

Impacts of R&D Expenditures on High Technology Product Exports in BRICST Countries

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Abstract

One of the best solutions for countries with foreign trade deficit and cannot increase total exports is to improve the added value of exported products. High technology products have the highest added value. The method to increase production and exports in high technology products is to increase R&D expenditures and qualified labor force available for the R&D sector. South Korea, for example, is one of the countries that significantly accelerate economic growth thanks to technology-intensive exports. South Korea, has recognized the importance of advanced technology-driven growth in its export-oriented economic growth strategy. South Korea has succeeded in transforming the composition of the manufacturing industry significantly over the years and transforming it from labor-intensive industry to capital-intensive and high-tech industries (Arslanhan and Ve Kurtosal, 2010). Again, China initially started with cheap and low quality products exports based on cheap labor. However, when China came to 2012, there were 170 automobile brands producing and exporting. There were advances towards the defense and space industry. In the same years, China has begun to take its place in the pharmaceutical industry with its advanced technology and mass production capacity (Ozsoylu and Algan, 2011; World Bank, 2012).

On the other hand, India has significantly accelerated its economic growth through computer software, natural healthy life support products and remote call center services it offers to developed countries thanks to the individuals it sent for education abroad in the 1960s (Hindistan, 2012). Members of BRICST countries, Brazil, Russia, India, China, South Africa and Turkey drew global attention due to their economic growth performance in recent years. Economic performance of these countries affects the foreign trade volume and economic growth for the rest of the world. In the present study, impacts of R&D expenditures and the size of the qualified R&D labor force on high technology exports were investigated for BRICST countries using panel data analysis for 1996-2014 period. We expected that the study findings would reveal a positive impact of R&D expenditures and qualified labor force in the R&D sector on exports in high technology products. The present study would contribute to the literature as it would draw the attention of developing countries to the significance of R&D expenditures and qualified labor force in the R&D sector.

Keywords: R&D expenditures; Qualified labor force in R&D; High technology exports; BRICST countries.



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1. Introduction

It is expected that countries would increase technological knowledge, develop new products and production techniques, increase high-tech product manufacturing and exports by R&D expenditures (Avci, 2017; Cetin, 2016). Naturally, it is of utmost importance that the R&D expenditures should be allocated efficiently and converted into final products. To achieve this outcome, it is necessary for the nations to have a highly qualified workforce. Therefore, the number of qualified personnel employed in this field should also be included in the analysis when studying the economic impacts of R&D.

In order to bridge the gap between the underdeveloped and developed high-income countries, developing countries should prioritize R&D expenditures, allocate more budgetary resources to meet the need for a qualified labor force and develop/modify the education curricula based on innovation (Cetin 2016). Developing countries could also sign training and industrial cooperation agreements with developed countries, focus on student and educational exchange programs, and encourage direct foreign investment, which allows for technology transfer.

The BRICST countries - Brazil, Russia, India, China, South Africa and Turkey - drew global attention with their economic growth performance in recent years. The economic performance of these countries also affected global foreign trade volume and economic growth. Behind the economic growth in these countries, especially in China and India, high volume exports of high-tech products played a significant role. While the BRICST countries of Brazil and Russia demonstrated a more economical presence based on natural resource exports, India and China achieved success with inexpensive manufacturing and high exports. On the other hand, South Africa and Turkey were supported partly by their natural resource exports and partly by their high economic growth performance.

One of the BRICST countries, China initially entered the world markets with low production costs, but it has been a good example for other countries as it has recently started to focus on high-tech products and achieved success in space, electronics and automotive industries. Started to open to the world after 1978, China initially opened its southern coasts, which were suitable for foreign trade, to foreign corporations to close the country's technological gap and speed up the economic growth. China provided significant incentives and facilities for FDI companies that would invest in free trade zones they have established in that coastline, dictated certain rules such as

obligatory joint investment with a domestic company and sale of the entire production to foreign markets during the initial years. Thus, domestic companies would be able to learn and internalize high-tech production techniques, and the domestic market and infant industries would be protected. Limitation on domestic sales by foreign companies was relaxed over time, thus enabling the domestic firms to compete with international companies (Yilmaz and Koyuncu, 2005). India, one of the BRICST countries, had a more interesting approach: with the Factory Act, which was introduced in 1946 to prevent unemployment, firing workers in the industrial sector was nearly impossible. In 1991, when India started to open up to global markets and invited foreign companies to invest in the country, foreign investors hesitated to invest in the manufacturing industries due to the above mentioned act. Instead, they invested in the service and R&D industries. Today, India is home to R&D laboratories of several developed nation corporations (Ozsoylu and Algan, 2011). Naturally, the information and technology developed in these labs have positive contributions to India's high-tech manufacturing, exports and economic growth.

Thus, R&D activities are of great importance for countries that desire to accelerate economic development, and other developing countries need to focus their efforts on this field. It is obvious that analyses and studies that would be conducted on the topic would have positive contributions to national economic performance by guiding governments, decision makers and scientists.

Thus, the aim of the present study was to examine the effects of R&D expenditures and the size of technical workforce in the sector on high-tech product exports by panel data analysis for the 1996-2014 period in BRICST countries. In the second section of the study, the economic overview of BRICST countries were examined with tables and graphs, in third section, a literature review was presented, an econometric analysis was conducted in the fourth section and the study concluded with a results and discussion in the fifth section. It is expected that the present paper would have a positive contribution to the studies on R&D and export of high-tech products, to the literature by including technical R&D workforce in the analysis and to national economies by drawing attention of scientists and policymakers on R&D and exports in high-tech products.

2. Economic Overview in BRICST Countries

With high economic growth performances of 9.2% and 8.8%, respectively in 2010 and 2011, Turkey was added to BRICS countries, which are considered as the engine of the global economy since 2001. BRICST countries account for 23.3% of the global gross domestic product (World Bank, 2017a), 17.6% of global exports (World Bank, 2017b) and 27.5% of global high technology exports (World Bank, 2017c) in 2015. Thus, BRICST countries are the engines of the global economy and the developments in these countries are closely followed by the whole world. Economic growth rates in BRICST countries are presented in Table 1.

Table-1. Growth Rates in BRICST Countries

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brazil	4.1	1.4	3.1	1.1	5.8	3.2	4.0	6.1	5.1	-0.1	7.5	4.0	1.9	3.0	0.5	-3.8
Russia	10.0	5.1	4.7	7.3	7.2	6.4	8.2	8.5	5.2	-7.8	4.5	4.3	3.5	1.3	0.7	-2.8
India	3.8	4.8	3.8	7.9	7.9	9.3	9.3	8.6	3.9	8.5	10.3	6.6	5.5	6.5	7.2	7.9
China	8.5	8.3	9.1	10.0	10.1	11.4	12.7	14.2	9.7	9.4	10.6	9.5	7.9	7.8	7.3	6.9
S. Africa	4.2	2.7	3.7	2.9	4.6	5.3	5.6	5.4	3.2	-1.5	3.0	3.3	2.2	2.3	1.6	1.3
Turkey	6.8	-5.7	6.2	5.3	9.4	8.4	6.9	4.7	0.7	-4.8	9.2	8.8	2.1	4.2	3.0	4.0

Source: World Bank (2017d)

Table 1 demonstrates that China was ranked first with a 9.6% average growth and India was second with a 7% average growth in the 2000-2015 period. Brazil, with its high growth in 2004, 2007 and 2010, Russia, with its average growth rate of 7% between 2000 and 2008, South Africa, with its achievements in 2005-2007 period, and Turkey, with high economic growth rates between 2002-2006 and 2010-2011 were on the spotlight. It was particularly striking that China and India continued to exhibit high growth rates despite the 2008 global economic crisis, and even the growth rate in India did increase in that period. One of the reasons for the growth in these two countries during the crisis was the increase in demand for inexpensive products manufactured by these countries due to declining global income levels. The share of BRICST country high-tech product exports in manufacturing industry exports is presented in Table 2.

Table-2. High-Technology Exports in BRICST Countries (% of Manufactured Exports)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brazil	18.7	19.2	16.5	12.0	11.6	12.8	12.1	11.9	11.6	13.2	11.2	9.7	10.5	9.6	10.6	12.3
Russia	16.1	14.0	19.2	19.0	12.9	8.4	7.8	6.9	6.5	9.2	9.1	8.0	8.4	10.0	11.5	13.8
India	6.3	7.0	6.2	5.9	6.0	5.8	6.1	6.4	6.8	9.1	7.2	6.9	6.6	8.1	8.6	7.5
China	19.0	21.0	23.7	27.4	30.1	30.8	30.5	26.7	25.6	27.5	27.5	25.8	26.3	27.0	25.4	25.8
S. Africa	7.0	6.5	5.2	4.8	5.5	6.7	6.5	5.6	5.1	5.4	4.6	5.0	5.4	5.5	5.9	5.9
Turkey	4.8	3.9	1.8	1.9	1.9	1.5	1.9	1.9	1.6	1.7	1.9	1.8	1.8	1.9	1.9	2.2

Source: World Bank (2017e)

Based on Table 2, China is the country with the highest rate of high-tech product exports in manufacturing exports. In China, high technology exports accounted for 25% of manufacturing exports. It was followed by Russia

with 13.8% and Brazil with 12.3%. The country with the lowest high technology product exports was Turkey. While significant incentives are provided in this industry and educational cooperation with the US and the EU extending to the Ottoman period, it was observed that the desired goals were not achieved in Turkey in this field. Thus, it would be useful to determine whether the incentives provided in Turkey were used adequately or whether these incentives were strictly audited and the reasons for the failure of educational efforts. Required structural reforms should be implemented as soon as possible. Similarly, India and S. Africa need to focus on high-tech product manufacturing. The share of R&D expenditures in GDP in BRICST countries is presented in [Table 3](#).

Table-3. Research and Development Expenditure (% of GDP)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Brazil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.1	1.2	1.2	1.3
Russia	1.0	1.2	1.2	1.3	1.2	1.1	1.1	1.1	1.0	1.3	1.1	1.1	1.1	1.1	1.2
India	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9
China	0.9	0.9	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.7	1.7	1.8	1.9	2.0	2.0
S. Africa	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.7
Turkey	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0

Source: World Bank (2017f)

As presented in [Table 3](#), the country with the largest share of R&D expenditures in GDP was China. Given the high GDP in China, it could be observed that R&D spending in China was much higher when compared to other countries. China was followed by Brazil and Russia. Turkey raised this rate to 1% with great efforts. Turkey aims to increase this rate to 3% in 2023. The countries with the lowest research and development expenditures were India and South Africa and these countries are required to allocate more resources to R&D for their future development. The number of technical personnel in R&D in BRICST countries is presented in [Table 4](#).

Table-4. Technicians in R&D (per million people)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Brazil	336	323	311	359	424	461	480	509	538	592	645	NA	NA	NA	NA
Russia	570	575	574	557	552	517	518	512	487	475	475	492	478	487	500.9
India	85	NA	NA	NA	NA	92	NA	NA	NA	NA	101	NA	NA	NA	NA
China	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S. Africa	NA	74	NA	109	109	109	129	122	120	114	105	107	125	NA	NA
Turkey	37	40	39	47	50	70	83	107	108	123	143	172	190	197	207.5

Source: World Bank (2017g)

Note: NA: Non-Available

Based on [Table 4](#), Brazil had the highest number of technical personnel in R&D. It was followed by Russia and Turkey. Russian figures were high during recent years. A significant increase was observed in Brazil and Turkey. South Africa had the lowest figures in this field. Since this data set contained significant deficiencies, economic analyses would be conducted with employment in R&D data (per million people) in the present study.

3. Literature Review

A summary of previous studies on the effects of R&D expenditures and number of workers in R&D on high tech product exports was presented below based on the date of publication.

[Yildirim and Kesikoglu \(2012\)](#) investigated the causal relations between R&D expenditures and exports in 25 sub-sectors in the Turkish economy for the period of 1996-2008 with panel data analysis and found a one-way causal relationship from R&D spending to exports.

[Gocer \(2013\)](#) analyzed the effects of R&D expenditures on high-tech exports, information and communication technology exports, total exports and economic growth, in addition to the effects of high-tech product exports on foreign trade balance using the panel data analysis method that accounted for the cross-section dependency of 11 Asian Countries. Analysis results demonstrated that 1% increase in R&D expenditures increased high-technology product exports by 6.5%, exports of information and communication technologies by 0.6% and economic growth by 0.43%.

[Kilic et al. \(2014\)](#) investigated the effects of R&D expenditures on high tech exports by panel data analysis with 1996-2011 data for G-8 countries. As a result of the study, it was determined that R&D expenditures and real effective exchange rate had a positive effect on exports of high-tech products. Furthermore, two-way causality between R&D expenditures and high-tech product exports and between R&D expenditures and real effective exchange rate was estimated in addition to a one-way causality from high-tech product exports to real effective exchange rate.

[Sandu and Ciocanel \(2014\)](#) investigated the effects of R&D expenditures and innovation on high-tech product exports in European Union member countries using 2006-2010 data. In the study, exports of high-tech products increased by 8.23% and 9.17% as a result of 1% increase in government and private spending on R&D, respectively.

[Sa and Am \(2014\)](#) analyzed the effects of R&D spending on R&D research, number of patents and high-tech product exports using 1996-2011 data for 47 European Countries. As a result of the analysis, it was found that there

was a strong correlation between R&D spending, number of university graduates and number of indexed scientific publications and high-tech product exports and economic growth.

Cetin (2016) examined the correlation between R&D expenditures and high-tech product exports in Mexico, Brazil, Thailand, Malaysia, China, South Africa and Turkey, 7 developing nations, with Granger panel causality test and conducted regression analysis both by fixed and random effects method. In the causality test, one-way causality was determined from R&D expenditures to export of high-tech products. In the regression analyzes, it was found that 1% increase in R&D expenditures increased exports of high-tech products by 0.43% in the fixed effect model and by 0.25% in the random effect model.

Avci (2017) examined the effects of R&D expenditures on exports in 21 EU member countries by panel data analysis on 2007-2014 data and found that R&D spending increased exports.

Yamak (2017) examined the correlation between R&D expenditures and high-tech product exports in theory and literature. In this study, the correlation between R&D expenditures and high-tech product exports and number of patent applications in 42 countries was analyzed for 2005-2014 period, and found that in countries with high R&D expenditures, there was a positive correlation between high tech product exports and patent applications.

Harris and Moffat (2017) investigated the correlations between exports, R&D spending and innovation in the UK for 2002-2009 and found that R&D spending and innovation increased national exports by increasing productivity.

In the literature review, it was observed that previous studies generally investigated the effect of R&D expenditures on high-tech product exports, but not the effects of number of research personnel employed in R&D field on high-tech product exports. In the present study, in addition to R&D expenditures, the effect of the number of research staff employed in the R&D industry on high-tech product exports was examined to make a contribution to the literature.

4. Econometric Analysis

4.1. Data Set

In this study, 1996-2104 R&D expenditures (RDEXP, US \$), R&D Researchers (RDRES, per million people) and high-technology exports (HTX, US \$) data for Brazil, Russia, India, China, South Africa and Turkey were used to reveal the effects of R&D expenditures and number of researchers employed in R&D on high-tech product exports. The data were obtained from the (World Bank, 2017c;2017f;2017h),. RDEXP values were % of the GDP, multiplied by GDP values and converted into current US \$. The Chinese data included the data obtained for China (Mainland), Hong Kong SAR and Macao SAR. Logarithmic transformation of the data was used in the analyses.

4.2. Model

In this study, the econometric models used to determine the impacts of R&D expenditures and number of researchers employed in R&D on high technology exports are presented below. The first model was created using the model developed by Gocer (2013) and Cetin (2016) and the second model was developed by the authors. Thus, it was considered that the present study would contribute to the literature.

$$\text{Model 1: } \text{LogHTX}_{i,t} = \beta_{0i} + \beta_{1i} \text{LogRDEXP}_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$\text{Model 2: } \text{LogHTX}_{i,t} = \alpha_{0i} + \alpha_{1i} \text{LogRDRES}_{i,t} + v_{i,t} \quad (2)$$

More variables could be included in the abovementioned models, however the main objective of the present study was to determine the effects of R&D expenditures and the number of researchers employed in R&D on high-tech product exports. That was the reason for reconstruction of the above models thusly.

4.3. Method

In this study, panel data analysis methods were used to investigate the effects of R&D expenditures and the number of researchers employed in R&D on exports of high technology products. In this context, stationarity of the series was tested by Fisher Augmented Dickey Fuller (ADF) and Fisher Phillips-Perron (PP) panel unit root methods, causality between the series was determined by Dumitrescu and Hurlin (2012) panel causality test, existence of co-integration between the series was determined by Westerlund (2007) Error Correction Model (ECM) panel co-integration test and the homogeneity of co-integration coefficients was investigated by Pesaran and Yamagata (2008) method. The individual co-integration coefficients were estimated with the Common Correlated Effect (CCE) method developed by Pesaran (2006) and general panel co-integration coefficients were estimated by using the Common Correlated Mean Group Effect (CCMGE) method developed by Pesaran (2006).

4.4. Panel Unit Root Test

In this study, stationarity of the series was investigated by Fisher ADF method developed by Maddala and Wu (1999) and Fisher PP method developed by Choi (2001). These tests included the unit root process, taking into account that there might be differences between the countries in the panel. The Fisher PP test is more powerful when compared to the Fisher ADF test in series that include trend, therefore both methods were employed in the study. The test hypotheses were as follows:

H_0 : The series are not stationary

H_1 : The series are stationary

Fisher ADF and Fisher PP unit root tests were conducted in the study and the results are presented in Table 5.

Table-5. Panel Unit Root Test Results

	Fisher ADF Tests				Fisher PP Tests			
	ADF - Fisher Chi-Square		ADF - Choi Z-Stat.		PP- Fisher Chi-Square		PP - Choi Z-Stat.	
	Test Statistics	Prob.	Test Statistics	Prob.	Test Statistics	Prob.	Test Statistics	Prob.
LogRDEXP	1.82	0.99	3.07	0.99	1.34	0.99	3.36	0.99
LogRDRES	11.37	0.49	0.64	0.74	28.52***	0.00	-0.38	0.35
LogHTX	16.21	0.18	-0.59	0.27	19.41*	0.07	-0.90	0.18
ΔLogRDEXP	32.44***	0.00	-3.23***	0.00	32.92***	0.00	-3.65***	0.00
ΔLogRDRES	64.54***	0.00	-5.58***	0.00	49.14***	0.00	-4.97***	0.00
ΔLogHTX	21.56**	0.04	-2.11**	0.01	56.88***	0.00	-5.48***	0.00

Note : *, **, and *** indicate stationarity at 10%, 5% and 1% significance level, respectively, respectively

Based on the results presented in Table 5; all series were non-stationary at level values and became stationary when their first differences were taken. That is, all series were $I(1)$. Although the *LogRDRES* and *LogHTX* series were stationary in level based on one test statistics in PP test, when these results were evaluated together with other test statistics, it was concluded that these series were also $I(1)$. Thusi it could be stated that analysis of these series included considerable fluctuations and that analyzes conducted with level values of the series might result in spurious regression problems and therefore, it was necessary to perform co-integration test before the regression analysis.

4.6. Panel Causality Test

Causality tests are conducted to determine if there was an interaction between the series used in the analysis. Thus, the test determines whether the variables included in the models were related or not. When the test provides causality between the dependent variable and the independent variables, it is adequate to establish regression between these variables. Otherwise, it would be a mistake to use non-correlated variables in the same model (Gocer, 2015). In the present study, the presences of causality between the series were examined with Dumitrescu and Hurlin (2012) causality test. In the Dumitrescu and Hurlin (2012) panel causality test process, the following equation system was utilized.

$$Y_{i,t} = \alpha_i + \sum_{k=1}^K \gamma_i^k Y_{i,t-k} + \sum_{k=1}^K \beta_i^k X_{i,t-k} + \varepsilon_{i,t} \quad (3)$$

$$X_{i,t} = \theta_i + \sum_{k=1}^K \delta_i^k X_{i,t-k} + \sum_{k=1}^K \xi_i^k Y_{i,t-k} + \nu_{i,t} \quad (4)$$

Where, K is the optimum lag length. Equation (3) examines the causality from X to Y and Equation (4) examines the same from Y to X. Dumitrescu and Hurlin (2012) causality test assumes that the coefficients might be different for cross sections. Hypotheses of these tests are:

$H_0 : \beta_i^{(k)} = 0$ for all i . There is no causality relationship between X and Y in all cross sections.

$H_1 : \begin{cases} \beta_i^{(k)} = 0 & \text{for } i = 1, 2, \dots, N_1 \\ \beta_i^{(k)} \neq 0 & \text{for } i = N_1 + 1, N_1 + 2, \dots, N. \end{cases}$ There is causality relationship between X and Y in some cross sections.

In order to conduct Dumitrescu and Hurlin (2012) panel causality test, it is necessary to determine the optimum lag length first. The results of the criteria for determining optimum lag length are presented in Table 6.

Table-6. Results of the Criteria for Determining Optimum Lag Length

	Lag	LR	FPE	AIC	SC	HQ
Model 1	0	NA	1.123804	5.792472	5.848023	5.814873
	1	664.1149	0.000594	-1.752144	-1.585490*	-1.684939*
	2	8.527795	0.000588	-1.763582	-1.485826	-1.651574
	3	11.64100*	0.000559*	-1.814946*	-1.426087	-1.658135
	4	5.057468	0.000574	-1.788495	-1.288533	-1.586881
Model 2	0	NA	3.069129	6.797146	6.852697	6.819548
	1	878.2824	0.000138	-3.209164	-3.042510*	-3.141960
	2	8.805792	0.000136	-3.223873	-2.946116	-3.111865
	3	20.29966*	0.000117*	-3.379558*	-2.990699	-3.222747*
	4	4.308349	0.000121	-3.343859	-2.843897	-3.142245

Note: * indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level),

FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.

In Table 6, based on LR, FPE and AIC criteria in Model 1, LR, FPE, AIC and HQ in Model 2, it was determined that the optimum lag length was 3. The inverse roots of the VAR characteristic model with 3 lag lengths are presented below.

Figure-1. Inverse Roots of AR Characteristic Polynomial of Model 1

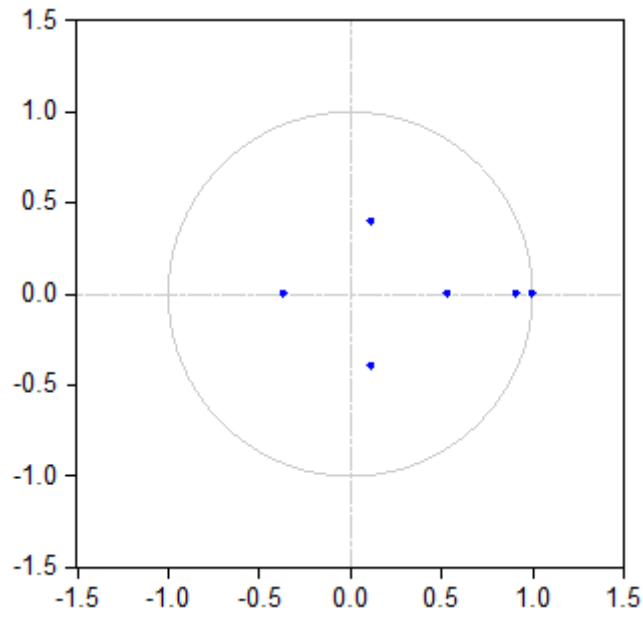


Figure-2. Inverse Roots of AR Characteristic Polynomial of Model 2

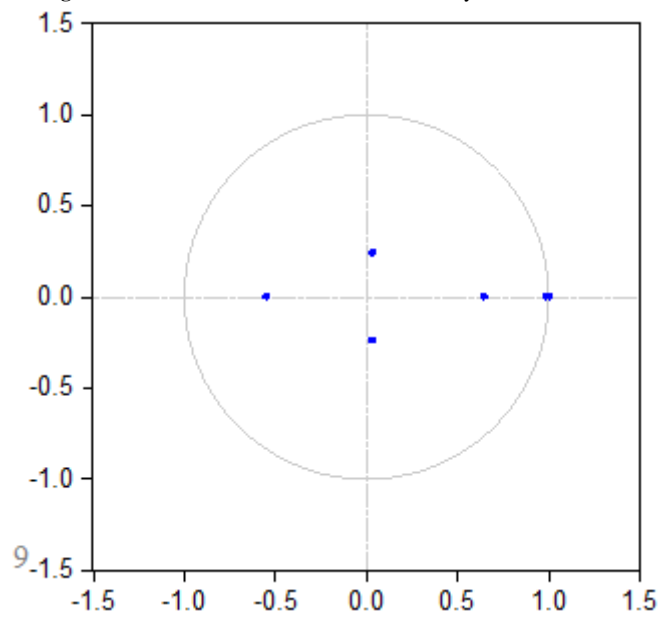


Fig1-2 be here

In Fig 1 and Fig 2, since the inverse characteristic roots remained within the unit circle, the VAR models established were stable and the results of the causality tests that would be performed based on these models were reliable. Dumitrescu and Hurlin (2012) panel causality tests were conducted separately for the models and the obtained results are presented in Table 7.

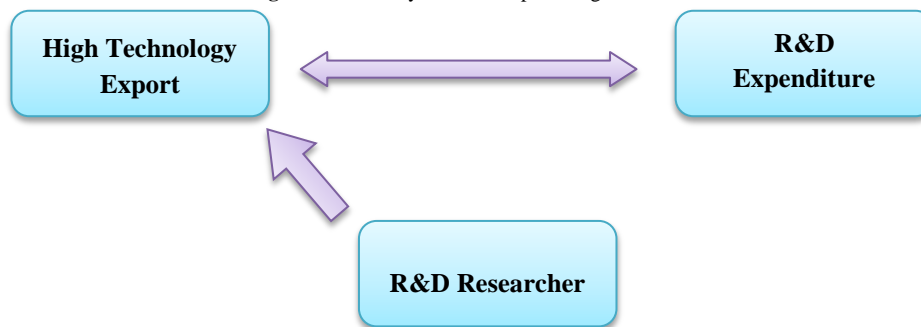
Table-7. Dumitrescu and Hurlin (2012) Panel Causality Test Results

	Null Hypothesis	Statistics	Statistics	Prob.
Model 1	$LnRDEXP \nrightarrow LnHTX$	8.75***	2.69***	0.00
	$LnHTX \nrightarrow LnRDEXP$	8.23**	2.40**	0.01
Model 2	$LnRDRES \nrightarrow LnHTX$	14.73***	5.98***	0.00
	$LnHTX \nrightarrow LnRDRES$	5.77	1.05	0.29

Note: *, **, and *** indicate the presence of the causality relationship from first variable to the second one at 10%, 5% and 1% significance level, respectively.

In order to make follow the results in Table 7 easily, Fig 3 is presented below:

Figure-3. Causality Relationship Among Variables



According to Fig 3, in BRICST countries; there was a two-way causality between high technology exports and R&D expenditures, one-way causality from number researchers in R&D to high technology exports. The findings were consistent with our theoretical premises. In the causality test for Model 1, while the increased R&D expenditures results in an increase in high-tech production and exports, increased export revenues and national income made it possible to allocate more resources to R&D activities. In the causality test for the Model 2, it was observed that increasing the number of R&D researchers also increased high technology exports, as predicted. These variables, therefore, interact with each other and using them in the same regression model would be meaningful.

4.7. Panel Co-integration Test

Engle and Granger (1987) stated that analyzes conducted with non-stationary series might include spurious regression problem, but also emphasized that the regression would be reliable if the error term series obtained as a result of estimating the co-integration with level values of non-stationary series were stationary. Thus, if the co-integration between the non-stationary series at the level values exists, the co-integration coefficient estimation results would be reliable and would not contain the spurious regression problem (Tari, 2012).

In the present study, presence of co-integration between the series was examined by Westerlund (2007) ECM panel co-integration test. This test can be used to determine whether there was a cross-section dependency between the countries in the panel. Hypotheses of the test were determined as follows:

H_0 : Series are not co-integrated

H_1 : Series are co-integrated

Four different test statistics were calculated to test these hypotheses; While P_τ and P_α panel statistics were used under the assumption of homogeneity of co-integration coefficients, G_τ and G_α group statistics were used under the assumption of heterogeneity. Then homogeneity test was required for the study. Pesaran and Yamagata (2008) slope homogeneity test was performed for this purpose. Hypotheses of the test were as follows;

H_0 : Slope coefficients are homogenous

H_1 : Slope coefficients are not homogenous

Pesaran and Yamagata (2008) developed two different test statistics to test the abovementioned hypotheses, Δ for large samples and Δ_{adj} for small samples. Pesaran and Yamagata (2008) homogeneity test was performed using the Gauss 9.0 software and the code written by Pesaran and Yamagata (2008) for this software. The findings are presented in Table 8.

Table-8. Slope Homogeneity Test Results

		Test Statistics	Prob.
Model 1	Δ	9.056 ***	0.000
	Δ_{adj}	9.822 ***	0.000
Model 2	Δ	12.991***	0.000
	Δ_{adj}	14.091***	0.000

Note: *** indicates that the slope coefficients are homogeneous at 1% significance level

Based on the results presented in Table 8, the H_0 hypothesis was strongly rejected and it was concluded that the slope coefficients were not homogeneous in the co-integration equation. In this case, the co-integration test should be based on group statistics. Furthermore, while the co-integration coefficients were calculated, it was more adequate to choose a method that would provide individual results. In the study, Westerlund (2007) ECM panel co-integration test was conducted with the Gauss 9.0 software and the code written by Westerlund (2007) for this software, and the findings are presented in Table 9.

Table-9. Westerlund (2007) ECM Panel Cointegration Test Results

		Test Statistics	Prob.
Model 1	P_τ	-3.521***	0.000
	P_α	-0.135	0.446
	G_τ	-1.625*	0.052
	G_α	-0.501	0.308
Model 2	P_τ	-10.941***	0.000
	P_α	-4.601***	0.000
	G_τ	-4.807***	0.000
	G_α	-0.072	0.471

Note: *** and * represents the presence of cointegration at 10%, 5% and 1% significance level, respectively

Based on the results presented in Table 9, the H_0 hypothesis was rejected in both models and it was concluded that the series were co-integrated. Thus, false regression problems would not be encountered for the regression estimates that would be determined with level values in these series.

4.8. Estimation of Panel Co-integration Coefficients

In the present study, individual co-integration coefficients were estimated for the countries by the CCE method developed by Pesaran (2006) and the co-integration coefficients for the general panel were estimated by the CCMGE method developed by Pesaran (2006). The reason for using these methods was that the slope coefficients did not appear to be homogeneous for the countries in the panel. Estimation of co-integration coefficients was conducted with Stata 11 software and the code written by Pesaran (2006) for this software and the findings are presented in Table 10.

Table-10. Estimation to Panel Cointegration Coefficients Results

	Model 1		Model 2	
Country	Constant	Cointegration Coefficients	Constant	Cointegration Coefficients
Brazil	2.43 [0.88]	0.07 [0.31]	-4.08 [-1.21]	-1.24 [-0.71]
Russia	7.16*** [3.42]	0.26 [0.82]	-5.03 [-0.20]	1.38 [0.58]
India	-4.37*** [-2.52]	0.70 [1.09]	-8.67*** [-2.88]	1.73*** [3.73]
China	-18.75*** [-4.31]	0.38** [2.29]	-3.92*** [-2.74]	1.65*** [6.18]
South Africa	6.98*** [3.93]	0.32* [1.59]	4.81** [1.65]	-1.01** [-2.01]
Turkey	1.83 [0.72]	0.83* [1.52]	-2.27 [-0.65]	0.62* [1.34]
CCMGE*	0.92 [0.24]	0.28** [1.75]	-4.57*** [-3.73]	0.63** [1.85]

Note: *, **, and *** implies that the coefficient is statistically significant 10%, 5% and 1% significance level, respectively. Values in brackets are t-statistics.

Based on the results obtained for Model 1 in Table 10, in Brazil, Russia and India, the impact of R&D spending on high-tech product exports was positive but statistically insignificant. In the case of Brazil, this was due to the fact that this country predominantly exports raw materials, while in the case of Russia, it was due to the fact that this country is also a predominantly raw material exporter and the R&D facilities in Russia are mainly on the weapons industry. The reason for India was believed to be that the R&D activities in this country are usually conducted by

foreign companies and that the integration of the developed technologies to production process, production and export phases remained in other countries (probably China or related foreign corporation's home country). A 1% increase in R&D spending increased high-tech product exports by 0.38% in China, 0.32% in South Africa and 0.83% in Turkey and these differences were statistically significant. It was considered that the reason for the higher impact in Turkey lied in the fact that the law of diminishing returns was still not valid in this country in terms of R&D expenditures. On average, a 1% increase in R&D spending increased high-technology product exports in BRICST countries by 0.28%. Thus, when R&D spending would increase in these countries, high-tech product exports would continue to increase. It would be beneficial for national policy makers to consider this fact.

Based on the results obtained for Model 2, it was found that the increase in the number of researchers employed in R&D had a statistically insignificant negative impact on high-tech product exports in Brazil and South Africa. This finding implied that the law of diminishing productivity on labor was valid for these countries. In India, China, Turkey and the overall panel, it was found that a 1% increase in the number of researchers employed in R&D increased high-technology product exports by 1.73%, 1.65%, 0.62% and 0.63% respectively. Especially in India and China, both elasticity coefficients were obtained and the degrees of significance were higher. This implied that researchers employed in R&D in India and China was more productive. When the overall panel findings were considered; it was determined that a 1% increase in the number of researchers employed in R&D increased high-technology product exports in BRICST countries by 0.63%. Thus, as the number of researchers employed in R&D increases in the country's workforce, high-tech product exports would continue to increase. It would be beneficial for national policy makers to consider this fact.

5. Conclusion

In order to bridge the gap with developed and high-income countries, developing countries should prioritize R&D expenditures, allocate higher budget share to meet the need for a qualified labor force and develop/modify the educational curricula parallel to innovations. Developing countries could also sign training and industrial cooperation agreements with developed countries, focus on student and educational exchange programs, and encourage direct foreign investment, which allows for technology transfer.

The BRICST countries - Brazil, Russia, India, China, South Africa and Turkey – became prominent in the global scale with recent economic growth performances. The economic performance of these countries also affects foreign trade and economic growth around the world. Among these countries, the country with the lowest high technology product exports is Turkey. Despite the state incentives, educational cooperation with the US and the EU that dates back to the Ottoman period, it was observed that the desired level of innovation in high technology products were not attained in Turkey. Thus, it is important to determine that whether the provided incentives in Turkey were used adequately or whether these incentives were strictly audited, and the reasons for the failure of the educational efforts should be assessed. Necessary reforms should be implemented as soon as possible. Similarly, India and S. Africa need to focus on producing high-tech products.

Among BRICST countries, China has the highest share of R&D in national income with 2% and South Africa is the lowest with 0.7%. Turkey was able to increase the share of R&D expenditures in GDP to 1% with great efforts. Turkey aims to increase this rate to 3% by 2023.

In the present study, 1996-2014 R&D expenditures, number of R&D research personnel and high-technology exports data for Brazil, Russia, India, China, South Africa and Turkey were used to determine the effects of R&D expenditures and number of researchers in R&D on high-tech product exports. Two separate models were employed in the panel data analysis. The stationarity of the series was tested with the Fisher ADF and Fisher PP panel unit root tests and it was found that all the series were not stationary at level values, but stationary when their first difference was taken, that is, they were $I(1)$.

Existence of causality between the series was tested by Dumitrescu and Hurlin (2012) panel causality test and it was found that there was a two-way causality between high-tech product exports and R&D expenditures, while there was a one-way causality relationship from the number of employees in R&D to high-tech product exports in BRICST countries. Thus, on one hand, while the increase in R&D expenditures in these countries increased the production and exports of high-tech products, increase in export revenues and national income made it possible to allocate more resources to R&D activities. Increasing number of R&D researchers was also expected to improve high technology exports.

The homogeneity of co-integration coefficients was investigated by Pesaran and Yamagata (2008) method and it was decided that the slope coefficients in the co-integration equation were not homogeneous. Thus, it was decided that co-integration test should be based on group statistics and a method that provided individual results was preferred during the calculation of co-integration coefficients.

The presence of co-integration between the series was examined by Westerlund (2007) ECM panel test and it was determined that the series in the models were co-integrated, in other words, spurious regression problem would not arise when the level values were analyzed; the series moved together in the long term and affected each other.

The individual co-integration coefficients were estimated with Pesaran (2006) CCE method and overall panel co-integration coefficients were estimated by CCMGE method developed by Pesaran (2006). A 1% increase in R&D spending improved high-tech product exports by 0.38% in China, 0.32% in South Africa, 0.83% in Turkey and 0.28% in the overall panel. A 1% increase in the number of researchers employed in R&D was estimated to improve high-tech product exports in India, China, Turkey and overall panel by 1.73%, 1.65%, 0.62% and 0.63%, respectively.

Based on these results, it could be stated that high-tech product exports would continue to increase as R&D expenditures and the number of R&D researchers in BRIC countries would increase. These countries in general have increasing returns on labor and capital. Thus, it would be beneficial for national policy makers to consider this fact. In this context, they could allocate higher share of national income to R&D, could revise their education system to increase the number of qualified researchers in the R&D, and could improve the benefits provided to these personnel. Thus, they could prevent the brain drain in their country.

It is also important to remember that every study, invention, patent in R&D is not converted into a product. Thus, it might be useful to establish coordination committees that are qualified, objective and prioritize national interests to coordinate R&D activities and determine the priority areas.

There is also a need to ensure national political and economic stability to attract higher foreign investments in R&D industry, for effective protection by the rule of law and fight against corruption and to effectively protect the intellectual property rights.

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