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Ar-Ge Harcamaları ile Ekonomik Büyüme Arasındaki İlişki: Seçilmiş Yeni Sanayileşen Ülkelerde Panel Veri Analizi

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ÖZ:
Dünya ekonomisinde meydana gelen gelişmeler ve ülkeler arasında artan rekabet ile birlikte, ekonomik büyümenin belirleyicileri değişikliğe uğramıştır. Bu bağlamda, 1980 sonrası dönemde, dünya ekonomisinde artan küresel rekabete bağlı olarak teknolojik yenilik olgusu önem kazanmış, teknolojik yeniliği ortaya çıkaran ve ekonomik büyümenin itici gücü olarak değerlendirilen araştırma geliştirme (Ar&Ge) faaliyetlerine verilen önem artmıştır. Çalışmada; Ar&Ge harcamaları ile ekonomik büyüme arasındaki ilişkiyi incelemek amacıyla seçilmiş yeni sanayileşen ülkelerde (Newly Industrialized Countries: NIC Countries: Güney Afrika, Meksika, Brezilya, Çin, Hindistan, Endonezya, Malezya, Filipinler, Tayland ve Türkiye) 1996-2019 dönemine ait Ar&Ge harcamaları (ARGEHAR, Milyon Dolar), Ar&Ge alanında çalışan araştırmacı sayısı (ARGEARS, 1000 000 kişi başına düşen) ve ülkelerin toplam faktör verimliliği (TFV) yıllık verileri Panel Veri Analizi Yöntemi kullanılarak incelenmiştir. Toplam Faktör Verimliliği verileri PWT (2020)'den ve diğer veriler World Bank (2020a, 2020b, 2020c, 2020d)'den alınmıştır. ARGEHAR verileri; Ar&Ge harcamalarının GSYH'ye oranı ve GSYH verileri kullanılarak tarafımızdan elde edilmiştir. ARGEHAR verileri 1996 yılından başladığı için çalışma 1996-2019 dönemi verileri kullanılarak gerçekleştirilmiştir. Analiz döneminde yer alan 2008 Küresel Ekonomik Krizi de kukla değişkenle analize dâhil edilmiştir. Korelasyon analizinde; NIC ülkelerinde Ar&Ge harcamaları ve Ar&Ge alanında çalışan araştırmacı sayıları ile ekonomik büyüme ve toplam faktör verimliliği arasında pozitif korelasyonların olduğu görülmüştür. Ekonomik büyüme ile olan korelasyonlar daha güçlü iken, toplam faktör verimliliği ile olanlar daha düşük çıkmıştır.

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Ar&Ge alanında çalışan araştırmacı sayısı ile ekonomik büyüme ve toplam faktör verimliliği arasındaki ilişkilerin, Ar&Ge harcamalarından daha büyük olduğu da görülmüştür. Bu çalışmadan elde edilen bulgulara dayanarak; Ar&Ge harcamalarının ve Ar&Ge alanında çalışan araştırmacı sayısının fazla olmasının ekonomik büyümeye ve toplam faktör verimliliğine olumlu yönde etki edeceği ancak, bu verilerin büyüklüğü kadar niteliğinin de önemli olduğu ifade edilebilir.

ANAHTAR KELİMELER: Ar&Ge Çalışmaları, Ekonomik Büyüme, Son Dönemlerde Sanayileşen Ülkeler, Panel Veri Analizi.

ABSTRACT:
It reveals that developments in the world economy and increased competition between countries have highlighted some other factors related to the economic growth. In this context, the determinants of economic growth include technological innovation due to the increasing global competition, and research and development (R&D) activities which are considered as the driving force of economic growth in the post-1980 period. The study investigates the effect of R&D spending, such as R&D expenditures (million dollars), the total number of researchers in the field (per 1000 000 people), as well as total factor productivity (TFP) annual reports on total factor productivity and economic growth in newly industrialized countries (South Africa, Mexico, Brazil, China, India, Indonesia, Malaysia, Philippines, Thailand, and Turkey) using panel data analysis over the period 1996-2019. The source of total factor productivity data come from PWT (2020) and other data from World Bank (2020a, 2020b, 2020c, 2020d). R&D spending indicator is measured using GDP data and the ratio of R&D expenditures to GDP. The study used the data of the years over 1996-2019 as the necessary data is available for that period. The 2008 global economic crisis, which took place during the analysis period, was also included in the analysis with the dummy variable. Correlation analysis showed positive correlations between R&D expenditures and the number of researchers working in the field of R&D in NIC countries and economic growth and total factor productivity. It was also observed that the relationship between the number of researchers working in the field of R&D and economic growth and overall factor productivity is greater than R&D expenditures. According to the research findings, it is suggested that R&D expenditures and the large number of researchers working in the field of R&D will have a positive impact on economic growth and overall factor productivity, but the nature of these data is as important as the size.

KEYWORDS: R&D Activities, Economic Growth, Newly Industrialized Countries, Panel Data Analysis.

INTRODUCTION

There is a considerable evidence that technological innovations can affect economic growth, research and development (R&D) activities is a driving force and strategic support for promoting technological progress. In this context, research and development (R&D) activities is a process intended to create and use information in support of the development of new product, new process or new information related to the design of new applications (Guellec and Potterie, 2000). Thus, R&D activities is an important way to promote total factor productivity and sustainable economic growth for developed and developing countries (Stokey, 1995; Jones, 1995).

Frank Ramsey's article “A Mathematical Theory of Saving”, published in 1928, became the foundation of the leading approach to economic growth, and then many economic growth theories were put forward. Ramsey's work was followed by the Harrod-Domar growth model developed by Harrod and Domar in 1946-1947, and new outstanding contributions were made to the body of knowledge in the field in the 1950s with the growth model developed by Solow (1956) and Swan (1956). These theories, called the Solow-Swan growth model or Neo-Classical growth models, have suggested that economy will not grow in the course of time, since the production function will have a decreasing returns to scale, and the technology will be an external variable. In the late 1980s, the Solow-Swan growth model or Neo-Classical growth models, which played a very important role in explaining the growth process but were insufficient in the subsequent process, were replaced by endogenous growth models. Endogenous growth models, where technology takes the form of internal variable, became an important research topic in the literature.

Endogenous growth models predicts increasing returns to scale and sustaining ongoing growth above the stationary state growth rate. With the endogenous growth models that emerged after the second half of the 1980s, knowledge began to take place in the model as a production factor. Therefore, since the late 1980s, in parallel with the developments in the world, the phenomenon of technological innovation has been pervasive across the world. In this context, R&D activities, which are the main element of growth, are included as an internal variable in the model established by Romer (1990). Romer's work in 1990 addressed the importance of R&D in the process of economic growth and indirectly in the process of innovation, and thus adds a new dimension to growth theories. Romer's growth model, established to refute the neo-classical approach hypotheses of perfect competition and constant returns to scale, argues that R&D activities lead to increasing returns by generating positive externality in sector activities. Knowledge is the fundamental dynamic behind long-term growth. Subsequently, Grossman and Helpman (1991a) and Aghion and Howitt (1992) further developed this model. According to the endogenous growth approach, human capital and R&D activities can play an important role in terms of their capacity to increase the existing stock of knowledge and boost technological innovations. Therefore, it has become one of the concepts on which both the private and public sector attach great importance in recent years. In this context, a large of body studies showing that R&D activities are critical enablers of innovation, efficiency and especially economic growth have contributed to the existing literature. R&D activities increase the competitiveness of countries in the international arena by enabling the development of new production techniques based on knowledge and technology, and therefore the creation of new products with high added value and increased productivity. It also contributes significantly to the growth of countries by enabling foreign capital for technology-oriented investments in the country (Guellec & Potterie, 2000; Stokey, 1995).

There is bi-directional relationship between R&D activities and economic growth phenomena (Pessoa, 2010: 152). For this reason, technology and R&D activities are cited as one of the most important reasons for differences in the level of economic development and income differences between countries (Bilbao-Osorio and Rodriguez-Peso, 2004). R&D activities in a knowledge-based economy may hold a key to achieve a higher technological progress and living standards (Bilbao-Osorio and Rodriguez-Peso, 2004; Stokey, 1995). This study seeks to reveal the the relationship between R&D spending, such as R&D expenditures (million dollars), the total number of researchers in the field (per 1000 000 people), as well as total factor productivity (TFP) annual reports on total factor productivity and economic growth in newly industrialized countries (South Africa, Mexico, Brazil, China, India, Indonesia, Malaysia, Philippines, Thailand, and Turkey) using panel data analysis over the period 1996-2019.

In the study, a set of primary studies conducted on the possible effects of R&D expenditures on economic growth were first mentioned; later, econometric analysis was carried out to give empirical content to the research question and eventually the findings were interpreted and evaluated.

1. Literature Review

There have been studies carried out to examine the effects of R&D expenditures on total factor productivity and economic growth. This section of the paper explores the relationship between R&D expenditures and total factor productivity and R&D expenditures and economic growth variables. In this context, the studies conducted on the topic show different results.

In their study, Grossman and Helpman (1991b) defined total factor productivity as an increasing function of R&D activities. In his study of the US and G5 economies, Jones (1995) rejects the assumption that the increase in total factor productivity is directly related to the level of resources allocated to R&D. In this context, while R&D expenditures and the level of R&D employees in these economies increased steadily, no growth was observed in total factor productivity. Park (1995) attempted to reveal the relationship between total factor productivity and R&D expenditures of 10 OECD countries. The study found that R&D expenditures lead to an increase in total factor productivity. Coe and Helpman (1995) investigated the relationship between domestic and International R&D activities of 24 countries and total factor productivity in their study. The study found that domestic and foreign R&D investments have a strong and meaningful relationship with total factor productivity. Bravo and Garcia (2011) noted that an increase in R & D spending will also lead to an increase in total factor productivity over a long period.

In his study, Lichtenberg (1993) examined the relationship between R&D expenditures and economic growth. To Lichtenberg, while there is a positive relationship between privately owned R&D expenditures and growth, public sector R&D expenditures have no effect on economic growth. In fact, public sector R&D expenditures can sometimes have a negative impact on economic growth. Goel and Ram (1994) examined the impact of R&D expenditures on economic growth. The study found that economic growth is associated only with R&D expenditures in high-income countries. Gittleman and Wolff (1995) investigated the relationship between R&D activities and growth. As a result of their study, it is suggested that R&D spending is an important factor in explaining growth only in developed countries, while in low-income and underdeveloped countries it is insufficient to explain growth. In addition, there is no casual relationship between variables of R&D expenditures and economic growth. R&D expenditures and economic growth do not imply a casual relationship. According to Sylwester (2001) and Lederman and Maoney (2003), R&D spending is an important variable that explains economic growth for countries leading in technology. In this context, R & D expenditures do not affect economic growth outside developed countries. In addition, there is no relationship between R&D expenditures and economic growth for selected OECD countries. However, considering the G-7 countries, there is a positive relationship between R&D expenditures and economic growth. Samimi and Alerasoul (2009) noted that the R&D expenditures of developing countries do not have any positive impact on economic growth. Samimi and Alerasoul further added that R&D expenditures do not have a significant impact on economic growth because developing countries have low R&D expenditures. Inekwe (2015) noted that R&D expenditures have a positive impact on economic growth in upper-middle income countries, but insignificant impact on increasing economic growth in low-middle income countries. Feki and Mnif (2016) examined the relationship between technological innovation and economic growth. The study found that the impact of technological innovations on short-term growth is negative and on long-term growth positive. Taş, Taşar and Açcı (2017) identified causal relationships running from economic growth to R&D expenditures. The study found that the reaction of R&D expenditures to a negative shock to growth translate into defaults for about four periods. Dereli and Salğar (2019) stated that R&D expenditures are an important factor in the realization and acceleration of growth. In this context, a mutual causal relationship has been reached between R&D expenditures and growth.

Freire-Seren (2001), Bassanini and Scarpetta (2001), Del Monte and Papagni (2003), Yanyun and Mingqian (2004), Zachariadis (2004), Bilbao-Osorio and Rodríguez-Pose (2004), Falk (2007), Sadraoui and Zina (2009), Piras et al. (2011), Gyekye et al. (2012), Eid (2012), Amaghouss and Ibourk (2013), Göçer(2013), Meçik (2014), Altıntaş and Mercan (2015), Pece et al. (2015), Tari and Alabash (2017) also stated that R&D expenditures has a positive impact on economic growth.

This study explores the relationship between R&D spending, such as R&D expenditures (million dollars), the total number of researchers in the field (per 1000 000 people), as well as total factor productivity (TFP) annual reports on total factor productivity and economic growth in newly industrialized countries (South Africa, Mexico, Brazil, China, India, Indonesia, Malaysia, Philippines, Thailand, and Turkey) over the period 1996-2019 through an econometric analysis. Annual data in the period 1996-2019 has been tested via the panel data analysis method. In this sense, research findings have also been represented concretely and made several contributions to the literature.

2. Econometric Analysis

2.1. Data Set

In the study, the data of R&D expenditures (RDEXP, million dollars), the total number of researchers in the field (RDNofR, per 1000 000 people), as well as total factor productivity (TFP) annual reports have been used in order to analyze the relationships between R&D spending (Y denotes real GDP per capita, US$, calculated at constant prices in 2010). TFP data source includes information retrieved through PWT (2020), and other data source through World Bank (2020a, 2020b, 2020c, 2020d). R&D spending indicator is measured using GDP data and the ratio of R&D expenditures to GDP. The study used the data of the years over 1996-2019 as the necessary data is available for that period. The 2008 global economic crisis, which took place during the analysis period, was also included in the analysis with the dummy variable. Descriptive statistics for the series used in the analysis are included in Appendix 1, and the correlation matrix is presented in Table 1.

Table 1. Correlation Matrix

	LnY	**LnTFP**	**LnRDEXP**	**LnRDNofR**
LnY	1	0.69258	0.28	0.66
LnTFP	0.69	1	0.04	0.33
LnRDEXP	0.28	0.04	1	0.66
LnRDNofR	0.66	0.33	0.66	1

Table 1 illustrates positive correlations between R&D expenditures, the number of researchers working in the field of R&D and economic growth and total factor productivity in NIC countries. Correlations with economic growth are stronger, while those with total factor productivity are lower. It seems that the relationship between the number of researchers working in the field of R&D and economic growth and overall factor productivity is greater than R&D expenditures.

2.2. Model

Cobb-Douglass production model functions with three inputs. Y is national income or production, L is labor, and K is capital. The production function is as follows:

$$Y = A * K^{\alpha} * L^{\beta} \tag{1}$$

Here, α denotes the sensitivity (flexibility) of production to capital, and β the sensitivity of production to labor. Solow (1986) explains the neoclassical growth model he developed with Equation (1), where he calls A as a external technology shock. Later, people used the term Solow residual to refer A because it represents the part of production that cannot be explained by Capital and labor. Romer (1986) and Lucas (1988) favored an endogenous model that replaced the technological progress variable (external variable in Solow's model) with a model in which the effective workforce became the key determinants. In this study, capital is represented by R&D expenditures and the labor force by the number of researchers working in R&D field. Thus, Equation (1) was converted into Equation (2) as follows:

$$Y = A * RDEXP^{\alpha} * RDNofR^{\beta} \tag{2}$$

Taking the natural logarithm of both sides of the equation in Equation 2, we have the following linear equation:

$$LnY = LnA + \alpha LnRDEXP + \beta LnRDNofR \tag{3}$$

When this equation is changed into an econometric model, we have the following Model 1

$$LnY_{it} = \alpha_0 + \alpha_1 LnRDEXP_{it} + \alpha_2 LnRDNofR_{it} + e_{it} \tag{4}$$

It should be noted that in Equation (4) α_0 represents the technology parameter (A), since it is a constant factor. However, there are also researchers who consider this parameter as the total factor productivity (TFP) of countries. It is quite plausible that the technology parameter or total factor productivity is affected by R&D spending in the country and the number of researchers working in the field of R&D. With this in mind, Model 2 can be measured using R&D expenditures in TFP and the number of researchers working in the field of R&D parameters as a function:

$$LnTFP_{it} = \beta_0 + \beta_1 LnRDEXP_{it} + \beta_2 LnRDNofR_{it} + e_{it} \tag{5}$$

When the crisis dummy variable is added to to these models, we have the following equations:

$$\text{Model 1: } LnY_{it} = \alpha_0 + \alpha_1 LnRDEXP_{it} + \alpha_2 LnRDNofR_{it} + \alpha_3 K_{2008} + e_{it} \tag{6}$$

$$\text{Model 2: } LnTFP_{it} = \beta_0 + \beta_1 LnRDEXP_{it} + \beta_2 LnRDNofR_{it} + \beta_3 K_{2008} + e_{it} \tag{7}$$

As R&D spending and the increase in the number of researchers working in the field of R & D are expected to increase production (Y) and total factor productivity (TFP) in the country, the coefficients of R&D expenditures variables are expected to be positive as a result of the analysis. Since the 2008 economic crisis is expected to negatively affect the economic growth of countries, α_3 <0 value can be obtained. But we do not have a priori expectation about the direction of the impact of the economic crisis on the overall factor productivity of countries.

This is because, as Schumpeter (1934) States in his theory of Creative Destruction, economic shocks may allow the least productive firms to replace more productive ones.

2.3. Method

In this study, the stationarity of the series were checked by Fisher ADF and Fisher-PP panel unit root tests developed by Maddala and Wu (1999), and panel cointegration tests introduced by Pedroni (2004) were applied to test cointegration relations between series. FMOLS (Fully Modified Ordinary Least Squares) test which was initially suggested by Phillips and Hansen (1990) and then developed by Phillips and Moon (1999), Pedroni (2000), Kao and Chiang (2000), was also applied to investigate long-and short-term analysis.

2.4. Unit Root Test

Unit root tests prefers previous period change as a threshold variable. For this purpose, Maddala and Wu (1999) modified the ADF test in the time series as follows:

$$\chi^2 = -2\sum_{i=1}^{N} \mathrm{Log}(\pi_i) \rightarrow \chi^2_{2N}, \qquad T \rightarrow \infty \tag{8}$$

Similarly, he modified the PP test in the time series as follows:

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N} \Phi^{-1}(y_i) \rightarrow N(0,1) \tag{9}$$

The difference between these two methods is that the probability values for unit root test statistics calculated for each cross section are different (Maddala & Wu, 1999). In this study, the stationarity degrees of the series were tested by Fisher ADF and Fisher PP panel unit root tests. The H_0 hypotheses of these tests are that "the serial unit contains a root", that is, the serial is not stationary. Fisher ADF and Fisher PP panel unit root test findings are presented in Table 2.

Table 2. Panel Unit Root Test Findings

	Fisher ADF				**Fisher PP**			
	Level		**First Difference**		**Level**		**First Difference**	
	^{2} Ist. Choi χ	**Fisher Z Ist.**	**Choi χ^2 Ist.**	**Fisher Z Ist.**	**^{2} Ist. Choi χ**	**Fisher Z Ist.**	**Choi χ^2 Ist.**	**Fisher Z Ist.**
LnY	6.95 (0.99)	4.57 (1.00)	87.25*** (0.00)	-6.47*** (0.00)	5.79 (0.99)	6.10 (1.00)	87.26*** (0.00)	-6.46*** (0.00)
LnRDEXP	22.38 (0.32)	1.11 (0.86)	95.59*** (0.00)	-7.21*** (0.00)	19.08 (0.51)	2.35 (0.99)	94.45*** (0.00)	-7.13*** (0.00)
LnRDNofR	16.90 (0.65)	0.83 (0.79)	104.52*** (0.00)	-7.60*** (0.00)	11.25 (0.93)	1.33 (0.90)	99.26*** (0.00)	-7.27*** (0.00)

LnTFP	33.75 (0.12)	-1.12 (0.13)	82.96*** (0.00)	-6.53*** (0.00)	48.30 (0.38)	-1.45 (0.17)	83.26*** (0.00)	-6.57*** (0.00)

Note: Optimal lag lengths was determined using the Schwarz information criterion (SIC). The figure which is *** shows %1 stationary significance level.

As the results in Table 2 shows, all series are stationary at first difference, not at level values. So the series is i (1). The problem of spurious regression can be encountered in direct analyses with series in this form (Granger and Newbold, 1974). Engle and Granger (1987) noted that in such cases, it is necessary to first test cointegration relations between series. If the series are co-integrated, there will be no problem with spurious regression in the analysis. For this reason, the cointegration test was preferred for the analysis.

2.5. Panel Cointegration Test

In the study, panel cointegration tests introduced by Pedroni (2004) were applied to test cointegration relations between series. Pedroni (2004) introduced seven different test statistics in the cointegration test. So cointegration relationship between series has been addressed in different ways. In this respect, similar panels can produce stronger results than cointegration tests (Gutierrez, 2005). These test statistics are obtained using the following equations (Pedroni, 2004):

$$\text{Panel } \vartheta \text{ statistic: } T^2N^{3/2}Z_{\hat{\vartheta}N,T} = T^2N^{3/2}Z_{\hat{\vartheta}N,T}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1} \tag{10}$$

$$\text{Panel } \rho \text{ statistic: } TN^{1/2}Z_{\hat{\rho}N.T} = TN^{1/2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\gamma}_i\right) \tag{11}$$

$$\text{Panel t statistic(PP Type): } Z_{tN,T} = \left(\tilde{\sigma}^2\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}\hat{\gamma}_i\right) \tag{12}$$

$$\text{Panel t statistic (ADF Type): } Z_{tN,T}^{*} = \left(\tilde{S}_{N,T}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}\hat{\gamma}_i\right) \tag{13}$$

$$\text{Group } \rho \text{ statistic: } N^{1/2}Z_{\hat{\rho}N,T-1} = TN^{1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\gamma}_i\right) \tag{14}$$

$$\text{Groupt statistic(PP Type): } N^{1/2}Z_{tN,T-1} = N^{1/2}\sum_{i=1}^{N}\left(\hat{\sigma}^2\sum_{t=1}^{T}\hat{\varepsilon}_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}-\hat{\gamma}_i\right) \tag{15}$$

$$\text{Group t statistic(ADF Type): } N^{1/2}Z_{tN,T}^{*} = N^{1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{s}_i^{*2}\hat{\varepsilon}_{i,t-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\varepsilon}_{i,t-1}\Delta\hat{\varepsilon}_{i,t}\right) \tag{16}$$

The H_0 hypothesis of this test is that “series are not co-integrated”. In the study, Pedroni (2004) panel cointegration test was performed for each model and the results obtained are presented in Table 3.

Table 3. Panel Cointegration Test Findings

	Model 1		Model 2	
	Test Stat.	**Weighted Test Stat.**	**Test Ist.**	**Weighted Test Stat.**
Panel ϑ - Stat.	2.40*** (0.00)	2.19** (0.01)	3.29*** (0.00)	2.69*** (0.00)
Panel ρ- Stat.	0.30 (0.62)	0.51 (0.69)	-1.24 (0.10)	-0.96 (0.16)
Panel PP - Stat.	-1.58* (0.05)	-1.04 (0.14)	-4.65*** (0.00)	-4.21*** (0.00)
Panel ADF - Stat.	-2.91*** (0.00)	-2.83*** (0.00)	-5.51*** (0.00)	-5.51*** (0.00)
Group ρ - Stat.	1.70 (0.95)	-	0.35 (0.63)	-
Group PP - Stat.	-0.54 (0.29)	-	-3.81*** (0.00)	-
Group ADF - Stat.	-2.51*** (0.00)	-	-5.38*** (0.00)	-

Note: Optimal lag lengths was determined using the Schwarz information criterion (SIC). The figure which are ***, **, * show respectively cointegration relations at %1, %5 and %1 significance level.

As the results in Table 3 shows, the series in both models are co-integrated. In this case, according to Engle and Granger (1987) approach, there will be no spurious regression problem in the analyses that will be used in these series. And the results that will be obtained and the policy recommendations that will be developed based on these results will be reliable.

2.6. Long Term Analysis

In this study, long-term relationships between series were analyzed using panel FMOLS. FMOLS test was initially suggested by Phillips and Hansen (1990) and then developed by Phillips and Moon (1999), Pedroni (2000), Kao and Chiang (2000). This method is unbiased estimator to non constant variance and autocorelation problems (Carlsson, Lyhagen and Österholm, 2007). In the study, we applied Panel FMOLS method to estimate both models, and the results of the long-term analysis were presented in Table 4.

As the results in Table 4 shows, the increase in R&D expenditures in NIC countries over the long term affects economic growth at a positive and statistically significant level, while it does not have a statistically significant effect on total factor productivity. An increase in the number of researchers working in the field of R&D has impacted economic growth negatively and statistically significantly. The reason for this situation is probably the fact that those researchers are not sufficiently qualified. An increase in the number of researchers working in the field of R&D has impacted total factor productivity positively and statistically significantly.

Table 4. Long-Term Analysis Findings

	Model 1	Model 2
LnRDEXP	0.30*** (0.00)	-0.001 (0.91)
LnRDNofR	-0.06* (0.08)	0.08*** (0.00)
K_{2008}	-0.06 (0.12)	0.03 (0.37)
Model Reliability Tests		
R^2	0.97	0.92
$\overline{R}^2$	0.97	0.91
SER	0.11	0.09
LRV	0.02	0.01
MDV	8.49	3.97
SDDV	0.75	0.32
SSR	2.80	1.87

Note: ***, ** and * figures respectively show that the coefficient is statistically significant at 1%, 5% and 10% levels. SER stands for Standard Error of Regression; LRV Long-Run Variance; MDV Mean Dependent Variable; SDDV Standard Deviation of Dependent Variable; and SSR Sum Squared Residual. The fact that these values are low is an indicator of the success of the estimate.

2.7. Short-Term Analysis

In this study, short-term relationships between series were also analyzed using panel FMOLS. In short-term analysis, first-order differences of series and error correction term (ECT) are used (Greene, 2002). The results obtained in the short-term analysis are presented in Table 5.

As the results in Table 5 shows, the increase in R&D expenditures in NIC countries again has impacted economic growth at a positive and statistically significant level in the short-term. Contrary to the long term, it has impacted the total factor productivity positively and statistically significantly in the short run. An increase in the number of researchers working in the field of R&D has also negatively affected economic growth in the short term, but this time statistically insignificant. The increase in the number of researchers working in the field of R&D has affected the total factor productivity at a negative, but positive and statistically significant level in the short term, opposite to that in the long term.

Table 5. Short-Term Analysis Findings

	Model 1	Model 2
ΔLnRDEXP	0.09*** (0.00)	0.07*** (0.00)
ΔLnRDNofR	-0.02* (0.08)	-0.003 (0.87)
ΔK_{2008}	-0.01** (0.01)	0.005 (0.41)
ECT_{t-1}	-0.03** (0.04)	-0.06** (0.02)
Model Reliability Tests		
R^2	0.51	0.17
$\bar{R}^2$	0.48	0.12
SER	0.02	0.03
LRV	0.0005	0.0009
MDV	0.03	0.002
SDDV	0.03	0.03
SSR	0.09	0.21

Note: ***, ** and * figures respectively show that the coefficient is statistically significant at 1%, 5% and 10% levels. SER stands for Standard Error of Regression; LRV Long-Run Variance; MDV Mean Dependent Variable; SDDV Standard Deviation of Dependent Variable; and SSR Sum Squared Residual. The fact that these values are low is an indicator of the success of the estimate.

The 2008 global economic crisis has a negative and statistically significant impact on economic growth in NIC countries in the short term. In both models, the coefficient of error correction term has been found to be negative and statistically significant. Based on these information, three inferences can be made: (i) the short-term deviations between the series has disappeared, and the series have come to equilibrium. (ii) the obtained long-term coefficients are reliable. (iii) there are long-term causal relationships running from the independent variables in the models (R&D expenditures and the number of researchers working in R&D) to dependent variables (economic growth and total factor productivity).

2.8. Panel Causality Test

Since there is cointegration relationship between the series, a causality test based on the Vector Error Correction model (Andersson, 1999) was utilized to test the causality relations between the series. Models used in the study to test causal relationships between R & D expenditures and the number of researchers working in R&D and economic growth are as follows:

$$\Delta LnY_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{1j}\Delta LnY_{it-j} + \sum_{j=1}^{p} \alpha_{2j}\Delta LnRDEXP_{it-j} + \sum_{j=1}^{p} \alpha_{3j}\Delta LnRDNofR_{it-j} + \alpha_4 ECT_{t-1} + e_{it} \quad (12)$$

$$\Delta LnRDEXP_{it} = \beta_0 + \sum_{j=1}^{p} \beta_{1j}\Delta LnRDEXP_{it-j} + \sum_{j=1}^{p} \beta_{2j}\Delta Y_{it-1} + \sum_{j=1}^{p} \beta_{3j}\Delta LnRDNofR_{it-j} + \beta_4 ECT_{t-1} + \varepsilon_{it} \quad (13)$$

$$\Delta LnRDNofR_{it} = \delta_0 + \sum_{j=1}^{p} \delta_{1j}\Delta LnRDNofR_{it-j} + \sum_{j=1}^{p} \delta_{2j}\Delta Y_{it-j} + \sum_{j=1}^{p} \delta_{3j}\Delta LnRDEXP_{it-j} + \delta_4 ECT_{t-1} + \epsilon_{it} \quad (14)$$

P denotes optimal lag length, and the test results to determine this value are included in Appendix 2 and Appendix 3. According to these reviews, the optimal lag length in both cases is 2. VECM test results of the causality relations between R&D expenditures and the number of researchers working in R & D and economic growth are included in Table 6.

Table 6. VECM Causality Test Findings (Economic Growth)

	Short-Term Causality (Independent Variables)			Long-Term Causality
Dependent Variable	ΔLnY	ΔLnRDEXP	ΔLnRDNofR	ECT_{t-1}
ΔLnY	-	4.66* (0.09)	14.71*** (0.00)	-0.02** (0.01)
ΔLnRDEXP	10.02*** (0.00)	-	7.49** (0.02)	-0.14* (0.09)
ΔLnRDNofR	6.05** (0.04)	1.59 (0.44)	-	-0.08* (0.07)

Note: The figure which are ***, **, * show respectively casuality relations at %1, %5 and %1 significance level.

As the results in Table 6 shows, there are causal relationships in the short and long term running from R&D expenditures and the number of researchers working in the field of R&D to the economic growth. These are the most significant findings to emerge from this test. This means that R&D expenditures in NIC countries and the number of researchers working in the field of R&D affect economic growth. Looking at other test results, there are causal relationships in the short and long term running from economic growth and the number of researchers working in the field of R&D to R&D expenditures. A causal relationship is found in the short term from economic growth to the number of researchers working in the field of R&D, but not the reverse. But it seems that there is a long-term causal relationship from economic growth and R&D spending to the number of researchers working.

Table 7 illustrates the VECM test results on causality relations between R&D expenditures and the number of researchers working in the R & D field and total factor productivity.

As the results in Table 7 shows, there exists a long-term causal relationship from R&D expenditures and the number of researchers working in R&D to total factor productivity, but not the reverse for the short term. A causal relationship is found from total factor productivity and the number of researchers working in the field of R&D to R&D expenditures. While results of long term indicate causal relationship from total factor productivity and R&D expenditures to the number of researchers working in R&D, short term results do not reveal a a causality relationship.

Table 7. VECM Causality Test Findings (Total Factor Productivity)

	Short-Term Causality (Independent Variables)			**Long-Term Causality**
Dependent Variable	ΔLnTFP	ΔLnRDEXP	ΔLnRDNofR	ECT_{t-1}
ΔLnTFP	-	0.84 (0.65)	3.22 (0.19)	-0.11** (0.02)
ΔLnRDEXP	12.76*** (0.00)	-	4.63* (0.09)	-0.06* (0.09)
ΔLnRDNofR	0.64 (0.72)	0.53 (0.76)	-	-0.11* (0.09)

Note: The figure which are ***, **, * show respectively casuality relations at %1, %5 and %1 significance level.

CONCLUSION

This study explores to reveal the effects of R&D expenditures and the total number of researchers working in R&D field on economic growth and total factor productivity in newly industrialized countries over the period 1996-2019 using panel data analysis method. Correlation analysis showed positive correlations between R&D expenditures, the number of researchers working in the field of R&D and economic growth and total factor productivity variables in NIC countries. Correlations with economic growth were stronger, while those with total factor productivity were lower. It was also observed that the relationship between the number of researchers working in the field of R&D and economic growth and overall factor productivity was greater than R&D expenditures.

In the study, the stationarity of the series were checked by Fisher ADF and Fisher-PP methods, and it was determined that all series are stationary at first difference. Panel cointegration tests introduced by Pedroni (2004) were applied to test cointegration relations between series, and all series are found to be stationary at first difference. Long and shortterm relationships between series were also analyzed using panel FMOLS. The analysis reveals that the increase in R&D expenditures in NIC countries over the long term affects economic growth at a positive and statistically significant level, while it does not have a statistically significant effect on total factor productivity. An increase in the number of researchers working in the field of R&D has impacted economic growth negatively and statistically significantly. The reason for this situation is probably the fact that those researchers are not sufficiently qualified. An increase in the number of researchers working in the field of R&D has impacted total factor productivity positively and statistically significantly. Based on these results, it is apparent that increasing R&D expenditures and the number of researchers working in the field of R&D will show a positive effect on economic growth and total factor productivity in newly industrialized countries. In the short term, increasing R&D expenditures in NIC countries again affected economic growth and total factor productivity at a positive and statistically significant level, but not the reverse for total factor productivity in the long term. An increase in the number of researchers working in the field of R&D has also negatively affected economic growth statistically insignificant in the short term. But this increase, as opposed to the long term, has affected the overall factor efficiency at a negative, but positive and statistically insignificant level in the short term. The 2008 global economic crisis had a negative and statistically significant impact on economic growth in NIC countries in the short term. In both models, the coefficient of error correction term was found to be negative and statistically significant. Based on these information, three inferences can be made: (i) the short-term deviations between the series has disappeared, and the series have come to equilibrium. (ii) the obtained long-term coefficients are reliable. (iii) there are long-term causal relationships running from the independent variables in the models (R&D expenditures and the number of researchers working in R&D) to dependent variables (economic growth and total factor productivity). The short-term analysis results show that increasing R&D expenditures will contribute to economic growth and total factor productivity in NIC countries or more broadly developing countries.

The VECM casuality test was used to test for casuality as the series are co-integrated. The test results illustrate that there are causal relationships in the short and long term running from R&D expenditures and the number of researchers working in the field of R&D to the economic growth. These are the most significant findings to emerge from this test. It means that R&D expenditures in NIC countries and the number of researchers working in the field of R&D affect economic growth. Looking at other test results, there are causal relationships in the short and long term running from economic growth and the number of researchers working in the field of R&D to R&D expenditures. A causal relationship is found in the short term from economic growth to the number of researchers working in the field of R&D, but not the reverse. But it seems that there is a long-term causal relationship from economic growth and R&D spending to the number of researchers working in the field of R&D. There exists a long-term causal relationship from R&D expenditures and the number of researchers working in R&D to total factor productivity, but not the reverse for the short term. A causal relationship is found from total factor productivity and the number of researchers working in the field of R&D to R&D expenditures in both short and long term. While results of long term indicate causal relationship from total factor productivity and R&D expenditures to the number of researchers working in R&D, short term results do not reveal a a causality relationship.

Based on the results presented in the study, it can be concluded that R&D expenditures and the large number of researchers working in the field of R & D will positively affect the economic growth and total factor productivity of countries. But the nature of these data is as important as the size. It should be noted that not every R&D expenditure will contribute to the production, and not every R&D employee may be an expert in their field. For example, it is a well-known fact that the vast majority of projects carried out, such as university R&D studies, do not result in patent acquisition and production.

Compliance with Ethical Standard

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APPENDIX

Appendix 1: Descriptive Statistics

	LnY	LnTFP	LnRDEXP	LnRDNofR
Mean	8.48	3.97	7.82	5.81
Median	8.73	3.88	7.96	5.78
Maximum	9.62	4.74	12.67	7.89
Minimum	6.57	3.39	4.04	3.58
Standard Deviation	0.76	0.33	1.83	0.91
Skewness	-0.65	0.74	0.20	0.02
Kurtosis	2.33	2.86	2.95	2.53
Jarque-Bera	21.39	21.86	1.71	2.19
Probability	0.00	0.00	0.43	0.34
Total	2035.74	953.90	1876.87	1393.97
Sum of Square	138.79	25.57	797.32	199.35
No of Observation	240	240	240	240

The table shows a distribution that is tightly clustered around the average. The difference between maximum and minimum values is low. In this case, the risk of non constant variance is low. The number of observations used in the analyses is N=10,T=24, 240 in total and is sufficient for a reliable panel data analysis.

Appendix 2: Results of Optimal Lag Length Determination (Economic Growth)

VAR Lag Order Selection Criteria
Endogenous variables: LNY LNRDEXP LNRDNofR
Exogenous variables: C
Sample: 1996 2019
Included observations: 160

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-594.1367	NA	0.350140	7.464208	7.521868	7.487622
1	619.5622	2366.713	1.01e-07	-7.594527	-7.363889	-7.500873
2	652.5302	63.05123*	7.49e-08*	-7.894127*	-7.490510*	-7.730232*
3	654.9492	4.535720	8.13e-08	-7.811865	-7.235270	-7.577730
4	661.8948	12.76254	8.35e-08	-7.786185	-7.036611	-7.481809
5	663.3215	2.568020	9.18e-08	-7.691519	-6.768966	-7.316902
6	665.1952	3.302445	1.01e-07	-7.602440	-6.506909	-7.157583
7	667.9161	4.693586	1.09e-07	-7.523952	-6.255442	-7.008854
8	674.7775	11.57851	1.12e-07	-7.497218	-6.055731	-6.911880

* 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

As shown in the table, the optimal lag length is 2 according to all information criteria. The presence of autocorrelation problem in dual VAR model was detected and the following results were obtained.

VAR Residual Serial Correlation LM Tests
Sample: 1996 2019
Included observations: 220

Null hypothesis: No serial correl ation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	17.42857	9	0.4124	1.956462	(9, 506.4)	0.4024
2	6.479606	9	0.6921	0.719577	(9, 506.4)	0.6791

Null hypo thesis: No serial correl ation at la s 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	17.42857	9	0.4234	1.956462	(9, 506.4)	0.4724
2	45.47733	18	0.4115	2.591016	(18, 580.3)	0.4069

*Edgeworth expansion corrected likelihood ratio statistic.

Since the probability values in this table are greater than 0.05, the VAR(2) model does not have an autocorelation problem. In the model, the problem of non constant variance was also detected and the following results were obtained.

VAR Residual Heteroskedasticity Tests (Levels and Squares)

Sample: 1996 2019
Included observations: 220

Joint test:

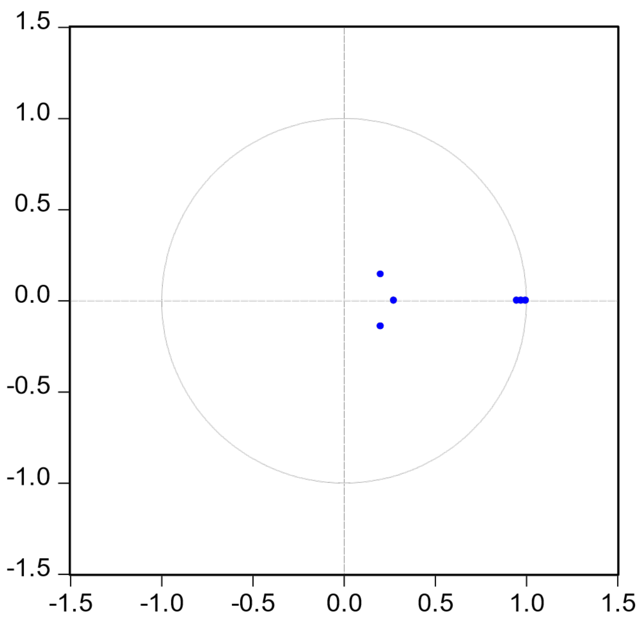
Chi-sq	df	Prob.
101.0620	72	0.135

Individual components:

Dependent	R-squared	F(12,207)	Prob.	Chi-sq(12)	Prob.
res1*res1	0.070438	1.307132	0.2162	15.49642	0.2154
res2*res2	0.097100	1.855099	0.0417	21.36193	0.0453
res3*res3	0.091258	1.732285	0.0620	20.07675	0.0656
res2*res1	0.059046	1.082452	0.3764	12.99005	0.3698
res3*res1	0.111359	2.161662	0.0147	24.49897	0.0174
res3*res2	0.051659	0.939669	0.5083	11.36509	0.4979

Since the probability values in this table are greater than 0.05, there is also no problem of non constant variance in the VAR(2) model. The inverse unit root graph below illustrates stableness of VAR(2) model.

Inverse Roots of AR Characteristic Polynomial



The VAR(2) model is stable because all inverse characteristic roots in this graph lie inside the unit circle. Therefore, the results of causality analysis with 2 delays will also be reliable.

Appendix 3: Results of Optimal Lag Length Determination (Total Factor Productivity)

VAR Lag Order Selection Criteria
Endogenous variables: LNTFP LNRDEXP LNRDNofR
Exogenous variables: C
Sample: 1996 2019
Included observations: 160

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-508.0593	NA	0.119387	6.388242	6.445901	6.411655
1	561.1348	2084.929	2.10e-07	-6.864185	-6.633547	-6.770531
2	588.4610	52.26133*	1.67e-07*	-7.093263*	-6.689646*	-6.929368*
3	591.7502	6.167233	1.79e-07	-7.021877	-6.445282	-6.787742
4	600.9366	16.88007	1.79e-07	-7.024208	-6.274634	-6.719832
5	603.6049	4.802970	1.94e-07	-6.945062	-6.022510	-6.570445
6	605.2098	2.828642	2.13e-07	-6.852623	-5.757092	-6.407766
7	607.6938	4.284745	2.31e-07	-6.771172	-5.502663	-6.256074
8	612.4922	8.097443	2.44e-07	-6.718653	-5.277165	-6.133315

* 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

As shown in the table, the optimal lag length is 2 according to all information criteria. The presence of autocorrelation problem in dual VAR model was detected and the following results were obtained.

VAR Residual Serial Correlation LM Tests
Sample: 1996 2019
Included observations: 220

Null hypothesis: No serial correl ation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	36.39667	9	0.8596	4.163138	(9, 506.4)	0.8478
2	3.817619	9	0.9230	0.422849	(9, 506.4)	0.9230

Null hypothesis: No
ser ial correl ıtion at la ;s 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	36.39667	9	0.5892	4.163138	(9, 506.4)	0.1894

2	72.03728	18	0.1257	4.199514	(18, 580.3)	0.2573

*Edgeworth expans ion corrected likelihood ratio statistic.

Since the probability values in this table are greater than 0.05, the VAR(2) model does not have an autocorelation problem. In the model, the problem of non constant variance was also detected and the following results were obtained.

VAR Residual Heteroskedasticity Tests (Levels and Squares)
Sample: 1996 2019
Included observations: 220

Joint test:

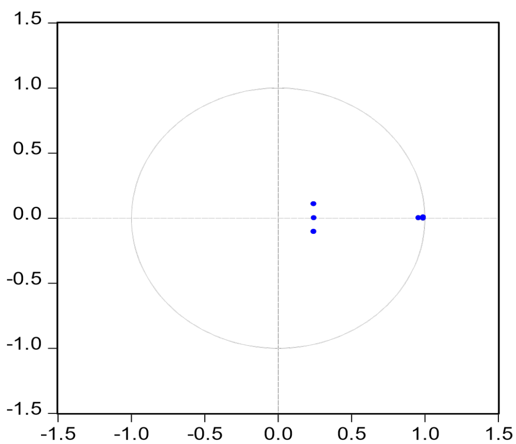
Chi-sq	df	Prob.
142.1316	72	0.2058

Individual components:

Dependent	R-squared	F(12,207)	Prob.	Chi-sq(12)	Prob.
res1*res1	0.091123	1.729465	0.4625	20.04705	0.0662
res2*res2	0.116647	2.277876	0.2598	25.66243	0.3120
res3*res3	0.119112	2.332510	0.0080	26.20462	0.0100
res2*res1	0.066638	1.231573	0.2631	14.66034	0.2605
res3*res1	0.146812	2.968291	0.0008	32.29867	0.0012
res3*res2	0.143668	2.894049	0.0010	31.60689	0.0016

Since the probability values in this table are greater than 0.05, there is also no problem of non constant variance in the VAR(2) model. The inverse unit root graph below illustrates stableness of VAR(2) model.

Inverse Roots of AR Characteristic Polynomial



The VAR(2) model is stable because all inverse characteristic roots in this graph lie inside the unit circle. Therefore, the results of causality analysis with 2 delays will also be reliable.