CHAPTER 4

A PANEL COINTEGRATION STUDY OF THE EFFECT OF R&D EXPENDITURES ON INNOVATION: THE CASE OF BRICS_T COUNTRIES

Hülya BULUT*

*Dr., Istanbul Arel University, School of Applied Sciences, Department of Banking and Finance, Istanbul, Turkey
E-mail: hulyabulut@arel.edu.tr

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Abstract

In academic and intellectual discussions on how to achieve sustainable growth and development in the world, it is stated that it is not easy for countries to gain, develop and maintain competitiveness in the globalization environment and often noted that it will not be possible without Research and Development (R&D) and innovation activities. In this context, this study examines the relationship between R&D expenditures to GDP ratio and global innovation index in the scope of BRICS_T countries (Brazil, Russia, India, China, South Africa, and Turkey). For this, panel cointegration and causality analyses were applied based on data covering the period 2007-2019. First, horizontal cross-sectional dependence between series was analyzed by the LM CD test developed by Pesaran (2004) and LM adj. test whose deviation was corrected by Pesaran et al. (2008). After cointegration coefficients were determined as heterogeneous, 1st and 2nd generation unit root tests were implemented. 1st generation unit root tests Maddala & Wu (1999), Choi (2001), and Im, Pesaran & Shin (2003) were applied; stationarity was tested by CADF test, one of the 2nd generation unit root tests; Westerlund & Edgerton's (2007) LM Bootstrap Panel Cointegration test was utilized for detecting long-run relationship between variables. After long-run coefficient estimations were performed through FMOLS, Dumitrescu & Hurlin (2012) causality test was applied. Consequently, the statistically significant positive effect of R&D on global innovation index GII was determined. The highest effect was in China and Russia. Panel-wide, a 4.3% enhancing effect was determined. In addition, two-way causality was detected between the R&D and GII variables.

Keywords: BRICS_T Countries, Research and Development, Innovation, Innovation Index.

1. Theoretical Background

There is an outward shift in the production possibility frontier (PPF) of the whole economy, which is one of the reasons for the economy's long-term development (Hale, Kahui, and Farhat, 2015). In terms of 'innovation', it can be said that this is one of the factors that will lead to a shift in the production possibility curve of the economy (Aghion, et al., 2018). Therefore, there must be an existence of R&D expenditures in the development of innovative services and products. According to Luthar (2015), investment policies for R&D teams are required for creating an incentive for innovation which will lead to the materialized form thereof. It will help transform the proceeds into the process of the economy using investment (King, 2015). Therefore, in the absence of private and the public expenditure on the research and development activities, the maximum of innovations cannot be implemented, and the productivity of the economy will not be feasible (Sauvé, Bernard & Sloan, 2016).

1.1. Innovation

It seems best to analyze the history of the word in order to appreciate the notion of innovation. The concept of innovation, derived from the Latin word 'innovatus', has been discussed in its development dimension by Mees (1920) and Holland (1928) and in its financial dimension by Maclaurin (1953) and Enos (1962). As Grovers (1974, p. 4) emphasized, in the context of public finance rooted in economics, the concept of innovation, which is especially important in terms of public policies and the effectiveness thereof, was accepted by Fischer (2001, p. 200) as the basis for achieving economic prosperity by ensuring sustainable competition; it was stated that the perception of innovation merely as R&D activities would reflect a very shallow point of view; and the concept of innovation was considered as a concept covering technical revolution, managerial revolution and development processes.

Again, in Chapter 12 entitled *Crumbling Wall in Capitalism, Socialism, and Democracy*, written by the economist and political scientist Schumpeter, the concept was explained as follows by means of including the expression of innovation itself: Nowadays, it is far simpler to perform anything apart from everyday routine. Unlike in the past, innovation itself has been reduced to a routine. Technological advancement is progressively becoming the work of the qualified professional teams who produce what is needed and make them operate in expected ways (Schumpeter, 2003, p.133). As can be understood from these explanations, innovation has been used as a concept referring to previous ways of business manners, changes that occur in business models and, technological advances.

The Oslo Manual by the Organization for Economic Co-operation and Development (OECD) provides the following information on innovation (OECD, 2005): The innovation concept is characterized as follows: Innovation is connected to uncertainty regarding the results of innovation operations. It includes investment, is likely to be affected by spillovers, requires either the utilization of new knowledge or a modern application or blending of the present knowledge, and aims to raise the efficiency of a company by means of obtaining a competitive advantage.

The document focusing on the measurement of innovation describes four types of innovation: Product innovation: A product or service that is original or remarkably upgraded. This involves important enhancements to technical requirements, parts and materials, product software, usability, and other functional features. Process innovation: A novel or considerably enhanced method of manufacturing or distribution. This involves substantial modification in the techniques, equipment, and/or software. Marketing innovation: A unique marketing technique suggesting important modifications in the design or packaging of products, product placement, product promotion or pricing. Organizational innovation: A novel organizational approach for business practices, organization of the workplace or external relations. Economists suppose that organizational change is a reaction to technical change. However, in point of fact, organizational innovation might be a prerequisite for technical innovation.

Furthermore, Godin (2008) stated that the history of innovation as "creativity" is comprised of three notions (plus their derivatives): Imitation leads to Invention and Invention leads to Innovation. There is a great deal of literature about imitation (theories of literature and art) besides invention (sociology, history, management, and technological economics). In this context, innovation is expected to create economic value, unlike invention. An invention is the beginning process of innovation, and it is necessary to study and develop it in a different way for it to be able to transform into a product/service that adds value to the market. Invention emerges as a result of R&D processes. For the development of R&D, the scientific/academic base of a country needs to develop. Essentially, the process can be expressed in the following order: Science/Academy, R&D, Invention/Patent, Innovation, Economic Growth/Welfare (Tiryaki, 2014).

Innovation is usually recognized as a major factor that enables countries to promote their economic growth and competition power. Therefore, embracing current technologies effectively and efficiently is a major means of continuing economic growth and development (Hu, 2015; Huggins et al., 2015).

As can be seen, compared to R&D activities, innovation is more comprehensive, involving advancements in logistics, support and sales/marketing efforts. Besides, the scope of innovation also covers the procurement of external know-how or industrial goods, which lies beyond the scope of R&D generally. The innovative actions which companies decide to engage in depend on their access to technology, information, and knowledge, as well as to financial and human resources. For the said reasons, it is better to take a closer look at R&D, which is an important component of innovation.

1.2. Research and Development (R&D)

R&D, which is one of the most important stages of innovation and is indeed a prerequisite thereto, helps innovation to emerge technically. However, it is useful to take a look at the concept of the research partnership in order to mention an effective R&D activity. Partnerships are described as cooperative arrangements that gather up businesses, universities, government agencies, and laboratories into several alliances to combine resources to achieve a mutual R&D goal (The Council on Competitiveness, 1996). Within this context, the concept of research partnership is expressed by Hagedoorn et al. (2000) as follows: in general, a research partnership is a connection that is based on innovation that requires major endeavor, at least in part, in research and development (R&D).

Bilbao & Rodriguez (2004) indicate that the fact that investment in R&D improves the chance of attaining higher technological standards in companies and countries enables them to implement new and better goods and/or procedures, leading to higher rates of revenue and growth. According to Samimi & Alerasoul (2009), R&D is the key to productivity and economic growth. Likewise, Kim (2011) indicates that doing and learning are the two principal functions of R&D activities. The transfer of knowledge, in this phase, is denoted as the “spillover effect”. Innovation arises by means of knowledge, thus, manufacturers can present unique products, decrease expenses, and enhance product quality. R&D is, therefore, strongly associated with productivity.

R&D activities are defined by OECD (2015) as follows: Research and experimental development (R&D) comprises of an inventive and methodical activity that is initiated in order to boost the stock of knowledge and develop novel practices for existing knowledge. R&D activities must meet five core criteria, which are novelty, creativity, uncertainty, systematicity, transferability, and/or reproducibility. Besides, R&D activities are classified into 3 different groups: These are Basic Research, Applied Research, and Experimental Development. Basic research is an empirical or theoretical study that investigates new

knowledge on the fundamental basis of phenomena and observable evidence, regardless of considering any specific application or usage. The second, Applied Research, is original research which is conducted to pursue a particular practical purpose or objective. Finally, Experimental Development is a methodical study that utilizes the knowledge acquired from exploration and applied experimentation with the purpose of creating new products or procedures or upgrading current products or procedures. The R&D system contains numerous flows of data and knowledge. Experimental development can provide data for basic research, and it is also possible that basic research can immediately result in new products or procedures. Furthermore, R&D Classification is specified to include the following fields: Natural sciences (Mathematics, physical sciences, computer & information sciences, etc.); Engineering & technology (Electrical engineering, information engineering, electronics, etc.); Medical & health sciences; Agricultural & veterinary sciences; Social sciences (Economics & business, political sciences, etc.); and Humanities & the arts.

Additionally, the Law on Supporting Research and Development Activities dated 28.02.2008 and numbered 5746, and the Law on Technology Development Zones dated 26.06.2001 and numbered 4691 are both principal codes regulating incentives intended for research and development projects in the financial sector of Turkey. From this perspective, the R&D definition is as follows. Research and development activity (R&D): Research and development refers to original work carried out on a methodical foundation, to improve the bank of knowledge made up of the knowledge of culture, people and society, and to use that knowledge to design new processes, systems, and applications; activities that provide scientific and technological development in their area through environmentally compatible product design or software projects, focusing on scientific and technological uncertainty, and whose outputs have original, experimental, scientific, and technical content.

According to the Regulation on Application and Control for Supporting Research, Development and Design Activities published in the Official Gazette dated 10.08.2016 and numbered 29797: The activities which are not evaluated within the scope of R&D and innovation activities are as follows:

- a) Marketing activities, market monitoring processes, marketing surveys or promotional sales programs
- b) Quality control
- c) Studies carried out in the field of social sciences
- d) Search and drilling exercises for petroleum, natural gas, and mineral reserves,

- e) The clinical studies of which at least two stages have not been performed domestically before a drug manufacturing license; and the clinical studies which are carried out after obtaining a manufacturing license,
- f) Utilization of procedures devised outside the extent of an R&D plan or usage of existing improved procedures,
- g) Stylistic variances involving aesthetic and visual changes in shape, color, decoration and the like, which are not intended for R&D and innovation activities,
- h) Software development exercises performed by utilizing existing software to help in the preparation of websites and the like, excluding instruction codes and operating systems,
- i) Software-related regular and repeated actions, which do not involve scientific or technological advances or the resolution of technological uncertainties,
- j) Research-related expenditures of enterprises and organizations
- k) Expenditures on investment projects intended for production and production substructure, projection of commercial manufacturing and mass production process,
- l) Duplicating and distributing copies from prototypes for providing samples, and consumer tests for advertising purposes,
- m) Transferring technology directly or in an embedded form, which does not subserve the presentation of a novel procedure, system or product without being a part of an R&D project,
- n) Activities for the protection of intellectual property rights, except for the acquisition of the said rights relating to a product or procedure designed by means of R&D and innovation projects.

2. Literature Review

In his study, Falk (2000) analyzed the impacts of R&D spending on economic growth among member nations of the OECD through panel data analysis based on the data from 1970 to 2004. The results show that both the ratio of corporate R&D spendings to GDP and the percentage of R&D investments in the cutting-edge high technology sectors have powerful positive impacts on both per capita income and average per capita hourly earnings in the long run. Segerstrom (2000) examined the impacts of R&D incentives on long-run growth. The result of this study was significant and showed that R&D incentives either promote or postpone the long-run economic growth. The result where the growth is delayed

depends on a range of reasonable parameter values. This research also presents a fresh view on why R&D subsidies have an impact (both positive and negative) on long-term financial development.

Coe et al. (2008) concluded that organizational differences are important determinants in terms of total factor productivity and that its grade is impacted by R&D spillover. Kim (2009) examined the impact of R&D operations on Korea's economic growth using the data for the period 1976-2009, via Cobb-Douglas' R&D-based production function. As a result, the experimental findings of the study present that the conventional factors of production (labor and capital) contribute to economic growth by almost 65%. Furthermore, R&D stocks contribute to economic growth by about 35%. When reviewed in detail, it can be observed that private and public R&D stocks contribute to economic growth approximately by 16% and 19%, respectively.

Nunes et al. (2012) performed an analysis to discover if there was a comparable connection between small and medium-sized businesses with leading-edge technology and those without, with regards to R&D intensity and growth. The findings show that concentration on R&D activities does not allow high-tech companies to develop at lower rates; on the contrary, it enables them to expand more. Nevertheless, R&D intensity limits the growth of companies that do not have advanced technology, in spite of their R&D level.

In order to investigate the dependencies between the R&D spendings, innovation, and economic growth, Huňady & Orviská (2014) utilized the data of EU 27 member states and evaluated the nations' innovation performances via summary innovation index issued by the European Commission (2013). Besides the summary innovation index, with the purpose of detecting active changes in the countries' innovation performances, they have additionally employed the innovation growth index, which is also assessed by the European Commission (2013). It was determined that the summary innovation index value and GDP per capita rate were positively correlated countrywide. It could indicate that intensive activities of innovation can lead to accelerated economic developments and increased productivity. To put it another way, the single outcome caused by a higher GDP rate might be further innovation investments.

By using the Johansen cointegration and the vector error correction models, Bozkurt (2015) investigates the long-term connection between R&D spending and economic growth in Turkey. According to the research findings, a unidirectional causality exists from economic growth towards R&D. Long term coefficients of the R&D variable are statistically extremely significant at a positive rate. If the share of R&D in the GDP rises by 1%, the GDP's growth

rate rises by 0.2630%. Gault (2015) states that attempts of countries to promote their innovation performance levels over many years results in achieving a higher economic growth rate in the future.

According to Leyden (2016), it cannot be claimed on the basis of a country's correlation assessment that the Research and Development department has a positive effect on the economy's growth level. The innovation index rate of a country and the volume of public spending on its research and development department are constructively correlated (Halsmayer & Hoover, 2016). A positive correlation can be found between the spendings in a country's R&D unit and innovation index figures such as the number of its scientific researchers (Hojnik & Ruzzier, 2016).

Janger et al. (2017) point out the constructive correlation between a country's innovation index and the GDP growth rate (Gross Domestic Product) of the economy. According to Rojas, Solis & Zhu (2018), it can be observed that if the spendings of a country's R&D unit rises, the number of researchers across the nation will automatically increase. Lerner & Stern (2019) present that increasing a country's innovation operations boosts the pace of its efficient economic growth, leading to a high productivity rate.

3. Methodology

For the analyzes, cross-sectional dependence and homogeneity tests were performed; Maddala & Wu (1999), Choi (2001), and Im, Pesaran & Shin (2003) first-generation unit root tests were applied; the stationarity was tested by CADF test from the second-generation unit root tests; Westerlund & Edgerton (2007) LM Bootstrap Panel Cointegration test was utilized to determine the long-run relationship between the variables. After long-run coefficient estimations were performed through FMOLS, Dumitrescu & Hurlin (2012) causality test was applied.

3.1. Description of the Data

In the study, BRICS_T countries were examined for the years 2007-2019, and panel cointegration analysis was applied to determine the relationship between the independent variable, R&D expenditure to GDP ratio (R&D) and the dependent variable, global innovation index (GII). The data were generated from the database of www.worldbank.org. The analyzes were obtained employing the Gauss codes and EViews 10.0. The variables used in the model are presented in Table 1.

Table 1. Description of the Variables Used in the Analysis.

Variable	Indication	Description
R&D expenditure to GDP (ratio)	R&D	Independent variable
Global innovation index	GII	Dependent variable

3.2. Cross-sectional Dependence and Homogeneity Test

The cross-sectional dependence between the series was determined through the LM CD test developed by Pesaran (2004) and the LM adj. test, whose deviation had been corrected by Pesaran et al. (2008), and the test results are presented in Table 2. Since the probability values of the test results were less than 1% and 5%, the null hypothesis (no cross-sectional dependence) was rejected, and the cross-sectional dependence was identified between the series. Additionally, homogeneity of cointegration coefficients was tested using the delta tilde and adjusted delta tilde tests of Pesaran & Yamagata (2008), and the test results are presented in Table 2.

Table 2. Cross-sectional Dependence and Homogeneity Test Results.

Cross-sectional dependence test (H_0 : No cross-sectional dependence)		
Test	Test statistics	p-value
LM (Breusch & Pagan (1980)	12.841	0.000
LM _{adj} (Pesaran et al. (2008)	36.015	0.000
LM CD (Pesaran (2004)	14.732	0.001
Homogeneity test (H_0 : Slope coefficients are homogeneous)		
Test	Test statistics	p-value
Delta_tilde	12.667	0.015
Delta_tilde_adj	15.233	0.000

Since the probability values of the test results were less than 1% and 5%, the null hypothesis (The slope coefficients are homogeneous) were rejected, and the cointegration coefficients were ascertained to be heterogeneous.

3.3. First and Second Generation Unit Root Test Results

First-generation unit root tests are divided into two as homogeneous and heterogeneous models. Since the coefficients were identified as heterogeneous, Maddala & Wu (1999), Choi (2001), and Im, Pesaran & Shin (2003) first-generation unit root tests were used.

Table 3. Panel Unit Root Test Results.						
Variables	Maddala & Wu Test		Choi Test		Im, Pesaran & Shin Test	
	Level	First difference	Level	First difference	Level	First difference
	Trend + Constant	Constant	Trend + Constant	Constant	Trend + Constant	Constant
R&D	0.326	0.000*	0.265	0.006*	0.372	0.000*
GII	0.228	0.000*	0.230	0.000*	0.109	0.004*
* Stationary variable for 0.05, Probability (p) values are given in the table. The null hypothesis of the tests is as there is unit root. The optimal lag length was determined using the Schwarz information criterion.						

As can be observed in Table 3, in their level values, every variable possesses a unit root. In contrast, the first-order difference series do not comprise unit roots. Therefore, it is seen that all variables are I (1), in other words, they are stationary for the first-order difference. First-generation unit root tests are based on the assumption that the cross-sectional units forming the panel are independent and that all the cross-sectional units are equally affected by a shock occurring to one of the units forming the panel. It is a more realistic approach that a shock to a cross-sectional unit which constitutes the panel would affect other units at different levels. In order to resolve this deficiency, second-generation unit root tests that analyze stationarity considering the dependence between cross-sectional units have been developed. If the presence of cross-sectional dependence in the panel data set is rejected, the 1st generation unit root tests can be used. However, if there is cross-sectional dependence in the panel data, using 2nd generation unit root tests ensure a more consistent, efficient, and powerful estimation. In this study, second-generation unit root tests were used since cross-sectional dependence was determined. CADF, one of the second-generation unit root tests, was used. The results of the CADF test developed by Pesaran (2007) are given in Table 4.

Table 4. Second Generation Panel CADF Unit Root Test Results.				
Variables	Level		First Difference	
	Constant	Constant + Trend	Constant	Constant + Trend
R&D	-1.109	-1.052	-9.462*	-9.887*
GII	-0.953	-0.915	-8.367*	-9.104*
* For 1% and 5%, H_0 is rejected, stationary variable				

In the CADF tests, the maximum lag length was used as 2, and the optimal lag length was determined according to the Schwarz information criterion. It is observed that the null hypothesis is rejected at the significance level of 1% and 5%. Unit root test results show that

the series are not stationary at the level, in other words, they contain unit roots, and the variables are stationary at the I(1) level.

3.4. Panel Cointegration Test

In this study, the LM bootstrap panel cointegration test developed by Westerlund and Edgerton (2007) to determine the long-term relationship between variables was employed. In this cointegration test, the dependence between the cross-sectional units is taken into consideration, and it has been observed that the test gives sound results in small samples. In this test, the H_0 hypothesis cannot be rejected, indicating that there is a cointegration relationship for all cross-sections.

Table 5. Westerlund & Edgerton (2007) LM Bootstrap cointegration test results.						
LM_N^+	Constant			Constant + Trend		
	Statistic	Asymptotic p-value	Bootstrap p-value	Statistic	Asymptotic p-value	Bootstrap p-value
	9.664	0.271	0.369	9.327	0.294	0.369

Bootstrap probability values were obtained from a distribution of 10,000 iterations. Asymptotic probability values were acquired from the standard normal distribution. It is seen that there is a cointegration relationship between the series for the country group ($p > 0.05$). In this case, the series move together in the long run. Once it is confirmed that the series are cointegrated, the coefficients in the model can be estimated through the cointegration estimators. Long-run coefficients of the model were estimated through FMOLS by taking the first-order differences of the variables.

3.5. Long-Run Cointegration Coefficients Estimation via FMOLS (Fully Modified OLS)

In this study, long-run cointegration coefficients were examined by FMOLS (Fully Modified OLS) method. The FMOLS method eliminates second-order bias effects, as it takes into account the simultaneous relationships between error terms of equations of the variables. The FMOLS estimator resolves diagnostic problems that occur with standard estimators. This method was developed by improving OLS, taking into account the autocorrelation problem.

Table 6. FMOLS Long-Run Cointegration Coefficients.	
Countries	D (R&D)
Brazil	0.042*
Russia	0.061*
India	0.055*
China	0.069*
South Africa	0.036*
Turkey	0.030*
PANEL	0.043*
* Statistically significant variable for 0.05, D represents the first-order difference.	

A statistically significant positive impact of R&D on global innovation index GII was determined for the countries addressed. The highest effect level was obtained for China and Russia.

3.6. Causality Analysis

The causality test to be employed varies according to whether a cointegration relation exists between the panel series. All panel causality tests perform estimates under the assumption of horizontal cross-sectional independence. Through the Dumitrescu & Hurlin (2012) test, both horizontal cross-sectional dependence and cross-sectional independence can be estimated, and effective results can be reached. The Dumitrescu & Hurlin (2012) test shows similarity to the Granger causality test for heterogeneous panels. This test signifies the average of individual Wald tests calculated for horizontal cross-section units within the Granger causality test. This test takes into consideration both heterogeneity and cross-sectional dependence. Another feature of the Dumitrescu & Hurlin test is that it works both in the presence and absence of a cointegrated relationship. In the panel causality test, three different statistical values are calculated.

Table 7. Dumitrescu & Hurlin (2012) Test Results.			
Null hypothesis	Test	Statistical values	p
The variable R&D is not the Granger cause of the variable GII	<i>Whnc</i>	5.731	0.013
	<i>Zhnc</i>	6.893	0.006
	<i>Ztild</i>	6.112	0.000
The variable GII is not the Granger cause of the variable R&D	<i>Whnc</i>	6.324	0.002
	<i>Zhnc</i>	7.542	0.000
	<i>Ztild</i>	7.093	0.014

As can be seen from Table 7, the two-way causality was detected between the R&D and GII variables. The variable R&D is the Granger cause of the variable GII, at the same time the variable GII is the Granger cause of the variable R&D ($R\&D \leftrightarrow GII$).

4. Conclusion

In the study, BRICS_T countries were examined for the years 2007-2019, and panel cointegration and causality analyses were applied to determine the effect of the R&D expenditure-to-GDP ratio (R&D) on the global innovation index (GII). Based on the study, a statistically significant positive effect of R&D on global innovation index GII was determined for the countries. The highest impact rate was obtained for China and Russia. For the overall panel, an enhancing effect of 4.3% was determined. As a result of causality analysis, a two-way causality was detected between the R&D and GII variables. Although it expresses a concept beyond Research and Development (R&D) activities, the concept of innovation, which is often perceived as an output of R&D activities, has a positive impact on sustainable growth and development within the context of its role in increasing employment, boosting productivity and enhancing competitiveness. However, in Turkey, the fact that the effect of R&D expenditures to GDP ratio on the global innovation index has been realized at the lowest level among BRICS_T countries shows that the benefits expected from innovation itself cannot be achieved continuously and effectively. In this context, it is thought that an ecosystem in which the control mechanism, an element of R&D and innovation-oriented legislation, is operated more effectively will be beneficial. Besides, when determining the right position for itself in the global economy, it is also important to design and implement the right economy, finance, industry, and trade policies regarding the products and services to be offered to the market. Having an ecosystem suitable for the production of goods and services attracting the market will be able to make the national economy stronger, due to the increase in the qualified labor force, employment, export level, national income level, and competitive power.

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