Marmara Üniversitesi İktisadi ve İdari Bilimler Dergisi • Cilt: 41 • Sayı: 2 • Aralık 2019, ISSN: 2149-1844, ss/pp. 493-502
DOI: 10.14780/muiibd.665751

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

THE RELATIONSHIP BETWEEN R&D EXPENDITURES AND INNOVATIVE DEVELOPMENT: A PANEL DATA ANALYSIS FOR SELECTED OECD COUNTRIES

AR-GE HARCAMALARI VE İNOVATİF GELİŞME ARASINDAKİ İLİŞKİ: SEÇİLMİŞ OECD ÜLKELERİ İÇİN BİR PANEL VERİ ANALİZİ

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Abstract

Research and development expenditures are one of the most important variables under consideration in order to achieve innovative development. Research and development (R&D) expenditures primarily increase the number of patents applied in a country. The increase in the number of patents applied contributes to the innovative development of the countries and shifts the countries' exports from low-tech products to high-tech products. In this study, the relationship between R&D expenditures, high-tech product exports and the number of patent applications were examined using data from 1997 to 2016 for 25 OECD member countries. In the study where the presence of cross-sectional dependence among the countries was determined, the stationary of the series were examined by the CIPS method, and it was determined that the series were stationary in the first difference. The cointegrations of the series were examined by the Westerlund method, and it was found that they were not cointegrations. Then, Dumitrescu and Hurlin's methods were used to test Granger causality. According to the test results, there is a mutual causality relationship between R&D expenditures and at least one unit of high-tech product exports and R&D expenditures and patent applications.

Keywords: R&D expenditures, innovative development, panel data analysis

JEL Classification: O32, Q55, C33

Özet

Araştırma ve geliştirme harcamaları, inovatif gelişmeyi sağlamak için göz önünde bulundurulması gereken en önemli değişkenlerden biridir. Araştırma ve geliştirme (Ar-Ge) harcamaları öncelikle bir ülkede uygulanan patent sayısını arttırmaktadır. Patent sayısının artması, ülkelerin inovatif gelişimine

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Makale Gönderim Tarihi: 10.09.2019
Yayına Kabul Tarihi: 02.12.2019

katkıda bulunmakta ve ülkelerin ihracatlarını düşük teknoloji ürünlerinden yüksek teknoloji ürünlerine kaydırmaktadır. Bu çalışmada Ar-Ge harcamaları, yüksek teknoloji ürün ihracatı ve patent başvuru sayısı arasındaki ilişki 25 OECD üyesi ülke için 1997-2016 dönemi verileri kullanılarak incelenmiştir. Ülkeler arasındaki yatay kesit bağımlılığın varlığının tespit edildiği çalışmada, serilerin durağanlığı CIPS yöntemiyle incelenmiş ve serinin birinci farkta durağan olduğu tespit edilmiştir. Seriler arasında eşbütünleşme ilişkisinin varlığını sınamak amacıyla Westerlund panel eşbütünleşme testi uygulanmış ve değişkenler arasında eşbütünleşme ilişkisi olmadığı tespit edilmiştir. Ardından, Granger nedensellik ilişkisini test etmek için Dumitrescu ve Hurlin panel nedensellik testi kullanılmıştır. Test sonuçlarına göre, Ar-Ge harcamaları ile yüksek teknoloji ürün ihracatı arasında ve Ar-Ge harcamaları ile patent başvuru sayıları arasında karşılıklı bir nedensellik ilişkisi olduğu anlaşılmıştır.

Anahtar Kelimeler: Ar-Ge Harcamaları, İnovatif Gelişme, Panel Veri Analizi

JEL Sınıflandırması: O32, Q55, C33

1. Introduction

Innovation is an important factor for sustainable economic development as well as economic growth. A successful innovation process is acknowledged as a prerequisite for achieving sustainable growth and competitiveness. In this context, it is seen that countries have given more importance to innovative development in recent years. Countries are increasing their R&D expenditures in order to reach more advanced technology levels. In addition to increasing expenditures on R&D, effective and efficient policies on technological innovation need to be implemented. For this purpose, it is necessary to investigate the relationship between R&D expenditures, which is the criteria of innovation performance and the levels of innovative development of countries.

Recent studies have shown that R&D expenditures may affect innovative development and thus economic development. Countries with a strong innovation system can access advanced technology levels faster. However, in order to be successful in the innovation process, first of all, organizational and presentation innovation must be realized. Organizational innovation; while means increasing competitiveness as a result of the development and use of new business conduct methods; on the other hand, presentational innovation means increasing competitiveness as a result of developing and using new marketing methods. These innovations will increase the income of the countries and increase the competitiveness in the international arena. Thus, countries will achieve higher economic growth and sustainable development goals. The first studies in the literature focused on the effects of R&D expenditures on economic growth, while not focusing on the effectiveness of R&D expenditures. Empirical studies conducted in recent years, on the other hand, focus on the effects of R&D expenditures on innovative development, namely the efficiency of R&D expenditures. Therefore, researching whether R&D expenditures are used effectively can provide important information about the international competitiveness and sustainable growth of countries.

In this study, the effect of R&D expenditures on innovative development is investigated. Firstly, the theoretical background of innovative development and R&D expenditures are emphasized. Afterward, studies on R&D expenditures and innovative development are presented in the

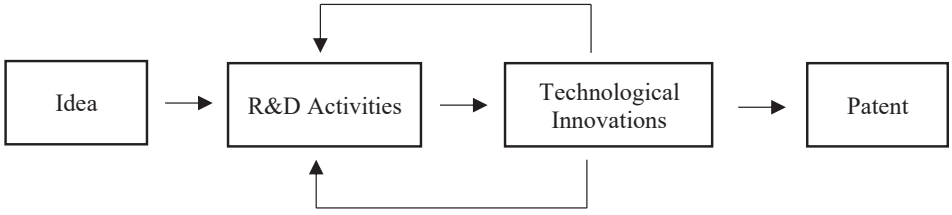
literature. Finally, the effect of R&D expenditures on innovative development has been examined empirically. In this context, the relationship between R&D expenditures and innovative development was analyzed empirically for 25 OECD countries and the period 1997-2016. In the model where R&D expenditures are used as independent variables, high-tech product export and patent applications are used as dependent variables. The model taking into consideration the cross-sectional dependence was estimated with panel unit root, panel cointegration, and panel causality tests.

2. Theoretical Background

With the technological change process, productivity increases and economic growth is realized all over the world. Romer (1986) stated that economic growth is based on internal factors and especially technological innovation and R&D activities. Since technology is one of the most important factors determining the competitiveness of an economy, R&D expenditures are one of the main factors determining both the foreign trade performance and growth of the country.[11] The relationship between R&D expenditures and technology has been studied from different aspects. In recent years, the development of econometric analysis techniques and the development of data sources with diversification have led to making better analysis in these areas. It has been emphasized in many practical studies that the fastest developing sectors in international trade are the sectors that export advanced technology products[2]. In this context, the export of advanced technology products by countries has become a very important policy target in terms of increasing their competitive advantage.

R&D expenditures directly affect the efficiency of both high-tech goods-producing sectors and the new product development process. Both developed and developing countries do not only produce innovations made as a result of R&D activities for the domestic market, but also export to other countries.

Figure 1. The Creation Process of Patent



Source: Ahmet Ayhan, Dünden Bugüne Türkiye'de Bilim-Teknoloji ve Geleceğin Teknolojileri, Beta Basım Yayım Dağıtım, İstanbul, 2002, p.2

1 Salim, R. A., Bloch, B. (2009). Business Expenditures on R&D and Trade Performances in Australia: is there a link?, Applied Economics, 41, pp. 351–361.

2 Srholec, M. (2007). High-Tech Exports from Developing Countries: A Symptom of Technology Spurts or Statistical Illusion?, Review of World Economics/Weltwirtschaftliches Archiv, 143 (2), pp. 227–255.

Another significant component of technological innovation is the number of patents in a developing or developed country. According to Ayhan (2002), there is a connection between patents and R&D expenditures, which are described as innovation to sell, produce, or import the product or idea within a specific period of time (Figure.1). The number of patents, which is an indication of the inventions of countries, is important in terms of showing the R&D capacity of the country and providing the measurement of its R&D based output. The number of patents in a country also demonstrates its innovation potential.

3. Literature Review

The relationship between R&D expenditures and the innovative is critical. In order to achieve innovative development, effective technology policies should be implemented and R&D expenditures should be used effectively. There are several studies that investigate the relationship between R&D expenditures and innovative development.

Author	Methodology	Country	Period	Conclusion
Mercan et. al. (2011)	Panel Data Analysis	25 OECD Countries	2003-2008	While R&D expenditures made by the private sector have a positive effect on the number of patents, a negative relationship was found between the R&D expenditures of the public sector and the number of patents.
Braunerhjelm-Thulin (2008)	Panel OLS	19 OECD Countries	1981-1999	While R&D expenditures increase the exports of advanced technology products, the gross domestic product size is statistically insignificant.
Seyoum (2004)	Cross Section Analysis	54 Countries	1996-1998	The number of researchers working in R&D increases the export of advanced technology products.
Kirankabeş and Erçakar (2012)	Panel Causality	31 EU Countries	1997-2007	There was a significant and positive relationship between R&D expenditures and patent applications.
Gülmez and Yardımcıoğlu (2012)	Panel Cointegration and Panel Causality	21 OECD Countries	1990-2010	As a result, it was found that the variables of R&D expenditures and economic growth per capita affect each other positively as expected and there is a mutually significant relationship between the variables.
Wang (2007)	Stochastic Frontier Methods	30 Countries (27 OECD Countries – 3 non-OECD Countries	Recent years (2003-2004)	In the study, which use, the data of 30 countries, it is stated that the countries that use R&D expenditures effectively will achieve a better economic growth performance.
Bednar and Halaskova (2018)	Spatial Panel Data	Western European NUTS 2 region Countries	2009-2012	It is revealed that R&D expenditures are a determinant for innovation performance and there is a positive relationship between innovation performance and R&D expenditures.

4. Econometric Analysis

In this study, the share of R&D expenditures of GDP, the share of high technology exports in total exports of good and patent application data will be examined for the period 2007-2016 in 25 OECD member countries (see Appendix I). The data to be used will be examined with the models given in Equation 1 and Equation 2.

4.1. Model

The effect of R&D expenditures on high-tech product export will be examined in Model 1. The contribution of R&D expenditures to the patent applications will be examined in Model 2.

Model 1: $HTEX_{it} = a_{1i} + a_{2i}RDEX_{it} + u_{it}$ (1)

Model 2: $PATAP_{it} = b_{1i} + b_{2i}RDEX_{it} + v_{it.}$ (2)

4.2. Dataset

In this study, 25 OECD countries were examined for the period 2007-2016. Data on the ratio of R&D expenditures to GDP was obtained from the OECD database, while high technology product export and patent application data were obtained from the World Bank database. Summary statistics are given in Appendix 2. A brief description of the data used in the study included in Model 1 and Model 2 established above are given below.

RDEX (%GDP): This variable is calculated by the ratio of R&D expenditures to the total value (GDP) of goods and services produced within the country in the relevant period.

HTEX (%Export): This variable is calculated by the ratio of the High-tech products exported to the total exports in the same period.

PATAP: This variable represents the number of patent applications made during the relevant period.

4.3. Cross-sectional Dependence Test

In the new generation of panel data analysis developed in recent years, it is suggested that the cross-sectional dependence between the countries constituting the panel may exist and it is recommended to test it first. If a dependency can be detected between cross-sections, it is necessary to use next-generation panel data analysis methods that take this into account. In this study, the presence of cross-sectional dependence among countries was examined by Pesaran (2015) CD test. H_0 hypothesis of this test; "There is no cross-section dependence". Cross-sectional dependence test was performed with Stata 14.0 program and the results are reported in Table 1.

Table 1: Pesaran CD Cross-Sectional Dependence Test Results

Variable	CD Test	p-value	corr	abs(corr)
RDEX	7.18***	0.000	0.131	0.512
HTEX	7.27***	0.000	0.133	0.434
PATAP	-0.70	0.486	-0.013	0.541

Note: H_0 hypothesis of Pesaran CD test: There is no correlation between units. CD ~ N(0,1)

*** Represents the significance level of 1%.

According to CD test results, H_0 hypothesis is rejected for RDEX and HTEX variables and it is understood that there is a correlation between units. Correlation coefficients were; 0.131, 0.133, – 0.013. For this reason, new generation panel data analysis methods that take the cross-sectional dependence into account have been applied in the later stages of the study.

4.4. Panel Unit Root Tests

The stationarity of the series are important for the reliability of panel data analysis results. Therefore, panel unit root tests should be applied to test the stationarity of the series. In this study, since the cross-sectional dependence of the panel was determined, the CIPS method was preferred from the third-generation panel unit root tests. In this method, the expanded version of ADF regression with lagged cross-sectional means is used and thus eliminates the cross-sectional dependence.[33] In the absence of autocorrelation, the dynamic heterogeneous panel data model is as follows;

$$Y_{it} = (1-f_i)m_i + f_i Y_{i,t-1} + u_i$$

If the u_{it} has a single factor structure, with f_t unobservable factors, it can be expressed as follows;

$$U_{it} = g_i f_t + e_{it}$$

$$\Delta Y_{it} = a_i + r_i Y_{it-1} + g_i f_t + e_{it}$$

H_0 hypothesis of this test; "The series is not stationary". The results obtained from CADF panel root test are presented in Table 2.

Table 2: Panel Unit Root Test Results (CIPS)

Variables	t-bar	cv10	cv5	cv1	Z[t-bar]	P-value
RDEX	-1.709	-2.100	-2.220	-2.440	-0.072	0.471
HTEX	-1.868	-2.100	-2.220	-2.440	-0.663	0.254
PATAP	-1.746	-2.100	-2.220	-2.440	-0.208	0.418
dRDEX	-2.437	-2.100	-2.220	-2.440	-2.787	0.003
dHTEX	-2.652	-2.100	-2.220	-2.440	-3.590	0.000
dPATAP	-2.186	-2.100	-2.220	-2.440	-1.849	0.032

Note: The lag lengths were selected as 1.

3 Tatoğlu, F. Y. (2017). Panel Zaman Serileri Analizi, İstanbul, Beta Yayınevi, p. 84

The output above shows CIPS test results only when the constant is allowed and the length is 1. Since the T-bar (CIPS) statistic of RDEX, HTEX and PATAP is less than the critical values given in the 90% (cv10), 95% (cv5) and 99% (cv1) confidence interval, the series are not stationary. It is understood that the series become stable when the first differences of the variables are taken.

4.5. Panel Cointegration Tests

In case of cross-sectional dependence, first-generation panel cointegration tests are weak. In this case, second-generation panel cointegration tests are used which take cross-sectional dependence into account. Westerlund's second generation cointegration test was used in our panel data analysis. The Westerlund (2007) panel cointegration test is obtained by introducing resistant critical values of the first generation Westerlund panel cointegration test into the bootstrap process.

Table 3: Westerlund Panel Cointegration Test Results

Statistic	Model 1 (RDEX-HTEX)			Model 2 (RDEX-PATAP)		
	Value	P-value	Robust p-value	Value	P-value	Robust p-value
G_t	-5.550	0.000	0.130	-4.538	0.000	0.350
G_a	-10.654	0.001	0.230	-8.726	0.080	0.790
P_t	-8.873	0.069	0.200	-10.083	0.004	0.900
P_a	-5.111	0.205	0.210	-6.859	0.003	0.960

Note: The fixed lag length is selected as 1.

The output above shows p values in the absence of cross-sectional dependence and bootstrap p values in the case of cross-sectional dependence. According to the results, the H_0 hypothesis could not be rejected for all statistics in both models, indicating that there is no cointegration relationship between RDEX-HTEX and RDEX-PATAP variables.

4.6. Panel Granger Causality Test

Dumitrescu and Hurlin (2012) stated that an economic situation that is valid for one country is likely to be valid for other countries as well. Because of this, it is possible to test the causality relationship more effectively in the observations in the panel data. In the Dumitrescu – Hurlin panel Granger causality test, when X and Y represent two stationary processes observed during the T period for N units, the following linear heterogeneous model is considered for each unit (i) at time t;

$$y_{i,t} = \alpha_i + \sum \gamma_i K(k)\, k=1\, y_{i,t-k} + \sum \beta_i K(k)\, k=1\, x_{i,t-k} + \varepsilon_{i,t}$$

In cases where the basic hypothesis was used, it was determined that no Granger causality relationship was determined among all the variables examined; in cases where the alternative hypothesis is used, it is shown that there is a relationship between two variables in one of the units. Although a heterogeneous model is established, the basic hypothesis is homogeneous and the alternative hypothesis is heterogeneous.

Table 4. Dumitrescu Panel Casuality Test Results

Null Hypothesis (H_0)	W-Bar	Z-Bar	P-Value
RDEX does not Granger-cause HTEX	2.2858	4.5461	(0.0000)***
HTEX, does not Granger-cause RDEX	6.1195	18.1001	(0.0000)***
RDEX does not Granger-cause PATAP	3.0341	7.1916	(0.0000)***
PATAP does not Granger-cause RDEX	8.0277	24.8465	(0.0000)***

*** Represents the significance level of 1%.

The output above includes Dumitrescu and Hurlin panel Granger causality test results. The lag length was selected according to the AIC and the Akaike information criterion determined the optimal lag length as one. According to the test results, the basic hypotheses that there is no causality relationship between the variables were rejected and it was understood that there was a causal relationship between R&D expenditures and at least one unit high tech product export and R&D expenditures and patent applications.

5. Conclusion

Increasing the welfare of countries through high-tech products export is a priority for all countries. In this study, the relationship between R&D expenditures, high-tech product exports and the number of patent applications have been examined by using next-generation panel data analysis methods by using the data of 25 OECD countries for the 1997-2016 period. The presence of cross-sectional dependence among the countries constituting the panel was examined by Pesaran CD test and it was observed that the cross-sectional dependence was present. Stationary of the series were examined by Pesaran (2007) CIPS method and it was determined that the series were stationary in the first difference. The relationship of cointegration between the series was tested by Westerlund (2008) method and it was determined that there was no relationship between them. Then, Dumitrescu and Hurlin methods were used to test Granger causality. According to the test results, there is a mutual causality relationship between R&D expenditures and at least one unit of high – tech product exports and R&D expenditures and patent applications.

Based on the findings of this study, it can be stated that R&D expenditures play an active role in innovative development for 25 OECD countries. The rise in R&D expenditures increases both the export of high technology products and the number of patents applied. At the same time, the increase in the number of patents applied and the export of high-tech products allow countries to allocate more resources to R&D activities. These activities increase patent applications and

commercialize and increase the export of high technology products. As a result of the findings of the analysis, it can be said that countries should allocate a higher share of R&D expenditures to GNP in order to produce high value-added products.

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Appendix I

Number	Countries
1	Austria
2	Belgium
3	Canada
4	Czech Republic
5	Denmark
6	Estonia
7	Finland
8	France
9	Germany
10	Greece
11	Ireland
12	Israel
13	Japan
14	Luxembourg
15	Mexico
16	Netherlands
17	Norway
18	Poland
19	Korea
20	Slovakia
21	Spain
22	Sweden
23	Turkey
24	United Kingdom
25	The United States

Appendix II

Variable	Obs	Mean	Std. Dev.	Min.	Max.
RDEX	**250**	**2.052544**	**1.035554**	**0.4260605**	**4.427683**
HTEX	**250**	**14.35098**	**6.222788**	**1.616625**	**31.38249**
PATAP	**250**	**32224.86**	**77652.14**	**20**	**330110**