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Examining the Relationship between Research and Development Expenditures (R&D) and Economic Growth by Kónya Causality Analysis Test in G7 Countries

1 Introduction

One of the chief goals of policymakers is to reach a consistent growth trend. Many instruments have been inserted in growth models to that end until today. One of those instruments is technological progress. Technological developments can mostly be created as a result of Research and Development (R&D).

Representatives of Classical and Neo-classical economics have added technological progress in growth models as an external variable; however, they have not endogenized technology to their models. Some countries, as from the last century, have provided significant technological progress achievements as the result of R&D activities. Related achievements cause a consistent economic growth trend and endogenous growth models to emerge. These models are the first ones that evaluate technology and R&D activities as an endogenous variable in economic growth models.

This study aimed to research the relationships between R&D expenditures and economic growth. G7 countries were scrutinized in line with this purpose. In the study, the variables between R&D expenditure and GDP will be analyzed with Kónya (2006) panel causality test with the help of the data of 1990–2019 period.

2 Literature Review

There are many researchers who review the effects of R&D expenditures on economic growth. Studies that belong to Griliches (1985), Lichtenberg (1992), Park (1995), Luh and Chang (1997), Freire-Serén (1999), Yanyun and Mingqian (2004), Falk (2007), Wu and Zhou (2007), Sadraoui and Zina (2009), Peng (2010), Kim (2011), Zhou, He, and Shen (2012), Sokolov-Mladenović, Cvetanović, and Mladenović (2016), Freimane and Băliña (2016), Dam and Yıldız (2016), Feng and Ke (2016), Bond and Guceri (2017), Minniti and Venturini (2017),

Uçak et al. (2018) show the positive and statistically significant effect of R&D expenditures on economic growth.

Guloglu and Tekin (2012), Wu and Zhou (2007), Dereli and Salğar (2019) conducted studies and found a two-way causality relation between R&D expenditures and economic growth. There was found a causality relation from R&D expenditures to economic growth in studies that belong to Altın and Kaya (2009), Akıncı and Sevinç (2013), Bozkurt (2015), Taş et al. (2017) with Duman and Aydın (2018). A one-way causality relation from economic growth to R&D expenditures was observed in studies that belong to Genç and Atasoy (2010).

Goel and Ram (1994) conducted a study only for developed countries and found a statistically significant relationship between R&D expenditures and economic growth in the long term while Sylwester (2001), Samimi and Alerasoul (2009), Tuna, Kayacan and Bektaş (2015), Shen, Lin and Wu (2019) could not observe a statistically significant relationship between R&D expenditures and economic growth. Moreover, for Silaghi et al. (2014), R&D expenditures of the private sector positively affect economic growth; on the other hand, there is no statistically significant relationship between R&D expenditures of the public sector and economic growth. Wang et al. (2013) did a research and found that R&D expenditures have no significant effect on economic growth in low and middle-income countries; the same expenditures have a remarkable impact on the economic growth of high-income countries. Again, Inekwe (2014) who worked by classification for income groups of countries, observed that R&D expenditures positively affect economic growth in middle-income countries; however, this impact is insignificant for middle-low income countries.

Many studies that review the relationships between R&D expenditures and economic growth show different results. The root causes of these differences are the differences in the development level of the relevant country or country groups, period, and analysis type. Although it is seen that there are different results among variables, there are significant interactions between related variables and economic growth.

3 Data

R&D expenditures¹ and gross domestic product (GDP)² variables of G7 that were obtained from the OECD database were utilized in analyzes in line with the

1 https://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=GERD_FORD&ShowOnWeb=true&Lang=en

2 <https://stats.oecd.org/index.aspx?queryid=60702>

purpose of this study. Two variables as R&D expenditures (*lrd*) and GDP (*lgdp*) were inserted in analyzes by taking logarithm to be million US dollars (constant prices and PPPs). The investigation period of study was selected as 1990–2016 because of the restriction of data of R&D expenditures.

4 Econometric Methodology

This study tested the relationships between variables with the help of a panel causality test that was developed by Kónya (2006). The key reason for selecting this test is that the test reveals causality relations for each of the countries one by one; moreover, there is no need to perform a unit root and/or cointegration test first. However, the prior conditions for this test are the presence of cross-sectional dependence in models and the requirement for models to be in a heterogeneous structure. This is because, before the Kónya (2006) causality test, we first tested the presence of cross-sectional dependence in the models. Secondly, we tested the homogeneity/heterogeneity of the slope coefficient in the models.

4.1 Cross-Sectional Dependence Tests

We tested the relationships between variables with the help of Models 1 and 2. Before the cross-sectional dependence, first, these two models are estimated by the least-squares method; the presence of a cross-section is tested in the residual terms of $u_{i,t}$ and $e_{i,t}$ belonging to these models.

$$lgdp_{i,t} = \beta_0 + \beta_i lrd_{i,t} + u_{i,t} \quad (1)$$

$$lrd_{i,t} = \alpha_0 + \alpha_i lgdp_{i,t} + e_{i,t} \quad (2)$$

In the models, β_0 and α_0 are constant terms; β_i and α_i are slope coefficients. β_i shows the effect of 1 % change in *lrd* on *lgdp*; α_i shows the effect of 1 % change in *lgdp* on *lrd*. The *i* index is the country dimension of the models; *t* is the time dimension of the models. The total number of countries (*N*) means that the total number of all *i* in the models is 7 countries; *T* indicates that the whole time dimension is 27.

For example, in Model 1, the residual terms ($u_{i,t}$) of the model should be inserted in the model in the case of testing cross-sectional dependence. Afterwards, cross-sectional dependence is tested by producing Model 3.

$$u_{i,t} = \alpha_i + \beta_i' x_{i,t} + \varepsilon_{i,t}$$

$x_{i,t}$ in the model shows independent variables at the $k \times 1$ dimension. There is $x_{i,t} = (u_{i,t-1} \dots u_{i,t-p})$ in cross-sectional dependence tests for the model. α_i is the constant term coefficient; β_i' is the slope coefficient. It is assumed that the residual term for each of the countries is $(\varepsilon_{i,t} = \varepsilon_{1,t}, \dots, \varepsilon_{N,t})_{i,t} \sim IID(0, \sigma_{i,\varepsilon}^2)$. Test statistics that are obtained in this way inform us about whether there is a cross-section with the help of the below hypotheses. Cross-sectional dependence in the models means that a shock in one country will create a shock in other countries.

4.2 Homogeneity Test

The model has a homogeneous structure if the slope coefficients of each of the countries in the panel data are equal to a single slope coefficient. The model has a heterogeneous structure if the coefficients of each of the countries are different. Determining this situation is both econometrically and economically significant. This study used a homogeneity test developed by Pesaran and Yamagata (2008) and based on the random coefficients model. Unlike Swamy's (1970) study, the homogeneity test developed by Pesaran and Yamagata (2008) gives reliable results at larger N and T dimensions. We can say for this study that the T = 19 dimension is a long period in terms of panel data models.

H_0 : $\alpha_i = \alpha, i = 1, \dots, N$ for all i. (Model is homogenous.)

H_1 : $\alpha_i \neq \alpha_j$, some of $i \neq j$ (The coefficient of at least one country is different. Model is heterogeneous.).

Pesaran and Yamagata (2008) suggest $\hat{\Delta}$ and $\tilde{\Delta}_{adj}$ are asymptotically powerful to test these hypotheses. H_0 is denied if the probability values of these test statistics are lower than statistical significance values such as 10 %, 5 %, and 1 %. This means that the slope coefficients of the models vary by country.

4.3 Kónya (2006) Panel Causality Test

The panel causality test developed by Kónya (2006) reviews relationships between variables based on the SUR developed by Zellner (1962).

The SUR system that includes *lgdp* and *lrd* variables whose causality relationships are analyzed is as follows:

$$\left. \begin{aligned} lgd p_{1,t} &= \varphi_{1,1} + \sum_{l=1}^{ml_lgdp_1} \alpha_{1,1,l} lgd p_{1,t-1} + \sum_{l=1}^{ml_lrd_1} \beta_{1,1,l} lrd_{1,t-1} + \xi_{1,1,t} \\ lgd p_{2,t} &= \varphi_{1,2} + \sum_{l=1}^{ml_lgdp_1} \alpha_{1,2,l} lgd p_{2,t-1} + \sum_{l=1}^{ml_lrd_1} \beta_{1,2,l} lrd_{2,t-1} + \xi_{1,2,t} \\ &\quad \cdot \\ &\quad \cdot \\ &\quad \cdot \\ lgd p_{2,t} &= \varphi_{1,2} + \sum_{l=1}^{ml_lgdp_1} \alpha_{1,2,l} lgd p_{2,t-1} + \sum_{l=1}^{ml_lrd_1} \beta_{1,2,l} lrd_{2,t-1} + \xi_{1,2,t} \end{aligned} \right\} (4)$$

and

$$\left. \begin{aligned} lrd_{1,t} &= \varphi_{2,1} + \sum_{l=1}^{ml_lrd_2} \beta_{2,1,l} lrd_{1,t-1} + \sum_{l=1}^{ml_lgdp_2} \alpha_{2,1,l} lgd p_{1,t-1} + \xi_{2,1,t} \\ lrd_{2,t} &= \varphi_{2,2} + \sum_{l=1}^{ml_lrd_2} \beta_{2,2,l} lrd_{2,t-1} + \sum_{l=1}^{ml_lgdp_2} \alpha_{2,2,l} lgd p_{2,t-1} + \xi_{2,2,t} \\ &\quad \cdot \\ &\quad \cdot \\ &\quad \cdot \\ lrd_{N,t} &= \varphi_{2,N} + \sum_{l=1}^{ml_lrd_2} \beta_{2,N,l} lrd_{N,t-1} + \sum_{l=1}^{ml_lgdp_2} \alpha_{2,N,l} lgd p_{N,t-1} + \xi_{2,N,t} \end{aligned} \right\} (5)$$

Wald test statistics are computed for each country's VAR equalities in a causality test. Just as in Kónya (2006), these test statistics are compared using critical bootstrap values.

5 Empirical Findings

This part of the study shows the refindings that were obtained using the methods above. The test results for cross-sectional dependence can be seen in Table 1.

There is cross-sectional dependence in both Model 1 and Model 2. It is inevitable for a shock that occurs in one country in the world to affect other countries. Moreover, this result proves the first condition required for the Kónya (2006) panel causality test. Table 2 shows the homogeneity test results.

The coefficients for both models vary from country to country; that is, they are heterogeneous in structure. This result provides the second condition required for the Kónya (2006) panel causality test. Table 3 shows The Kónya causality test results.

Table 1 : *Cross-Section Dependence Test Results*

Models	Model 1		Model 2	
Test	Test Statistics	P-value	Test Statistics	P-value
BP_{LM}	34.230*	0.0001	41.782*	0.0001
CD_{LM}	11.524*	0.0001	14.608*	0.0001
LM_{BC}	11.467*	0.0001	14.550*	0.0001
LM_{adj}	-0.506***	0.6125	-1.879***	0.0602

Note: *, *** indicates the rejection of the null hypothesis at the 1 % and 10 % significance level, respectively.

Table 2: *Cross-Section Dependence Test Results*

Modeller	Model 1		Model 2	
Test	Test Statistics	P-value	Test Statistics	P-value
$\hat{\Delta}$	22.568*	0.0001	26.528*	0.0001
$\hat{\Delta}_{adj}$	23.884*	0.0001	28.075*	0.0001

Note: * indicates the rejection of the null hypothesis at the 1 % significance level.

The causality test results in Table 3 show a one-way causality relation from *lgdp* to *lrd* is seen in Italy and Japan. The sign of causality relationships is negative for Italy and positive for Japan. The one-way causality relation from *lrd* to *lgdp* for UK and US. We also see that the sign of these causality relations is positive. Besides, there seems to be a bi-directional causality between *lgdp* and *lrd* for France. Also, there is a relation between negative from *lgdp* to *lrd* and positive from *lrd* to *lgdp*.

6 Conclusion

This study investigated the relationship between R&D expenditures and GDP of the G7 countries' (Canada, France, Germany, Italy, Japan, the UK, and the US) for the period 1990–2016. According to Kónya (2006) panel causality results, a one-way causality relationship is seen from GDP to R&D expenditures in Italy and Japan. The sign of causality relationships is negative for Italy and positive for Japan. The one-way causality relation from R&D expenditures to *GDP* in the UK and US. We also see that the sign of these causality relations is positive. Besides, there is bi-directional causality between GDP and R&D expenditures in France.

Table 3: *Kónya (2006) Panel Causality Test Results*

<i>H₀: lgdp is not the Granger causality for lrd (Model 1)</i>					
Countries	Coefficients	Test Statistics	Critical Values ****		
	<i>lgdp</i>	Wald	10 %	5 %	1 %
Canada	0.033	2.348	6.148	9.068	18.060
France	-0.083	7.855***	6.584	9.674	18.957
Germany	0.050	0.518	11.857	17.085	32.025
Italy	-0.075	8.667**	5.785	8.446	15.379
Japan	0.231	7.340***	5.870	8.937	17.302
UK	-0.114	4.022	6.409	9.578	18.588
US	-0.101	3.891	6.353	9.474	19.603
<i>H₀: lrd is not the Granger causality for lgdp (Model 2)</i>					
Countries	Coefficients	Test Statistics	Critical Values ****		
	<i>lrd</i>	Wald	10 %	5 %	1 %
Canada	-0.129	1.208	6.179	8.943	17.890
France	0.268	10.650**	5.252	7.680	14.675
Germany	0.459	3.037	6.567	9.493	18.446
Italy	0.017	0.164	5.323	7.855	15.023
Japan	0.336	0.532	5.816	8.738	16.234
UK	0.772	21.393*	5.406	7.937	14.238
US	0.715	38.509*	6.354	9.248	17.813

Note1: *, **, ***, **, and *** indicate rejection of the null hypothesis at the 1, 5, and 10 % levels of significance, respectively.

Note2: **** the bootstrap is based on 1000 replications.

Also, there is a relation between negative from *GDP* to R&D expenditures and positive from R&D expenditures to *GDP*. Finally, there is a no bi-directional causality between *GDP* and R&D expenditures in *Canada* and *Germany*.

For analysis results, an increase in the *GDP* of Italy decreases the R&D expenditures. Regarding data of The World Bank database, the *GDP* of Italy increased approximately by 0.74 % in the 1990–2016 period, that is the time interval of our analysis. This growth rate is so low for a developed country as well as the Italian economy tightened in the 2008 global crisis, 2009, 2012, 2013 and 2014. However, there is seen a steady increase (even if just a drop) in share for R&D expenditures in the *GDP* of Italy as of 1995. This result shows that the 2008 global crisis may be a reflection of ignoring R&D expenditures and tighten the Italian economy. The share for R&D from *GDP*, in Italy, was at 1.39 % in 2016;

this is the lowest ratio in G7 countries. For analysis results, Italy reserves a so little share for R&D expenditures from GDP; this may be the reason for the lack of causality from R&D expenditures to GDP.

Regarding Japan, analyzes show that an increase in GDP, namely a one-way causality, increases R&D expenditures. Japan reached an approximately 1.12 % growth rate in the 1990–2016 period. Japan, especially since 1994, has followed an increasing trend on share for R&D expenditures from GDP. Related share was the highest ratio among the shares of G7 countries and almost 3.26 % in 2016. This table confirms the analysis results as well. Accordingly, we can say that Japan prefers to reserve more share for R&D in line with GDP increasing rate day by day.

There was found a one-way and positive marked causality relation from R&D expenditures to GDP in the United Kingdom and the United States. The growth rate of the UK and the US respectively were 2.06 % and 2.46 % for the analysis period. Moreover, the share that was reserved for R&D expenditures from inside of GDP in the UK was 1.70 % in 2016 while this ratio was as high as 2.82 % for the US in the same year. It can be said that both countries use R&D expenditures in productive areas; this situation, thus, accelerates economic growth.

A two-way causality relation was observed between variables for France. Any increase in GDP negatively affects R&D expenditures; any increase in R&D expenditures positively affects GDP. The average growth rate in France for the 1990–2016 period was 1.59 %. Regarding R&D expenditures, the related share reached a plateau from 1990 and remained at 2.2 % in GDP by 2016. France could not increase R&D expenditures under the present conditions; however, France accepts keeping the share of R&D expenditures in GDP at 2 % levels as a policy. It is seen that this 2 % threshold value that is specified for R&D expenditures is enough to positively affect the GDP of France.

There was not found a causality relation between variables for Canada and Germany. R&D ratio that was 2 % for Canada in 2001 regressed to 1.54 % till 2016. Although Canada reached an economic growth rate as almost 2.6 % from 2001 to 2016 and is in a tendency to increase R&D expenditures around the world, a decrease in R&D expenditures can still be seen. This table may result from the focal point that is another field rather than R&D expenditures in Canada. Regarding Germany, the share for R&D expenditures in GDP was 2.1 % in 1994 while this ratio increased to 3.13 % in 2016. Germany seems like a country that considers and increases R&D expenditures. Again, the economic growth rate of Germany approximately was 1.44 % in the 1994–2016 period. For Germany, it is a surprising result that there is no causality relation on GDP, although R&D expenditures are such a high. Discussing this issue by evaluating different variables may reveal much more reliable results.

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