associating economic growth with foreign trade and openness. (1989, 1990) In their studies, Grossman and Helpman defined three fundamental production activities within a multiple country, dynamic general equilibrium model; including that of conventional products, modern industrial products, and R&D efforts that lead to development of industrial products through generation of knowledge. Accordingly, products developed through technological advancement enable a comparative superiority in foreign trade, create an increase in global trade, and drive growth (Grossman and Helpman, 1989).

Less developed countries that cannot allocate sufficient resources for R&D investments may obtain the technologies they need by increasing their openness and making technology transfers from developed countries. However, technology transfers will not happen spontaneously. Incentives for technology transfers and advantages that less developed countries offer to multinational companies play a significant role in this purpose (Grossman and Helpman, 1991).

On the other hand, Aghion and Howitt developed a model in 1992, where companies depending on process innovation and using the Schumpeterian creative destruction concept make R&D expenditures to increase the quality of their existing products. Creative destruction can be defined as a process where a newly developed product makes older ones obsolete, and puts an end to the advantages manufacturers gain from monopoly (Schumpeter, 1970). In this case, the growth process includes an environment where losses are as possible as gains. In line with Schumpeter, the model assumes that individual innovations are sufficiently important to impact the economy as a whole (Aghion and Howitt, 1992).

According to the endogenous growth approach, countries aiming to increase economic growth cannot give up on R&D activities because of the positive exogenities they create. Governments may directly support the research institution; or support these activities through required legal regulations. In developing countries, the government needs to implement active policy measures to increase the knowledge stock and promote R&D (Rivera-Batiz and Romer, 1991).

3. R&D EXPENDITURES IN THE WORLD AND TURKEY

World economies face an environment of strong competition. This is not only due to competition created by globalization, but is also a result of developments in information and technology. This new competition necessitates attaching greater importance to R&D activities. R&D expenditures have a strong impact on the level of development of a country. A country's development level is measured by the scale of resources allocated for R&D expenditures.

Analysis of the development of R&D expenditures in Turkey and in the world shows a continuously increasing trend. In 1996-2013, there has been a steady increase in the share of R&D expenditures within GDP in Turkey. However, there is a significant difference between the rates of R&D expenditures in national income in Turkey and in developed countries.

Table 1: Gross Domestic Expenditure on R&D, 1996- 2013 (% of GDP)

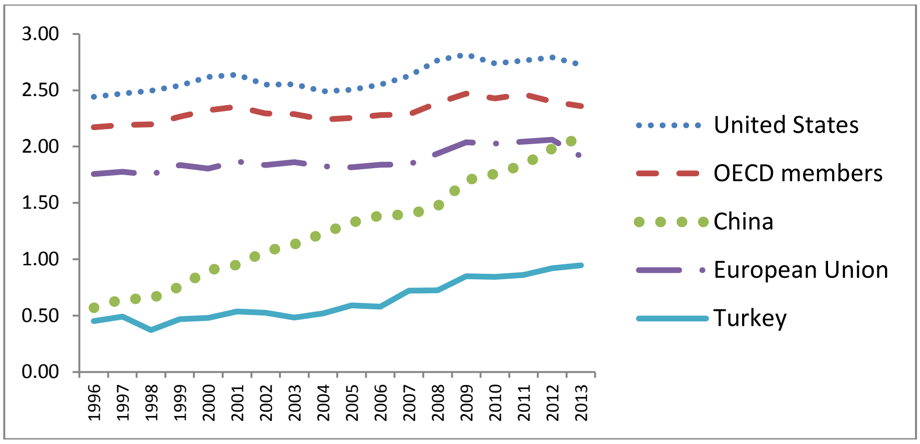
Country Name	1996	2000	2005	2010	2011	2012	2013
Korea, Rep.	2.42	2.30	2.79	3.74	4.04	4.03	4.15
Japan	2.77	3.00	3.31	3.25	3.39	3.34	3.47
Finland	2.53	3.35	3.48	3.90	3.80	3.55	3.31
Austria	1.60	1.93	2.46	2.80	2.77	2.84	2.95
Germany	2.20	2.47	2.51	2.80	2.89	2.92	2.85
United States	2.44	2.62	2.51	2.74	2.76	2.79	2.73
OECD members	2.17	2.32	2.26	2.43	2.46	2.40	2.36
France	2.27	2.15	2.11	2.24	2.25	2.26	2.23
China	0.57	0.90	1.32	1.76	1.84	1.98	2.08
Netherlands	1.98	1.94	1.90	1.86	2.03	2.16	1.98
European Union	1.76	1.81	1.82	2.03	2.04	2.06	1.91
United Kingdom	1.80	1.79	1.70	1.77	1.78	1.72	1.63
Canada	1.65	1.91	2.04	1.86	1.79	1.73	1.62
Portugal	0.56	0.73	0.78	1.59	1.52	1.50	1.37
Italy	0.98	1.04	1.09	1.26	1.25	1.27	1.26
Spain	0.81	0.91	1.12	1.40	1.36	1.30	1.24
Russian Federation	0.97	1.05	1.07	1.13	1.09	1.12	1.12
Turkey	0.45	0.48	0.59	0.84	0.86	0.92	0.95
Poland	0.65	0.64	0.57	0.74	0.76	0.90	0.87
Brazil	-	1.02	0.97	1.16	1.21	-	-
India	0.63	0.74	0.81	0.80	0.81	-	-

Source: World Bank, OECD.

According to Table 1, Turkey's R&D expenditures in 2013 were only 0.95% of the GDP. However, USA allocates 2.73% of its national income for R&D expenditures. R&D expenditures are 3.47% the national income in Japan, 2.85% in Germany, 2.23% in France, 1.63% in UK, 1.26% in Italy, 1.98% in Netherlands, 2.95% in Austria, 3.31% in Finland, and 4.15% in South Korea. Among these countries, according to 2011 data only Poland and India allocate a smaller share than Turkey for R&D.

As of 2013, the share of R&D expenditures in GDP is on the average 1.91% in the EU and 2.36% in the OECD countries; whereas Turkey lags far behind. It has been observed that from 1996 onwards China, South Korea and Japan's investments for R&D expenditures have increased significantly. Although R&D expenditures in Turkey have been increasing, these are still on a low level compared to the acceleration gained by China during this time. The rate of R&D expenditures in GDP was 0.57% in China and 0.45% in Turkey in 2016 and as of 2013 it rose to 2.08% in China, but could not yet reach 1% in Turkey (Figure 1).

Figure 1 . Gross Domestic Expenditure on R&D in The Selected Countries (% of GDP)



Source: World Bank, OECD

R&D expenditures in Turkey are made basically by the public sector, private sector, and the higher education sector. Private sector has the greatest share with 47.5% in Gross Domestic R&D Expenditures, followed by the higher education sector with 42.1%, and the public sector with 10.4%. Breakdown of R&D expenditures according to financial resources shows that in 2013 the share of the public sector was 26.6%, of the private sector 48.9%, and of the higher education sector was 20.4% (TÜİK, 2014).

As of 2013, R&D expenditures in Turkey reached 14.807 billion TL. In line with Turkey's targets for 2023, R&D expenditures are expected to increase to least 85 billion TL in order to reach 3% of GDP. The private sector in particular has a significant role to play for this end. In the process of translating R&D expenditures into high value-added products, cooperation and coordination should be established between the industry and universities. While the higher education sector educates manpower with global qualifications, the private sector needs to undertake projects supporting R&D activities (TÜBİTAK, 2011).

4. AMPIRIC LITERATURE

There have been many studies examining the relationship between R&D expenditures and economic growth with the acceptance of new growth theories on the technological change as being one of the most important factors effecting economic growth. Accordingly, results of the major empirical studies examining the relationship between R&D expenditures and economic growth are as below.

Lichtenberger (1993) examined the relationship between the private and public sector R&D expenditures and economic growth for 1964-1989 period and 74 countries. It was concluded that there was a positive and significant relationship between R&D expenditures financed by the private sector and both growth and productivity but there was no impact on public sector.

Goel and Ram (1994) has demonstrated that the elasticity of R&D expenditures related to real production is statistically significant and positive, in their study that they have explored the impact of capital, labor and R&D expenditures on real production via production function model covering 18 developed and 36 underdeveloped for 1960-1980 period.

Park (1995), in a study covering 1970-1987 period and 10 OECD countries, has reached the conclusion that the local private sector R&D investments are important determinants for the increase in local and foreign factor productivity.

Coe and Helpman (1995), in their study covering 22 countries for 1971-1990 period, have examined the relationship between R&D capital stock and total factor productivity. They have reached the conclusion that there is a significant correlation between total factor productivity and domestic and foreign R&D activities.

Freire-Serein (1999) has examined the impact of R&D spending on economic growth for 21 OECD countries during 1965-1990 period. It was concluded that there is a very strong and positive relationship between R&D expenditures and growth and 1% increase in R&D expenditures would increase real GDP by 0.08%.

Sylwester (2001), analyzed the relationship between R&D expenditures and economic growth for 20 OECD countries using multivariable regression analysis. They have concluded that there is a no positive relationship between economic growth and R&D expenditures for G20 countries but there is a positive relationship for G7 countries.

Bassanini ve Scarpetta (2001), have examined the effect of R&D expenditures on economic growth via panel data analysis in 21 OECD countries. They have found out that the effect of R&D expenditures on economic growth is positive and a 1% increase in R&D expenditures increases the economic growth rate by 0.4%.

Guellec and van Pottelsberghe (2004), in their study covering the 1980-1998 period and 16 OECD countries, have explored the impact of R&D activities of private sector, public sector and foreign companies on productivity growth. The long term results of the study suggested that each of the three R&D activities is a significant determinant of growth in productivity.

Ülku (2004), has investigated the relationship between R&D, innovation and economic growth for a total of 30 countries (20 OECD, 10 non-OECD) during the 1981-1997 period. As a result of analysis with panel data, a significant and positive relationship between GDP per capita and R&D and innovation was demonstrated for both 20 OECD countries and 10 non-OECD countries.

Yanyun and Mingqian (2004), analyzed the relationship between R&D expenditures and economic growth for 8 ASEAN (Association of South East Nations) countries and Korea, Japan and China for the period between 1994-2003 by using panel data set. According to the data obtained, there is an interactive relationship between R&D expenditures and economic growth.

Zachariadis (2004), in the study covering 10 OECD countries in 1971-1995 period, has investigated the impact of the increase in R&D expenditures on economic growth. It was concluded that increase in R&D expenditures had positive effect on productivity growth and increase in output level. The author found the evidence of a positive impact of aggregate R&D intensity on the growth rates of productivity and output.

Falk (2007), in the study covering 15 OECD countries for the years 1970-2004, has explored the relationship between R&D expenditures, investment in R&D for high-tech research and GDP per capita. As a result, they have found out that both the ratio of business enterprises' R&D expenditures to GDP and the share of R&D investment in the high-tech sector have strong positive effects on GDP per capita and GDP per hour worked in the long term.

Goel, Payne and Ram (2008), have examined the US economy for the 1953-2000 period and explored whether there is a relationship between long-term economic growth and federal and non-federal R&D expenditures. According to the results of the study, the relationship between the federal R&D expenditures and economic growth is stronger than the relationship between non-federal R&D expenditures and economic growth.

Özer ve Çiftçi (2008), in their study covering all OECD countries for 1990-2005 period, have explored the effect of R&D expenditures, number of researchers and patent numbers on GDP. It has been found out that all three variables have positive and strong impact on GDP.

Saraç (2009), has explored the relationship between R&D expenditures and economic growth in 10 OECD countries for the 1983-2004 period. It was concluded that R&D expenditures had a positive effect on economic growth.

Samimi and Alerasoul (2009) have analyzed the relationship between economic growth and R&D expenditures for 30 developing countries for the period 2000-2006 using panel data methods. A negative and meaningless relationship was found in general. Despite they concluded that there is no positive impact of R&D expenditures on growth, they underscored the need to raise R&D activities for positive impact on economic growth for developing countries such as Turkey.

Altın and Kaya (2009), in their study covering Turkey's economy from 1990 to 2005, demonstrated that in short term there is no causality neither from economic growth to R&D nor from R&D to economic growth. However, they found a positive relationship from R&D expenditures towards economic growth in long-term.

Korkmaz (2010) examined the existence of a long-term relationship between R&D activities and economic growth by Johansen Co-integration test for the period 1990-2008 in Turkey. In the results of the study, it was stated that R&D expenditures are effecting GDP both in the short term and long term positively.

Yaylalı, Akan and Işık (2010), have explored the relationship between economic growth and R&D expenditures in Turkey for 1990-2009 period with the help of Granger causality test. It was concluded that there is a one-way causal relationship from R&D expenditures towards economic growth.

Genç and Atasoy (2010), in their study covering 34 countries for 1997-2008 period, concluded that there is a causal relationship from R&D expenditures towards economic growth.

Horvath (2011), in the study where the relationship between R&D activities and long-term economic growth was explored, concluded that R&D activities have positive effect on long-term economic growth.

Güloğlu and Tekin (2012), have studied the causal relationship between R&D expenditures, innovation and economic growth in their study covering 13 OECD countries for the period 1991-2007. Bidirectional causalities between innovation and R&D expenditures, technological innovation and economic growth were demonstrated as a result of the study.

Kırankabeş and Erçakar (2012), have studied the relationship between the individual R&D expenditures, number of patent applications and economic growth for 31 EU countries covering 1997-2007. They noted existence of a significant and positive relationship between R&D expenditures and patent applications.

Gülmez and Yardımcıoğlu (2012), have studied the long term relationship between R&D expenditures and economic growth in their study covering 21 OECD countries for the period 1990-2010. According to research results, 1% increase in R&D expenditures for the majority of OECD countries, leads to 0.77% increase in economic growth in the long term.

Wang, Tiffany and Liu (2013), have analyzed the R&D expenditures in high-tech sectors and its impact on economic growth in 23 OECD countries and Taiwan for 1991-2006 period. As a result, they have found out that high tech industrial R&D expenditures have a positive and strong effect on per capita real income.

Göçer (2014), examined 11 Asia countries for 1996-2012 period via horizontal cross sectional dependency panel data analysis method. The results show that 1% increase in R&D expenditures increased high tech exports by 6.5%, information-communication technology exports by 0.6% and economic growth by 0.43%.

Inekwe (2014), examined examines the role of R&D spending on economic growth of developing economies between the period of 2000 and 2009 for 66 countries using dynamic system GMM, pooled mean group and three stage least square-GMM models. The results show that the effect of R&D spending on growth is positive for upper middle-income economies while insignificant in lower income economies.

Silaghi, Alexa, Jude and Litan (2014), explored the impact of private and public R&D expenditures on growth for 1998-2008 period in Central and Eastern European countries via GMM panel method. They have found that the impact of private R&D expenditures on growth is positive in short term but statistically not significant. However, the impact of public R&D expenditures on growth is positive and statistically significant.

Altıntaş and Mercan (2015), have studied the effect of R&D expenditures on economic growth for 21 OECD countries for 1996-2011 period using production function. They have concluded that R&D expenditures have a positive impact on economic growth, this effect is higher than capital formation and increase in labor and a 1 unit increase in R&D expenditures increases economic growth by 3.4 units.

Bozkurt (2014), has studied the relationship between R&D expenditures and economic growth in Turkey for the 1998-2013 period. It was found out that there is a unidirectional causal relationship from economic growth to GDP. The growth of GDP was estimated to increase by 0.263% if R&D shares in GDP increases by 1%.

5. ECONOMETRIC METHOD AND EVALUATION OF RESULTS

5.1. Panel Data Analysis

Panel data analysis is a method for predicting economic relationships by using horizontal cross-sectional data in a time series. In this analysis, time series and horizontal cross-sectional series are gathered to create a data set that has both time, and cross-sectional dimensions (Greene, 2003).

In order to create a panel data set, T observations in N economic units should be reviewed together. In these studies values for any one year represent the panel's cross-sectional dimension; and values of economic units per year show the time dimension. Consequently, there is a time series corresponding to every economic unit. In general, a panel data model can be expresses as follows:

$$Y_{it} = \alpha_{it} + \beta X_{it} + \varepsilon_{it}$$

Here i denotes the units in the cross section (i = 1,…, N), and t denotes time (t =1,…, T). In this equation there is an individual effect that does not change according to time but includes characteristics of cross-sections. Various characteristics of units are included in the error term (Baltagi,2005).

Panel data analysis offers certain advantages compared to other methods. Panel data sets include greater variability compared to time series and cross-sectional data analyses, and therefore have less problems with multiple connections. Furthermore, they have the information that the cross sections they include are heterogenous; therefore the data set is controlled against heterogeneity. Because the number of observations is relatively high, the degree of freedom in predicted models is higher. It also permits analysis in cases where the time series is short, or cross-sectional observations are insufficient (Baltagi,2005).

In general, panel data models might be grouped in two as Classical Models (Pooled Models) where the constant and slope does not change; and models where the constant and/or slope is variable. Models where constants change according to units and/or time and slopes are fixed are generally used in analysis. Models where the constant changes only due to units or time are called unilateral models; and models where the constant changes both according to units and to time are called bilateral models. Unilateral and bilateral panel data models can be grouped as Fixed Effects Models and Random Effects Models (Tatoğlu, 2012)

Fixed effects model creates a different constant for every horizontal cross-section. In this model, it is assumed that slopes do not change, however constants vary only between time data or among both data. If there's a differentiation in panel data according to both time and the cross-section, these are called bilateral fixed effects models. If the differentiation is only due to time, unilateral fixed effects model is valid. However, panel data analyses are mostly unilateral, as most of the time the research is about the cross-sectional effect rather than the time effect (Hsiao, 2002).

In the random effects model, changes due to cross-sections or time are included in the model as a component of the error term. The advantage of this model compared to the fixed effects model is that in these models, there is no loss of the degree of freedom. Furthermore, random effects models also enable effects outside the sample to be included in the model (Greene, 2003).

5.2. Data and Model

Panel data analysis is frequently used in econometric research. This method has many advantages over only time series or cross sections. Therefore, in this study panel data analysis has been preferred to explain the relationship between R&D expenditures and economic growth, and the following model has been constructed:

$$LnGDP_{it} = \alpha_{it} + \beta \ Ln \ RD_{it} + \varepsilon_{it}$$

where GDP is the dependent variable, R&D expenditures (RD) is the independent variable, and ε_{it} is the error term.

It was thought that benefiting from a single source of data to be used in the model will give healthier and realistic results. Therefore, World Bank data were utilized in terms of compliance to each other. Additionally, the data graphs were examined and logarithmic use of all variables were decided. The model was set up based on the R&D expenditures and GDP data for 1990-2013 period and 15 countries. Countries included in the analysis were as follows, respectively: Russia, Finland, France, Germany, Spain, USA, Italy, Japan, Netherlands, Austria, Poland, United Kingdom, Turkey, Canada and Portugal.

5.3. Panel Data Analysis Results and Discussion

Primarily an LR test was conducted to determine the presence of unit and time impact for the appropriate panel data model selection on R&D expenditures and GDP data covering 1990-2013 period.

The test statistics probability value is 0.00 (LR Test=618,71 (0.000)) < 0.05 for unit and time impact, thus hypothesis H_0: $\sigma_\mu = \sigma_\lambda = 0$ is rejected, hypothesis H_1: $\sigma_\mu \neq \sigma_\lambda \neq 0$ has been accepted and one of either unit and/or time effects are valid within the model. According to the the LR test statistics, the zero hypothesis indicating non existence of unit effect ($H_{0:}$ σ_μ=0) is rejected, thus the unit effect will take place in the model. Also, it was concluded that according to the LR test statistics, the zero hypothesis indicating non existence of time effect ($H_{0:}$ σ_μ=0) is accepted, thus the time effect will not take place in the model. After testing for the presence of unit and time effects in the model, Hausman Test was used to choose from Fixed Effects Model or Random Effects Model.

Hausman test method is based on the examination of correlation between specific error term of units and explanatory variables and it is used to determine the existence of the correlation between explanatory variables and unit effects. In the test, zero hypothesis denotes that there is no correlation between independent variables and the unit effects whereas the alternative hypothesis denotes that there is a correlation. In the test statistics if the zero hypothesis is rejected, Fixed Effects Model is preferred. If the zero hypothesis is accepted, Random Effects Model is preferred (Hausman, 1978).

Table 2: Hausman Test Model Determination Results

Coefficients	**(b)**	**(B)**	**(b-B)**	**Sqrt (diag/U_b-U_β)**
RD	**Fixed Effect**	**Random Effect**	**Difference**	**S.E.**
	0,613487	0,6274509	-0,0139639	0,002775
Hausman Test	25,32 (0,000)			

Here Hausman test statistic is tested according to the hypothesis Ho: Random Effects Model and H1: Fixed Effects Model. As seen in the Table 2, probability value of zero hypothesis stating random effects takes place is less than 5%. Thus this implies the rejection of the zero hypothesis and acceptance of the alternative hypothesis. Accordingly, Unidirectional (Unit Effects) Fixed Effects Model was chosen. Results are as follows in Table 3.

Table 3: Fixed Effects Model Resuls

Dependent Variable (GDP)	**Coefficient**	**Standard Error**	**Test Statistics**	**Probability Value**
RD	0,613487	0,0151181	40,58	0,000
Constant	13,16249	0,353356	37,25	0,000
R^2	0,8272			
Ftest	F (14,344) = 153,32 (0,000)			

Preferred model has to be tested whether it tests the econometric assumptions. Therefore, tests have been conducted to review the existence of heteroscedasticity, autocorrelation and cross correlation between units.

Table 4 : Testing Deviation From The Assumptions

Dependent V ariable (GDP)	**Coefficient**	**Standard Error**	**Test Statistics**	**Probability Value**
RD	0,613487	0,0151181	40,58	0,000
Constant	13,16249	0,353356	37,25	0,000
Ftest	F(14,344) = 153,32 (0,000)			
Wald Test	Chi2(15) = 10630,99 (0,000)			
Bhargava Durbin Watson	0,021260357			
Baltagi-WuLBI	0,49012374			

The existence of heteroscedasticity problem in the model was tested via Modified Wald Test. As can be seen in Table 4, Wald Test probability ratio was less than 5%, thus zero hypothesis of constant variance is rejected and heteroscedasticity is accepted to take place in the model.

Autocorrelation is an important issue in the panel data analysis like in the all time series analysis. As known, one of the main assumptions of regression analysis is there is no correlation between errors of different observations. If the error terms are associated with one another, this is called autocorrelation or serial correlation (Tatoğlu, 2012). Bhargava Durbin Watson Test and Baltagi-Wu Locally Best Invariant Test were used to test to the autocorrelation in the error term.

Bhargava Durbin Watson Test and Baltagi-Wu Locally Best Invariant Test does not have a critical value that the test statistic can be compared. However, if test statistics is below 2 this is interpreted as autocorrelation is important (Tatoğlu, 2012). According to the test statistics in Table 4, it is seen that both the test statistics are less than 2. Therefore, an autocorrelation problem may be noted in the error term.

As a result, it was understood that due to autocorrelation, heteroscedasticity and correlation, the standard errors that has lost the effectiveness should be corrected. As known, the deviation from three assumptions affects the parameter non-deviation leaves standard errors biased, so it is sufficient only to correct standard errors by avoiding modifications of estimated parameters. Driscoll-Kraay standard errors are also resistant to three problems.

Table 5 : The Final Model With Corrected Deviations From The Assumptions

Dependent Variable (GDP)	Coefficient	Standard Error	Test Statistics	Probability Value
RD	0,613487	0,048524	12,64	0,000
Constant	13,16249	1,137657	11,57	0,000
R^2	0,8272			
Ftest	159,84 (0,000)			

According to the final model results with the corrected assumptions in Table 5, the explanatory power of independent variable on dependent variable is approximately 83%. So, 83% of the variation in GDP can be explained by changes in R&D expenditures in the regression model. The impact of independent variable on economic growth equation took place in line with expectations. Besides, it is seen that variables are statistically significant. According to the findings obtained from the analysis, there is a positive relationship between R&D expenditure and economic growth. It has been determined that an increase in R&D expenditures by 1%, increases GDP by approximately 0.61%.

Table 6: Determinants of Economic Growth and Countries

Dependent Variable (GDP)	Coefficient	Standard Error	Test Statistics	Probability Value
Russia	0.8303229	0.02983	27.84	0.000
Finland	0.4640476	0.0179555	25.84	0.000
France	1.06674	0.0704496	15.14	0.000
Germany	0.5360611	0.0394392	13.59	0.000
Spain	0.4947765	0.0201695	24.53	0.000
USA	0.8168871	0.0308787	26.45	0.000
Italy	0.5312239	0.0806439	6.59	0.000
Japan	0.4823705	0.0289503	16.66	0.000
Netherlands	0.986708	0.0631271	15.63	0.000
Austria	0.3782348	0.0084054	45.00	0.000
Poland	0.6272366	0.1045929	6.00	0.000
United Kingdom	1.272507	0.0717919	17.72	0.000
Turkey	0.5530386	0.019517	28.34	0.000
Canada	0.6964529	0.043612	15.97	0.000
Portugal	0.2636111	0.0276475	9.53	0.000

The Table 6 shows that the coefficients are meaningful in explaining the dependent variable for all countries. It is also noteworthy that the coefficients of France, Netherlands and United Kingdom are estimated higher compared to the rest of the countries and their effect on dependent variable is high. According to these results supporting our hypothesis, R&D expenditures positively affect the economic growth. These results are also supporting the R&D based growth models defined within endogenous growth theories.

6. CONCLUSION

Globalization in the world and increasing international trade and technological developments has increased countries' competitive power. Technological innovations play an active role in economic growth. R&D activities are the major drivers of innovation.

In endogenous growth theories, relations between R&D expenditures and economic growth have been the subject of numerous studies and analysis. Because of the significant role over economic growth of R&D expenditures in particular, many countries have started to allocate a higher share for R&D investments. Attaching greater importance to R&D expenditures has increased the competitive powers of companies and countries in the international market, and contributed to countries attaining their target of sustainable economic growth.

In this study, relations between R&D and economic growth in 1990-2013 have been tested through panel data analysis. The results are in line with the assumptions stipulated by economic growth models based on R&D activities that are developed within the context of endogenous growth theories. It's deduced that in order for developing countries to achieve a high and sustainable rate of economic growth and close the development gap between themselves and developed countries, they need to allocate a greater share of national income for

R&D. According to the study including 15 OECD countries, the impact of R&D expenditures on economic growth is found be positive and statistically significant. It has also been found that increase in R&D expenditures by 1% leads to an average increase of 0.61% in the economic growth.

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