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R&D Expenditures-Innovation Relationship: Panel Data Analysis for Selected Countries

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Abstract

In the study, the concept of innovation, which is an important phenomenon in the process of economic growth and development, has been analyzed. This study aims to reveal the relationship between innovation, which is an important factor in economic development and growth, and research and development expenditures. In the study, an econometric model was established in order to determine the effect of research and development expenditures on innovation. In this model, the number of domestic patent applications was taken to represent innovation as the dependent variable. As independent variables; R&D expenditures and gross capital data were used. Panel data analysis was conducted for the sample of 35 countries, covering the period 2000-2019. The country sample was formed from among the top 49 countries whose data is available in the 2022 global innovation index ranking.

In the analysis, it has been concluded that R&D expenditures have a significant positive effect on innovation. The gross capital variable, on the other hand, negatively affects the patent variable, which represents innovation. In the study, it was concluded that R&D expenditures have a significant positive effect on innovation. In order to increase innovation, countries should first allocate more resources to research and development activities.

Keywords: Innovation, R&D, Panel Data Analysis

Ar-Ge Harcamaları-İnovasyon İlişkisi: Seçilmiş Ülkeler için Panel Veri Analizi

Öz

Çalışmada ekonomik büyüme ve kalkınma sürecinde önemli bir olgu olan inovasyon kavramı analiz edilmiştir. Bu çalışma, günümüzde ekonomik kalkınma ve büyümede oldukça önem kazanan bir faktör olan inovasyon ile araştırma geliştirme harcamalarının arasındaki ilişkiyi ortaya koymayı amaçlamaktadır. Çalışmada araştırma geliştirme harcamalarının inovasyon üzerindeki etkisini belirleyebilmek amacıyla ekonometrik bir model oluşturulmuştur. Bu modelde bağımlı değişken olarak yerli patent başvuru sayıları inovasyonu temsil etmek için kullanılmıştır. Bağımsız değişkenler olarak ise; Ar-Ge harcamaları ve brüt sermaye verileri kullanılmıştır. 35 ülke örneklemi için 2000-2019 dönemini içeren panel veri analizi yapılmıştır. Ülke örneklemi, 2022 küresel inovasyon endeksi sıralamasında verilerine erişilebilmesi mümkün olan ilk 49 ülke arasından oluşturulmuştur.

Analizde Ar-Ge harcamalarının inovasyonu önemli ölçüde pozitif yönde etkilediği sonucuna ulaşılmıştır. Brüt sermaye değişkeni ise inovasyonu temsil eden patent değişkenini negatif yönde etkilemektedir. Çalışmada inovasyon üzerinde Ar-Ge harcamalarının pozitif yönde önemli bir etkisinin olduğu neticesine varılmıştır. İnovasyonu arttırmak için ülkeler öncelikli olarak araştırma geliştirme faaliyetlerine daha fazla kaynak ayırmalıdırlar.

Anahtar Kelimeler: İnovasyon, Ar-Ge, Panel Veri Analizi

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Introduction

Today, innovation has an important place in economic development and growth. The importance of obtaining, disseminating, and applying knowledge significantly impacts economic development. Knowledge accumulation is seen as the driving force behind economic development and growth. Both developed and developing countries have to improve their innovation levels and adopt sensible innovation policies to maintain economic growth and development and rise competitiveness. Countries notice the driving force of economic growth and development of innovation develop, implement policies that support innovation in this framework. Today, R&D activities are becoming more critical and seen as a policy element. In addition, R&D activities are necessary for innovations to emerge.

Governments should support research and development. Businesses' use of new technology products should be encouraged by methods such as tax deductions (Şahin, 2012). Furthermore, European policymakers should devote more resources to R&D and industrial robot production if they do not want to lose their export position and reduce people's welfare in the coming years (Şahin & Kutluay Şahin, 2020).

The study aims to analyze the impact of R&D spendings and gross capital on innovation and develop policy recommendations in the direction. For this purpose, firstly, the theoretical background related to innovation is included in the study, and afterward, empirical studies in the literature are examined. Finally, after reviewing academic information and empirical literature analyses, an econometric model was set to determine the factors affecting this creation and performed panel data analysis. This study analyzes the factors that determine innovation for 2000-2019 within 35 country samples. For this purpose, the number of domestic patent applications is a dependent variable; R&D expenditures and gross capital formation were taken as independent variables, and an econometric model was established. In this context, the working differs from previous workings in the literature in terms of sample size, explanatory variables, and the time interval it covers.

1. Literature Review

1.1. Theoretical Literature Review

The concept of innovation was widely used from the 16th century to the 19th century. However, Joseph Schumpeter was the first to use innovation in the modern sense of valuable and creative change (Morck & Yeung, 2001). Schumpeter (1939) defines innovation as the emergence of a new production function and accepts the production function as the change in the output amount caused by the difference in the factors of production. However, for innovation to be made, a change in the structure of the production function must occur instead of a change in aspects. For example, this may be with the emergence of recent goods or with this realization of changes such as a unique organizational situation in a merger or opening new markets. Therefore, innovation refers to new combination levels or new combinations of production factors.

Schumpeter defined the concept of innovation as "creative destruction" in 1942. The creative destruction process begins when innovative firms bring new products and technologies to the economy; it results in the extinction of existing companies due to their inability to adapt to the unique situation. Schumpeter mainly examined the effects of innovation on firms. It can take a long time to understand whether an innovation is disruptive or not (Schumpeter, 1942). Schumpeter (1942), the concept of innovation as follows:

- To create a new product or a higher quality product,
- Developing a new production method,
- Finding new markets for the product,
- Using a new search or raw material,
- Establishing a new industrialization system.

According to Schumpeter, a product that will enter the market goes through three phases: Invention, innovation, and diffusion. Sometimes the first two or all three processes together are defined as the innovation process. These phases are (Oğuztürk, 2003):

1. Invention; is carried out by scientists and is the process of discovering a new technical discipline.

2. Innovation; is the process of commercializing an invention and is carried out by the entrepreneur.

3. Diffusion; the spread of innovation in commercial use.

One of the most widely accepted definitions of innovation is the definition made by the Organization for Economic Cooperation and Development (OECD) and the Statistical Office of the European Union (Eurostat). The innovation concept is defined by OECD-Eurostat (2005) as the acquisition of recent or advanced goods or stage, new organizational method, or new marketing method in external relations, workplace organizations, or internal applications. Different classifications are made in the category of innovation types in the literature. The study of OECD and Eurostat (2005) is critical in evaluating the concept of innovation. OECD makes classification based on private sector and firm. Innovations; are classified according to their fields as marketing, process, product, and organizational innovation (OECD & Eurostat, 2005).

Classical economists stated that with factors such as division of labor and technological development, productivity would increase and affect economic growth, but they considered technological development external. In neoclassical theory, technological change is divided into two as included and not included, according to whether technology is included in the factors of production. If a technological change occurs due to new aspects of production such as unused machinery new skilled labor, it is contained in technological development. If productivity increases over time, given the existing production and input level factors, this is also an uncontained technological change. Solow's growth model shows that long-run per capita growth results from technological change. The source of technological change is determined by non-model factors and is external. Although the neoclassical growth theory is insufficient to explain the source of technology, it has drawn attention to the fact that the only source of growth, in the long run, is technological development. Therefore it is emphasized that it is essential to focus on the development of technology (Turanlı & Sarıdoğan, 2010).

Solow (1956) cited technological development as the primary source of economic growth. Solow (1957) is essential in that it is the first study in which technological development is included in the modeling process in the Neo-classical approach. With this study, Solow could not go beyond certain assumptions and internalize the technological development, but it guided the investigations that followed. Solow (1957) examined the changes in per capita output by adding technical change to the model, unlike previous studies. According to Solow, a shift in the short-run production function indicates technological change. In addition, accelerations, decelerations, improvements, and all similar changes in workforce training are defined as technical changes. While any movement on the production function shows that there is no technological change, the shift of the production function as a whole denotes that there is a technical change.

Solow (1957) added the technical change for the US economy, including the period 1909-1949, to the model as a function of time. In the model, analysis was made using the assumptions that the return to scale is constant, technical change is neutral, and the marginal products determine the rate of use of the factors of production. As a result of the analysis, it was found that approximately 87% of the growth rate in the USA was due to technological change, not the increase in capital and labor goods. In other words, it is claimed that one-eighth of the said increase is due to the change in capital, while seven-eighths of it is expected to technological change. In addition, it was found that the production function shifted upwards on average 1.5 units per year, which means an average of 1.5% growth per year in that period.

Joseph A. Schumpeter made the first systematic and detailed analysis of innovation and development. According to Schumpeter (1939), the process that begins with all the effects of the invention and the responses given by the economic system is called economic evolution. Therefore, innovation emerges when the operating structure of production is diversified, not the number of production factors. Hence, Schumpeter expressed creation as a new production function. This includes finding a new organizational structure or new markets and creating a new product in addition to similar situations.

1.2. Empirical Literature Review

According to the literature, the work done by Jaffe in 1989 is the first work on innovation. However, this study aims to reveal the university-private sector relationship. Jaffe (1989) used eight years of data, namely 1972-1977, 1979, and 1981, to study the US economy. It has been researched how university research and private sector R&D investments affect the innovation process by dividing the sectors into sub-sectors as pharmaceuticals, chemistry, and electricity. In the working, it was found that there is a favorable relation between university research with innovation. While this relationship is statistically stronger on innovations in the pharmaceutical industry, this effect is weaker in the electricity and chemical industries compared to the pharmaceutical industry. According to the analysis consequences, the rise in university research leads to an rise in sectoral research and development investments, thus increasing innovation production.

Studies on the determinants of innovation were mainly carried out after 2000. Porter and Stern (2000) took the number of patents as the explained variable to represent innovation. Explanatory variables are regional patent stock, the number of scientists and engineers working full-time, patent stock, exports, population, patent stock per capita, GDP, imports, world patent stock, workforce, capital, and total factor productivity. They analyzed 17 OECD member countries in the 1973-1993 period with the panel data method. As a result of the analysis, they found that innovation was positively related to human capital and national knowledge stock in the R&D sector. In addition, they concluded that innovation is negatively related to foreign information sources (exports, imports).

Popp (2001) took the number of patents as the disclosed variable representing innovation. Public research and development expenditures, information stock, and energy prices were used as explanatory variables and analyzed with the simple double logarithmic regression econometric method. As a result of the study, it was concluded that both energy prices and the quality of available information have strong and significant positive effects on innovation.

Furman, Porter, and Stern (2002) contributed to the empirical identification of explainers of innovation. First, they developed the concept of national innovation capacity to measure innovation. The strength of the infrastructure required for creation and the power of the relationship between the general innovation infrastructure formed in industrial clusters in countries and specific groups constitute the basis of this concept. Starting from this, they conducted empirical research on the country-level determinants of international patents. Accordingly, variables such as research and development workforce and expenditures, intellectual property rights, being open to global trade, and this proportion of search conducted by academic institutions with paid for by the private sector characterize this production function for international patents. In addition, the study states that patent efficiency is based on the knowledge stock of all countries. They also observed convergence of innovation capacity in OECD countries.

Zachariades (2003) used the data of the 1963-1988 period in the US manufacturing industry and the patent numbers as the explained variable within the scope of Schumpeterian endogenous growth theories; research and development intensity, output growth rate per employee, and productivity growth rate were taken as independent variables and used panel data analysis method. The equations established to estimate a system of three equations implied by the R&D-driven growth model relate R&D intensity to patenting, patenting to technological progress, and technological progress to economic growth. As a result of the study, it was found that R&D intensity positively affects patent rates and the patent rate has a positive effect on technological development. In addition, in the study that associates technological development with economic growth, it was concluded that there is a positive relationship between technological development and economic growth rate.

Jaumotte and Pain (2005), in the study examining the relation between patents with research and development expenditures, took the amount of patents as this explained changeable with the previous values of patent data, private-sector research and development costs, public sector research and development expenditures, the age range of 25-64, population data are used as explanatory variables. In addition, they made a regression analysis for 19 OECD countries with the data of the years 1986-2000. As a consequence of the working, a positive relation was determined between population with R&D spendings and patents. Furthermore, it was concluded that private-sector research and development expenditures were more effective on innovation than public sector research and development expenditures. The main reason public sector R&D expenditures have less impact on innovation than private-sector R&D expenditures is that the public sector does not have commercial concerns. However, the effect of public sector research and development expenditure on patents may differ from country to country according to the qualifications of the country's public research institutions.

Hu and Mathews (2005) conducted a regression analysis by taking the examples of East Asian countries with the 1975-2000 period annual data on the determinants of national innovation capacity. While patent numbers are used as the variable explained in the analysis, as explanatory variables; R&D expenditures, GDP per capita, intellectual property rights, frequency of antitrust policies, population, percentage of privately funded R&D, the total number of scientists and engineers employed, capital, market ratio, international investments and trade openness, the strength of the venture capital market, the workforce, the proportion of higher education expenditures to GDP, specialization and the number of publications of academic journals were used. As a result of the study, it was found that intellectual property rights protection had negative effects on innovation. In addition, it has been concluded that R&D expenditures made by the private sector, human capital employed in R&D and industrial specialization are positively related to innovation.

Schneider (2005) used the number of patents as the explained variable to determine the factors affecting innovation. Electricity production, human capital stock, patent protection index, import rate of high-tech goods from improved countries, FDI, research and development expenditures, and GDP variables were explanatory variables. In addition, panel data analysis was performed. In this analysis covering the period, 1970-1990 for the examples of 19 developed countries and 28 developing countries, improved countries and emergent countries were modeled separately, and it was possible to compare the factors determining innovation between the two country groups. In the analysis findings, market size, research and development, infrastructure variables, human capital stock, and high technology imports positively affect innovation in both improved countries and emergent countries; however, this power of influencing varies in-country groups. While human capital stock, R&D expenditures, and high technology imports are the main factors affecting innovation in developed countries, it has been found that infrastructure variables and market size are the main variables affecting innovation in developing countries. In addition, while the variables of intellectual property rights and foreign direct investments positively affect innovation in developed countries, the variable of intellectual property rights has negatively affected innovation in developing countries, and the variable of foreign direct investments has been statistically insignificant.

Lebel (2008) created the innovation index as the dependent variable representing innovation. The study covers 103 countries from different geographical regions between 1980-2005. The study aims to determine the effects of public policies on innovation. The independent variables in the model are the ratio of national savings to GDP, the proportion of foreign direct investments to GDP, the balance of exports and imports to GDP, scientific publications per capita, real interest rate, corruption index, and political, financial, economic and environmental country risk index. In the working, panel data analysis was applied to estimate this model. This innovation index reflecting the average impact of R&D and patents has been developed in the study due to reasons such as the number of patents and the low rate of monitoring of R&D spending, especially in developing countries, the inaccessibility of the required amount of information on patents, and the delayed effect of patents. In the study scientific publications were used to represent R&D and net royalties (copyright payments) to represent patents. In analysis, it has been concluded that the level of commercial dependence and the national savings rate is effective determinants of innovation.

Mercan et al. (2011) analyzed the relationship between patent acceptance as an innovation indicator, entrepreneur rates, number of researchers, and R&D activities. The panel data analysis method was used in the test. As a consequence of the test, the t-statistic of the entrepreneurship variable is meaningless, indicating that entrepreneurship does not affect innovation. Research and development expenditures made by the private sector and higher education positively affect the number of patents. In contrast, the direction of the relationship between research and development expenditures made by the public sector and the number of patents is negative. While the number of researchers working in the public sector and higher education positively affects the patents, the number of private sector researchers affects negatively. This has shown that the efficiency of innovation activities in the private sector can be expressed by the ratio allocated to R&D more than the number of working researchers.

Güloğlu and Tekin (2012) analyzed the relation between R&D spending, innovation, and economic growth using GMM and panel VAR methods from 1991 to 2007 in high-income OECD countries. In analysis, it has been concluded that R&D investments cause technological change. In addition, it has been determined that technological change also increases economic growth.

2. Data

Data of 35 countries (Austria, Australia, Belgium, Bulgaria, Canada, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Israel, Japan, Korea Rep., Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey, UK, USA) were used in the analysis. The data are chosen from the first 49 countries whose data can be accessed in the 2022 global innovation index ranking.

The study aims to analyze the impacts of R&D spendings and gross capital on innovation. In the working, data covers this period from 2000 to 2019. Therefore, annual data were used in the working. In addition, patent applications, research and development expenditure, and gross fixed capital formation data were taken from the World Development Indicators.

3. Methodology

The panel data method can be described as gathering cross-sectional investigations such as firms, states, and households within a specific period. The panel data analysis method is frequently used in innovation, a convergence of growth, purchasing power parity, and international R&D diffusion by using countries' data mutually (Baltagi, 2005; Hsiao, 2003).

The panel data analysis method in innovation analysis is used more, especially in developing countries, because statistical data do not date back long (Hsiao, 2003). Thus, this method becomes useful as it can solve the problems of data shortage, a large number of country samples, and total time intervals (Baltagi, 2005).

There are two types of panel data analysis, unbalanced and balanced. In balanced analysis, the data should include a time series of equal length in all sections, while in unbalanced panel data, the length of the time series should vary in all sections (Uncu, 2009). In addition, panel data regression can be estimated based on slope coefficient, constant coefficient, and error term assumptions (Gujarati, 2006).

Panel data models are divided into random effects and fixed effects models. If the units are chosen randomly, the random effects model is used. In the random effects model, since the units are chosen randomly, the differences between the units are also random. In addition, the degree of freedom problem seen in the fixed effects model does not occur in this model. The sample panel data model is as follows (Baldemir & Keskiner, 2004):

$$Y_{it}=\beta_{1it} + \beta_{2it} X_{2it} + \beta_{3it} X_{3it} + e_{it} \tag{1}$$

i= 1,2, ..., n ve t=1,2, ... , n

$\beta_{1it} = \beta_1 \quad \beta_{2it} = \beta_2 \quad \beta_{3it} = \beta_3$

In this model, the only variable that changes is the constant parameter. This difference in the constant term is relative to the cross section. When both time and cross-section are evaluated, the model is as follows:

$$Y_i = x_1\beta_{1j} + X_N\beta_s + e \quad (2)$$

The random effects model is the result of the sampling process and this process works as follows (Gujarati, 2006):

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + u_{it} \quad (3)$$

If we add β_{1i} to the model as a random variable, not a constant it can be modeled as $\beta_{1i} = \beta_1 + \varepsilon i$ i: 1,2, ..., N

$$Y_{it} = \beta_1 + \beta_2 X_{2it} + \beta_3 X_{3it} + \varepsilon_{it} + u_{it} \quad (4)$$

$$Y_{it} = \beta_1 + \beta_2 X_{2it} + \beta_3 X_{3it} + w_{it} \quad (5)$$

In this equation $w_{it} = \varepsilon_{it} + u_{it}$

u_{it}, due to the union of the cross section and the time series is the specific error term that occurs. ε_{it}, is the cross-section-specific error component. w_{it}, is an error component consisting of two components.

Panel unit root tests are divided into first and second-generation tests. First generation panel unit root tests are based on the assumption that there is no correlation between units. On the other hand, the main feature of the second generation panel unit root tests is that they are based on the assumption that there is a correlation between the series belonging to the units (Yerdelen Tatoğlu, 2012).

Panel data unit root tests are divided into first and second-generation tests. Before the panel unit root test is performed, whether there is a relationship between the horizontal sections that make up the panel should be checked. While there is no relationship between cross-section units in the first generation tests, it is assumed that they are related to each other in the second generation tests (Bektaş, 2017).

First-generation panel unit root tests assume no cross-sectional dependence in cross-section units. However, since countries are related to each other, the assumption that there is a cross-section dependency between cross-sectional units and those other countries are affected at different levels by a shock in one country is seen as a more rational approach. Therefore, second-generation panel unit root tests have been developed considering cross-sectional dependence between cross-sectional units (Mercan, 2014).

Pesaran panel unit root test, one of the second generation panel unit root tests, suggested a simple method to eliminate the correlation between units. The extended version of the ADF regression with delayed cross-sectional means is used, and the first difference of this regression eliminates the correlation between units. This is also called CADF (Yerdelen Tatoğlu, 2012). Westerlund panel cointegration tests were conducted to investigate whether there is a long-term relationship between the variables.

Westerlund (2007) proposed four-panel cointegration tests based on an error correction model to test cointegration's existence while working with panel data. The basis of these tests is to test the existence of cointegration by deciding whether each unit has its error correction. Features of Westerlund panel cointegration tests are as follows:

- It is based on four statistics. These tests are pretty flexible. It allows heterogeneity in the error correction model's short and long-run parameters.

- It allows unbalanced panel with unequal series lengths in units.

- If there is a possibility of inter-unit correlation, the resistant critical values can be obtained due to self-inference.

After determining a long-term relationship between the variables as a result of the panel cointegration test, the Panel Dynamic Least Squares (DOLS) estimation method was used to estimate the long-term parameters.

The DOLS method is a parametric approach that eliminates the autocorrelation problem by adding delayed first differences to the model (Breitung, 2005). DOLS method provides solid and consistent estimations when there is endogeneity and autocorrelation in the independent variables (Esteve & Requena, 2006).

Within the framework of the variables used in the study, the DOLS model is as follows:

$$P_{it} = \propto_{it} + \beta_1 \, ln R_{it} + \beta_2 \, ln C_{it} + \sum \beta_1{}^{A} \, \Delta R_{i,t-1} + \sum \beta_2{}^{B} \, \Delta C_{i,t-1} + \varepsilon_{it} \qquad (6)$$

P: Patent applications R: Research and development C: Gross capital formation

4. Empirical Results

In the study, panel data analysis covers the period of 2000-2019. The dependent variable fp in the study represents innovation. The independent variable fr represents R&D expenditures, and fc represents gross capital formation.

In this study, the panel data method was used. In the first stage, the cross-section dependency test was conducted. Then, since dependency was detected between cross-sections, the second generation panel unit root test and the Westerlund cointegration test have been applied. Finally, the DOLS estimator was used in the study.

Table 1: Cross-section Dependency Test

Tests	Statistic	P-value
LM	1096	0.0000
LM adj	28.88	0.0000
LM CD	7.755	0.0000

Reference: Own calculations, using Stata.

Cross-section independence can not accepted. In other words, there is a cross-section dependency because p-values are lower than the critical value (0,05) (Table 1). For this reason, a second-generation unit root test was applied to determine stability.

Table 2: Pesaran Second Generation Unit Root Test

Variables	CIPS	%10	%5	%1
lnP	-1.984	-2.03	-2.11	-2.25
ΔP	-4.351	-2.03	-2.11	-2.25
lnR	-2.141	-2.03	-2.11	-2.25
ΔR	-3.492	-2.03	-2.11	-2.25
lnC	-1.858	-2.03	-2.11	-2.25
ΔC	-3.226	-2.03	-2.11	-2.25

Δ: The first difference

Reference: Own calculations, using Stata.

The Pesaran second-generation unit root test was applied to determine the stability of the variables, and ΔP, ΔR, ΔC are stable in the CIPS test (Table 2).

In addition, the long-run relationship between variables has been investigated. Westerlund ECM Cointegration estimated the existence of a long-run relationship between the variables.

Table 3: Westerlund Cointegration Test Results

lnP-lnR				lnP-lnC			
Statistic	**Value**	**z-value**	**p-value**	**Statistic**	**Value**	**z-value**	**p-value**
Gt	-2.644	-5.666	0.000	Gt	-2.151	-2.381	0.009
Ga	-9.617	-2.637	0.004	Ga	-7.989	-0.860	0.195
Pt	-6.276	2.416	0.992	Pt	-13.407	-4.623	0.000
Pa	-3.275	1.394	0.918	Pa	-8.165	-4.911	0.000

Reference: Own calculations, using Stata.

According to the Westerlund cointegration test, it has been determined that there is a long-term relationship between the variables (Table 3).

Table 4: DOLS Results

ΔP	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
ΔR	0.5352134	0.10789	4.96	0.000	0.3237406	0.7466861
ΔC	-0.389360	0.09187	-4.24	0.000	-0.5694245	-0.2092964
Prob > chi2	0.0000		Wald value	32.18		

Reference: Own calculations, using Stata.

Prob > chi2 indicates the significance of the model. If, prob > chi2 value < 0.05, the model is significant. The wald value expresses the significance of the variables in the model. If the wald value is > 2, it is understood that the variables should be included in the model. According to the estimation results, a one-unit increase in R&D expenditures increases the number of patents by 0.53 units in the long run. Furthermore, a one-unit increase in gross capital reduces the number of patents by 0.38 units in the long run (Table 4).

This result coincides with Romer's (1990) theory, which argues that the importance of R&D in the innovation process and the positive externalities that occur are due to investments in the R&D sector. According to Romer, economic growth results from technological changes brought about by investors who want to maximize their profits.

5. Conclusion

The phenomenon of innovation has become an essential factor in economic growth and development. This study has been analyzed how and to what extent R&D and gross capital factors affect innovation. Today, R&D activities are becoming more critical and seen as a policy element. In addition, R&D activities are necessary for innovations to emerge. Since R&D is an essential input in innovation production, it is included in the model as an independent variable. The gross capital formation was included in the study to measure the effect of total investment expenditures on innovation as a variable representing fixed capital stock. The coefficients of the long-term cointegration relationship between the variables were investigated with the DOLS method.

According to the analysis results, R&D expenditures have a significant and positive effect on innovation. This result supports the results of the studies of Jaumotte and Pain (2005), Schneider (2005) and Güloğlu and Tekin (2012) which indicate that there is a positive relationship between research and development expenditures and patents in the literature. And also this result coincides with Romer's theory, which argues that the importance of R&D in the innovation process and the positive externalities are due to investments in the R&D sector. According to Romer, economic growth results from technological changes brought about by investors who want to maximize their profits.

In the study, it was concluded that the most influential factor on innovation is R&D expenditures. To increase innovation, countries should first allocate more resources to R&D activities in this context. Governments should make long-term R&D investments to maintain their growth performance. In the long term, the public and private sectors should attach importance to R&D investments to sustain their existence in the globalizing world. With the increase of R&D and thus innovation, new companies that can produce high technology emerge. In addition, the rise in R&D activities increases the technology export rate and reduces foreign dependency. Innovation should be created in areas with high added value. Thus, countries will gain global competitiveness, ensuring sustainable economic growth in the long run.

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Genişletilmiş Özet

İnovasyon, günümüzde ekonomik gelişme ve büyümede önemli bir konuma sahiptir. Hem gelişmiş hem de gelişmekte olan ülkeler, ekonomik büyüme ve gelişmeyi sürdürebilmek ve rekabet edebilirliği artırmak için inovasyona önem vermelidirler. İnovasyonun gelişmesinin itici gücünün farkında olan ülkeler, bu çerçevede inovasyonu destekleyen politikalar geliştirmekte ve uygulamaktadır. İnovasyonların ortaya çıkması için gerekli olan araştırma geliştirme faaliyetleri, günümüzde daha da önemli hale gelmekte ve bir politika öğesi olarak görülmektedir.

İnovasyon kavramı 16. yüzyıldan 19. yüzyıla kadar yaygın olarak kullanılmasına rağmen, inovasyonun yaratıcı ve yararlı değişim anlamını ifade eden modern kullanımı ilk defa Schumpeter tarafından yapılmıştır (Morck & Yeung, 2001). 1939 yılında Schumpeter tarafından inovasyon, yeni üretim fonksiyonunun meydana gelmesi şeklinde tanımlamaktadır. Ayrıca üretim fonksiyonu bu üretim faktörlerindeki farklılaşmanın çıktı miktarında oluşturacağı değişme şeklinde kabul edilmektedir. İnovasyon kabul edilebilmesi için üretim fonksiyonunun yapısına ilişkin bir değişikliğin olması gerekmektedir. Bu süreç yeni ürün meydana gelmesi ile de olabilir bunun yanında birleşme biçiminde organizasyonel farklı bir durum ya da farklı piyasalar açılması gibi değişikliklerle de meydana gelebilir. Dolayısıyla inovasyon, üretim faktörlerindeki yeni oluşum seviyelerini veya yeni kombinasyonları kastetmektedir.

Schumpeter, 1942 yılında inovasyon olgusunu "yaratıcı yıkım" şeklinde tanımlamıştır. Yaratıcı yıkım olarak adlandırılan süreç, yenilikçi firmaların yeni ürün ve teknolojiler getirmesi ile başlayıp; var olan firmaların yeni düzene uyum sağlayamamaları sebebi ile ortadan kalkmaları ile neticelenmektedir. Schumpeter, genellikle inovasyonun firmalar kapsamındaki etkileri bazında incelemeler yapmıştır. Bir inovasyon yıkıcı mı değil mi bunu fark edebilmek uzun bir süreç alabilmektedir. Schumpeter kavram olarak inovasyonu; yeni ya da daha yüksek kalitede bir ürün yaratmak, üretimde farklı bir yöntem geliştirmek, ürüne yeni pazarlar keşfedilmesi, yeni bir hammadde ya da ara malını üretim sürecinde kullanmak ve sanayileşmede yeni bir sistem kurmak şeklinde tanımlamıştır (Schumpeter, 1942). İnovasyon kavramının tanımı ile ilgili genel kabul gören tanımlardan biri OECD ve Eurostat tarafından yapılmıştır. İnovasyon; dış ilişkiler, işyeri organizasyonları ya da firma içindeki uygulamalarda farklı veya ileri seviyede geliştirilmiş olan farklı bir ürün veya aşama, yeni bir organizasyonel method ya da farklı bir pazarlama methodunun elde edilmesi olarak ifade edilmiştir (OECD ve Eurostat, 2005: 50). Ampirik literatür incelendiğinde ise 1989 yılında Jaffe tarafından yapılan çalışma ilk çalışma olup; inovasyonu belirleyen faktörlere yönelik çalışmalar ağırlıklı olarak 2000 yılından sonra yapılmıştır.

Bu çalışma, araştırma geliştirme harcamaları ve brüt sermayenin inovasyon üzerindeki etkisini analiz etmeyi amaçlamaktadır. Bu amaçla çalışmada öncelikle inovasyon ile ilgili teorik altyapıya yer verilmiştir. Literatürde yer alan hem teorik hem de ampirik çalışmaların ardından çalışma amacı doğrultusunda ekonometrik bir model kurulmuştur. Modelde; yerli patent başvuru sayısı bağımlı değişken olup; araştırma geliştirme harcamaları ve brüt sermaye oluşumu bağımsız değişkenler olarak alınmıştır. Çalışmada veriler 2000-2019 yıllarını kapsamaktadır ve yıllık veriler kullanılmıştır. Bu çalışmada 35 ülkenin verileri (Avusturya, Avustralya, Belçika, Bulgaristan, Kanada, Hırvatistan, Estonya, Danimarka, Çekya, Almanya, Fransa, Finlandiya, İzlanda, Macaristan, Yunanistan, Hindistan, Japonya, İsrail, Kore Cumhuriyeti, Litvanya, Letonya, Yeni Zelanda, Hollanda, Lüksemburg, Portekiz, Polonya, Norveç, Romanya, İsveç, İspanya, Slovakya, ABD, İngiltere, İsviçre, Türkiye) analizde kullanılmıştır. Ülke örneklemi, 2022 küresel inovasyon endeksi sıralamasında verilerine erişilebilen ilk 49 ülkeden seçilmiştir. Bu bağlamda çalışma, literatürdeki önceki çalışmalardan örneklem büyüklüğü, açıklayıcı değişkenler ve kapsadığı zaman aralığı açısından farklılık göstermektedir.

Panel veri yöntemi firmalar, ülkeler, haneler gibi kesitsel gözlemlerin belirli bir süre içerisinde toplanması olarak tanımlanabilir. Panel veri analizi yöntemi, ülke verilerinin karşılıklı olarak kullanılarak inovasyon, ekonomik büyümenin yakınsaması, satın alma gücü paritesi ve uluslararası araştırma geliştirmenin yayılması gibi konularda sık olarak kullanılmaktadır (Baltagi, 2005; Hsiao, 2003). Panel veriye ilişkin modeller; rastsal ve sabit etkiler modeli olarak iki gruba ayrılır. Birimler rastsal şekilde seçildiler ise model olarak rastsal etkiler kullanılmakta ve bu modelde birimler arasında ortaya çıkan farklılıklar da rastsal olarak oluşmaktadır. Bunun yanında sabit etkiler de var olan serbestlik derecesi sorunu bu modelde oluşmamaktadır (Baldemir & Keskiner, 2004).

Panel birim kök testleri birinci nesil ile ikinci nesil testler şeklinde iki grupta sınıflandırılmaktadır. Birim kök testlerinden birinci nesil olan testler, birimler arasında korelasyonun olmadığı varsayımını içermektedir. İkinci nesil olan testlerin temel niteliği de birimlere ilişkin serilerin arasında bir korelasyon bulunduğu varsayımına dayalı olmalarıdır (Yerdelen Tatoğlu, 2012). Birinci nesil panel birim kök testleri, yatay kesitin her bir biriminde yatay kesit bağımlılığı bulunmadığını varsayar. Fakat, ülkeler birbiriyle ilişki içerisinde bulunduğundan, yatay kesite ilşkin birimler arasında yatay kesit bağımlılığının bulunduğu ve bir ülkedeki bir şok neticesinde diğer ülkelerin farklı düzeylerde etkilenmesi ihtimali daha akılcı bir yaklaşım gibi benimsenmektedir. Bu nedenle, yatay kesite ilişkin birimler arasındaki yatay kesit bağımlılığı dikkate alınarak ikinci nesil olan testler oluşturulmuştur (Mercan, 2014). Panel birim kök testlerinden ikinci nesil testlerden biri olan Pesaran birim kök testi, birimler arasındaki korelasyonu yok etmek amacı ile bir method önermiştir. Gecikmeli kesit ortalamalı ADF regresyonunun genişletilmiş versiyonu kullanılır ve bu regresyonun birinci farkı, birimlerin arasındaki korelasyonu ortadan kaldırır. Buna CADF de denir (Yerdelen Tatoğlu, 2012).

İnovasyon olgusu, ekonomik büyüme ve kalkınmada temel bir faktör haline gelmiştir. Bu çalışmada araştırma geliştirme ve brüt sermaye faktörlerinin inovasyonu nasıl ve ne ölçüde etkilediği analiz edilmiştir. Günümüzde araştırma geliştirme faaliyetleri gitgide önemli hale gelmekte ve bir politika öğesi olarak kabul edilmektedir. Bunun yanında inovasyonların ortaya çıkması amacıyla araştırma geliştirme faaliyetleri gereklidir. Araştırma geliştirme, inovasyon üretiminde önemli bir girdi olması sebebi ile modelde bağımsız bir değişken olarak yer almıştır. Brüt sermaye oluşumu, sabit sermaye stokunu temsil eden bir değişken olarak toplam yatırım harcamalarının inovasyon üzerindeki etkisini ölçmek için çalışmaya dâhil edilmiştir. Çalışmadaki bağımlı değişken fp inovasyonu temsil etmektedir. Bağımsız değişken fr, Ar-Ge harcamalarını, fc ise brüt sermaye oluşumunu temsil etmektedir. Bu çalışmada method olarak panel veri yöntemi kullanılmıştır. İlk önce yatay kesite ilişkin bağımlılık testi uygulanmıştır. Yatay kesit bağımlılığının olup olmadığı araştırılırken p değeri kritik değerden (0,05) küçük olması sebebi ile yatay kesit bağımlılığı olduğu bulunmuştur. Daha sonra yatay kesit bağımlılığı bulunduğundan ikinci nesil birim kök testi uygulanmıştır. Değişkenlerin durağanlığını belirlemek için Pesaran ikinci nesil birim kök testi uygulanmış olup, CIPS testinde ΔP, ΔR, ΔC durağan bulunmuştur. Değişkenlerin arasında uzun dönem içerisinde bir ilişki olup olmadığını analiz etmek için Westerlund panel eşbütünleşme testleri yapılmıştır. Panel eşbütünleşme testi neticesinde değişkenlerin arasında uzun dönemli bir ilişki belirlendikten sonra, eşbütünleşme ilişkisinin katsayılarını tahmin etmek için Panel Dinamik En Küçük Kareler (DOLS) tahmin yöntemi kullanılmıştır.

DOLS yöntemi, modele gecikmeli birinci farklar ekleyerek otokorelasyon problemini ortadan kaldıran parametrik bir yaklaşımdır (Breitung, 2005). Tahmin sonuçlarına göre, araştırma geliştirme harcamalarındaki bir birimlik artış, uzun dönemde patent sayısını 0,53 birim artırmaktadır. Ayrıca brüt sermayedeki bir birimlik artış, uzun dönemde patent sayısını 0,38 birim azaltmaktadır. Analiz sonuçlarına göre, araştırma geliştirme harcamalarının inovasyon üzerinde anlamlı ve pozitif bir etkisi vardır. Bu sonuç Jaumotte ve Pain (2005), Schneider (2005) ve Güloğlu ve Tekin'in (2012) literatürde yer alan araştırma geliştirme harcamaları ile patentler arasında pozitif bir ilişki olduğunu gösteren çalışmaların sonuçlarını destekler niteliktedir. Ayrıca araştırma geliştirme harcamalarındaki artışın inovasyon üzerinde pozitif yönlü önemli bir etkisinin olması sonucu Romer'in (1990) inovasyon sürecinde araştırma geliştirmenin öneminin ve ortaya çıkan pozitif dışsallıkların araştırma geliştirme sektörüne yapılan yatırımlardan kaynaklandığını savunan teorisi ile bağdaşmaktadır. Romer'e göre iktisadi büyüme, kârlarını maksimize etmek isteğinde olan yatırımcıların getirdiği teknolojik değişikliklerden kaynaklanmaktadır.

Çalışmada inovasyon üzerinde araştırma geliştirme harcamalarının önemli bir faktör olduğu sonucuna varılmıştır. İnovasyonu artırmak için ülkeler öncelikle bu kapsamda araştırma geliştirme faaliyetlerine daha fazla kaynak ayırmalıdır. Hükümetler, büyüme performanslarını sürdürmek için uzun vadeli araştırma geliştirme yatırımları yapmalıdır. Uzun vadede kamu ve özel sektörün küreselleşen dünyada varlığını sürdürebilmesi için araştırma geliştirme yatırımlarına önem vermesi gerekmektedir. Araştırma geliştirmenin ve böylelikle inovasyonun artması ile birlikte yüksek teknoloji üretimi yapabilen yeni firmalar ortaya çıkmaktadır. Bunun yanında araştırma geliştirme faaliyetlerindeki artış teknoloji ihracat oranını artırmakta ve dışa bağımlılığı azaltmaktadır. Katma değeri yüksek alanlarda yenilik yaratılmalıdır. Böylece ülkeler küresel rekabet gücü kazanarak uzun vadede sürdürülebilir ekonomik büyümeyi sağlayabileceklerdir.