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Innovation for Economic Growth: G7 vs E7

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ABSTRACT

Purpose: The main objective of this research is to examine the impact of R&D expenditures and Global Innovation Index ranking on per capita income in E7 and G7 country groups.

***Methodology*:** Logistic regression model was used as the research method in the study. Stata 18 Data Analysis and Statistical Software Program was used in the analysis of the data. At the hand of Stata 18 Data Analysis and Statistical Software Program, regression analysis was used to estimate the possible and unknown effects of independent variables on the dependent variable. During the collection of the data used in the study, the archive scanning method, which is one of the qualitative research methods, was used. Archival reports and official records were also used in the study.

Findings: According to the research results, 83.56% of the model is explained by explanatory variables. With all other explanatory variables constant, a 1% increase in R&D expenditure will result in an increase of 0.5243% on GDP per capita. At the same time, this coefficient gives the flexibility of GDP per capita relative to R&D expenditure (%GDP). It is also found out that there is a positive relationship between GDP per capita and R&D expenditure and also, there is a negative relationship between GDP per capita-GII ranking. In this study, which deals with the innovation efficiency of the G7 countries and the E7 countries, and the effect of this performance on the GDP per capita, it is seen that the G7 countries spend more on innovation.

Originality: It contributes to the literature as there is no other study in the literature that deals with per capita income, Global Innovation Index ranking and R&D expenditures comparatively between the G7 and E7.

Keywords*:* Innovation, Global Innovation Index, G7, E7.
JEL Codes: O19, 032, Q55.

Ekonomik Büyüme için İnovasyon: G7, E7'ye Karşı

ÖZET

Amaç: Bu çalışmanın amacı E7 ve G7 ülke gruplarında Ar-Ge harcamaları ve Küresel İnovasyon Endeksi sıralamasının kişi başına düşen gelir üzerindeki etkisinin incelenmesidir.

***Yöntem*:** Araştırmada araştırma yöntemi olarak lojistik regresyon modeli; verilerin analizinde Stata 18 Veri Analizi ve İstatistik Yazılım Programı kullanılmıştır. Stata 18 Programında bağımsız değişkenlerin bağımlı değişken üzerindeki olası ve bilinmeyen etkilerini tahmin etmek için regresyon analizi kullanılmıştır. Ayrıca araştırmada kullanılan verilerin toplanması sırasında nitel araştırma yöntemlerinden biri olan arşiv tarama yöntemi kullanılmıştır. Araştırmada arşiv raporlarından ve resmi kayıtlardan yararlanılmıştır.

Bulgular: Araştırma sonuçlarına göre model, %83,56 oranında belirlenen değişkenler tarafından açıklanmaktadır. Diğer tüm açıklayıcı değişkenler sabitken, Ar-Ge harcamalarındaki %1'lik bir artış, kişi başına düşen GSYİH'de %0,5243'lük bir artışla sonuçlanacaktır. Bu katsayı aynı zamanda kişi başına düşen GSYH'nin Ar-Ge harcamalarına (%GSYH) göre esnekliğini de vermektedir. Kişi başına düşen GSYİH ile Ar-Ge harcamaları arasında pozitif bir ilişkinin olduğu, kişi başına GSYH-GII sıralaması arasında ise negatif bir ilişkinin olduğu tespit edilmiştir. Firmaların inovasyon performansının ölçülmesini sağlayan global inovasyon endeksinde (GII), Ar-Ge harcaması yapan işletmelerin üst sıralarda ve zirveye yakın olduğu, kişi başına düşen GSYİH'nın daha yüksek olduğu belirlendi. G7 ülkeleri ile E7 ülkelerinin inovasyon performansının ve bu performansın kişi başına düşen GSYİH'ye etkisinin ele alındığı bu çalışmada, G7 ülkelerinin inovasyona daha fazla harcama yaptığı görülmektedir.

Özgünlük: Literatürde kişi başına düşen gelir, Küresel İnovasyon Endeksi sıralaması ve Ar-Ge harcamalarının G7 ve E7 açısından karşılaştırmalı olarak ele alan bir başka çalışma olmadığından literatüre katkı sağlamaktadır.

Anahtar Kelimeler*:* İnovasyon, Küresel İnovasyon Endeksi, G7, E7.
JEL Kodları: O19, 032, Q55.

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1. INTRODUCTION

Throughout the history, countries have done their best so as to maintain the competitive advantage they have. For sustainable economic development and increased GDP, innovation is the key driving force nowadays.

With the industrialization, there has been a recognizable escalate in the global population. The rise in the global population has followed by the reduction of natural resources and degradation of environment. In today's fast paced and dynamic environment, the importance of innovation is inevitable. The increased awareness of innovation leads individuals, companies, and countries rational and efficient use of the limited resources.

Under these circumstances, companies face the necessity to generate new ideas and create innovation. Due to its role in increasing both productivity and competitiveness, innovation has a very crucial function in the growth of national economies. Innovation triggers the growth of an economy measured in terms of GDP.

There are various innovation measurement techniques such as the European Innovation Scoreboard, the World Economic Forum (WEF), and the Global Innovation Index (GII). The World Intellectual Property Organization (WIPO) is a leader organization in supporting the intellectual property ecosystem for a sustainability-driven future. For this reason, by creating and calculating the Global Innovation Index (GII), it provides a roadmap for nations to see their current innovation performance and develop their capacities (Brás, 2023).

For the econometric analysis Global Innovation Index (GII) is considered. Published annually by Cornell University, INSEAD (European Institute of Business Management) and WIPO (World Intellectual Property Organization), this index ranks countries according to indicators using many variables that affect innovation. Besides, innovation performance is measured based on sub-input and sub-output indices.

This research's main aspiration is to find and figure out the differences between G7 group of developed countries (USA, Germany, UK, Japan, Canada, France, Italy) and the group of developing E7 countries' (Brazil, China, India, Indonesia, Mexico, Russia, and Türkiye) R&D expenditures to their GDP, GII rankings and GDP per capita during 2013-2022. GDP per capita is considered as the dependent variable in this research whereas the ratio of countries' R&D expenditures to their GDP and their GII rankings are considered as independent variables. The contribution of this paper is twofold. First, it gives the chance to emphasize the advantages and superiority of developed countries (G7). Secondly, it gives an insight to developing countries (E7) to reach the developed countries from innovation perspective.

The rest of the study is organized along these lines. Section 2 defines the innovation whereas Section 3 gives information regarding Global Innovation Index and Sub-indices. Section 4 emphasizes Research& Development and the connection between R&D and Innovation. In Section 5, the relationship between dependent and independent variables and econometrically analzed and finally Section 6 concludes.

2. INNOVATION CONTEXT

In today's world, markets have perfectly competitive structure, and there are fierce competitions between companies in these markets. In this competitive environment, companies try to maximize their profits, while contributing to and serving social welfare. In a competitive market environment, free competition-based economic relations between businesses are the most basic requirement of an efficient and healthy financial system. As a result of the dynamic structure of perfectly competitive markets, people trying to maximize their individual benefits also try to ensure the effectiveness of both themselves and the whole market. In order to ensure both individual and social welfare, companies need to carry out their activities effectively and efficiently and create innovation in pusuance of gaining desire to surpass other peers in the perfect competition market. The ability of businesses to keep up with the highly dynamic and exceedingly competitive market conditions under all circumstances depends on their ability to innovate (Rekabet Kurumu, 2023).

Moreover, the extremely rapid expansion in the global population causes the voracious depletion of natural resources and production factors, which are already limited and scarce, faster. Therefore, both individuals, companies and governments should be extremely careful and rational in the benefit of these limited resources and ensure the usage and distribution of these resources in the most optimal way. The existence of this aforementioned problem causes companies to put into practice new methods and practices in order to utilize limited resources more efficiently. And thus, companies face the necessity to generate new ideas and create innovation. Due to its role in increasing both productivity and competitiveness, innovation has a far-reaching function in the growth of national economies. For this reason, it is possible to say that innovation is an essential element that has an active function in the management of economic activities on a global scale (Şahinli and Kılınç, 2013).

Although there are many interpretations in the literature about what the concept of innovation is, it would not be correct to talk about the existence of only one definition on which a consensus has been reached. Innovation can be interpreted as “alteration” or “a new method, idea, product, etc.” in its most basic and simple form.

Innovation is clarified as “the first introduction or major renewal of a good, service or process; in the form of a new or unused or non-existent marketing method, or the introduction of a first or renewed organizational method” by the OECD (2018). Considering another definition, Twiss (1989) emphasizes that innovation is a process and states that it is a field that combines science, economics, and many other disciplines. Innovation is also stated as the process of commercialization from the birth of an idea to its production and even consumption (Twiss, 1989).

While Rowley et al. (2011) agree with the idea that innovation is a process, they argue that this process is a comprehensive, multi-layered, and gradual process. At the heart of this process lies the idea of companies converting their ideas into products or services and processes with various motivations. In addition, the motivations underlying the innovation of enterprises can be various factors such as having a strong position in the markets in which they operate, gaining competitive power or standing out from their competitors by being different.

According to another definition, innovation is the sine qua non of corporate life for companies and is expressed as the key to their survival. To put it more clearly, innovation is the lifeblood of companies and the only way to grow. Innovation also enables companies to both create value and gain competitive advantage in order to stand out from their competitors or peers (Zahra and Covin, 1994).

From another point of view, the notion of innovation, which expresses both a process and a result of this process, has become an important determinant in addressing innovation competitive advantage today (Özbey ve Başdaş, 2018).

According to the definition of innovation in another source, the phenomenon of innovation is shaped by two main components: the release or definition of something completely new to the market, or a brand-new idea, method, or tool/device (Merriam-Webster, 2017).

On the other hand, innovation represents a new knowledge according to Afuah (1998). This new information is included in every step of production and consumption from products to processes and services.

Schumpeter (1982), who is considered and seen as the founding father of innovation theory in the field of economics, states that innovation is the most basic and fundamental source of technological development and growth. According to Schumpeter (1934),

- Launching a new product or a new and higher quality version of an existing product to the market, which they are not familiar with or close to,
- Introducing and implementing a new mode of production that did not exist before,
- Entering a market or a market that has never operated or existed before,
- Discovery of a new raw material or semi-product that did not exist before,
- The establishment of a new monopolistic position in the market or the deterioration of an existing monopolistic position,
- The execution of a new commercial activity or form of financial organization in any sector ensures the emergence of innovation.

The phenomenon of innovation, which expresses both a procedure (renewal) and an outcome (innovation), is not actually an invention. It fundamentally means adding new effective features to add value to an existing product & service and presenting it to the service of humanity again. In terms of the innovation phenomenon, the important thing at this stage is that the changing new feature is effective and that it adds a unique feature to the existing or new product or service as a result of the creation of innovation (Baş, 2020).

Although there are many definitions of innovation, the inability to talk about a single correct definition that has been agreed upon, and the fact that there are discussions on the accuracy and deficiencies of each definition, brought along the evaluation of innovation on concrete measures. For this reason, the approach of evaluating innovation with concrete measures and measuring it over its sub-components is adopted and used intensively.

The global innovation index (GII) is determined as one of the most widely used criteria that serves this purpose and is used to measure innovation in a healthy way. For this reason, first of all, it was deemed necessary to deal with the global innovation index (GII) and it’s subfactors that make up this index in detail with the aim of understanding the comprehensive construction of innovation more clearly in this study.

3. GLOBAL INNOVATION INDEX

The fact that different countries have different innovation capacities causes the development of a common measurement system in order to compare these capacities. And thus, it is ensured that the innovative capacity assessment, which will be a standard measurement on a global scale, can be carried out more accurately and healthily. Although many institutions and organizations try to develop and measure different indices for this purpose, there are some main indices that are most frequently preferred in the literature. The European Innovation Scoreboard, the World Economic Forum (WEF), and the Global Innovation Index (GII) are the ultimate cases of such considerable world-wide measurement mechanisms. Among these indices, the most comprehensive and frequently preferred index on a global scale in practice is the KIE. While the index ranks (from the largest to the smallest) the innovation performance of the countries whose data are available every year, it also highlights certain gaps in innovation criteria (Baykul, 2022).

Published annually by Cornell University, INSEAD (European Institute of Business Management) and WIPO (World Intellectual Property Organization), this index also ranks countries according to indicators using many variables that affect innovation. Through this index, researchers can also analyze many variables (by sub-indexes) can be expressed numerically (Gürtuna and Polat, 2020).

The GII is an analysis based on an increasing number of countries every year, providing a comprehensive evaluation opportunity for the evolution of innovative competency in addition to the systematic examination of the scores. The Global Innovation Index (GII) also assesses the innovation progress of nations by benefiiting from a vast number of signals that influence innovation (Baykul, 2022).

The World Intellectual Property Organization (WIPO) is a leader organization in supporting the intellectual property ecosystem for a sustainability-driven future. For this reason, by creating and calculating the Global Innovation Index (GII), it provides a roadmap for countries to see their current innovation performance and develop their capacities. GII consists of 81 indicators in 2022 that are grouped as innovation input & output sub-index (Brás, 2023).

The Global Innovation Index consists of the Innovation Input Sub-Index and the Innovation Output Sub-Index sub-indexes, and the resulting overall GII is computed by calculating the average of the two key indices and rankings in this context. Briefly GII is the average of the Innovation Input and Output Sub-Indices, and the innovation performance rankings of countries are calculated through the GII (WIPO, 2020; GII, 2022). The Global Innovation Index report, which was presented in 2022 and symbolized 94.3% of the global population and 99.0% of the global GDP, covers 132 countries and the innovation performances of these countries are compared (Dutta et al., 2022).

Innovation Input Sub-Index: The Innovation Input Sub-Index, which consists of five main headings, includes elements that enable innovative activities of the economy. These headings are: institutions, human capital and research, infrastructure, market sophistication, and business sophistication. These five main indicators given and listed above have been determined and used to express developments that include innovation, which is one of the most fundamental values in terms of national economies (Sıcakyüz, 2023).

Innovation Output Sub-Index: It is calculated as the result of innovative activities in the economy and is equally weighted with the Innovation Input Sub-Index in calculating the Global Innovation Index scores, although it consists of only two basic components. These components are: knowledge and technology output and creative outputs.

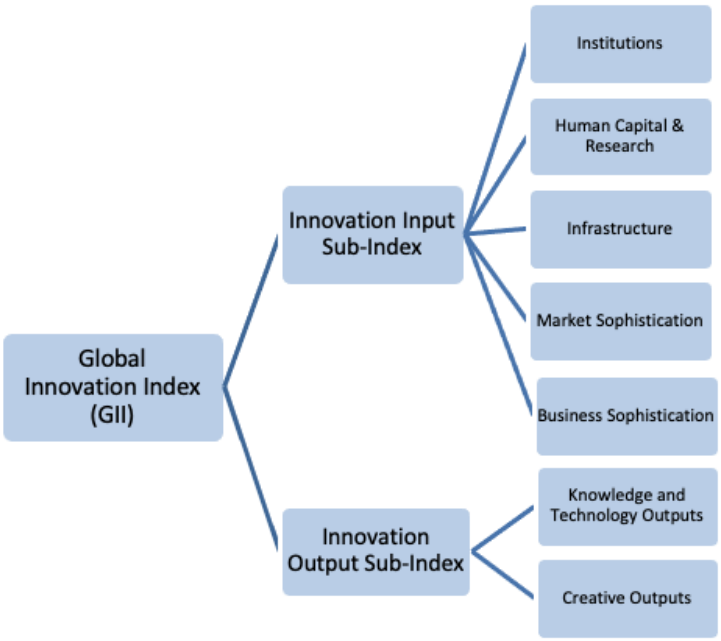


Figure 1. Global Innovation Index (GII) structure (WIPO, 2020).

Each main topic is divided into three main subheadings, and innovative performance is determined with reference to a total of 81 indicators. As seen in Figure 2,

- the political environment, regulatory environment and business environment constitute the "Institutions" main component,
- education, tertiary education and research and development (R&D) "Human Capital and Research" component,
- information and communication technologies (ICTs), general infrastructure and ecological sustainability "Infrastructure" component,
- credit, investment, trade, diversification, and market scale constitute the "Market Sophistication" component,
- knowledge workers, innovation linkages and knowledge absorption constitute the "Business Sophistication" component.

On the other hand, "Knowledge and Technology Outputs" heading consists of knowledge creation, knowledge impact and knowledge diffusion while "Creative Outputs" heading includes intangible assets, creative goods and services, and online creativity. These two main headings constitute the innovation output sub-index.

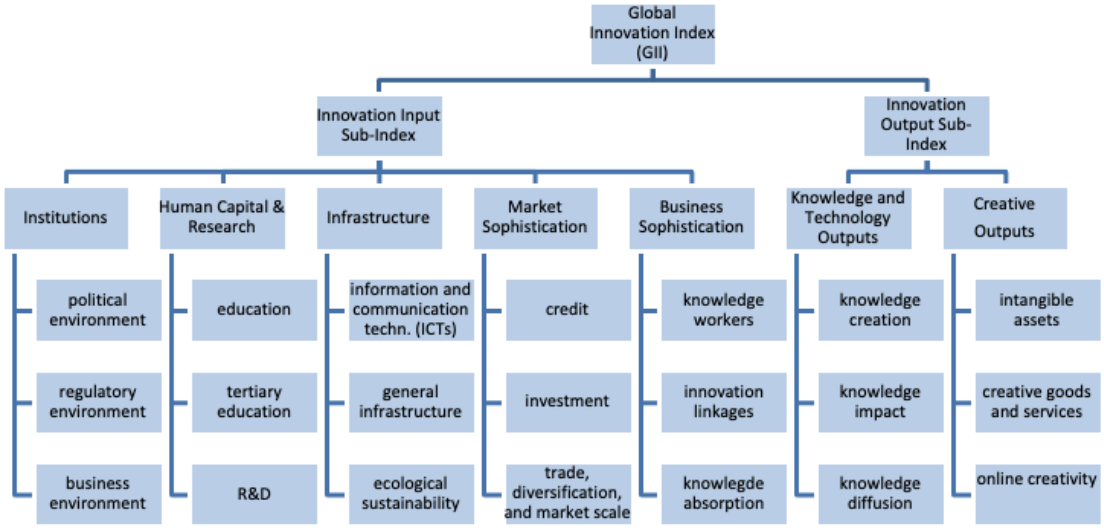


Figure 2. Global Innovation Index components (WIPO, 2020)

With an emphasis on the innovation capacities and potentials of the countries, it is necessary to determine and know the current position and standard of the education and research activities carried out by the said countries. The measurement in question means the measurement of the human capital owned by the countries, and this measurement is carried out under the title of human capital and research, which is the sub-component of the global innovation index.

In the first of the sub-factors that make up the human capital and research pillar, there are several indicators determined in order to fulfill the aim of being successful at the primary and secondary education level. In this direction, education expenditures and education (school) life expectancy serve as an important and appropriate sub-pillar for the aforementioned related factors, and its ability to represent the pillars is quite strong. On the other hand, the level of education expenditure that the states have made for each student at the secondary education level provides vital information about the importance and priority level that the nations give to secondary education. In addition, to measure the quality of education, the outcome of the OECD Program for International Student Assessment (PISA) and the performances of 15-year-old students in both reading and also mathematics and science classes are used as data (Dutta et al., 2015).

Another component of the human capital and research factor is tertiary (higher) education. Tertiary (higher) education is an integral part of national economies and is extremely important in terms of going beyond the basic and simple production processes and outputs of the value chains of countries. While the tertiary (higher) education sub-pillar evaluates participation in tertiary education, priority is given to the main fields that can be directly associated with innovation in various traditional senses, such as engineering, basic sciences, manufacturing, or construction. Beyond that, the sharing and exchange of ideas and skills that occur during the mobility of students studying in higher education institutions within the scope of the tertiary education sub-factor is quite necessary to create innovation (Dutta et al., 2015).

The R&D sub-indicator, which is the third and last sub-component of the human capital and research factor, uses the indicators of full-time researchers, gross expenditure and the characteristics of science and research institutions in order to measure the volume and current quality of the R&D activities conducted. The basis of this sub-indicator is to determine the existence of minimum 3 higher education organizations in the top 700 in the global ranking and scale within each economy. However, determining the mediocre degree of all existing institutions and organizations for a given economy is not among the main tasks of this sub-determiner (Dutta et al., 2015).

In short, human capital and research benefit from education and research activities in determining the innovation ability and potential of nations. In this direction, the current level of both education and research activities of nations and the standards they are involved in are the most basic factors used in determining the level of innovation. The human capital and research sub-component are considered as vital indicators to measure the personnel resources of the nations. The human capital and research sub-component aims to sustain and even increase the achievements of nations in secondary education. In addition, it is very important in terms of increasing the value chain of higher education and should be handled carefully.

4. LITERATURE REVIEW

Innovation enables countries to increase their production by providing improvements both in the products and services they produce and, in the methods, used in production, thus increasing the export and welfare of the countries. Therefore, today, companies trying to maximize both their profits and welfare give particular attention to research and development (R&D) activities (Akcalı ve Şişmanoğlu, 2015:768). In line with this aim, it is very important for countries to take meaningful steps towards science and technology in a stable and regular manner and to make targeted investments in this direction. Aside from the private sector, the public sector should always support the private sector in relation to the issue by acting consistently in R&D investments (Soumitra et al., 2020).

Amongst most crucial determinants of the economic power of countries is their innovative abilities and capacities. The innovative power of the countries is an important supporter of the institutional structures and support systems that carry out innovative activities. The innovative power of countries, in other words, their innovative capacities also shape their investments and policies in the public and private sectors at the same time, which will encourage their R&D activities and make them more efficient. At the same time, innovative capacity affects the long-term efforts of countries on innovation and the success of these efforts.

Improving the innovation capacity and performance is one of the most important and fundamental ways for countries to get ahead in today's tough global competitive races. Countries with a strong competitive advantage both show a breakthrough in economic growth and increase exports and therefore international trade activities as a result of economic growth. However, on the other hand, production is not the only way for enterprises to increase their export volumes and international trade. It is also very important for countries to benefit from new technologies by conducting R&D in gaining competitive advantage. The fact that

countries produce new goods and services because of conducting R&D activities and even have the opportunity to be the first exporter of new goods and services allows them to grow faster (Aktaş, 2022). For this reason, the third and last sub-component of the human capital and research factor is the R&D sub-indicator.

The lack of human capital to encourage and increase R&D effort is considered as the topmost handicap in the creation and execution of innovation and is considered as the most important bottleneck which prevents innovation. Considering the countries in the middle-upper class income group, it is possible to say that both the human capital, which is very important for the execution of R&D activities, and the innovation linkage are equally effective, but on the other side, innovation is one of the most fundamental difficulties even for these countries. (Bate et al., 2023).

Spendings expressed as research and development (R&D) expenses in the literature refer to the expenses incurred directly in the research and development of the goods or services that will be produced by the enterprises producing goods or services, or any intellectual property rights arising within the production process. To put it more clearly, R&D expenses can be defined as all direct expenses incurred by companies during the production technologies, design, production, and all other processes, efforts to develop and innovate during the production of products or services (Frankenfield, 2022). It is in question that businesses often incur R&D expenses in the process of creating, finding or revealing a brand-new product or service. Boosting the volume of R&D expenditures, which is a very important expense item in terms of companies, is one of the main targets that both companies and countries set in achieving sustainable economic growth.

The total of R&D expenditures is of great importance in fulfilling the 9th objective (SDG-9), one of the sustainable development goals, of the United Nations, as well as being a data that states should follow on the path of economic growth. UN SDG-9 requires the endorsement of a sustainable development approach, stating the goal of "*building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation*". In this context, SDG-9 emphasizes the necessity of promoting innovation. In addition, for this purpose, it is emphasized that the sum of individuals working on R&D per 1 million people and the R&D expenditures made by both the public and private sectors should be greatly increased in the process until 2030 (UIS, 2023). As SDG Target 9.5 mentions developing scientific research and studies in all countries, especially in developing countries, and increasing the technological capacity of industries directly linked to industry are another important point (UNECE, 2023).

Although there are many studies in the jurisprudence delving into the relationship between R&D and innovation, most of these studies try to determine and evaluate the impact of R&D expenditures on innovation. Many studies reveal that the R&D expenditures of organizations precisely impact their ability to innovate, and it is even considered as the most effective factor determining these capabilities (Dosi, 1988; Freeman and Soete, 1997; Shefer and Frenkel, 2005). R&D investments of companies enable them to gain a competitive advantage by gaining a strong position against rival companies (or peers) even at the very beginning of the innovation diffusion process (Shefer and Frenkel, 2005).

In the study of Aghion and Howitt (1992), which selected companies operating in the USA as a sample, economic growth was handled in an R&D-based way. In the aforementioned study, the relationship between R&D expenditure and economic growth was examined and it was identifed that this relationship was not a strong one. Although the relationship is not strong, it has been emphasized that it has an effect and can be utilized in a valid endogenous growth model that can be used for the USA.

In the study carried out by Wakelin (1998), it was tried to determine the function of innovation on the possibility of exporting and export tendency behavior of enterprises. According to the findings obtained because of the research, businesses that carry out and do not carry out innovation activities in England differ in terms of export behavior. Large-scale enterprises tend to export more, and they are more likely to enroll in export markets.

In the study carried out by Crosby (2000), the place and importance of savings, invesment, human capital and innovation in the economic growth of nations were stated and the findings of the study supported the new growth theories. According to the study, in line with the new growth theory, it is emphasized by considering the companies operating in Australia that innovation has a very important function in economic growth. It is also stated in the study that the increase in the number of patents obtained as an outcome of innovation is extremely important not only in terms of economic growth but also productivity of labor.

Wakelin (2001) investigated whether there is any relationship between the R&D expenditures of the companies and the efficiency they provide in production. In this direction, in the aforementioned study, 170 companies operating in the UK were examined and the intensity of R&D activities and efforts associated to these enterprises were evaluated. As findings of this study shows, it's been found that there is a positive

and also significant relationship between the R&D expenditures and companies' production growth, and the success of innovative enterprises in R&D has been determined as more remarkable.

In another study, Ülkü (2004) investigated the relationship between GDP per capita, R&D expenditure and innovation within the scope of two groups of countries, both OECD members and non-OECD members, in the period between 1981-1997. According to the findings obtained as a result of the said study, it was found out that there is a strong positive relationship between GDP and innovation for both country groups; emphasized that R&D investments have a positive and supportive effect on innovations.

Vogiatzoglou (2009) examined 28 different countries within the scope of the study, and as a result of the regression analysis he conducted, he revealed that R&D and human capital are statistically extremely important for national economies, especially regarding information and communication technologies.

Bogliacino and Pianta (2013), who consider R&D efforts as the most fundamental component of innovative activities, did not limit technology indicators only to R&D and patents in their studies, but also tried to measure innovation in all its dimensions by making use of pioneering researches (Archibugi and Pianta, 1996; Smith, 2005) in the field in a comprehensive and detailed way.

Gökçe et al. (2012) conducted a panel causality analysis by collecting data from 27 different countries between 1997 and 2007. As a result of the research conducted, the existence of the existing relationship between high-tech exports and R&D has been proven. It was also stated that there is a correlation between high R&D expenditures and large exports of highly technological products.

In another research, Akcali and Sismanoğlu (2015) tried to reveal the relationship of innovation with growth of national economies in terms of developing countries and developed countries. According to the results of this study, in which Swamy's random cooficient model was used, it was determined that there is a positive relationship between R&D investments and economic growth.

Rodil et al. (2016) explored the relationship between innovation and export behavior at the micro (company) level and as a result, they concluded that there is a positive relationship between innovation and export.

In another study examining the relationship between R&D expenditures and economic growth in the literature, E28 countries were chosen as a sample and the effect of R&D expenditures in these countries on real GDP was monitored between 2002 and 2012. According to the results of this study, in which the multiple regression model was used, 1 unit surplus in R&D expenditures creates a more than 2 times increase in real GDP (Sokolov-Mladenović et al., 2016).

Muñoz-Bullón et al. (2020), in their study, examined the R&D loci regarding the innovation performance of family firms (FF) and other non-family firms (NFF) operating in Spain between 1990 and 2016. In line with the findings obtained by means of this study, it has been concluded that FF have more effort and success in turning their combined R&D activities into innovation performance compared to companies that are not FF. In this direction, in the conclusion part of the study, the success and innovation performance of family businesses in this regard has been evaluated.

In another study, it was investigated whether the effect of R&D expenditures and the government had an effect on the growth of states. In the study, to measure innovation, R&D expenses were considered as a measurement factor. In the same way, GDP was determined as the basic (fundamental) indicator in order to measure growth. In this study, which tries to determine whether innovation has an effect in the development of African countries, a linear regression model was applied to the data obtained from 4 African countries determined between the years 2000-2016. The findings got from the research show that R&D has a critical importance for the realization of economic growth in Africa (Olaoye et al., 2021).

According to the study conducted by Benetyte et al. (2021), innovation is the basis of a "sustainable economy" approach. Within the framework of this understanding, it has been emphasized that innovation is one of the most basic and critical resources that companies can benefit from in order to contribute to their national economies. For this reason, the contribution of R&D to the sustainable economy approach has been evaluated within the scope of the study. In line with this view, it is extremely important for the company and the country's economy to adopt and manage the risks related to R&D in a healthy way by companies (Benetyte et al., 2021).

In both studies by Adıyaman and Hayaloğlu (2020) and Eygü and Coşkun (2020), the relationship between innovation and economic development was evaluated between 1995 and 2018 and it was shown that R&D expenditures and innovation had a positive effect on economic development both. While Adıyaman and Hayaloğlu (2020) used panel data analysis while examining 30 developing countries within the scope of their study, Eygü and Coşkun (2020) benefited from time series analysis in their study conducted in Türkiye. Reaching the same conclusion, Elverdi and Atik (2021), on the other hand, analyzed the data of 127

countries within the scope of the 2017 GII report, using the structural equation model, and again concluded that there is a positive and strong relationship between development and innovation economically.

Hammar and Belarbi (2021) analyzed the impact of R&D expenditures on innovation at 36 countries covering the period 2002–2014. Secondly, the impact of innovation on productivity, and thirdly the impact of innovation on medium-high technology exports are investigated.

Pelikánová (2019) analyzed the relationship between R&D expenditure and innovation in the EU countries with an emphasis on sustainable development. Dritsaki and Dritsaki (2023) examined the relationship between R&D expenditures and the GII in the scope of EU countries. The findings indicate the higher investment on R&d results with higher innovative performance.

Chen et al. (2022) investigated the output by examining patents of listed companies with and without R&D expenditure disclosures by using Chinese listed firms. The study emphasizes the impact of voluntary R&D disclosure on innovation performance prediction.

Kučera, J. and Fiľa (2022) quantified the possible impact of R&D expenditure on innovation performance and possible impact of the innovation performance on economic development of the EU countries.

When the existing literature is examined in detail, it is seen that there are studies that evaluate the development levels of countries and innovation performance together. However, on the other hand, no study has been found that aims to mutually evaluate the innovation performance between G7 countries, which represent developed countries, and E7 countries, which define developing countries. Therefore, in this study, these countries with different development levels were compared in order to fill this existing gap in the literature. This study thst is conducted, contributes to the literature as there is no other study in the literature that deals with per capita income, Global Innovation Index ranking and R&D expenditures comparatively between the G7 and E7.

5. IMPLICATION

In this section, the G7 group of developed countries (USA, Germany, UK, Japan, Canada, France, Italy) and the group of developing E7 countries (Brazil, China, India, Indonesia, Mexico, Russia, and Türkiye) have carried out R&D activities between 2013-2022. These country groups are chosen because the factors that affect the high innovation performance of G7 is emphasised. With an emphasis on G7, E7 can focus on factors that trigger being a developed country. GII is calculated since 2013, for this reason the mentioned time interval is used for the empirical analysis.

The possible effects of expenditures and their ranking in the global innovation index on economic growth have been analyzed. A comparative analysis was carried out between the G7 and E7 countries. As independent variables, the ratio of countries' R&D expenditures to their GDP and their GII rankings were determined.

As seen in the literature, there is a close relationship between the innovation status of countries and their economic development (Wang, 2013; Inekwe, 2015; Sohn et al., 2016; Franco and Oliveira, 2017 etc.). Among the most concrete determinants of innovation efforts is human capital and research. In other words, the budget allocated by countries for R&D investment directly affects their innovation efforts. A concrete output of the innovation efforts of countries is their ranking in the global innovation index. Therefore, in this research, the effect of R&D expenditure and innovation ranking on the economic situation of the countries was tried to be determined. For this purpose, firstly, data on R&D expenditures of both E7 and G7 countries were collected.

Table 1. GDP per capita for E7 and G7 countries

Countries	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Brazil	12358	12175	8846	8857	9978	9194	8914	6970	7754	8995
China	7039	7645	8034	8063	8760	9848	10170	10525	12572	12813
India	1438	1559	1590	1714	1957	1974	2050	1913	2234	2379
Indonesia	3684	3533	3367	3605	3885	3947	4194	3932	4362	4798
Mexico	10578	10967	9857	8788	9342	9753	10025	8533	9869	10867
Russian Federation	15928	14007	9257	8723	10723	11261	11555	10180	12617	15444
Türkiye	12488	12079	10973	10891	10628	9507	9132	8612	9654	10618
Germany	46299	48035	41107	42124	44636	47961	46798	46735	51237	48636
US	53245	55083	56729	57839	59878	62787	65077	63577	70159	76348
UK	43492	47476	45085	41275	40666	43377	42797	40347	46421	45294
France	44144	44616	37937	38348	40134	43060	41924	40385	45185	42409
Italy	35534	35836	30463	31190	32648	34917	33628	31784	35842	34113
Japan	40934	38522	35005	39411	38903	39850	40547	40117	39882	33821
Canada	52708	51020	43626	42382	45191	46625	46449	43383	52387	55085

Source: Created by the author using data from www.worldbank.org

According to Table 1, as of 2013, the US has the highest income level with a GDP per capita of $53245. Among the G7 countries, the USA was followed by Canada ($52708) and France ($44144). In 2013, Italy ($35534), Japan ($40934) and UK ($43492) had the lowest GDP per capita level among the G7 countries, respectively. When E7 countries are evaluated in 2013, the countries with the topmost GDP per capita levels in this group were determined as Russian Federation ($15928), Türkiye ($12488), and Brazil ($12358). Among the E7 countries, the countries with the lowest GDP per capita levels as of 2013 are India ($1438), Indonesia ($368), and China ($7039) respectively. By 2022, Germany took the place of France in the ranking. Italy, Japan and France were the G7 countries with the lowest GDP per capita levels as of 2022. Speaking in terms of E7 countries, while Brazil's GDP per capita value decreased, China made a big attack and became one of the three largest E7 countries. In Table 2, where the ratio of countries' R&D expenditures to GDP per capita is shown, the R&D expenditures of E7 and G7 countries between 2013 and 2022 are indicated as a percentage, both on the basis of scores and ranking.

Table 2. R&D expenditures % of GDP

		2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Brazil	Score	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.2	1.2
	Ranking	31	31	30	29	32	27	28	30	34	34
China	Score	1.8	2.1	2	2	2.1	2.1	2.1	2.1	2.2	2.4
	Ranking	21	19	17	15	17	14	15	13	13	13
India	Score	0.8	0.8	0.8	0.8	0.8	0.6	0.6	0.6	0.7	0.7
	Ranking	43	41	42	40	43	52	50	57	52	53
Indonesia	Score	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.3
	Ranking	98	105	109	105	105	107	109	85	89	80
Mexico	Score	0.4	0.4	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3
	Ranking	21	66	62	59	59	61	65	79	81	78
Russian	Score	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1	1	1.1
Federation	Ranking	33	32	33	31	34	33	33	37	38	38
Türkiye	Score	0.8	0.9	0.9	1	1	0.9	1	1	1.1	1.1
	Ranking	38	38	37	35	37	38	37	39	36	39
Germany	Score	2.8	2.9	3	2.8	2.9	2.9	3	3.1	3.2	3.1
	Ranking	8	7	8	9	9	7	8	7	6	9
US	Score	2.8	2.8	2.8	2.7	2.8	2.7	2.8	2.8	3.1	3.5
	Ranking	10	11	10	10	10	10	9	9	8	5
UK	Score	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.7
	Ranking	20	21	21	21	21	20	22	21	21	22
France	Score	2.2	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.3
	Ranking	15	14	14	13	12	12	12	12	14	14
Italy	Score	1.3	1.3	1.3	1.3	1.3	1.4	1.4	14	1.4	1.5
	Ranking	29	30	27	26	26	24	24	26	25	26
Japan	Score	3.3	3.3	3.5	3.6	3.5	3.1	3.2	3.3	3.2	3.3
	Ranking	5	5	3	3	3	5	5	5	4	6
Canada	Score	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.5	1.5	1.7
	Ranking	23	23	24	22	22	22	21	23	23	23

Source: Created by the author using data from www.worldbank.org

Table 3. GII Ranking for E7 and G7 countries

Year	*Factor*	*Brazil*	*China*	*India*	*Indonesia*	*Mexico*	*Russian Federation*	*Türkiye*	*Germany*	*US*	*UK*	*France*	*Italy*	*Japan*	*Canada*
2013	Global Innovation Index	64	35	66	85	63	62	68	15	5	3	20	29	22	11
	Innovation Input	67	46	87	115	68	52	81	20	3	4	23	28	14	9
	Innovation Output	68	25	42	62	60	73	53	10	12	4	17	29	33	13
2014	Global Innovation Index	61	29	76	87	66	49	54	13	6	2	22	31	21	12
	Innovation Input Sub-Index	63	45	93	117	62	56	78	19	4	3	20	32	15	8
	Innovation Output Sub-Index	64	16	65	60	70	45	39	8	7	4	26	33	27	20
2015	Global Innovation Index	70	29	81	97	57	48	58	12	5	2	21	31	19	16
	Innovation Input Sub-Index	65	41	100	114	58	52	71	18	5	6	17	29	12	9
	Innovation Output Sub-Index	74	21	69	54	49	49	46	8	9	5	23	32	26	22
2016	Global Innovation Index	69	25	66	88	61	43	42	10	4	3	18	29	16	15
	Innovation Input Sub-index	58	29	72	99	60	44	59	18	3	7	15	28	9	10
	Innovation Output Sub-index	79	15	59	76	62	47	37	8	7	4	19	31	24	23
2017	Global Innovation Index	69	22	60	87	58	45	43	9	4	5	15	29	14	18
	Innovation Input Sub-index	60	31	66	99	54	43	68	17	5	7	15	29	11	10
	Innovation Output Sub-index	80	11	58	73	60	51	36	7	5	6	18	29	20	23
2018	Global Innovation Index	64	17	57	85	56	46	50	9	6	4	16	31	13	18
	Innovation Input Sub-index	58	27	63	90	54	43	62	17	6	4	16	29	12	10
	Innovation Output Sub-index	70	10	57	73	61	56	43	5	7	6	16	32	18	26
2019	Global Innovation Index	66	14	52	85	56	46	49	9	3	5	16	30	15	17
	Innovation Input Sub-index	60	26	61	87	59	41	56	12	3	6	16	30	14	9
	Innovation Output Sub-index	67	5	51	78	55	59	49	9	6	4	14	29	17	22
2020	Global Innovation Index	62	14	48	85	55	47	51	9	3	4	12	18	16	17
	Innovation Input Sub-index	59	26	57	91	61	42	52	14	4	6	16	33	12	9
	Innovation Output Sub-index	64	6	45	76	57	58	53	7	5	3	12	24	18	22
2021	Global Innovation Index	57	12	46	87	55	45	41	10	3	4	11	29	13	16
	Innovation Input Sub-index	56	25	57	87	62	43	45	14	3	7	17	33	11	8
	Innovation Output Sub-index	59	7	45	84	51	52	41	8	4	6	10	25	14	23
2022	Global Innovation Index	54	11	40	75	58	47	37	8	2	4	12	28	13	15
	Innovation Input Sub-index	58	21	42	72	70	46	49	12	2	7	13	31	11	9
	Innovation Output Sub-index	53	8	39	74	55	50	33	7	5	3	11	15	12	23

Table 3 shows the innovation index ranking of G7 and E7 countries. As reported by the table, the general GII performances of the countries are seen, as well as the country ranking based on innovation input and innovation output sub-indicies, which are GII sub-pillars.

5.1. Dataset and Methodology

Stata 18 analysis program was implied to examine the data within the scope of the study. With the help of Stata 18 Data Analysis and Statistical Software Program, regression analysis was employed to estimate the possible and unknown effects of independent variables on the dependent variable. During the collection of the data used in the study, the archive scanning method, one of the qualitative research methods, was used. Archival reports and official records were used in the study. To find out how much Y changes when X changes one unit the linear regression model was used to when conducting the research process. Data on innovation, R&D expenditure and GDP of countries were collected for the period between 2013-2022. Since the main objective of this study is to reveal whether there is any effect on the innovation ranking based on the innovation sub-pillar R&D expenditure and the global innovation index, GDP per capita is considered as the dependent variable in the study. The innovation factors of G7 and E7 countries constitute the independent variables in the study. The dependent and independent variables used in the study can be expressed as in the table below.

Table 4. Dependent and Independent Variables Used in the Study

Variable Labels	*Definition of the Variable*
Dependent Variable	
GDPpc	GDP per capita
Independent Variables	
GIIranking	Global Innovation Index (GII) ranking
RD	R&D Expenditure % of GDP
G7	E7=0; G7=1

It is observed whether the variables have any effect on GDP per capita represented by the dependent variable (GDP) in the study, if there is an effect, to what extent and in which direction, whether there is a significant relationship between the listed independent variables and GDP. The regression model established for this purpose is expressed in Equation 1.

$$GDP_{it} = \beta_{oi} + \beta_{1i} RD_{it} + \beta_{2i} GIIranking_{it} + \beta_{3i}\, G7 + e_{it} \quad (1)$$

The hypotheses created within the scope of the model can be expressed as follows:

H_1: There is a statistically significant relationship between R&D and innovation.

H_2: There is a statistically significant relationship between the rankings of countries in the global innovation index (GII) and economic growth.

6. FINDINGS

Before performing the logistic regression analysis, it is very important to determine the variables or factors that will be included in the established regression model. For this reason, before moving on to the findings obtained as a result of the regression analysis, the descriptive statistics regarding the variables used in the model are given below.

Table 5. Descriptive statistics

Variable	*Mean*	*Standard Deviation*
RD	1.63	0.95
lnRD	0.23	0.85
GDP	26506.42	19694.84
lnGDP	9.76	1.05
GIIranking	34.28	25.78
G7	0.5	0.50

The regression coefficients obtained in the logistic regression analysis explain the size and direction of the relationship between the predictive variables and the response variable. The coefficients are the numbers in which the values of the terms in the regression model are multiplied. Regression coefficients are used to determine whether a change in a prediction variable (independent variable) makes the observed event more likely or less likely. The estimated regression coefficient for an independent variable shows the

change in the link function as a result of each unit change that will occur in this independent variable, while all other independent variables are constant.

The relationship between coefficient and probability is determined by many dimensions of the analysis, such as reference values for categorical variables and reference event. Mostly positive coefficients make the predicted event more probable; on the contrary, negative coefficients make the event less likely. As the estimated regression coefficient approaches 0, it shows that the predictive power of the independent variable is small (Minitab, 2019).

In this part of the study, it is determined whether the independent variables in the research model have an effect on the dependent variable of GDP per capita. The expected values of the dependent variable are expressed as probabilities.

Table 6. Regression analysis results

lnGDP	*Coefficient*	*Std.Error*	*T*	*P*	*t*	*95% Confidence Interval*
lnRD	0.12	0.82	1.51	0.13	-0.38	0.29
GIIranking	-0.01	0.00	-3.00	0.00	-0.18	-0.00
G7	1.28	0.12	10.28	0.00	1.03	1.52
_cons	9.46	0.18	51.80	0.00	9.10	9.82

In this part, the findings obtained as a result of logistic regression analysis are reported and interpreted. Parameter estimates, standard deviations, z-score, p-value, odds ratio, and odds ratio (confidence interval) lower and upper limits for the regression model selection methods information is shown in Table 6. The equation of the model can be restated as in Equation 2.

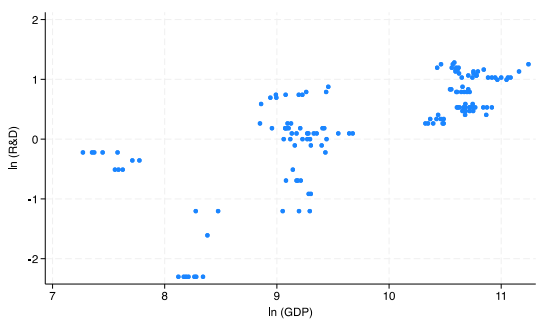
$$GDP_{it} = 9.461971 + .1241591\, RD_{it} - .0105565\, GIIranking_{it} + 1.276084\, G7 + e_{it} \quad (2)$$

The F statistic, which was used to evaluate whether the model was significant as a whole, was F (3, 136) = 230.43, and the F table value was F0.05(3, 136) = 2.60. Since F (3, 136) = 230.43 > F0.05(3, 136) = 2.60, the H0 hypothesis is rejected. In other words, all explanatory variables in the model can explain the dependent variable with a margin of error of 0.05.

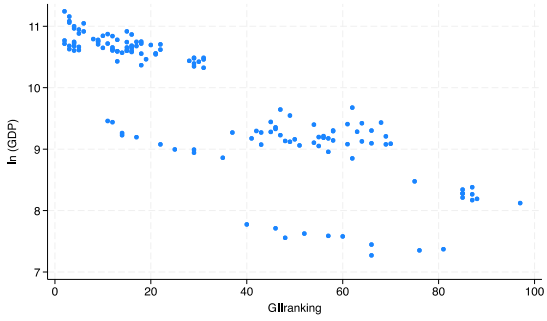
The probability value for the F statistic was found to be p = 0.0000. If this probability value is less than 0.05, the H_0 hypothesis that all coefficients in the model is equal to zero is rejected. Since 0.05 > p = 0.0000, the H_0 hypothesis is rejected. Again, we can say that all of the explanatory variables in the model can explain the dependent variable. It can be seen that R^2 is equal to 0.8356. This means that 83.56% of the model is explained by explanatory variables.

The constant term of the model is 9.461971. GDP per capita takes the value 9.461971 while all other explanatory variables are equal to zero. The coefficient of the lnrRD variable, which is one of the slope coefficients, was found to be 0.1241591. With all other explanatory variables constant, a 1% increase in R&D expenditure will result in an increase of 0.5243% on GDP per capita. At the same time, this coefficient gives the flexibility of GDP per capita relative to R&D expenditure (%GDP). The other slope coefficient, GIIranking, is -0.0105565. All other explanatory variables held constant, a 1% increase in the GII ranking will result in a 0.0105565% decrease in GDP per capita. This coefficient gives the elasticity of GDP per capita according to the global innovation index ranking.

The positive relationship between GDP per capita and R&D expenditure and the negative relationship between gdp per capita-GII ranking can be seen with the help of the graphs below.



GDP per capita – R&D Expenditure (%GDP)



GDP per capita – GII Ranking

Figure 1. GDP per capita- R&D expenditure (%GDP) & GII ranking correlation

7. CONCLUSION

Today, intense competition wars between companies and countries reveal that increasing productivity in production is a very important factor in gaining competitive advantage. Responsible, conscious, and innovative production methods have been preferred at every stage, especially after the rational and optimal use of limited natural resources in production was placed first on the agenda of countries. The possibility of using natural resources, which is decreasing gradually, directs the enterprises to newer and more technological production methods in production. For this reason, it is a common situation for businesses and countries to turn to innovation today. Innovation has become evident in every field with the existence of the understanding of sustainable development, which has become increasingly important in recent years.

Innovation covers the process rather than a result, and it can serve the purpose of creating a solution to a need that has not yet been resolved or to an unsolved problem. In addition, as a result of innovation's R&D efforts, a brand-new raw material, material, product, technology, or idea is at the stage of finding a solution to existing problems. It can also be revealed in the form of more effective use.

At this stage, the importance of R&D in terms of innovation is undoubtedly very great. R&D is an integral part of innovation and it is clear that the more importance is given to R&D, the more successful companies and countries will be in innovation. In this study, findings parallel to the opinions in the literature were obtained. Both innovation and R&D are of great importance in terms of ensuring the growth and sustainability of the national economies of the countries. R&D activities and efforts were measured by the ratio of R&D expenditures to GDP in the study, and it was ensured that each country's R&D expenditures could be expressed proportionally. According to this, while countries' R&D expenditures are transformed into economy as growth, it is seen that countries with higher GDP per capita allocate larger budgets to R&D expenditures and spend more R&D. On the other hand, in the GII, which provides the measurement of the innovation performance of the companies, it has been determined that the enterprises that make R&D expenditures are in higher ranks and close to the peak, and their GDP per capita is higher. In this study, which deals with the innovation performance of the G7 countries representing the developed countries and the E7 countries representing the developing countries, and the effect of this performance on the GDP per capita, it is seen that the G7 countries spend more on innovation. For this reason, E7 countries should increase the part they allocate from the national budget to innovation, especially R&D, like the G7 countries, in order to rise to the top in the innovation ranking. The findings of the study are in line with one of the most recent studies conducted by Dritsaki and Dritsaki (2023). Findings of the paper reveal that highly developed and innovative European countries are those with high rate of investment in R&D.

A number of limitations were encountered during the conduct of the study. First of all, the last 10 years were chosen as the time window, and this may cause different results in the innovation evaluations of countries over a longer period of time. In addition, there are many factors affecting the GDP volume, and the complex and comprehensive structure of GDP, consisting of many components, was not evaluated within the study. Ignoring some other factors that have the power to affect the economic growth of countries constitutes another limitation of the study. Within the scope of this study, a comparison was made between the current situations of 7 developing countries (E7) and 7 developed countries (G7) for the last 10 years. Although it is possible to reach a conclusion based on the findings obtained within the scope of the study, further research should be carried out to talk about an absolute result. This study, which was conducted in terms of studies with different scopes and covering different time periods, can be considered as a guiding pioneer study. Despite the fact that the paper focuses only on the GII rankings, which can be referred as a limitation of the study, our study contributes to the literature in terms of guiding other studies to be conducted in the literature. This study can be seen as an exemplary study specifically for G7 and E7 countries, and a more comprehensive research can be conducted in future studies by including more developed and developing countries within the study and extend the scope of the research. If the study is replicated over a longer period of time, it will be possible to obtain results that can be interpreted more broadly. Finally, it is recommended that different innovation rankings be used for further studies or country comparisons can be made on a sub-pillar basis. So, as to make a more general evaluation, the study needs to consider countries in a broader context.

Author Contributions
Gökçe Sinem Erbuğa: Literature Review, Conceptualization, Methodology, Data Curation, Analysis, Writing-original draft *Ayşegül Gürsoy*: Modelling, Writing-review and editing

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Compliance with Ethical Standards
It was declared by the authors that the tools and methods used in the study do not require the permission of the Ethics Committee.

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It was declared by the authors that scientific and ethical principles have been followed in this study and all the sources used have been properly cited.

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