INDUSTRIAL POLICY
A Scientific Journal Dedicated to Economic Development and Industrial Policy

OPEN ACCESS

Dissertation www.indpol.org

DOI: 10.61192/indpol.1331487 *IndPol, 2023; 3(2): 39-46*

R&D Expenditures and Economic Growth: A Panel Data Analysis for Selected Developing Economies

Furkan Kalın[a]

[a]Istanbul Technical University, Graduate School, Economics Program, ORCID: 0000-0002-4215-3385

Abstract

Growth theory suggests that technological development is the primary determinant of long-term economic growth, and research and development (R&D) activities are considered the driving force of technological development. This study aims to investigate the relationship between economic growth and R&D spending. To this end, we study the relationship between gross domestic product (GDP) per capita and the ratio of R&D expenditures to GDP in a group of developing and newly developed economies (namely, Brazil, Chile, Colombia, Indonesia, India, Peru, Republic of Korea, Russian Federation, Singapore, Thailand, and Türkiye) using annual data from 2000 to 2020. Using the fixed effects model, a panel data analysis is estimated, where gross domestic product (GDP) per capita is used as the dependent variable; R&D expenditures as a ratio of GDP, number of technicians in the R&D sector, and number of researchers in the R&D sector are used as independent variables. We also utilized gross fixed capital formation, labor force, and aggregate government expenditures as a ratio of GDP as control variables. The results indicate a significant and positive relation between economic growth and R&D-related explanatory variables. We also find that the model's control variables have positive and significant effects on economic growth. Given its favorable impact on economic growth, especially developing countries may be advised to allocate more resources to R&D activities.

Article History
Received July 23, 2023
Accepted December 4, 2023

Keywords
Economic Growth, R&D Expenditures, Fixed Effects Model

JEL Codes
014, 030, 032

1. Introduction

Emerging market economies have become more significant to the global economy over the past few decades. About 80% of the output of all emerging markets comes from the seven biggest emerging economies - China, Russia, India, Brazil, Türkiye, Mexico, and Indonesia. Similar to the G7 (the Group of Seven major advanced economies), this group, which is commonly referred to as EM7, has also been the primary driver of growth in emerging markets and their integration into the global economy. Particularly with those in their respective neighborhoods, the EM7 economies have strong trade and financial ties with other emerging markets (EM) and frontier markets (FM). Egypt, Indonesia, Mexico, South Korea, Saudi Arabia, Taiwan, and Türkiye round out the top ten emerging and developing economies by nominal or PPP-adjusted GDP, along with the other four BRICS nations (Brazil, Russia, India, China, and South Africa) growth in the EM7 could have significant global economic spillovers due to their size and integration.

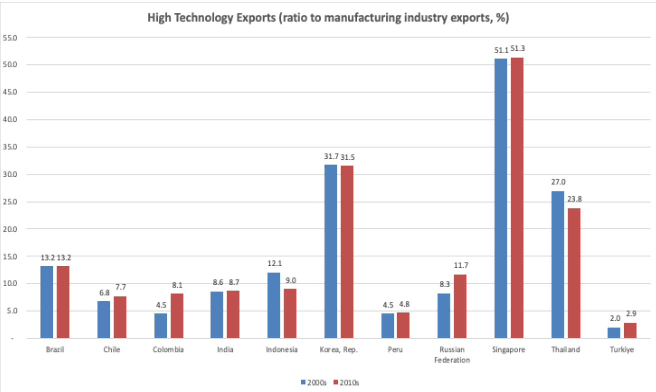
Emerging markets are characterized economically by low-income, high-growth economies that rely heavily on market liberalization. Undoubtedly, emerging economies can progress past this stage and move into the post-emerging stage. Emerging markets become developed economies once they graduate from that economic status. Israel, Poland, South Korea, Taiwan, the Czech Republic, and city-states like Singapore have made the transition from emerging to

CONTACT Furkan Kalın kalin@itu.edu.tr

developed economies. Compared to those classified as emerging markets, these markets tend to have higher incomes and more stable political systems.

A common problem that most EM encounter is high trade and current account deficits and, in return, their dependence on international liquidity and foreign capital inflows. In order to mitigate their macroeconomic vulnerability in this respect, EM may decrease their foreign dependency by means of decreasing their trade deficit. While many EMs are part of the global value chain, some of them largely produce and export low-value-added products. For instance, while Türkiye's ratio of medium and high technology products exports to total industrial exports has been around 30%, its high technology product ratio to total industrial exports is only about 3% (Figure 1).

Figure 1. Exports of high technological products (ratio to manufacturing industry exports, %)



Source: World Bank; World Development Indicators

Among industrial goods, high-value-added products are typically high-technology products. Countries that need to import such high-value-added products or that cannot produce, and export high-value-added products commonly give trade deficits. In order to mitigate their trade deficit, and thereby their reliance on foreign capital, EM should be increasing the share of high-technology productions and exports. The high value-added nature of high-technology products also contributes to the growth of countries. Since economic growth is particularly important for the welfare of households in EM, producing high-technology products is critical for EM. Since an important determinant of producing high-technology products is research and development (R&D) activities, we assert that policymakers should be allocating enough resources for product development and innovation. Against this background, this paper investigates the eleven countries Singapore, Russia, Thailand, South Korea, Peru, Chile, Brazil, Türkiye, Indonesia, and India in terms of their economic infrastructure, economic features, and the impact of R&D expenditures on economic growth via empirical analysis.

2. Literature Review

One of the most fascinating and exciting fields of economics is still economic growth. This interest is undoubtedly related to issues that economic growth addresses. In its simplest form, the idea of economic growth can be defined as the gradual increase in a nation's economic output. Both developed, and developing nations have serious concerns about the phenomenon of economic growth. Nevertheless, while developed countries typically emphasize increases in GDP, developing countries typically attach more importance to economic development, including economic growth, ensuring income equality in the nation, increasing employment, and decreasing inflation.

There are two contemporary growth theories: exogenous and endogenous growth. The Harrod-Domar model and the Neo-Classical Growth model are well-known exogenous growth theories. In exogenous growth models, while production is made with capital and labor by using appropriate technologies, technological development is not explained in these models.

In endogenous growth models, the works of Romer (1986) and Lucas (1988) stand out. In these theories, growth is provided by human capital, technical and technological knowledge, and R&D expenditures. Through its impact on innovation and total factor productivity, R&D spending is likely to promote economic growth. When a company invests in R&D, it is anticipated that new concepts, intermediate products, cost-cutting techniques, and finished consumer goods will be created, enhancing the company's productivity and profitability. R&D has public benefits as well as positive spillovers within and between businesses, industries, and geographical areas. Due to the non-rival nature of knowledge created through R&D, businesses can profit from the R&D expenditure of other businesses, even if they are located in different industries or geographical areas (Arrow, 1962; Aghion and Howitt, 1992).

Using panel data analysis, Lichtenberg (1992) investigated the relationship between R&D expenditures financed by the public and private sectors and economic growth in a study of 74 countries spanning the years 1964–1989. The study's conclusions are as follows: When R&D expenditures are financed by the public sector, there is no effect on economic growth and, in rare circumstances, an adverse effect; when private sector financing is used, it has been observed that there is a positive and significant relationship between growth and productivity.

Park (1995) also examined the relationship between R&D investments and growth in production in 10 OECD countries, for the years 1970–1987. The author finds that local private sector R&D investments were a more significant determinant for the rise in both local and foreign factor productivity than public sector R&D investments. Furthermore, it was discovered in the study that public spending had a secondary impact on productivity growth by encouraging private sector investments in foreign public R&D projects.

Samimi and Alerasoul (2009) examined the impact of R&D expenditures in 30 developing countries for the period 2000-2006. They did not find a significant relationship between R&D spending and economic growth. The authors contend that this is due to low R&D expenditures in the subject countries, and they suggest developing countries increase their R&D expenditures.

Examining the relationship between innovation performance as measured by per capita R&D expenditure and the Global Competitiveness Index in 11 Central and Eastern European nations, Kiselakova et al. (2018) find that raising R&D spending can significantly help countries become more competitive, which will lead to growth. In a similar vein, Simionescu et al. (2017) R&D spending has a positive impact on the competitiveness of Romania, Hungary, and the Czech Republic.

R&D encompasses systematic efforts aimed at utilizing all forms of knowledge to design new applications. In the context of a continuously evolving global process, mankind has transformed into an entity that learns, adapts, adopts innovative approaches, and integrates economic activities into this evolution. Consequently, macroeconomic goals have shifted from labor-intensive production to technology-based R&D and innovation-dependent economic growth and development. This transition represents a shift towards "R&D-based innovative production processes" beyond traditional capital and labor production. Countries that grasp the significance of R&D-based technological advancements that positively impact their economy and industrial structure treat science and technology policies as a system and prioritize R&D significantly. Within the framework of innovation policies, developed countries aim to increase their competitive advantages by gradually enhancing R&D spending and the number of technical personnel and researchers employed in R&D activities. This study delves into R&D data, recognized worldwide as the most critical key to international competitive advantage and development. It examines various indicators such as the ratio of R&D spending to Gross Domestic Product (GDP), the distribution of R&D expenditures across sectors, the distribution of R&D spending by source of finance, the number of personnel engaged in R&D activities, and the sectoral distribution of the labor force employed in R&D activities for the European Union (EU) and Turkey. A comparative analysis of these R&D indicators provides insights into Turkey's position concerning its technological, sectoral, economic structure, and level of development compared to EU countries (Göze Kaya, D, 2019).

The study conducted by Ayyıldız and Demirci (2022) sheds light on the pivotal role of research and development (R&D) spending in Turkey's economic development and growth trajectory. Highlighting the surge in R&D expenditures globally since 1980, the research reflects Turkiye's intensified interest and commitment in this domain. Notably, the allocation of funds to R&D, catapulting from 0.53% of the Gross Domestic Product (GDP) in 2001 to 1.09% in 2020, stands as a testament to this enthusiasm. In this context, public support for R&D activities emerges as a crucial driver, invigorating endeavors in this sphere. Analyzing the socio-economic goals of Turkey, the study explores the correlation between R&D budget allocations and expenditures from the central government budget and economic growth within the 2008–2035 timeframe. Utilizing artificial neural networks for predictive modeling and employing the Autoregressive Distributed Lag Bound Test (ARDL) analysis, the research identifies the energy sector as the category of R&D spending with the most pronounced positive impact on economic growth, while expenditures related to the health sector exert the least influence. These findings underscore the significance of R&D funding allocation and its sectoral distribution in shaping Turkey's economic development and growth landscape.

3. Data and Methodology

This study aims to analyze the relationship between economic growth and R&D spending in a total of 11 countries (Brazil, Chile, Colombia, Indonesia, India, Republic of Korea, Peru, Russian Federation, Singapore, Thailand, and Türkiye). We utilize the real gross domestic product (GDP) per capita as the dependent variable. The precise expression of the level of innovation activities is an important factor in empirical research on the impact of economic growth rate. The most commonly used data on innovative activities are the share of research and development expenditure in GDP. This approach is highly acceptable because it is suitable for quantitative and qualitative analysis. Hence, we also utilize R&D expenditures as a ratio of GDP as a dependent variable. Gross capital formation (representing domestic investments), labor force, number of researchers and technicians working on research, and government spending are used as control variables. We use annual data and the data spans from 2000 to 2020.

We employ a multiple regression model with fixed effect (FE) in our study. This strategy is chosen because we decided to examine the impact of a few variables that change over time. The fixed effect model examines the relationship between a dependent variable and independent and control variables within each individual entity (in our case, the countries that were observed). Each individual determines how independent and control variables will affect the dependent variable (in this case, real gross domestic product (GDP) per capita) based on their unique characteristics.

When using FE, we assume that a factor present in the countries may have an effect on the predictor or outcome variables, and we must take measures to mitigate this. Another crucial premise of the FE model is that the entity's time-invariant characteristics are specific to it and shouldn't be correlated with those of other entities. Since each entity is unique, its error term and constant (which captures its unique characteristics) shouldn't be correlated with those of the other entities (Wooldridge, 2002).

3.1 The model

For 11 countries (i = 1, ..., 11) and multiple time periods (t = 1, …, 21), a multiple regression model was developed

$$y_{it} = \alpha + x_{it}\beta + c_i + u_{it} \qquad (3.1)$$

where c_i is the country-specific effect, y_{it} is the dependent variable, is the intercept, x_{it} is the K-dimensional row vector of explanatory variables, β is the K-dimensional column vector of parameters, and u_{it} it is the error overall term. The matrices below summarize the T (T = 21) observations for each nation: dependent variable y_i is symbolized as follows:

$$y_i = \begin{bmatrix} y_{i1} \\ . \\ . \\ y_{i5} \\ . \\ . \\ y_{i21} \end{bmatrix}, y_i = [21X1]$$

For independent variable X_i, it is represented by:

$$X_i = \begin{bmatrix} X'_{i1} \\ . \\ . \\ X'_{i5} \\ . \\ . \\ X'_{i21} \end{bmatrix}$$

Given that regression involves four independent variables, $X_i = [21 \times 6]$, The general error term matrix is as follows:

$$u_i = \begin{bmatrix} u_{i1} \\ . \\ . \\ u_{i5} \\ . \\ . \\ u_{i21} \end{bmatrix}, u_i = [21X1]$$

Since $E(u_{it})=0$ and $E(c_t)=0$, the data generation process can be described as linear:

$y_{it} = \alpha + x_{it}\beta + c_i + u_{it}$

The model is linear in parameters α and β, individual effect c_i, and overall error u_{it}

Independence: $\{Xi, yi\}_{i=1}^{N}$ (independent and identically distributed).

The observations are independent between people but perhaps not across time. The random selection of nations ensures this.

Strict exogenicity: $E = (u_{it} \mid X_i, c_i)$

The explanatory variables for all past, present, and future time periods of the same person are assumed to be uncorrelated with the overall error term, or u_{it}. This strong premise, for instance, disqualifies lagged dependent variables. Additionally, it is presupposed that the overall error is unrelated to the effect that is unique to each person. We can distinguish between the fixed effects model and the random effects model using additional presumptions (Schmidheiny, 2013).

3.2 Random effects versus fixed effects models

The individual-specific effect in the random effect model is a random variable that is unrelated to the explanatory variables.

Unrelated effect: $E = (c_i \mid Xi_i) = 0$

According to this supposition, the individual-specific effect is a random variable that is not related to the explanatory variables for any of the individual's past, present, or future time periods. Typically, economists do not like such a strong assumption. We can infer from this that the random effect model would not be applied in this study. Later, we used the proper test to demonstrate this.

The individual-specific effect in the fixed effects model is a random variable that is permitted to be correlated with the explanatory variables.

Related effect: $E = (c_i \mid X_i) \neq 0$

Variance effect: $V = (c_i \mid X_i) = \sigma^2 < \infty$; $V = (c_i \mid Xi) = c_{i,t}^2(X_i) < \infty$

This assumes constant variance of the individual-specific effect.

Identifiability rank $(\ddot{X})=K < NT$ and $E(X_i\ddot{X})$ where typical element $x_{it} \doteq x_{it} - \bar{x}$ and $\bar{x} = \frac{1}{T}\sum x_{it}$

This is based on the assumption that all regressors have non-zero within-variance and that the explanatory variables are not perfectly collinear. As a result, neither a constant nor any other time-invariant variables can be included in X_{it} (Schmidheiny, 2013).

4. Empirical Results

4.1 Serial correlation and heteroskedasticity

We must address the possibility of serial correlation in the error term and homoskedasticity for time series data. With the Breusch-Godfrey test and the Breusch-Pagan test, we will check for serial correlation and homoskedasticity, respectively, and provide solutions for correction if necessary (Stock & Watson, 2003).

Table 1. Results of breusch-godfrey/wooldridge test for serial correlation in panel models

chisq = 137.14, alternative hypothesis	df = 6 serial correlation in idiosyncratic errors	p-value < 2.2e-16

Table 2. Results of breusch-pagan test

BP = 47.888	df = 6	p-value = 9.96e-10
Null Hypothesis (H0):	Homoscedasticity is present (the residuals are distributed with equal variance)	

The absence of serial correlation is the null hypothesis for the Breusch-Godfrey test. The test's p-value indicates that we can rule out the null hypothesis and verifies that our error term contains serial correlation.

Just as we addressed heteroscedastic errors, we can apply computes the corresponding Wald confidence intervals to rectify serial correlation. To ensure a covariance matrix that accommodates heteroskedasticity and simultaneously considers autocorrelation, we will utilize the HC sandwich estimators with the method Arellano, encompassing both aspects (Stock & Watson, 2003).
To check for cross-sectional dependence, we use the Pesaran cross-sectional dependence test.

4.2 Cross sectional dependence

Table 3. Pesaran CD test for cross-sectional dependence in panels

z = 10.841	p-value < 2.2e-16
alternative hypothesis	cross-sectional dependence

The null hypothesis is that there is no cross-sectional dependence, as we've seen with other tests. However, the p-value indicates that there is cross-sectional dependence and that we must correct it. In general, there are two methods for addressing cross-sectional dependence.

The cross-sectional and serial correlation (SCC) method by Driscoll and Kraay (1998) is preferred for obtaining heteroskedasticity and autocorrelation consistent errors that are also robust to cross-sectional dependence because it addresses the drawbacks of Beck and Katz's PCSE method. We can obtain the SCC-corrected covariance matrix (Stock & Watson, 2003).

We will decide which model to choose before determining the mods on the outputs. Then we will make the modifications and reach the result.

4.3 Simple linear regression

Introducing independent variables into the model sequentially, the model results are presented in Table 7.

We begin our analysis with a summary of descriptive statistics in Table 4 and Table 5.

Table 4. Descriptive statistics and names of variable

Variable	Mean	Std dev	**Min**	**Max**
GDPPC	11597	13081	442	66859
RDEXP	1.02	0.97	0.05	4.81
INVGDP	0.25	0.06	0.15	0.42
LABOR	0.48	0.07	0.33	0.62
GGCE	14.31	3.25	6.53	20.79
TECHN	398	299	16	1311
RES	2207	2369	57	8713

Table 5. Average of variables by country between 2000-2020

Country	GDPPC	INVGDP	GGCE	RDEXP	TECHN	RES	LABOR
Brazil	7854	0.18	19.32	1.12	599	580	0.48
Chile	11087	0.24	12.83	0.36	275	406	0.45
Colombia	5275	0.21	14.78	0.22	49	73	0.49
India	1218	0.34	10.82	0.75	89	174	0.37
Indonesia	2560	0.3	8.68	0.17	23	237	0.48
Korea, Rep.	23655	0.32	14.18	3.36	872	5422	0.52
Peru	4655	0.21	11.86	0.12	476	701	0.52
Russia	8908	0.22	17.9	1.1	505	3119	0.52
Singapore	44735	0.26	10.24	2.05	459	5946	0.51
Thailand	4637	0.25	15.22	0.46	206	830	0.57
Türkiye	8755	0.27	13.76	0.75	139	935	0.36

The standard deviation exceeds the mean real GDP per capita of 11597. Significant deviation was also present in the explanatory variables (dependent variable and control variables). This might serve as one of the indicators to use the fixed effect model in this paper's upcoming regressions. We assume that each nation has some unique characteristics that have an impact on real GDP growth in various ways.

Table 6 represents a correlation matrix between independent variables and predictors. The simple correlation with GDPPC and other predictors is modest. There is not a strong correlation between independent variables, which is good for our future regressions.

Table 6. Correlation matrix

	GDPPC	RDEXP	INVGDP	LABOR	GGCE	TECHN	RES
GDPPC	1						
RDEXP	0.54	1					
INVGDP	0.17	0.28	1				
LABOR	0.45	0.26	-0.06	1			
GGCE	-0.15	0.1	-0.59	0.008	1		
TECHN	0.08	0.05	0.07	-0.03	0.05	1	
RES	0.008	-0.05	0.06	-0.06	0.18	0.57	1

We start by performing a simple linear regression. The real GDP growth rate is the dependent variable we use. Government final consumption spending, gross fixed capital formation, R&D as a percentage of GDP, labor force, and number of technicians and researchers are the independent variables. In Table 7, the regression result is presented.

Table 7. Results of OLS

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	6.8	0.63	18.33	< 2e-16 ***
log(RDEXP)	-0.15	0.05	9.58	< 2e-16 ***
log(INVGDP)	-0.25	0.29	-1.24	0.197
log(GGCE)	-1.33	0.29	-1.23	0.218
log(LABOR)	-0.43	0.31	8.909	2.44e-16 ***
log(TECHN)	0.33	0.12	2.73	0.007062 **
log(RES)	0.47	0.09	4.824	3.96e-06 ***

The R-squared value, which represents 50.46% of the variance in real GDP per capita, is explained by our regression model. Our regression model's number of variables is taken into account, but adjusted R-Squared has a similar interpretation. The evidence between our independent variable and a dependent variable that accounts for all other variables is essentially what we are looking for. Real GDP growth rate has no relationship with final government consumption expenditures as a percentage of GDP, gross fixed capital formation as a percentage of GDP.

Ceteris paribus applies to the interpretation of the multiple regression coefficients. The p-values for final government consumption expenditures as a percentage of GDP and gross fixed capital formation as a percentage of GDP are particularly high and indicate no significant effect from them. This is the first indication of the regression that we found.

We draw the conclusion that an OLS regression model is ineffective on the basis of two main arguments. The first is that neither the p values of our independent variables, nor the p values of either of the two control variables, are significant. Accordingly, we prefer either the Fixed Effect or Random Effect regression model for our analysis.

4.4 Results for fixed effect regression model

Firstly, the independent variables were entered into the model differently. Table 8 shows that R&D expenditures are significant and positive. The analysis was continued using model 10 as the final model.

Table 8. The relationship between R&D expenditures and economic growth

The Relationship between R&D Expenditures and Economic Growth

Variable / target variable = GDPPC	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
log(RDEXP)	0.71***	0.6***	0.25***	0.57*	0.25**	0.36***	0.13*	0.1*	0.25**	0.27***
log(INVGDP)		1.71***			1.1***	1.88***	1.24**	1.42**	1.51**	1.47***
log(LABOR)			2.73***		2.3***		2.16***	1.9**	1.21**	1.07***
log(GGCE)				0.86*		1.42***	0.82*	1.5**	1.05	3.11***
log(TECHN)								0.1*		0.33**
Rlog(ES)									0.28*	0.11***
No of Observation	231	231	231	231	231	231	231	231	231	231
No of Country	11	11	11	11	11	11	11	11	11	11
Serial Correlation Problem	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cross Sectional Dependence Problem	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note:*** p<0.01, ** p<0.05, * p<0.10

The following table represents the results, where all the independent variables are included into the regression.

Table 9. Multiple regression using fixed effect model

	Estimate	Std. Error	t value	Pr(>|t|)
log(RDEXP)	0.27	0.09	2.83	0.005***
log(INVGDP)	1.47	0.208	7.08	2.329e-110 ***
log(GGCE)	1.07	0.315	3.39	0.0008328 ***
log(LABOR)	3.11	0.54	5.86	1.865e-08 ***
log(TECHN)	0.33	0.12	2.73	0.07062 **
log(RES)	0.11	0.09	4.824	3.96e-06 ***
R-Squared	0.51901			
F-statistic:	53.9524	p-value	< 2.22e-16	

Note:*** p<0.01, ** p<0.05, * p<0.10

All predictors have statistically significant p values, as shown in Table 9. The inference drawn from Table 9 is that ceteris paribus, a 1% increase in R&D spending as a percentage of GDP will have an effect on real GDP growth rates in the observed economies by 0.27 percentage points over the course of the observation period. 51.9% is the coefficient of determination.

In the model, it was discovered that the R&D expenditures variable's coefficient was both positive and statistically significant. Panel data tests were run in this main model, and the conclusion was made. This model predicts that an increase of 1% in R&D expenditures as a percentage of GDP will lead to an increase of 0.27 percent in GDP per capita in a select group of countries.

The analysis' findings indicate that the model's labor control variables and domestic investment controls have a favorable impact on economic growth. According to the model, a 1% increase in the share of gross fixed capital investments in GDP causes an increase in economic growth of 1.47% in these countries; a 1% increase in employment causes an increase in economic growth of 3.11%.; increase in the share of Government Expenditures in GDP causes an increase in economic growth of 1.07% in these countries.

4.5 Hausman test for endogeneity of the model

We perform a Hausman test to determine whether to use fixed or random effects, with the null hypothesis being that random effects are preferred over fixed effects. The main test is whether the regressors and the unique errors (ui) are correlated; the null hypothesis is that they are not.

We will compare the fixed effects and random effects model results with the hausman test and determine which result to choose. Table 10 displays the Hausman test results.

Table 10. Results of hausman test

chisq = 115.41	df = 6	p-value < 2.2e-16
alternative hypothesis	one model is inconsistent	

The Hausman test tests the null hypothesis that the coefficients calculated with the efficient random effects estimator are the same as those estimated with consistent fixed effects. According to the Hausman test result, fixed effects is a more effective model.

4.6 Results

We know from the test results in Section 4.1 and 4.2 that although the results are statistically significant, we rejected the null hypothesis in the serial correlation, homoskedasticity and cross-sectional dependence tests and will be corrected accordingly. In this section, besides the significance of the variables, we will use some modified functions to test whether we can use them in the final model or not.

We will start with the HAC function that we will use for Serial Correlation and Homoskedasticity. After this step, we will continue with SCC and our model will take its final form.

Table 11. Results of HAC

	Coefficient
log(RDEXP)	0.27***
log(TECHN)	0.33
log(RES)	0.11**
log(INVGDP)	1.48***
log(GGCE)	1.07**
log(LABOR)	3.17**

Note: *** p<0.01, ** p<0.05, * p<0.10

We can see that with heteroskedasticity and autocorrelation consistent (HAC) standard errors, the number of technicians is no longer a significant predictor in our model.

Table 12. Comparison of coefficients and significance

Variable	FE	FE after HAC	**SCC**
log(RDEXP)	0.27***	0.27***	0.27**
log(TECHN)	0.33**	0.33	0.33
log(RES)	0.11***	0.11**	0.11
log(INVGDP)	1.48***	1.48***	1.47***
log(GGCE)	1.07**	1.07**	1.07**
log(LABOR)	3.17**	3.17**	3.11**

Note: *** p<0.01, ** p<0.05, * p<0.10

We can see that with SCC, the number of researchers is no longer a significant predictor in our model. We see the modified model in the equation 1.

$$\mathrm{Log(GDPPC)} = 0.27\mathrm{Log\,(RDEXP)} + 1.47\mathrm{Log(INVGDP)} + 1{,}07\mathrm{Log(GGCE)} + 3.11\mathrm{Log(LABOR)} \qquad (1)$$

Although R&D expenditures' significance declines in the final case, the final coefficients have been reached within the bounds of statistical significance for all four variables using the SSC method.

In the model, it was discovered that the R&D expenditures variable's coefficient was both positive and statistically significant. Panel data tests were run in this main model, and the conclusion was made. This model predicts that an increase of 1% in R&D expenditures as a percentage of GDP will lead to an increase of 0.27 percent in GDP per capita in a select group of countries.

The analysis' findings indicate that the model's labor control variables and domestic investment controls have a favorable impact on economic growth. According to the model, a 1% increase in the share of gross fixed capital investments in GDP causes an increase in economic growth of 1.47% in these countries; a 1% increase in employment causes an increase in economic growth of 3.11%.; increase in the share of Government Expenditures in GDP causes an increase in economic growth of 1.07% in these countries.

5. Conclusion

Technology advancement, physical and human capital, natural resources, and an increase in population-based labor are some of the factors that contribute to growth. According to studies and models developed to date, R&D activities that are produced using knowledge are among the most significant production resources that influence the welfare level and development of nations. The amount of physical and human capital that nations possess determines the production of new technologies required for new products and methods of production. R&D initiatives by nations, the number of patents, the number of R&D employees, and the number of resources allocated to R&D expenditures as a ratio to GDP can all be used to gauge the country's R&D activities.

Productivity and the competitiveness of the nations will rise as a result of R&D activities brought on by the effective and correct application of technology and high-rate production. It is clear that the R&D sector has evolved into the foundation of the nation's economy as a result of R&D activities. New technologies are created as a result of R&D activities, and these activities take on increasing importance as new products are developed. Investments in knowledge, research, and development will lead to the development of new technologies, which will improve national welfare and permit significant increases in national income levels.

In this study, we analyzed the effect of R&D activities on the economic growth of 11 countries that are considered to be fragile due to their reliance on foreign capital. Specifically, the effect of R&D expenditure as a ratio of GDP on the growth of GDP per capita in Brazil, Chile, Colombia, Indonesia, India, Peru, Russian Federation, Singapore, Thailand, Republic of Korea, and Türkiye for the years 2000–2020 is analyzed in this study.

The findings indicate that the share of R&D expenditures in GDP, fixed capital formation, and labor force are all found to be statistically significant and have a positive impact on economic growth. Control variables such as the labor force and fixed capital formation also have a statistically significant and favorable impact on economic growth. The variable with the greatest impact on economic growth is found to be the labor force, followed by gross capital investments, government expenditures, and R&D expenditures, respectively, according to the size of the coefficients. Hence, our results are in line with most of the studies cited in the literature review part that demonstrate that R&D expenditures have a positive and significant impact on economic growth.

Particularly the countries that run current account deficits should increase the value of their exports and should rely less on importing high-value-added products. Because higher R&D expenditures typically enable countries to produce high-technology, so high-value-added products, it is especially important for developing and fragile economies to increase their R&D activities.

References

Aghion P., & Howitt P. (1992), A Model of Growth Through Creative Destruction. Econometrica, 60(2), pp. 323-351.

Arrow, K. J. (1962). Economic Welfare and the Allocation of Resources for Invention. In The Rate and Direction of Inventive Activity: Economic and Social Factors. Princeton University Press.

Ayyıldız, F. V. & Demirci, O. (2022). Ar-Ge harcama gruplarının ekonomik büyüme üzerindeki etkileri: Türkiye örneğinde yapay sinir ağları ile ARDL analizi . Trends in Business and Economics , 36(4), pp. 346-358.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. Review of economics and statistics, 80(4), 549-560.

Göze Kaya, D. (2019). Ar-Ge Harcamalarının Gelişimi: Tr-Ab Üzerine Bir Değerlendirme. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi , 33(3), pp. 791-812.

Griliches, Z. (1992), The Search for R&D Spillovers. The Scandinavian Journal of Economics. 94, pp. 29-47.

Kiselakova, D., Sofrankova, B., Cabinova, V., Onuferova, E., & Soltesova, J. (2018), The impact of R&D expenditure on the development of global competitiveness within the CEE EU countries, Journal of Competitiveness, 10(3), pp. 34–50.

Lichtenberg, F. (1992) R&D Investment and International Productivity Differences. NBER WP, 4161.

Lucas Jr, R. E. (1988), On the Mechanics of Economic Development. Journal of Monetary Economics, 22(1), pp. 3-42.

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

Romer, P. M. (1986), Increasing returns and economic growth, American Economic Review, 94(5), pp. 1002-1037.

Samimi, A. J., & Alerasoul, S. M. (2009). R&D and Economic Growth: New Evidence From Some Developing Countries. Australian Journal of Basic and Applied Sciences, 3(4), pp. 3464-3469.

Simionescu, M., Lazányi, K., Sopková, G., Dobeš, K., & Balcerzak, P. A. (2017), Determinants of economic growth in V4 countries and Romania, Journal of Competitiveness, 9/1: 103–116.

Schmidheiny, K. (2013). Short Guides to Microeconometrics. Basel: Unversitat Basel

Stock, J. H., & Watson, M. W. (2020). Introduction to Econometrics. Pearson.

Wooldirdge, J. (2002). Econometric analysis of cross section and panel data. Massachusetts: MIT Press.

World Bank. (2023). World Development Indicators. Retrieved from: https://databank.worldbank.org/source/world-development-indicators