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The Relationship of Economic Growth and Implied Tax Subsidy Rates on R&D Expenditures: A Dynamic Panel Data Analysis for OECD Countries

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Abstract

The current study examines the effect of implied tax subsidy rates on research and development (R&D) expenditures for large-scale firms on economic growth within the scope of 26 OECD countries. A panel data analysis is employed by using annual data for the period 2004-2020. Difference GMM, one of the dynamic panel data analysis methods, is used in the analysis. Annual growth rate is used as explained variable. Implied tax subsidy rates on R&D, gross fixed capital formation as a share of GDP, secondary school enrollment rate, and the ratio of labor force participation rate are also used as explanatory variables in the estimated model. Results show that there is a statistically significant effect of the implied tax subsidy rates on R&D on economic growth. The tax subsidy rate on R&D expenditures has a positive impact on economic growth. This study underscores the importance of the tax subsidies on R&D expenditures for economic growth.

Keywords:

Economic Growth, OECD Countries, Panel Data Analysis, Tax Subsidies on R&D Expenditures

JEL CODES: C23, H25, O38, O57

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Ar-ge Harcamalarındaki Vergi Teşvik Oranları ile Ekonomik Büyüme İlişkisi: OECD Ülkeleri İçin Panel Veri Analizi

Öz

Bu çalışma, 26 OECD ülkesi kapsamında büyük ölçekli firmaların araştırma ve geliştirme (Ar-Ge) harcamaları üzerindeki vergi teşvik oranlarının ekonomik büyüme üzerindeki etkisini incelemektedir. Çalışmada 2004-2020 dönemi için yıllık veriler kullanılarak panel veri analizi yapılmıştır. Analizde dinamik panel veri analiz yöntemlerinden biri olan fark GMM kullanılmıştır. Yıllık büyüme oranı açıklanan değişken olarak kullanılmıştır. Tahmin edilen modelde açıklayıcı değişkenler olarak Ar-Ge'ye uygulanan vergi teşvik oranları, gayrisafi sabit sermaye oluşumu oranı, ortaokul okullaşma oranı ve işgücüne katılım oranı da kullanılmıştır. Sonuçlar, Ar-Ge üzerindeki vergi teşvik oranlarının ekonomik büyüme üzerinde istatistiksel olarak anlamlı bir etkisi olduğunu göstermektedir. Ar-Ge harcamaları üzerindeki vergi teşvik oranı ekonomik büyüme üzerinde pozitif bir etkiye sahiptir. Bu çalışma, Ar-Ge harcamaları üzerindeki vergi teşviklerinin ekonomik büyüme için önemini vurgulamaktadır.

Anahtar Kelimeler:

İktisadi Büyüme, OECD Contries, Panel Veri Analizi, Ar-ge Vergi Teşvik Oranları

Jel Kodu: C23, H25, O38, O57

Introduction

One of the basic conditions for countries to advance in international competitiveness is to develop technological innovations and increase the number of patents. The importance of many fields involving sophisticated algorithms and knowledge-intensive technologies such as artificial intelligence and digital transformation is increasing day by day. Developments in knowledge-intensive technologies such as biotechnology, pharmaceuticals and nanotechnology, which have become important sectors for competitiveness, are also linked to technological diversification. Therefore, adequate financing of technological progress strategies and subsidies ensure countries' competitiveness at the international level.

The discourse of *"knowledge itself is power"* in Sir Francais Bacon's work, Meditationes Sacrae (1597), has increased its importance from the past to the present. For this reason, knowledge-intensive technologies have become the cornerstone of effective innovation dynamics. The development of high-tech inventions depends on the efficiency of knowledge-oriented investments. The fact that transnational information waves have gained a new dimension with the development of technologies has privileged countries with technology transfer power. This situation also enables the social interactions and development of underdeveloped countries through scientific and technical knowledge. Furthermore, companies with leading technologies have easier access to raw materials, enter new markets, make better labor resources, and benefit from tax breaks in export-oriented production. Thus, they carry out effective policies in creating their national technological infrastructure (Perrin, 1992:10-82). R&D expenditures play a crucial role in this context.

Recent years have witnessed an increased academic interest in the relationship between economic growth and R&D expenditure. A large number of studies, such as Lichtenberg (1993), Goel ve Ram (1994), Ceo & Helpman (1995), Luh & Chang (1997), Gullec & Van Potteire (2004), Falk (2007), Goel & Payne & Ram (2008), Sadraoui & Zina (2009), Eid (2012), Taş & Taşar & Açcı (2017), Güneş (2019), Cinel & Yamak (2021), Çınar & Has (2022a) and Çınar & Has(2022b) have examined the relationship between economic growth and R&D expenditures. However, surprisingly, one factor that has drawn little attention is the effect of tax subsidies on R&D expenditures on economic growth. In contrast, tax subsidies for R&D are critical in encouraging these expenditures. In addition to this, R&D subsidies include human capital

investments, new R&D facilities, protection of intellectual property rights, and tax subsidies. Tax subsidies for R&D expenditures, on the one hand, optimize social returns; on the other hand, enable productivity growth and stimulate competitiveness through fiscal policy. There have been few quantitative studies linking tax subsidies on R&D expenditures with economic growth. This issue causes deficiencies in emphasizing the importance of tax subsidies on R&D expenditure on economic growth. Therefore, the current study aims to address the issue through the estimated model, results, and suggestions. In this context, the study addresses the effect of implied tax subsidy rates on R&D expenditures for large-scale firms on economic growth within the scope of 26 OECD countries. Economic tools such as tax policies are often used to encourage R&D spending in OECD countries. Encouraging R&D spending can increase economic growth by supporting innovation and technological progress. Therefore, the effectiveness of tax incentives applied to support R&D expenditures and the impact of these incentives on economic growth are vital issues for OECD countries. Tax subsidies can be an important catalyst for increasing R&D spending. In addition, these subsidies can encourage companies to invest in R&D activities, which can increase innovation and increase competitiveness and productivity. Therefore, analysis of the effects of tax incentives on R&D expenditure can help determine effective policies to support economic growth and increase competitiveness. On the other hand, examining the relationship between tax incentive rates and R&D expenditure can help determine the right policies to stimulate economic growth and support innovation. In addition, creating an effective tax incentive system to support R&D expenditures can be an important step to ensure long-term economic growth and increase welfare. Tax policies and incentives are very important to encourage R&D expenditure, especially for OECD countries. Because innovation and technological progress support economic growth by increasing competitiveness. Therefore, the effectiveness of tax incentives in this area is of great importance. A detailed examination of the relationship between tax incentive rates on R&D expenditures and economic growth is necessary both to evaluate the effectiveness of public policies and to develop better policies. A good understanding of the impact of tax incentives on R&D expenditures can help maximize the benefits of properly designed incentive systems for the economy. Additionally, understanding the impact of tax incentives on R&D expenditures on economic growth can help decision-makers make strategic plans and make economic growth sustainable. Such analyses can contribute to the creation of more effective and efficient policies to encourage R&D expenditure, which can make a positive contribution to economic development in the long term. However, we see that there are mostly studies in literature focusing on the relationship between R&D expenditures and economic growth, and there are very few studies examining the effect of tax incentives on R&D expenditures on economic growth. In this context, we assume that the present study can contribute to this gap in literature.

The present study examines the effect of implied tax subsidy rates on R&D for large firms on economic growth. The second section discusses countries' R&D expenditures, innovation capacities, and economic growth. In the third section, tax subsidies on R&D expenditures are detailed. In the literature, various studies examining the relationship between R&D expenditure, economic growth and tax subsidy rates are presented in the fourth section. The relationship between tax subsidies on R&D expenditures and economic growth is analyzed in the fifth section using the Difference GMM approach. Finally, the current analysis provides some policy recommendations based on OECD countries.

R&D Expenditures and Economic Growth

According to Frascati Guide (2002), research and development are "*creative studies carried out on a systematic basis to increase the knowledge of people, culture, and society and to design new applications of this repertoire.*" Applied research, general research, and experimental development are the three elements of R&D. Each of the three steps is intended to create new products, services, and processes. In these stages, procedures such as SWOT analysis, numerous tests for the target audience, business analysis, product development are used to develop ideas. All these factors influence the international commercialization of products and processes.

Considering technology as an endogenous variable in economic growth models has led to the use of R&D as an explanatory variable in economic growth. In this context, it would be appropriate to examine the historical development of the use of technology in growth models. Based on the 1950s, according to the "Neoclassical Growth Theory", technology is considered as an exogenous variable. In addition, technological development is accepted as the focus of capital stock and productivity. Technological development is considered a residual in the Neoclassical-Solow (1956,1957) model. Considering the 1970s, developments in evolutionary economics made R&D a key element of innovation and there was an increase in studies on this subject. Since the Solow model is not considered sufficient in explaining the source of technological development, developments have made it inevitable to create endogenous growth models. After the 1980s, the literature on endogenous growth models has come to the fore. Technology considered exogenous is included in models as an endogenous variable. Lucas (1988) argues in his study that technology is an endogenous variable and emphasizes that human capital should be considered one of the determinants of economic growth. However, Romer (1990) includes R&D as an endogenous variable in his economic growth model. Romer's model is developed in the study of Grossman and Helpman (1991) and Aghion and Howitt (1992).

With the development of endogenous growth theory, technological advances have been considered one of the determinants of sustainable economic

growth. Technological advances also have a spillover effect on the economy. *"The technological spillovers in endogenous growth models lead to increasing returns to scale at the aggragate level."* (Verspagen, 2005: 503). In this context, the factors that direct technological advances and spillovers can be considered the capitalist's profit motive, the increase in competitiveness, and the globalization of knowledge. Schumpeter assumes the creative destruction that will arise with technological innovations as the trigger for economic growth (Schumpeter, 2012). In this context, it has become inevitable to carry out studies to increase R&D activities. R&D expenditures are also substantial for countries to have a well-organized technological infrastructure. In addition to economic growth, these expenditures provide competitive advantages, encourage foreign capital investments in the relevant country, increase productivity, cost minimization, raise the quality of human capital and direct research ability, and efficient use of information through correct networks.

The original output created due to effective resource transfer in R&D expenditures are an essential factor in reducing the foreign dependency of countries. In addition, reducing foreign dependency in the production of high-tech products and having a voice on the global platform in terms of high value-added products are closely related to increased R&D expenditures. The commercialization of research results and the prominence of countries in the production of technology-intensive products are dependent on the intensity of R&D investments. Increasing the export of high technology products in fields such as biotechnology and nanotechnology positively affects the foreign trade and GDP of the country. This leads to an increase in economic growth.

Country Overview of Tax Subsidies on R&D Expenditures for OECD Countries

Considering the positive relationship between R&D expenditures and economic growth, the importance that countries attach to R&D subsidies in technological innovation and branding is increasing day by day. Direct subsidies include the establishment of new research centers, the protection of intellectual property rights, investments to increase qualified human capital, the financing of R&D, and tax subsidies for R&D expenditures. In addition, practices related to the protection of competition are considered indirect subsidy policies. Tax subsidies for R&D expenditures are implemented through fiscal policy, aiming to achieve the optimum level of social welfare. (Griffith, 2009: 9).

According to the European Commission (2014), R&D tax subsidies are as follows: tax credits, increased allowances, accelerated depreciation, and corporate tax reduction rates. Table 1. includes the tax distribution and functions for revenues related to R&D expenditure and intellectual property rights.

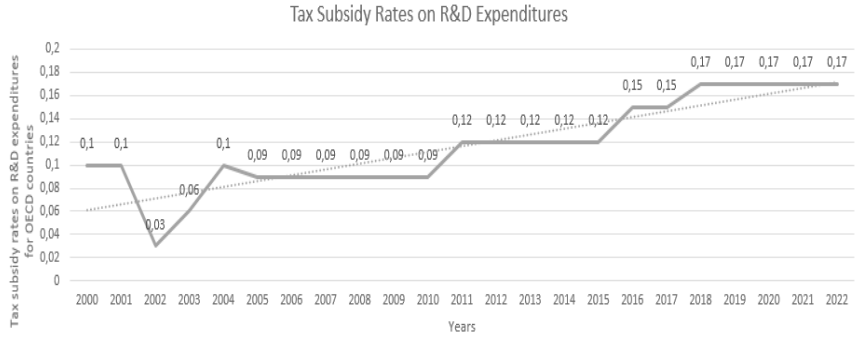
Table 1. R&D Tax Subsidies Distribution

Tax credits (R&D expenses)	The text credit lowers the company's corporate tax rate. The rate can be performed to corporate tax, payroll tax paid to R&D employees or personal income in case of self-employment.
Increased allowances (R&D expenses)	Increased allowances support the increase of R&D expenditure. It also provides a tax base advantage. For instance, If the R&D spending is 100 Euros and the increased allowance rate is 1.5, the R&D spending will increase to 150 Euros. This will positively affect the position in the tax base.
Accelerated depreciation (R&D expenses)	Accelerated depreciation enables the asset purchased to be depreciated at higher rates during the first years of its life. Thus, it is possible to reduce the taxed portion of income in certain periods.
Corporate tax reduction rate (intellectual property income)	The corporate tax reduction rate on intellectual property income ("Patent Box") is an output-related subsidy. It reduces the part of the corporate income devoted to commercialization related to the innovative products of the firms conserved by intellectual property (IP) rights.

Resource: *European Comission, A Study on R&D Tax Incentives Final Report (2014) https://ec.europa.eu/futurium/en/system/files/ged/28-taxud-study_on_rnd_tax_incentives_-_2014.pdf, (10.02.2023).*

Due to the market failure caused by the private sector, the government applies various tax subsidies to R&D expenditures through fiscal policy. Tax subsidies are considered to maximize social benefits, reduce social costs and minimize the negative effects of market failure on welfare (Evci, 2004: 9).

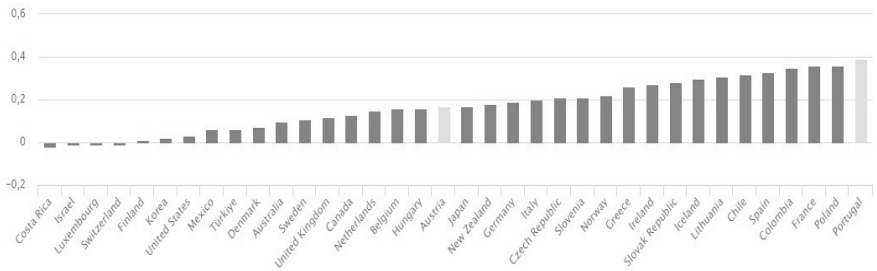
Figure 1. Total Implied Tax Subsidy Rates on R&D Expenditures for Large Firms in OECD Countries, 2022.



Source:*https://stip.oecd.org/Stats/SB-StatTrends.html?i=ITSR_LGEP_I&v=1&t=2022&file=data/SB/SB-RDsub.csv&s=HRV, (20.07.2023).*

According to the data in Figure 1., Axis y represents time period and axis x also represents implied tax subsidies of R&D expenditures for large firms in OECD Countries. There is an increase in the implied tax subsidy rate on R&D expenditures across OECD countries between 2017 and 2018, and a stable trend between 2018 and 2022. On the other hand, the individual representation of OECD countries in this regard is presented in Figure 2.

Figure 2. Implied Tax Subsidy Rates on R&D Expenditures for Large Firms in OECD Countries, 2022.



Source*: https://stip.oecd.org/Stats/SB-StatTrends.html?i=ITSR_LGEP_I&v=1&t=2022&file=data/SB/SB-RDsub.csv&s=HRV, (Date of Access: July 20, 2023)*

Figure 2. shows that Portugal is the country that allocates the most resources for implied tax subsidies on R&D expenditures. Portugal government and various research organizations allocate their R&D expenditures across several sectors. Some of the areas that receive significant R&D expenditures in Portugal are information and communication technologies (ICT), renewable energy, life sciences and biotechnology, aerospace and defense, advanced manufacturing, sustainable agriculture and sustainable agriculture and food technology. Portugal has adopted policies to promote innovation and R&D activities. In order to increase innovation capacity, enhance international cooperation in the field of innovation and stimulate economic growth, Portugal offers tax subsidies and various financial supports to enterprises within the scope of R&D activities. In this context, subsidies related to R&D are kept high in the country.

Literature Review

A review of the literature on R&D expenditures and economic growth reveals that R&D expenditures have a positive impact on economic growth. In a study covering the 1964-1989 years and 74 countries, Lichtenberg (1993) examines the relationship between economic growth and research and development spending, which provides financing by the private and public sectors. In the study, Mankiw-Romer and Weil (MRW) model is used. As a result of the

analysis, expenditures in research and development positively affect both economic growth and productivity. Furthermore, Goel, Payne, and Ram (2008) examine the relationship between R&D spending and economic growth in federal and non-federal countries in the United States from 1953 to 2000. In the study, a model is created using the ARDL method. Results show that there is a strong relationship between research and development expenditure and economic growth in both federal and non-federal countries. In another study, Sadraoui and Zina (2009) examine the relationship between R&D expenditures and economic growth via the Generalized Moments method for 1992-2004 in 23 countries. In the study, there exists a positive and significant relationship between research and development expenditures and economic growth in all countries. Eid (2012) also investigates the relationship between R&D expenditure and growth in 17 OECD countries from 1981 to 2006. The countries included in this research are selected from the high-income group. According to the results obtained using the Dynamic Panel Data method, R&D expenditures cause an increase in productivity. Studies generally show that R&D expenditures are one of the determinants of economic growth, a vital element in explaining economic growth.

There are also those who argue that there is a negative and insignificant relationship between economic growth and R&D expenditures. Samimi and Alerasoul (2009) investigate the relationship between R&D expenditures and economic growth for 2000-2006 within the scope of 30 developing countries. The results of the panel data analysis show that there is a negative and insignificant relationship between economic growth and R&D expenditures. Moreover, the authors emphasize that the main reason for this is the inefficient allocation of resources within the scope of R&D expenditures of developing countries.

The number of patents, firm growth, and R&D investment expenditures are all connected with the effect of tax subsidy rates on R&D expenditures in the literature. Westmore (2013) examines the relationship between research and development tax subsidies and patenting for 19 selected OECD countries. According to the research, there is a positive and significant relationship between tax subsidy rates for R&D and patenting. A decrease of 0.05% in the BIndex increases the number of patents by 2.5%. On the other hand, Soare et al. (2014) analyze the relationship between research and development tax subsidy rates and firm growth for different technology-based and knowledge-intensive industries. In the study, tax policies for R&D increase companies' sales and have a positive effect on growth. Ragusa and Grigolini (2015) conduct an empirical study of the effect of R&D tax subsidies on R&D investments in 9 OECD countries from 1981 to 1996. According to the findings, while research and development tax subsidy rates cause a decrease of 1% in R&D costs, they also cause an increase of 0.30% in R&D investments. Guceri (2016) emphasizes that research and development subsidies have a positive impact on R&D

spending. He states that with the rise of research and development subsidies, the size of the increase in research and development spending in companies varies between 4% and 30%. This varies according to the policies used, the size, and the age of the company.

There is a gap in the literature on the relationship between economic growth and R&D tax subsidy rates. Kutbay and Öz□s Study can be given as an example of very few studies examining related variables. Kutbay and Öz (2017) analyze the relationship between tax subsidies for research and development expenditures and economic growth. In this study, data is used for Türkiye and selected 9 OECD countries for 1999-2016. The results of the panel cointegration analysis show that a 1% increase in tax subsidies for small companies increases R&D investments by 0.15%. A 1% increase in tax subsidies for large companies increases R&D investments by 0.17%. Moreover, a 1% increase in R&D investments causes an increase of 95% in national income. Studies examining the relationship between R&D expenditures and economic growth are pretty abundant in literature. Whereas there have been few quantitative studies focusing on the relationship between economic growth and tax subsidies on R&D. Therefore, the current study aims to gain deeper insight into the effect of tax subsidies on R&D expenditures on economic growth within the scope of endogenous growth theory.

Methodology

Data and Method

The present study aims to examine the effect of implied tax subsidy rates on R&D expenditures for large-scale firms on economic growth for 26 OECD countries during 2004-2020. There is no missing data in the panel data sets. The dependent variable used in the study is annual growth (real gross domestic product), and the independent variables are implied tax subsidy on R&D expenditures for large-scale companies, gross fixed capital formation as a share of GDP, secondary school enrollment and labor force participation. All data are obtained from OECD and World Bank databases. In the study, there are 26 OECD countries and these are Austria, Belgium, Canada, Chile, Czechia, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Israel, Italy, Korea, Latvia, Luxemburg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden. E-Views 12 econometric program is used for econometric analysis.

The use of dynamic models in panel data analysis is quite common, and there are lags in the variables in these models (Tatoğlu, 2013:65). The use of lagged dependent variables in models with fixed and random effects causes some problems. One of them is the correlation between the lagged dependent variable and the error term. In order to eliminate this problem, Anderson and Hsiao (1982) recommend performing a first difference transformation and using an instrumental variable instead of a lagged dependent variable

(Tatoğlu, 2013:75). However, in cases where the first difference error terms are negatively correlated, it is recommended to apply the GMM (Generalized Method of Moments) in the study of Arellano and Bond (1991) (Tatoğlu, 2013:80).

Arellano and Bond (1991) suggest that all lagged variables should be used as instrumental variables. This approach, known as Difference GMM, takes the first differences of variables to eliminate the effect of specific effect components and includes the lagged values of independent variables as instrumental variables in the model. In this context, Difference GMM, one of the methods in dynamic panel data analysis, is used in the econometric analysis in the present study.

Model Estimation and Emprical Results

The functional representation of the model used in the study is as follows:

$y = f(l, c, h, r)$ (1.1)

In the functional representation of the model, independent variables for labor (l), physical capital (c), human capital (h) and R&D (r) are used. Here, the equivalents of the functional representation's elements are as follows:

Table 2. Functional Representation's Elements

Label	Variable	Source
y	annual growth rate (%) (Real GDP)	World Bank
l	ratio of labour force participation rate (%)	OECD
c	gross fixed capital formation as a share of GDP (%)	World Bank
h	secondary school enrollment (% gross)	World Bank
r	implied tax subsidy rate on R&D expenditures for large-scale companies (as a share of GDP %)	OECD

Note: Variables are obtained on August 1, 2023 by researchers.

The mathematical representation of the econometric model is given in the equation (1.2).

$\Delta y_{it} = \alpha \Delta y_{it-1} + L\, \Delta l_{it} + C\, \Delta c_{it} + H\, \Delta h_{it} + R\, \Delta r_{it} + \Delta \varepsilon_{it}$ i=1,...N ve t=1,...T (1.2).

In this model, y_{it} represents the dependent variable while y_{it-1} denotes its first lag, highlighting the dynamic nature of the relationship. The explanatory

variables l_{it} , c_{it} , h_{it}, and r_{it} refer to independent factors that may affect the dependent variable. $\Delta\varepsilon_{it}$ represents the idiosyncratic shocks across time and individuals. α, L, C H, and R reflect the short-run effects of the explanatory variables on the dependent variable. The methodological purpose of the current study is to examine the effect of implied tax subsidy rates on R&D expenditures for large-scale firms on economic growth for 26 OECD countries during 2004-2020.

Baltagi (2005) emphasized that cross-sectional dependence should be taken into account in the time dimension over 20-30 years. Accordingly, since the time dimension of the data set in this study is T=17, no cross-sectional dependence analysis is performed. On the other hand, descriptive statistics are summarised in Table 3.

Table 3. Descriptive Statistics

	y	r	l	c	h
Mean	0.430485	0.125950	0.861913	2.892460	109.5420
Median	0.916530	0.110000	0.754406	2.902469	104.9187
Maximum	16.47167	0.550000	12.54057	100.9380	163.9347
Minimum	-22.49860	-0.030000	-8.925581	-47.45739	88.97956
Std. Dev.	5.528702	0.139497	1.647414	10.53566	15.15894
Skewness	-0.661341	0.662233	1.209677	1.888864	1.767991
Kurtosis	4.859912	2.389262	14.33460	22.52813	6.172677
Jarque-Bera	0.5786	0.1208	0.3765	0.0325	0.0023
Sum	190.2744	55.67000	380.9654	1278.467	48417.56
Sum Sq. Dev.	13479.85	8.581651	1196.862	48951.07	101338.9
Observations	442	442	442	442	442

Descriptive statistics for the variables are included in the Table 3. Accordingly, the number of observations for the period 2004-2020 is determined as 442. When the probability values of the Jarque-Bera statistics are examined, we see that all variables except c and h are normally distributed. When the averages of the variables are examined, we determine that the highest average is in variable h.

The results for Difference GMM technique are shown in Table 4.

Table 4. Difference GMM Results
Dependent Variable: y

Variable	Cefficient	Std. Error	t-Statistic	Prob.
y(-1)	0.8458	0.0096	87.9598	0.0000***
r	4.9412	1.3446	3.6746	0.0003***
l	0.1183	0.0645	1.8337	0.0675*
c	-0.1739	0.0050	-34.5020	0.0000***
h	0.0443	0.0390	1.1334	0.2577

*Note: *** 1%, ** 5% and * 10% indicate significance level.*

Table 4 interprete after evaluating of the Table 5. Before evaluating the results in Table 4, we investigate whether the difference GMM estimators are consistent or not. For this purpose, 3 tests are applied to the estimated model. These are Wald test, Sargan test, and Arellano-Bond test. These test results are presented in Table 5.

Table 5. Consistency Test Results

Test	Prob.
Wald	0.0000***
Sargan	0.2412
AR(1)	0.0063***
AR(2)	0.6937

*Note: *** 1%, ** 5% and * 10% indicate significance levels.*

The consistency of the independent variables in explaining the dependent variable in the model is investigated using the Wald test.

H_0 = "The independent variables have no significant effect in explaining of the dependent variable."

H_1 ="The independent variables have significant effect in explaining of the dependent variable."

Prob value (0.0000 < 0.05) indicates that we reject the null hypothesis and that the independent variables have significant effect in explaining of the dependent variable. In other words, the estimated model is significant as a whole.

On the other hand, Sargan test investigates whether there is an endogeneity problem in the model.

H_0 = " Instrumental variables are exogenous."

H_1 = "Instrumental variables are endogenous."

Prob value of Sargan test (0.2412 > 0.05) shows that we can not reject the null hypothesis and instrumental variables are exogenous. Accordingly, there is no an endogeneity problem for all instrumental variables used in the model. Moreover, error terms are not correlated with the independent variables.

For a dynamic panel data model to be valid, the AR(1) process must be autocorrelated, while the AR(2) process must be free of autocorrelation. Arellano-Bond test results are given in the Table 5. Accordingly, Arellano-Bond test is employed for investigating of the autocorrelation problem.

H0 = " There is no autocorrelation." H_1 = " There is autocorrelation." For AR(1): Prob value (0.0063 < 0.05) indicates that we reject the null hypothesis and there is autocorrelation in AR(1) process.

For AR(2): Prob value (0.6937 > 0.05) indicates that we cannot reject the null hypothesis and there is no autocorrelation in AR(2) process.

Panel regression results show that the effects of explanatory variables on economic growth are statistically significant except for secondary school enrollment rate. In addition, the coefficient signs of the independent variables are also generally compatible with economic theory. Here, 1% , 5% and 10% significance levels are taken as the basis for examining the statistical significance levels of the variables. The present study reveals a positive and significant effect of the labor force on economic growth. Labor contributes to economic growth by increasing the stock of human capital through education, training and skills development. Across OECD countries, skilled workers engage in more productive and innovative activities. This contributes to technological progress, which is recognized as a key driver of long-term economic growth. In OECD countries, investing in training and upskilling labour leads to the development of new technologies, which in turn leads to higher productivity and economic growth.. On the other hand, gross fixed capital formation, which is accepted as one of the explanatory variables of economic growth, has a negative effect on economic growth in the estimated model. Here, there are diminishing returns to capital. As economies accumulate more capital, each additional unit of capital contributes less to overall economic growth. This reduces the marginal productivity of capital over time and leads to a slowdown in economic growth.

The increase in tax subsidies on R&D expenditure for large-scale companies positively affects economic growth. Knowledge-intensive technologies are usually found in large-scale firms in OECD countries. In this context, R&D tax

subsidies driving these technologies increase innovation and productivity capacities and lead to economic growth by providing high valueadded outputs. Tax subsidies for R&D expenditures play a vital role in obtaining high-tech product patents and reducing external dependence through country-specific technologies. Reducing external dependence through the export of high-tech products is also assumed to positively affect the economic growth of these countries. Here, the strategic position of the government regarding tax subsidies on R&D investments should also be addressed. It can be thought that government has a significant impact on the efficiency of R&D investments and knowledge-intensive output production in OECD countries. In this context, government is at the center of the R&D mechanism to mitigate market failures arising from the private sector in the context of R&D investments and to eliminate the negative effects of uncertainties in the investment process. The government's support for tax subsidies on R&D expenditures in OECD countries has been effective in providing all these advantages. Thus, R&D investments are transformed into high value-added outputs, social benefits are distributed fairly across the whole society with the support of the government and the economic growth increases in OECD countries.

Discussion And Conclusion

Considering the effects of economic crises, entrepreneurs tend to save on R&D expenditures and avoid making high-budget investments in innovation in order not to reduce their profitability ratios. In this context, tax subsidies are one of the most powerful tools to incentivize research and development spending and increase the scope of technological innovation. For this reason, tax subsidies are becoming increasingly popular around the world. The number of beneficiaries is likewise increasing. Moreover, given the cost dimension of breakthrough innovations, tax subsidies significantly reduce the pressure and uncertainty on R&D investments and enable companies to be more efficient in the innovation process. Tax incentives reduce the pressure on capital and pave the way for the production of high valueadded products, processes and services. This is effective in achieving a social optimum and competitive advantage in the relevant countries.

This study examines the relationship between tax subsidy rates on R&D expenditures and economic growth for 26 OECD countries. The results show that tax subsidies on R&D have a positive impact on economic growth. As a result, the tax subsidy rate on R&D expenditures is significant in explaining economic growth. In this context, the application area of tax subsidies in innovation policy should be expanded and support for entrepreneurs should be increased. In the process of producing high value-added goods and services, policymakers' comprehensive road maps on tax subsidies can provide long-term contributions to the national economy. Considering that R&D practices play an important role in improving products and processes and ensuring

sustainable growth and development in the innovation process, it is also essential to ensure cooperation for subsidy policies. Tax subsidies in fields such as digital transformation, artificial intelligence, knowledge intensive technologies, automotive and pharmaceutical sectors can increase productivity and drive economic growth, while at the same time turning countries into knowledge and technology bases. The fact that countries are at the forefront with national technologies increases international recognition and provides sustainable competitive advantage.

When the literature is examined, there have been few quantitative studies examining the relationship between tax subsidies on R&D expenditures and economic growth. There are a few studies that reach the same results with our present study. Such as Lichtenberg (1993), Goel & Payne & Ram (2008), Sadraoui & Zina (2009), Eid (2012), Taş & Taşar & Açcı (2017), Güneş (2019), Cinel & Yamak (2021), Çınar & Has (2022a) and Çınar & Has(2022b). Specifically, our study aims to investigate the impact of tax incentives on R&D expenditures and how this ultimately affects economic growth. By filling this gap in the literature, we hope to provide valuable insights for policymakers looking to promote sustainable economic development through strategic R&D investment. By exploring the impact of tax incentives on R&D expenditures and ultimately economic growth, we aim to provide valuable insights for policymakers and businesses. Understanding how tax incentives influence R&D spending can lead to more targeted and effective policies that support sustainable economic development. By examining the impact of tax incentives on R&D expenditures and economic growth, we can gain a more comprehensive understanding of how policy decisions can drive innovation and productivity. This research can provide valuable insights for policymakers looking to foster sustainable economic development through targeted incentives and investments in research and development. On the other hand, this issue causes to obstacles in examining the relationship between the two variables on a quantitative basis and in building consensus about the subject. The generalisability of the results in the present study is subject to this limitation. A growing number of studies emphasizing the importance of government support in R&D expenditures may increase the validity of the results on the subject and provide helpful insight for designing a competitive and dynamic innovation system. Therefore, researchers should guide policymakers by working on this issue and contribute to implementing policies that can be applied in practice. Thus, the positive effect of tax subsidy rates on R&D expenditures on economic growth may be better understood, and policymakers may design more effective systems in this regard.

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