Causality Relationships Between Per Capita Income and Research and Development (R&D) Expenditures in Asian Tigers, China, and Turkey

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Asya Kaplanları, Çin ve Türkiye'de Kişi Başına Düşen Gelir ile Araştırma ve Geliştirme (Ar-Ge) Harcamaları Arasındaki Nedensellik İlişkileri

Abstract

This study investigates the relationship between R&D expenditures and per capita income for Asian Tigers (Hong Kong, Korea, Singapore), China, and Turkey. For this purpose, the relationships between variables are investigated using the bootstrap panel causality test developed by Konya (2006). In the study, analyses are made using data between 1998 and 2016. According to the analysis results, there is a unidirectional causality relationship between R&D expenditures to per capita income in Hong Kong and Korea. On the other hand, there is a unidirectional causality relationship from per capita income to R&D expenditures in China and Turkey. The coefficients of these causality relationships are positive.

Keywords   :   R&D Expenditures, Economic Growth, Per Capita Income.

JEL Classification Codes :   O32, O47, P24.

Öz

Bu çalışmada Asya Kaplanları, (Hong Kong, Güney Kore, Singapur), Çin ve Türkiye için Ar-Ge harcamaları ile kişi başına düşen gelir arasındaki ilişkilerin araştırılması amaçlanmaktadır. Bu amaç doğrultusunda değişkenler arasındaki ilişkiler Konya (2006) tarafından geliştirilen bootstrap panel nedensellik testi kullanılarak araştırılmaktadır. Çalışmada 1998-2016 dönemi verileri kullanılarak analizler yapılmaktadır. Analiz sonuçlarına göre Hong Kong ve Güney Kore'de Ar-Ge harcamalarından kişi başına düşen gelire doğru tek yönlü nedensellik ilişkisi vardır. Öte yandan, Çin ve Türkiye'de ise kişi başına düşen gelirden Ar-Ge harcamalarına doğru tek yönlü nedensellik ilişkisi vardır. Son olarak, bu nedensellik ilişkilerinin katsayıları ise pozitiftir.

Anahtar Sözcükler   :   Ar-Ge Harcamaları, Ekonomik Büyüme, Kişi Başına Düşen Gelir.

1. Introduction

Rapid developments in technology have significantly affected the dominance of countries in international markets and are even a manifestation of the struggle for existence. The main objectives of this struggle are to increase per capita income and to maintain stable economic growth. Schumpeter (1939) intends to express the process of evolution in machinery along with technological developments and the increase in the variety of new and quality products and their effects on the markets. One of the most important of these effects has been the implications that the old products are replaced by new ones and that companies and countries that cannot adapt to this process will fall behind in the markets. Moreover, Schumpeter (1939: 83-84) states that factors such as innovation, creative destruction, and technological competition significantly affect economic growth, and even technological developments are an important determinant of economic growth. Similarly, Shefer and Frenkel (1998: 187) state that technological innovations, while providing a competitive advantage in the markets, will be a driving force behind stable growth.

In the 1950s, the contribution of technological changes and developments to the economies of some countries caused attention to focus on this area. Then, R&D activities, which are the leading efforts behind the acquisition of technological developments, whose main motivation is economic growth, began to be encouraged. Per capita income is the most critical indicator of the economic performance and economic growth of the countries. It is also a sign of welfare. Therefore, this research aims to investigate the impact of R&D expenditures on per capita income, representing economic growth. In this paper, Hong Kong, Korea, Singapore, which are among the Asian Tigers, and China and Turkey are included in the study. In the 1970s, Asian Tigers initiated a process of structural transformation based on the principle of manufacturing industry-oriented development (Papageorgiou & Spatafora, 2012: 4). In the 1990s, all the efforts of these countries paved the way for their economic growth. In the emergence of economic growth in these countries, however, the emergence of new products and the use of new technologies has a large share (Nelson & Pack 1999: 418-419). In this context, China was added to the study in order to determine whether the factors that are valid for Asian Tigers in China's rapid economic growth since the early 1990s are valid in China. Also, determining the relationship between the per capita income and the R&D expenditures is important for Turkey. It is important to demonstrate the effect of R&D expenditures in the convergence of Turkey's per capita income to the per capita income of Asian Tigers. Due to this reason, Turkey is also included in the study.

In this study, which aims to investigate the relationship between R&D expenditures and per capita income representing economic growth; First, the theoretical framework of the subject is discussed. Next, a literature review is done for previous empirical studies on the subject. Then, data on R&D expenditures and per capita income variables of the countries subject to the research are introduced. After that, information is given about the methods used in analyzing the relationships between variables. Then, the empirical findings obtained are presented. Finally, in the conclusion section, the findings obtained are evaluated, and economic and political implications are made.

2. Theoretical Framework

The foundations of economic growth theory are based on classical economists. Especially the studies of economists such as Adam Smith, David Ricardo, Thomas Robert Malthus, and then Frank P. Ramsey, in Allyn A. Young, and Joseph Alois Schumpeter form the basis of growth theories (Barro & Sala-i Martin, 2004: 16). In these studies, another important factor affecting growth was discussed as technological advances and mechanization in addition to factors such as division of labour, foreign trade, population growth, capital accumulation, and other important factors affecting growth. In fact, the first economists to investigate the effects of technological advances on economic growth were classical school economists. Smith considers economic growth as an endogenous process, with an emphasis on the impact of capital accumulation on labour productivity. According to Smith, growth depends on the decisions and actions of economic actors, such as their savings and investment behaviour, creativity, and their ability to be innovative (Kurz & Salvadori, 2003: 3-6). Smith attributes the growth in the UK compared to the European countries to the division of labour in the manufacturing industry, the use of new machines, and the specialization skills of those using the machines. Ricardo (2007: 71) was also aware of the developments in the machines, similar to Smith's thoughts. He thinks that the developments in the machines show positive results for all classes except for the working class. Ricardo does not adopt Smith's positive ideas about the production function and growth. According to Ricardo, production functions in agriculture and industry are under the influence of different laws. Therefore, the law of return on production in agriculture in the long run will determine the quality of the production function in the whole economy. In other words, the law of diminishing returns in agriculture will also affect the industry sector, and the whole economy will be dependent on the law of diminishing returns. Jean Baptiste Say has a much more optimistic perspective. According to him, technological innovations will continuously decrease costs and lead to an increase in efficiency (Küçükkalay, 2010: 216).

Schumpeter was the first to clearly express that technological development was the main engine of economic growth (1939: 83-84). In his studies, Schumpeter emphasized the importance of the impact of innovations and technological development on economic development processes as well as the competitive advantage in the capitalist economy. Karl Marx, who made an essential contribution to the literature of growth during the period when the classical school was dominant, believed that innovations were the driving force of economic growth, while he also included inventions and innovations among the determinants of growth (Keirstead, 1948: 90). Moreover, Marx (2015: 362-363) stated that some of the seemingly simple tools invented became machines just before and at the first stage of the Industrial Revolution, and the beginning of the Industrial Revolution started with the invention of these machines. Although the studies of the classical school representatives could not include the technology as an endogenous variable in their growth models, they are a guide for the research of the economists of the following periods.

The founder of the Keynesian school, which was the dominant view in the world after the classics in economic theory, Keynes conducted studies on the recovery of economies

from recession rather than growth. The addition of growth theories in Keynesian economics was accompanied by the contributions of economists such as Roy Harrod and Evsey Domar, who were considered pioneers of modern economic growth in the period between 1936 and 1956 (Snowdon & Vane, 2005: 598). The studies by Harrod (1939) and Domar (1946) is more commonly known as the Harrod-Domar model because of the similarities between them. Harrod and Domar included the capacity-building effect of investments neglected by Keynes. In the model, $\Delta Y/\Delta K$ reflects the ratio of the increase in production capacity to the increase in capital stock, and it is symbolized by σ. Increasing the economic growth in the Harrod-Domar model depends on the savings rate or the increase in the efficiency of the capital (Ozel, 2012: 65). Although the Harrod-Domar model is not sufficient, it has an important place in the economics literature in terms of guiding later studies. In the 1950s, the neoclassical growth model emerged under the leadership of Robert Solow and Trevor Swan, who dominated the literature on economic growth until the 1980s. In particular, Solow's emphasis on the definition of technological development has led him to be more highly regarded than any other neoclassical economist. The growth model suggested by Solow (1956: 85), one of the leading representatives of the neoclassical school, is *Y=AF(K,L)*. In the model, *Y* represents income, *K* capital, and L labour. *A* refers to the time-varying technological change added to the model as an endogenous variable. Solow's study was criticized for not being able to fully explain the technology that it treats as an endogenous variable within the model in which it was established, but also for giving place only to the USA within the model.

With the studies of Arrow (1962) and Uzawa (1965), some studies began to be carried out that technology can be explained as an endogenous variable within the model, as opposed to Solow's growth model. In the continuation of a process that started with the study of Paul Romer (1986; 1990), especially affected by Arrow's approach, some economists' endogenizing technology as a variable dependent on their models led to the emergence of new theories under the name of New Endogenous Growth Models. Romer endogenized the technology by including the researchers seeking new ideas, who aimed to make a profit with their inventions, in his model (Jones, 2001: 91). This model, unlike Solow's model, assesses the developed countries in the world as a whole. Besides, efforts to create technological advances are considered to be R&D activities.

Romer included the term *A* as an endogenous variable, which Solow assumes increasing at an exogenous and constant rate. In economies with R&D activities, technological development, and knowledge, the output per hour with constant capital accumulation can increase without being constant. According to Romer (1990: 71-83), A refers to the stock of knowledge or new designs acquired in a given period. $\dot{A} = \bar{\delta}L_A$ is the production function, then $\bar{\delta}$ symbolizes the rate of finding new designs, while L_A stands for employment in the R&D sector. As indicated in the equality, the number of new designs will increase if R&D activities are supported with more human capital. In addition, the increase in the stock of knowledge in the R&D sector will also increase human capital efficiency. With the acceptance of R&D as the driving force of growth, achieving sustainable growth is directly proportional to the amount of human capital transferred to R&D activities. The more qualified human capital transferred to the R&D sector, the higher the growth rate in the

current economy. The new technology, according to Romer, is generated by human capital. Due to limited access to knowledge, the potential for growth becomes unlimited, and productivity increases thanks to the productivity of knowledge. In short, output per hour will increase with increased capital accumulation in economies where technological development and knowledge are available in Romer's model.

One of the endogenous growth models based on technological developments and inventions is the study of Gene M. Grossman and Elhanan Helpman. Grossman and Helpman also believe that technological developments will increase productivity, and this will increase economic growth. They examined the growth model to be realized through technological innovations under two categories. The first of these categories is the growth caused by technological innovations arising from product diversity, and the other is the knowledge and growth effect with public characteristics (Eaton & Kortum 2006: 13). Besides, Grossman and Helpman treat R&D activities as an economic activity and compare the return of R&D activities to the monopolistic profit in the imperfect competition markets. According to the authors, R&D aims to reduce production costs or invent a new product (Grossman & Helpman, 1991: 45). They regard knowledge as a special good such as physical capital and express that R&D activities have two outcomes, which are new design and knowledge. The new design brings an income to its investor in the form of a monopoly profit. Knowledge is also defined as a set of ideas and methods that the next generations can use. If knowledge is considered as private capital, growth is interrupted in the long run. Grossman and Helpman assume, in some cases, that researchers who contribute to their knowledge cannot prevent the free use of this knowledge by others. For this reason, knowledge is considered as a public input in the R&D process (Helpman, 1993: 1251).

Philippe Aghion and Peter Howitt established a new model of endogenous growth that explores the impact of technological developments on economic growth as a result of R&D activities with "A Model of Growth Through Creative Destruction" in 1992 and "Endogenous Growth Theory" in 1998. According to the authors, there are two sectors in the market, namely research, which shows the effort to produce intermediate goods for final goods production, and production for final goods production. Inventions and innovations are products of research sector activities. These outputs of the research sector reduce the importance and benefit of the innovations previously achieved. In such a case, growth takes place when innovations replace old ones. Innovations, which are the achievements of R&D, increase the quality and variety of products in the market, causing old products to be less preferred or even vanquished from the market. As a result, Schumpeter's creative destruction process operates through R&D activities (Aghion & Howitt, 1992: 323-351; 1998: 53-67). In other words, researchers state that innovations bring about several "creative destruction" in the range of existing production inputs and that each new input replaces the previous one, thus ending the monopoly (Freeman & Soete, 2003: 373). According to them, innovations are produced entirely as a result of activities in the R&D sector. The fact that R&D activities create positive exogeneity in the model allows political governments to use R&D as an instrument to achieve economic growth (Aghion & Howitt, 1992: 324). Briefly, growth in the economic growth model raised by Aghion and Howitt based on Schumpeter's creative destruction process emerges as a result of technological developments based on the

competition engaged by companies operating in the R&D sector, which provides the formation of innovations, in order to maintain their power in the market.

In contrast to the neoclassical growth model, Rebelo (1991: 517) established a model to endogenize technological developments based on Romer's study (1986). This model, which belongs to Rebelo, is in the form of $=AK$, where A is a positive constant, and K represents the technological level and capital stock. This model is based on the assumption that the return on capital will not decrease while the capital stock will increase. Although in this model, which is based on the view that there are constant returns to scale, the law of diminishing returns is not applicable, and growth can be accelerated by increasing investments, is not very realistic, the fact that K also includes human capital makes this argument more reasonable (Barro & Sala-i-Martin, 2004: 63-64).

It can be concluded that technological developments, albeit with different approaches, have been an important input for growth in the process that has passed from classical school representatives to the present day. Starting with Schumpeter and the New Endogenous Growth Theories, there seems to have been a consensus that R&D activities are one of the most important tools for growth and the emergence of technological developments.

3. Literature Review

Many researchers study the effects of R&D expenditures on economic growth within the framework of these aforementioned theoretical approaches. These researchers, who examined the relationships among different variables, included variables such as the GDP, the per capita income, the productivity, and the output in their studies representing economic growth. Griliches' (1985) study for the USA is one of the first studies on the subject. In the study conducted using the data of the 1957-1977 period, it was found that R&D expenditures increase the amount of output. It has also been found that private-financed R&D is more efficient than public-financed R&D. Aghion and Howitt (1992), who also conducted a US-specific study, found that there was no strong relationship between R&D expenditure and economic growth. In another study, Lichtenberg (1992) highlighted that R&D expenditures financed by the private sector in 74 countries in the period 1964-1989 had a positive and statistically significant effect on economic growth. The results of the analysis showed that the R&D expenditures financed by the public had no statistical effect on economic growth. In the study in which the data of 18 developed and 34 underdeveloped countries were used over the period of 1960-1985, Goel and Ram (1994) determined a statistically significant relationship between R&D expenditures spent only by developed countries and economic growth. Gittleman and Wolff (1995) also concluded that R&D expenditures were an important factor in explaining economic growth only in developed countries based on the data from 1960-1988. Park (1995) conducted a study on R&D expenditures of the public and private sector and included data from 10 OECD countries in his model for the period 1970-1987. The study results showed positive and statistically significant results between R&D expenditures and economic growth in both sectors. Luh and Chang (1997) conducted a study for Taiwan's 1980-1991 period and stated that R&D expenditures were an important

determinant of economic growth. Lee and Yu (1998), who conducted a study in South Korea between 1975-1997, suggested a statistically significant and positive relationship between R&D expenditure and economic growth. Freire-Serén (1999) revealed that R&D expenditures positively affected economic growth in the study conducted by 21 OECD countries with the data of the 1965-1990 period. Sylwester (2001), on the other hand, used the data of the 20 OECD countries for the period 1981-1996 and could not achieve any statistical relationships between R&D expenditures and economic growth. However, in his study of the G-7 countries, he achieved positive and statistically significant relationships between industrial R&D expenditures and economic growth. Zachariadis (2004) concluded that R&D expenditures had a positive impact on productivity and growth in the study, which used data from 10 OECD countries for the period 1971-2004. Yanyun and Mingqian (2004) found that R&D expenditure had a positive effect on economic growth in their study with 1994-2004 data from Korea, Philippines, Malaysia, Japan, Thailand, Singapore, Indonesia, and China. Falk (2007) examined the relationships between R&D expenditures and economic growth for 15 OECD countries. According to the analysis results for the data between 1970 and 2004 in the study, a positive and strong relationship was found between R&D expenditures and economic growth. It is seen that Falk (2007) also obtained findings similar to other studies.

Wu and Zhou (2007) found that China had a bidirectional causality relationship between R&D expenditures and economic growth in the long run, with data from the period 1953-2004. Yu-ming et al. (2007) investigated the relationship between R&D expenditure and economic growth in China for the period 1953-2004 and determined a bidirectional causality relationship between R&D expenditures and economic growth in the long-run. Altın and Kaya (2009) conducted a study using data over the period of 1977-2006 in Turkey and revealed a causal relationship between R&D expenditures and economic growth. Similarly, Yaylalı, Akan, and Isik (2010) conducted a study using Turkey's 1990-2009 data and identified a unidirectional causality relationship from R&D investment expenditures to economic growth. Genç and Atasoy (2010) determined a unidirectional causality relationship from R&D expenditures to economic growth in Turkey in their study with 1997-2008 data. Peng (2010) suggested that R&D expenditures had a positive impact on economic growth in his study of Chinese data from 2000-2007. Bravo-Ortega and Marin (2011) studied data from 65 countries between 1965 and 2005 and concluded that R&D expenditure increased total factor productivity. Kim (2011) determined that R&D stock had a positive impact on economic growth in their study by using Korea's data from 1976-2009. Guloglu and Tekin (2012) found that there is a bidirectional causality relationship between R&D expenditures and economic growth based on data from 13 OECD countries from 1991 to 2007. Zhou, He, and Shen (2012) indicated that R&D improves productivity in their study with 2005-2007 data for more than 30000 Chinese firms. Akıncı and Sevinç (2013) conducted a study on Turkey's data from 1990-2011 and determined a causal relationship from R&D expenditures to economic growth. In their study using 1990-2011 data from 15 OECD countries, including Turkey, Ozcan and Arı (2014) found that R&D expenditures positively affected economic growth in both Turkey and all countries on the panel. In the results of the study conducted in Turkey with data for the period 1998-2013, Bozkurt (2015) only revealed the finding of a unidirectional causality relationship from economic growth to

R&D expenditures. Tuna, Kayacan, and Bektaş (2015) could not determine any relationship between R&D expenditures and economic growth in Turkey in their study for the period 1990-2013. Sokolov-Mladenović, Cvetanović, and Mladenović (2016) stated that R&D expenditures had a positive impact on economic growth in their study of EU28 country with the data for the period of 2002-2012. Freimane and Bāliņa (2016) found that R&D expenditures had positive effects on economic growth in European Union member states from 2000 to 2013. Dam and Yıldız (2016) observed that the impact of R&D expenditures on economic growth was positive and statistically significant in their study using annual data from BRICS and Turkey and Mexico between 2000 and 2012. Sungur, Aydın, and Eken (2016) examined Turkey's 1990-2013 period and found that there was a causal relationship from R&D expenditures to growth. Feng and Ke (2016) concluded that R&D had positive contributions to company productivity with data from China for the period of 2005-2007. Bond and Guceri (2017) expressed that R&D expenditure had a positive impact on productivity as a result of analysis by UK firms with data covering the period of 1997-2008. Minniti and Venturini (2017) found that R&D improved productivity as a result of their analysis using the data of 1975-2000 for U.S. manufacturing industries. Kutbay and Oz (2017) suggested that R&D expenditures had a positive effect on economic growth in their study with the analysis by a panel data model for the period of 1999-2016 in Turkey and selected countries. In their study for the period of 1996-2015 in 12 European Union member countries and Turkey, Ozkan and Yilmaz (2017) reached a unidirectional causality relationship from economic growth to R&D. Tari and Alabaş (2017) concluded that R&D expenditures in Turkey had a positive impact on economic growth both in the short-run and in the long-run in their study for the period of 1990-2014. Based on data from the period of 2005-2015, Taş et al. (2017) determined a causal relationship from economic growth to R&D expenditures. Kesikoğlu and Saraç (2017) identified a positive causal relationship between R&D expenditures and economic growth in Turkey with the data of 2010-2014. Uçak et al. (2018) deduced that the long-run impact of R&D on economic growth was positive in their research conducted in Turkey with data from 1990-2016. Duman and Aydın (2018) identified a causal relationship between R&D expenditures and economic growth in Turkey with data for the period of 1998-2015. Türkmen, Ağır, and Günay (2019) found that R&D expenditures had a positive contribution to economic growth in their research of 20 OECD countries over the period of 1991-2016. Dereli and Salğar's (2019) study of Turkey's 1990-2015 data revealed a bidirectional causality relationship between R&D expenditures and economic growth. Shen, Lin, and Wu (2019) studied the effects of R&D on productivity and growth in 30 provinces of China with the help of data from 1978-2014, but they found no positive results. Pala (2019) carried out a panel study on 29 developing countries and concluded that R&D expenditures in China had negative effects on economic growth, while the number of R&D researchers in the countries of Turkey and China, which are in the research sample, had a significantly positive impact on the economic growth of these countries.

Many studies examining the relationship between R&D expenditures and economic growth have concluded different results. The main reasons for these differences are the countries or groups of countries, the levels of development of countries, the periods included in the model, and the different analysis methods used. However, although different results

are observed between the variables, it can be assumed that there are significant relationships between these variables and economic growth in general. In this study, the use of a method previously not used for this subject and for the group of countries subject to the study distinguishes the study from these studies in the literature. It is seen that time series analysis and other panel data analysis were used in previous studies. Thanks to the fact the panel causality test used in Kónya (2006) bootstrap panel causality is based on Seemingly Unrelated Regressions (SUR), both the shocks between countries are considered, and causality relationships can be acquired for each country separately.

4. Research Data

In line with the research objectives, the variables of the log of per capita income (*lpgdp*) and the ratio of R&D expenditures to GDP (*R&D*) are used in the analysis based on the data taken from the World Bank Database, including the countries of Hong Kong, Korea, and Singapore, which are called the Asian Tigers as well as China and Turkey. The study period was determined as 1998-2016 because the data of these countries in the World Bank database is balanced during the specified period. Descriptive statistics for variables of countries are described in Table 1.

Table: 1
Descriptive Statistics

Variables:	lpgdp_CHN	R&D_CHN	lpgdp_HKG	R&D_HKG	lpgdp_KOR
Mean	8,845	1,439	10,659	0,679	10,190
Median	8,890	1,372	10,723	0,727	10,240
Maximum	9,572	2,108	10,904	0,794	10,463
Minimum	8,074	0,646	10,354	0,428	9,763
Std. Dev.	0,500	0,465	0,190	0,120	0,204
Jarque-Bera	1,521	1,195	1,853	3,889	1,268
J-B Probability	0,467	0,549	0,395	0,143	0,530
Observations	19	19	19	19	19
Variables:	R&D_KOR	lpgdp_SGP	R&D_SGP	lpgdp_TUR	R&D_TUR
Mean	3,099	11,077	2,095	9,747	0,660
Median	3,000	11,100	2,104	9,755	0,691
Maximum	4,288	11,346	2,620	10,071	0,944
Minimum	2,066	10,748	1,737	9,460	0,362
Std. Dev.	0,806	0,196	0,200	0,201	0,178
Jarque-Bera	1,866	1,438	1,680	1,281	1,632
J-B Probability	0,393	0,487	0,431	0,526	0,442
Observations	19	19	19	19	19

CHN: China, HKG: Hong Kong, KOR: Korea, SGP: Singapore, TUR: Turkey.

According to Table 1, the highest *lpgdp* is in Singapore based on an average of 19 years. The highest *R&D* is in Korea. China has the lowest *lpgdp,* and Turkey has the lowest *R&D*. Besides, the variables belonging to all countries are normally distributed according to the Jarque-Bera normality test.

5. Methodology

In this study, relationships between variables are examined with the panel causality test developed by Kónya (2006). The most important reason for choosing this test is because it separately reveals causality relationships for each country and because there is no need for unit root and/or cointegration testing prior to it. However, the prerequisite for this test is that

the models have cross-sectional dependence and a heterogeneous structure. For this reason, before Kónya (2006) bootstrap panel causality test, the study firstly tested the existence of cross-sectional dependence on models and then tested the homogeneity/heterogeneity of slope coefficients in models. The following part indicates more information about these tests.

5.1. Cross-Sectional Dependence Tests

In the study, the relationships between variables are examined with the help of Model 1 and Model 2 and shown below. Before the cross-sectional dependence, firstly, these two models are estimated by the ordinary least squares method, and the existence of the cross-sectional dependence is tested in the residual values of $u_{i,t}$ and $e_{i,t}$ of these models.

$$lpgdp_{i,t} = \beta_0 + \beta_i R\&D_{i,t} + u_{i,t} \tag{1}$$

$$R\&D_{i,t} = \alpha_0 + \alpha_i lpgdp_{i,t} + e_{i,t} \tag{2}$$

In this equation, β_0 and α_0 are the constant terms and β_i and α_i are the slope coefficients. β_i shows the effect of a 1% change in *R&D* on *lpgdp*, while α_i shows the effect of a 1% change in *lpgdp* on *R&D*. The index i indicates the country size of the models, and t indicates the time dimension of the models. The total number of countries (N) expressing the total number of all i's (i=1, 2,…, N) included in the models includes 5 countries, and T, which expresses the entire length of time, is 19 (N=5, T=19).

For example, when the cross-sectional dependence for Model 1 is tested, $u_{i,t}$ residual terms for the model should be obtained first. Then the cross-sectional dependence is tested by deriving Model 3 seen below.

$$u_{i,t} = \alpha_i + \beta_i' x_{i,t} + \varepsilon_{i,t} \tag{3}$$

$x_{i,t}$ in the model represents the independent variables in the k × 1 dimension. In cross-sectional dependence tests for the Model, $x_{i,t} = (u_{i,t-1}, \ldots u_{i,t-p})$, where α_i is constant term and β_i' is the slope coefficient. The residual term for each country is assumed as ($\varepsilon_{i,t} = \varepsilon_{1,t}, \ldots, \varepsilon_{N,t}$) $\varepsilon_{i,t} \sim IID\ (0, \sigma_{i,\varepsilon}^2)$. The test statistics obtained by using this information provide results about whether there is cross-sectional dependence with the help of the following hypotheses. Using this information, the following hypotheses are tested using BP_{LM} developed by Breusch & Pagan (1980), CD_{LM} developed by Pesaran (2004), LM_{adj} developed by Pesaran, Ullah, & Yamagata (2008), and finally LM_{BC} developed by Baltagi, Feng, & Kao (2012) tests[1], which are frequently used in panel econometrics and are superior to each other in terms of N and T dimensions.

H_0: cov ($\varepsilon_{i,t}$, $\varepsilon_{j,t}$) = 0 or σ_{ij}=0 ve i ≠ j. (No cross-sectional dependence on Model 1.)

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[1] *Since all of these tests were applied to the models in the study, detailed information about the tests was not given separately.*

H$_1$: cov ($\varepsilon_{i,t}$, $\varepsilon_{j,t}$) $\neq 0$ or $\sigma_{ij} \neq 0$ (Cross-sectional dependence on Model 1.)

When deciding on hypotheses, the probability values of the test statistics are checked. If the probability values of the test statistics are less than the statistical significance levels of 10%, 5%, and 1%, then the H$_0$ hypothesis is rejected. This means that there is a cross-sectional dependence on the model. The same operations are performed in Model 2's residual term $e_{i,t}$ and the cross-sectional dependence is tested on Model 2. The meaning of the existence of cross-sectional dependence in the models is that a shock in one of the countries included in the models can create a shock in other countries.

5.2. Homogeneity Test

The fact that the slope coefficients of each country in the panel data are equal to a single slope coefficient indicates that the model is homogeneous and that the coefficient of each country is different means that the model is heterogeneous. The determination of the slope coefficient has both econometric and economic importance. Firstly, its importance in terms of econometrics is that depending on whether there is homogeneity in the determined model, the tests used in the next steps change. If there is homogeneity in the model, first-generation panel cointegration and panel causality tests can be used. In contrast, second-generation panel cointegration and panel causality tests are used if there is no homogeneity. In terms of economics, especially in the case of heterogeneity, detailed interpretations can be made by observing the similarities and differences between countries for the defined models. In this study, the homogeneity test is used as suggested by Pesaran and Yamagata (2008) based on Swamy's (1970) "Random Coefficients Model". The homogeneity test developed by Pesaran and Yamagata (2008) gives reliable results in larger N and T sizes, unlike in Swamy's (1970) study. In this study, it can be said that dimension T=19 is a long period in terms of panel data models. For example, hypotheses in testing are established for Model 2 as follows:

H$_0$: $\alpha_i = \alpha$, for all i's i=1,...,N (Homogeneous model)

H$_1$: $\alpha_i \neq \alpha_j$, some i≠j (Different coefficient of at least one country. Heterogeneous model)

To test these hypotheses, Pesaran and Yamagata (2008) propose asymptotically reliable statistics[2] of $\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$. If the probability values of the test statistics are less than the statistical significance levels of 10%, 5%, and 1%, then the H$_0$ hypothesis is rejected. This means that the slope coefficients of the model vary in different countries.

5.3. Kónya (2006) Bootstrap Panel Causality Test

The panel causality test developed by Kónya (2006; 982) analyses relationships between variables using the Seemingly Unrelated Regression (SUR) estimator proposed by

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[2] *Detailed information on test statistics can be obtained from the study of Pesaran and Yamagata (2008).*

Zellner (1962). It is also emphasized that Kónya (2006; 983) is a more effective estimator than the SUR estimator's OLS (Ordinary Least Squares) estimation.

The SUR system of the *lpgdp* and *R&D* variables, whose causality relations are examined, are shown as follows:

$$
\left.
\begin{aligned}
lpgdp_{1,t} &= \varphi_{1,1} + \sum_{l=1}^{ml\_lpgdp_1} \alpha_{1,1,l} lpgdp_{1,t-1} + \sum_{l=1}^{ml\_R\&D_1} \beta_{1,1,l} R\&D_{1,t-1} + \xi_{1,1,t} \\
lpgdp_{2,t} &= \varphi_{1,2} + \sum_{l=1}^{ml\_lpgdp_1} \alpha_{1,2,l} lpgdp_{2,t-1} + \sum_{l=1}^{ml\_R\&D_1} \beta_{1,2,l} R\&D_{2,t-1} + \xi_{1,2,t} \\
&\quad\quad\quad\quad\quad\quad \vdots \\
lpgdp_{N,t} &= \varphi_{1,N} + \sum_{l=1}^{ml\_lpgdp_1} \alpha_{1,N,l} lpgdp_{N,t-1} + \sum_{l=1}^{ml\_R\&D_1} \beta_{1,N,l} R\&D_{N,t-1} + \xi_{1,N,t}
\end{aligned}
\right\} \quad (4)
$$

and

$$
\left.
\begin{aligned}
R\&D_{1,t} &= \varphi_{2,1} + \sum_{l=1}^{ml\_R\&D_2} \beta_{2,1,l} R\&D_{1,t-1} + \sum_{l=1}^{ml\_lpgdp_2} \alpha_{2,1,l} lpgdp_{1,t-1} + \xi_{2,1,t} \\
R\&D_{2,t} &= \varphi_{2,2} + \sum_{l=1}^{ml\_R\&D_2} \beta_{2,2,l} R\&D_{2,t-1} + \sum_{l=1}^{ml\_lpgdp_2} \alpha_{2,2,l} lpgdp_{2,t-1} + \xi_{2,2,t} \\
&\quad\quad\quad\quad\quad\quad \vdots \\
R\&D_{N,t} &= \varphi_{2,N} + \sum_{l=1}^{ml\_R\&D_2} \beta_{2,N,l} R\&D_{N,t-1} + \sum_{l=1}^{ml\_lpgdp_2} \alpha_{2,N,l} lpgdp_{N,t-1} + \xi_{2,N,t}
\end{aligned}
\right\} \quad (5)
$$

Equation 4 is used to test the causality relationship from *R&D* to *lpgdp*. In contrast, Equation 5 is used to test the causality relationship from *lpgdp* to *R&D*. In models, *ml_lpgdp* and *ml_R&D* represent the lag lengths of the variables, while *l* represents the lag length. These lag lengths are calculated by the combination that minimizes Akaike Information Criterion (AIC) and the Schwartz Information Criterion (SIC). As Kónya (2006, p.980) states, there is the Vector Autoregressive (VAR) equation developed by Sims (1980) as much as the number of countries (N) in each system of equations. As with VAR equations in the SUR system, variables do not have to be either stationary or cointegrated. The reason for this is the uniform correlation between the VAR models belonging to the countries.

In the causality test, Wald Test statistics are calculated for each VAR equality of countries. As in Kónya (2006), these test statistics are compared with bootstrap critical values. Causality relations obtained as a result of comparison are as follows:

- There is a unidirectional Granger causality relationship from *R&D* to *lpgdp* if the coefficient $\beta_{1,i}$ is not equal to zero for all countries, whereas the coefficient $\alpha_{2,i}$ is equal to zero for all countries.
- There is a unidirectional Granger causality relationship from *lpgdp* to *R&D* if the coefficient $\beta_{1,i}$ is equal to zero for all countries, whereas coefficient $\alpha_{2,i}$ is not equal to zero.
- There is a bidirectional Granger causality relationship between *lpgdp* and *R&D* if both coefficients are not uniformly equal to zero.

- There is no Granger causality relationship between *lpgdp* and *R&D* if both coefficients are uniformly equal to zero.

In the above hypotheses, the decision rule is to reject H_0 hypotheses if the calculated Wald test statistics are higher than the bootstrap critical values. To summarize, hypotheses for each country can be listed up as follows:

H_0: For any *i* country, *R&D* does not Granger cause *lpgdp* (Model 1), or *lpgdp* does not Granger causes *R&D* (Model2).

H_1: For any *i* country, *R&D* Granger causes *lpgdp* (Model 1), or *lpgdp* Granger causes *R&D* (Model2).

6. Findings

In this chapter of the study, the findings obtained using the methods mentioned above are analysed. Firstly, Table 2 contains the results of the cross-sectional dependence test. According to the results of the cross-sectional dependence test, both Model 1 and Model 2 have cross-sectional dependence. In the already globalized world, inevitably, a shock occurring in one country will affect other countries. This finding is, therefore, not surprising. Furthermore, this result shows that the first prerequisite of Kónya (2006) bootstrap panel causality test is met.

Table: 2
Cross-Sectional Dependence Test Results

Models	Model 1		Model 2	
Tests	t-statistic	Probability	t-statistic	Probability
BP_{LM}	120,249*	0,0001	63,112*	0,0001
CD_{LM}	23,534*	0,0001	10,758*	0,0001
LM_{BC}	23,395*	0,0001	10,619*	0,0001
LM_{adj}	10,365*	0,0037	6,736*	0,0001

* *shows the cross-section dependence at the level of 1% significance.*

Table 3 indicates the homogeneity test results. According to the test results, it was determined that the coefficients for both models vary in different countries; that is, the models are heterogeneous. In other words, the effect of a change in the *R&D* of a country on the *lpgdp* or the effect of a change in the *lpgdp* on the *R&D* varies across countries. Thus, this result provides the second prerequisite of Kónya (2006) bootstrap panel causality test.

Table: 3
Homogeneity Test Results

Models	Model 1		Model 2	
Test	t-statistic	Probability	t-statistic	Probability
$\tilde{\Delta}$	15,045	0,0001	6,182	0,0001
$\tilde{\Delta}_{adj}$	16,319	0,0001	6,705	0,0001

* *shows the heterogeneity at the level of 1% significance.*

In Table 4, Kónya (2006) bootstrap panel causality test results show a unidirectional causality relationship from *R&D* to *lpgdp* for Hong Kong and Korea. Additionally, these

causality coefficients are positive. The unidirectional causality relationship from *lpgdp* to *R&D* is found in China and Turkey. The causality relationships in both countries are positive. Based on these results, both the existence of causality relationships and the coefficients of the relations vary significantly across countries.

Table: 4
Causality Test Results

Country	Coefficient****	t-statistic	Critical Value****		
H₀: R&D does not Granger cause lpgdp (Model 1)					
	R&D	Wald	10%	5%	1%
China	-0,004	0,007	5,710	8,335	17,324
Hong Kong	0,229	26,962*	5,331	7,832	15,283
Korea	0,030	8,544**	5,510	7,924	15,571
Singapore	-0,018	0,297	5,743	9,101	19,995
Turkey	0,128	2,037	5,658	8,367	16,674
H₀: lpgdp does not Granger cause R&D (Model 2)					
Country	Coefficient ****	t-statistic	Critical Value****		
	lpgdp	Wald	10%	5%	1%
China	0,624	36,924**	17,819	25,194	45,992
Hong Kong	-0,022	0,129	10,959	15,609	28,498
Korea	1,283	11,126	15,253	20,877	36,275
Singapore	0,285	2,216	7,771	11,217	20,289
Turkey	0,428	15,280***	13,653	18,544	30,543

*, **, and *** respectively indicates %1, %5, and %10 causality.
**** The bootstrap critical values are derived by making 10000 bootstraps.

Analysis results of Hong Kong and Korea are in line with the study results of Yanyun and Mingqian (2004), Altın and Kaya (2009), Genç and Atasoy (2010), Yaylalı, Akan and Işık (2010), Akıncı and Sevinç (2013), and Duman and Aydın (2018). The significant positive causality relationship from R&D expenditures to per capita income in these countries shows how important R&D expenditures are, especially in sustainable economic growth and development. This significant relationship determined for Hong Kong and Korea, which are in the high-income group, should set an example for developing countries.

Analysis results of China and Turkey are in line with the study results of Bozkurt (2015), Taş et al. (2017), and Ozkan and Yılmaz (2017). This finding can be interpreted that as the economic growth and development develop in these countries, the importance of R&D expenditures is understood, and therefore, the share allocated to R&D expenditures increases. Because in many studies, both theoretically and empirically, the importance of R&D expenditures in the development adventures of developed countries is revealed. It is a fact that both of these countries are in low ranks in terms of per capita income. For this reason, the effect of R&D expenditures on per capita income should be increased by spreading R&D expenditures made in these countries to more effective areas.

7. Conclusion

This study investigated the relationship between R&D expenditures and per capita income representing economic growth using data from the 1998-2016 period in China and Turkey, together with Hong Kong, Korea, Singapore, so-called Asian Tigers. According to Kónya (2006) bootstrap panel causality results, it was found that there was a causality relationship from research and development expenditures to per capita income in Hong

Kong and Korea. It was also determined that the coefficient of this causality relation is positive. No such results were acquired for the other countries that are analysed in this research. This means that only research and development expenditures in Hong Kong and Korea contribute to the level of welfare. In particular, the fact that Korea has the highest share of research and development expenditures in the gross domestic product is considered to have caused this effect. Although Hong Kong's share of research and development expenditures in the gross domestic product is relatively low compared to other countries, both its stable and steady rise in per capita income may reveal the reason for significant effect. It is also a sign of the efficiency of expenditures. Similar to Korea, although Singapore's share of research and development expenditures in the gross domestic product is high, it is an unexpected result that no significant relationship effect was found. Considering the share of Singapore's research and development expenditures in the gross domestic product in the 1998-2017 period, it is observed that it has decreased seriously, especially after 2008, and it has not reached the high level recorded in 2008 again. In other countries, it is seen that these expenditures increased more steadily. It is, therefore, considered that no significant relationship effect in Singapore was found. When evaluating China, where significant relationships were revealed, the effect of the population is undoubtedly unavoidable. Compared to other countries in the research, China's population is many times higher. Also, the fact that research and development expenditures in China focus on lower-cost products instead of producing high value-added products may also be effective in this. In Turkey, it is an important factor that the share of research and development expenditures in the gross domestic product is lower than in other countries. Moreover, according to the data of the World Bank compared to other countries, the low export of high technology products and the fact that research and development expenditures could not be directed to productive areas may have resulted in no significant relationship.

There is a causality relationship from research and development expenditures to per capita income in China and Turkey. In particular, developing countries such as Turkey have to reserve a portion of their national income for research and development expenditures, which are considered to be high costs. While the research and development expenditures made by such countries may seem a burden on economic growth in the short-run, they are an important factor for stable economic growth in the long-run. Therefore, the per capita income increase in Turkey is thought to increase research and development expenditures. In China, the most important reason for this effect to be significant may be due to the fact that China spends a significant part of its income on research and development expenditures. The fact that the increase in per capita income in other countries has no effect on research and development expenditures shows that these countries have exceeded the threshold value for research and development expenditures. The reason is that economic growth (per capita income) up to a certain threshold affects research and development expenditures, and after this threshold value is exceeded, research and development expenditures affect economic growth. That such a causality relationship did not emerge in Hong Kong, on the other hand, could be due to the fact that the research and development expenditures that they have separated from their income are directed to sectors that can achieve high efficiency, as discussed above.

Consequently, in light of the findings obtained in this study, the following suggestions can be emphasized:

- In the case of Hong Kong, however, it shows the importance of directing research and development expenditures towards productive areas, because according to World Bank data, the share of this country's total exports in high-tech product exports in 2017 is 13.5%, which is quite high (The World Bank Data, 2020).
- Korea entered into a structural transformation process based on the principle of manufacturing industry-oriented development with the 1970s, and it has gained a great economic growth momentum with the 1990s thanks to the returns on their efforts. The development of new products and the use of new technologies, as well as high research and development expenditures, greatly contributed to the emergence of this economic growth.
- If the research and development expenditures are not stable, the effect on per capita income can become insignificant, as in the example of Singapore.
- As in the case of China, the population is still the most important factor for per capita income. Although it ranks top in the world in gross domestic product rankings, it has a serious problem in per capita income ranking. For this reason, population control is of crucial importance. Thus, the effect of per capita income on research and development expenditures, which is the most important factor in growth, can increase. Moreover, the fact that the increase in per capita income of this country, which is in an effort to become a global power, has increased the research and development expenditures reveals the importance of these expenditures.
- For Turkey, it is thought that these expenditures may have a positive impact on per capita income by increasing research and development expenditures and directing them to more productive areas. The fact that the share of high technology product exports among total exports in Turkey is 2.3% shows why there is no causality relationship from per capita income to research and development expenditures. However, as research results highlight, Turkey has an effort to increase its research and development expenditures (The World Bank Data, 2020). These increased research and development expenditures must be directed to productive areas and must be sustainable. Thus, R&D expenditures can have an impact on per capita income. As a result, Turkey's per capita income can rise to the level of developed countries in this way.

References

Aghion, P. & P. Howitt (1992), "Model of Growth Through Creative Destructio", *Econometrica*, 60(2), 323-351.

Aghion, P. & P. Howitt (1998), *Endogenous Growth Theory*, MIT press.

Akinci, M. & H. Sevinç (2013), "The Relationship between R&D Expenditures and Economic Growth: The Case of Turkey, 1990-2011", *The Journal of International Social Research*, 6(27), 7-17.

Altin, O. & A. Kaya (2009), "Analysis of The Casual Relationship between R&D Expenditures and Economic Growth for Turkey", *Ege Academic Review*, 9(1), 251-259.

Arrow, K.J. (1962), "The Economic Implications of Learning by Doing", *The Review of Economic Studies*, 29(3), 155-173.

Baltagi, B.H. & Q. Feng & C. Kao (2012), "A Lagrange Multiplier Test for Cross-Sectional Dependence in a Fixed Effects Panel Data Model", *Journal of Econometrics*, 170(1), 164-77.

Barro, R.J. & X. Sala-i Martin (2004), *Economic Growth*, The MIT Press, ABD.

Bond, S.R. & I. Guceri (2017), "R&D and Productivity: Evidence from Large UK Establishments with Substantial R&D Activities", *Emerging Markets Finance and Trade*, 26, 108-20.

Bozkurt, C. (2015), "R&D Expenditures and Economic Growth Relationship in Turkey", *International Journal of Economics and Financial Issues*, 5(1), 188-198.

Bravo-Ortega, C. & Á.G. Marín (2011), "R&D and Productivity: A Two Way Avenue?", *World Development*, 39(7), 1090-1107.

Breusch, T.S. & A.R. Pagan (1980), "The Lagrange Multiplier Test and Its Applications to Model Specification in Econometrics", *The Review of Economic Studies*, 47(1), 239-253.

Dam, M.M. & B. Yildiz (2016), "Impact of R&D and Innovation on Economic Growth at BRICS-TM Countries: An Econometric Analysis", *Akdeniz University Journal of Economics & Administrative Sciences*, 16(33), 220-236.

Dereli, D.D. & U. Salgar (2019), "Relationship between R&D Expenditures and Economic Growth: An Evaluation on Turkey", *Journal of Life Economics*, 6(3), 345-360.

Domar, E.D. (1946), "Capital Expansion, Rate of Growth, and Employment", *Econometrica Journal of the Econometric Society*, 137-147.

Duman, K. & K. Aydin (2018), "The Relationship between R&D Expenditure and GDP in Turkey", *Gazi Journal of Economic & Business*, 4(1), 49-66.

Eaton, J. & S. Kortum (2006), "Innovation, Diffusion, and Trade", *National Bureau of Economic Research Working Paper Series*, No: 12385.

Feng, P. & S. Ke (2016), "Self-selection and Performance of R&D Input of Heterogeneous Firms: Evidence from China's Manufacturing Industries", *China Economic Review*, 41, 181-95.

Freeman, C. & L. Soete (2003), *Economics of Industrial Innovation*, (trans. E. Türkcan), TÜBİTAK Publishing, Ankara.

Freimane, R. & S. Bāliņa (2016), "Research and Development Expenditures and Economic Growth in the EU: A Panel Data Analysis", *Economics and Business*, 29(1), 5-11.

Freire-Serẹn, M.J. (1999), "Aggregate R&D Expenditure and Endogenous Economic Growth", *UFAE and IAE Working Papers*, No WP 436-99.

Genc, M.C. & Y. Atasoy (2010), "The Relationship between R&D Expenditure and Economic Growth: Panel Data Analysis", *The Journal of Knowledge Economy & Knowledge Management*, 5(2), 27-34.

Gittleman, M. & E.N. Wolff (1995), "R&D Activity and Cross-Country Growth Comparisons", *Cambridge Journal of Economics*, 19, 189-207.

Goel, R.K. & R. Ram (1994), "Research and Development Expenditures and Economic Growth: A Cross-Country Study", *Economic Development and Cultural Change*, 42(2), 403-11.

Griliches, Z. (1985), "Productivity, R&D, and Basic Research at The Firm Level in the 1970's", *American Economic Review*, 76(1), 141-54.

Grossman, G.M. & E. Helpman (1991), "Quality Ladders in the Theory of Growth", *The Review of Economic Studies*, 58(1), 43-61.

Guloglu, B. & R.B. Tekin (2012), "A panel causality analysis of the relationship among research and development, innovation, and economic growth in high-income OECD countries", *Eurasian Economic Review*, 2(1), 32-47.

Harrod, R.F. (1939), "An Essay in Dynamic Theory", *The Economic Journal*, 49(193), 14-33.

Helpman, E. (1980), "Innovation, Imitation, and Intellectual Property Rights", *Econometrica*, 61(6), 1247-1280.

Jones, C.I. (2001), *Introduction of Economic Growth*, (Trans. S. Ateş & İ. Tuncer)*, Literatür Publishing, Istanbul.

Keirstead, B.S. (1948), *The Theory of Economic Change*, Macmillan, Toronto.

Kesikoğlu, F. & Ş. Saraç (2017), "The Effect of R&D Expenditures on Economic Growth: Comparative Analysis of Nuts Level 1", *Int. Journal of Management Economics and Business*, 13(13), 617-626.

Kim, J.W. (2011), "The economic growth effect of R&D activity in Korea", *Korea and the World Economy*, 12(1), 25-44.

Kónya, L. (2006), "Exports and Growth: Granger Causality Analysis on OECD Countries with A Panel Data Approach", *Economic Modelling*, 23(6), 978-992.

Kutbay, H. & E. Öz (2017), "Comparison of Tax Incentives Implemented for R&D Activities in Turkey and Selected Countries", *Yönetim ve Ekonomi: Celal Bayar Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 24(3), 783-802.

Küçükkalay, A.M. (2010), *History of Economic Thought*, Beta Publishing, Istanbul.

Lee, J.W. & B.G. Yu (2002), "An Endogenous Growth Model Approach to the Korean Economic Growth Factors", *The Journal of Productivity*, 8, 1-13.

Lichtenberg, F.R. (1992), "R&D Investment and International Productivity Differences", *Working Paper* No. 4161, National Bureau of Economic Research, Cambridge.

Luh, Y.H. & S.K. Chang (1997), "Building the Dynamic Linkages Between R&D and Productivity Growth", *Journal of Asian Economics*, 8(4), 525-545.

Marx, K. (2015), *Capital*, First Volume, 11th Edition, (Trans. A. Bilgi), Ankara: Sol Publications.

Minniti, A. & F. Venturini (2017), "The long-run growth effects of R&D policy", *Research Policy*, 46, 316-26.

Ozcan, B. & A. Arı (2014), "The Relationship Between Research & Development Expenditures and Economic Growth: Panel Data Analysis", *Maliye Dergisi*, 166(1), 39-55.

Ozel, H.A. (2012), "Theoretical Grounds of Economic Growth", *Çankırı Karatekin University Journal of the Faculty of Economics and Administrative Sciences*, 2(1), 63-72.

Ozkan, G. & H. Yılmaz (2017), "The Effects of R&D Expenditures on High Technology Export and Per Capita Income: A Practice for Turkey, and 12 Member Countries of the European Union (1996-2015)", *The Journal of Knowledge Economy &Knowledge Management*, 12(1), 1-12.

Pack, H. & R.R. Nelson (1999), "The Asian Miracle and Modern Growth Theory", *Economic Journal*, 109(457), 416-36.

Pala, A. (2019), "Innovation and Economic Growth in Developing Countries: Empirical Implication of Swamy's Random Coefficient Model (RCM)", *Procedia Computer Science*, 158, 1122-1130.

Papageorgiou, C. & N. Spatafora (2012), "Economic Diversification in LIC's; Stylized Facts and Macroeconomic Implication", *IMF Staff Discussion Notes*, 12/13.

Park, W.G. (1995), "International R&D Spillovers and OECD Economic Growth", *Economic Inquiry*, 33(4), 571-591.

Pesaran, M.H. & A. Ullah & T. Yamagata (2008), "A bias-adjusted LM test of error cross-section independence", *The Econometrics Journal*, 11(1), 105-127.

Pesaran, M.H. & T. Yamagata (2008), "Testing slope homogeneity in large panels", J*ournal of Econometrics*, 142(1), 50-93.

Pesaran, M.H. (2004), "General Diagnostic Tests for Cross Section Dependence in Panels", *Cambridge Working Papers in Economics*.

Rebelo, S. (1991), "Long-run policy analysis and long-run growth", *Journal of Political Econom*, 99(3), 500-521.

Ricardo, D. (2007), *Principles of Political Economy and Taxation*, Belge Publishing, Istanbul.

Romer, P.M. (1986), "Increasing Returns and Long-Run Growth", *The Journal of Political Economy*, 95(5), 1002-1037.

Romer, P.M. (1990), "Endogenous Technological Change", *Journal of political Economy*, 98(5), 71-102.

Schumpeter, J.A. (1939), B*usiness Cycles: A Theoretical, Historical, and Statistical Analysis of The Capitalist Process*, McGraw-Hill: New York and London.

Shefer, D. & A. Frenkel (1998), "Local Milieu and Innovations: Some Empirical Results", *Annals of Regional Science*, 32(1), 185-200.

Shen, X. & B. Lin & W. Wu (2019), "R&D Efforts, Total Factor Productivity, and the Energy Intensity in China", *Emerging Markets Finance and Trade*, 55(11), 2566-2588.

Sims, C.A. (1980), "Macroeconomics and Reality", *Econometrica*, 48(1), 1.

Snowdon, B. & H.R. Vane (2005), *Modern macroeconomics: its origins, development and current state*, Edward Elgar Publishing.

Sokolov-Mladenović, S. & C. Slobodan & M. Igor (2016), "R&D Expenditure and Economic Growth: EU28 Evidence for the Period 2002-2012", *Economic Research*, 29(1), 1005-20.

Solow, R.M. (1956), "A Contribution to the Theory of Economic Growth", *The Quarterly Journal of Economics*, 70(1), 65-94.

Sungur, O. & H.İ. Aydın & M.V. Eren (2016), "The Relationship among R&D, Innovation, Export and Economic Growth in Turkey: Asymmetric Causality Analyis", *Suleyman Demirel University The Journal of Faculty of Economics and Administrative Sciences*, 21(1), 173-192.

Swamy, P.A.V.B. (1970), "Efficient Inference in a Random Coefficient Regression Model", *Econometrica*, 38(2), 311-323.

Sylwester, K. (2001), "R&D and Economic Growth", *Knowledge, Technology & Policy*, 13(4), 71-84.

Tari, R. & M.M. Alabaş (2017), "The Relationship between R&D Expenditures and Economic
    Growth: The Case of Turkey (1990-2014)", *Bolu Abant İzzet Baysal Üniversitesi Sosyal
    Bilimler Enstitüsü Dergisi*, 17(2), 1-17.

Taş, Ş. & İ. Taşar & Y. Açcı (2017), "Relationship between R&D Expenditures and Economic
    Growth: Example of Turkey", *Omer Halisdemir University Academic Review of
    Economics and Administrative Sciences*, 10(2), 197-206.

The World Bank (2020), *GDP per capita (constant 2010 US$)*,
    <https://data.worldbank.org/indicator/NY.GDP.PCAP.KD>, 14.12.2019.

The World Bank (2020), *Research and development expenditure (% of GDP)*,
    <https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS>, 14.12.2019.

Tuna, K. & E. Kayacan & H. Bektaş (2015), "The Relationship between Research & Development
    Expenditures and Economic Growth: The Case of Turkey", *Procedia-Social and
    Behavioral Sciences*, 195, 501-507.

Türkmen, S. & H. Ağır & E. Günay (2019), "R&D and Economic Growth in Sellected OECD
    Countries: New Evidences from Panel Cointegration Approach", *Bilgi Ekonomisi ve
    Yönetimi Dergisi*, 14(2), 89-101.

Uçak, S. & Ö. Kuvat & A.G. Aytekin (2018), "The Relationship between R&D Expenditures and
    Growth in Turkey: ARDL Approach", *Manisa Celal Bayar Üniversitesi Sosyal Bilimler
    Dergisi*, 16(2), 129-160.

Uzawa, H. (1965), "Optimum Technical Change in an Aggregative Model of Economic Growth",
    International Economic Review, 6(1), 18-31.

Wu, Y. & L. Zhou & J.X. Li (2007), "Cointegration and causality between R&D expenditure and
    economic growth in China: 1953-2004", *In International Conference on Public
    Administration*, 76.

Yanyun, Z. & Z. Mingqian (2004), "R& D and Economic Growth: Panel Data Analysis in
    ASEAN+3 Countries", *A Joint Conference of AKES, RCIE, and KDI: Korea and the
    World Economy, III*, July 3-4. Sungkyunkwan University, Seoul.

Yu-Ming, W. & Z. Li & L. Jian-Xia (2007), "Co-integration and Causality between R&D
    Expenditure and Economic Growth in China: 1953-2004", *International Conference on
    Public Administration*, 869-876.

Zachariadis, M. (2004), "R&D-induced Growth in the OECD?", *Review of Development Economics*,
    8(3), 423-439.

Zellner, A. (1962), "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests
    for Aggregation Bias", *Journal of the American Statistical Association*, 57(298), 348-68.

Zhou, Y. & X. He & Y. Shen (2012), "An evaluation of the efficiency of Chinese industry
    enterprises' innovation performance", *Economic Research Journal*, 5, 107-119.