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Effects of Productivity, R&D and Income Inequality on Economic Growth: An Empirical Estimation Using Panel Data

Hakan Aydoğan[1], Hakan Yıldırım[2]

ABSTRACT

Purpose: The purpose of this paper is to empirically consider the effects of Total Factor Productivity (TFP), R&D, and income inequality on economic growth using panel data covering a broad range of developing and developed countries.

Methodology: Panel data on relevant variables observed between 1998 and 2018 for 29 countries were analyzed. Cross-sectional dependence and stationarity tests of the variables were performed, then panel data regression models were tested and parameters were estimated. Then, the most appropriate model was determined and model assumptions such as autocorrelation, heteroskedasticity and cross-sectional dependence of model errors were tested. In all analyses, R statistical program was used.

Findings: According to the analysis results, it has been determined that while productivity and R&D variables affect economic growth positively, increasing of income inequality also affects economic growth negatively.

Originality: This research fills the gap in the literature in some ways: Our analysis covers a wider range of countries in both developing as well as developed countries, and emphasizes on recent period Gini coefficients, R&D expenditures, and productivity, from 1998 to 2018. Furthermore, the results of this research will not only facilitate the economic policymakers of the countries but will also be effective in realizing how important R&D expenditures and productivity are in economic growth.

Keywords: Economic Growth, R&D, TFP, GINI, Panel Data Analysis.

JEL Codes: D24, C33, O40, O47.

Verimlilik, Ar-Ge ve Gelir Dağılımı Eşitsizliğinin Ekonomik Büyüme Üzerindeki Etkileri: Panel Veri Analiziyle Ampirik Bir Kestirim

ÖZET

Amaç: Bu çalışmanın amacı, gelişmiş ve gelişmekte olan ülkelere ait panel veriler kullanılarak verimlilik, Ar-Ge ve gelir dağılımı eşitsizliğinin ekonomik büyüme üzerindeki etkilerini ampirik olarak değerlendirmektir.

Yöntem: Bu amaçla, 29 ülke için 1998-2018 yılları arasında gözlemlenen ilgili değişkenlere ilişkin panel veriler analiz edilmiştir. Değişkenlerin yatay kesit bağımlılığı ve durağanlık testleri yapılıp panel veri regresyon modelleri test edildikten sonra parametre kestirimleri yapılmıştır. Daha sonra, en uygun model belirlenerek model hatalarındaki otokorelasyon, değişen varyans ve yatay kesit bağımlılığı gibi varsayımlar test edilmiştir. Çalışmada gerçekleştirilen tüm analizlerde R istatistik programı kullanılmıştır.

Bulgular: Analiz sonuçlarına göre verimlilik ve Ar-Ge değişkenleri ekonomik büyümeyi pozitif yönde etkilerken, gelir dağılımı eşitsizliğinin artmasının da ekonomik büyümeyi negatif yönde etkilediği tespit edilmiştir.

Özgünlük: Bu çalışma bazı açılardan literatürdeki boşluğu doldurmaktadır: Çalışmada hem gelişmiş hem de gelişmekte olan ülkelere ait veri setleri kullanılarak daha geniş bir yelpazede analiz yapılmış ve 1998'den 2018'e kadar yakın dönemdeki Gini katsayıları, Ar-Ge harcamaları ve Toplam Faktör Verimliliği (TFV) değişkenleri üzerine odaklanılmıştır. Ayrıca, bu araştırmanın sonuçları yalnızca politika yapıcılarına kolaylık sağlamakla kalmayacak, aynı zamanda da Ar-Ge harcamaları ve TFV'nin ekonomik büyümede ne derece etkili olduğunun da anlaşılmasına katkı sağlayacaktır.

Anahtar Kelimeler: Ekonomik Büyüme, Ar-Ge, Toplam Faktör Verimliliği, GINI, Panel Veri Analizi.

JEL Kodları: D24, C33, O40, O47.

[1] Kastamonu University, Department of Forest Industrial Engineering, Kastamonu, Türkiye
[2] Marmara University, Faculty of Business Administration, Department of Quantitative Methods, İstanbul, Türkiye

Corresponding Author: Hakan Aydoğan, hakanaydogan@kastamonu.edu.tr

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1. INTRODUCTION

Nowadays, most of the governments have begun to give importance to the driving forces of economic growth in order not only to increase economic output, but also to increase the welfare level of their countries in social terms, to ensure equality, to adapt to the globalization trend, and to be included in the fierce competition in the world. Moreover, a few percent increases or decreases in a country's growth rate may have major consequences in one or two generations on the well-being and the quality of living of its citizens (Acemoglu, 2012). The main drivers of economic growth are productivity increases (Schreyer and Pilat, 2001) and technology production (Acemoglu and Azar, 2020) of countries. Furthermore, innovation is highlighted as a vital mechanism for reducing income inequality and promoting sustainable economic growth. Studies indicate that higher investments in R&D can open new employment avenues and ultimately reduce income disparity, particularly in developing countries (Khan and Pazir, 2023; Ali et. al., 2022).

In the Neoclassical economic growth model proposed by Solow (1956), Cobb and Douglas (1928) realized that the output of the production function cannot be explained using traditional labor force input and physical capital stock. This unexplained part of economic growth represents the technical and technological change that drives growth as an exogenous force called 'Solow's Residual' or Total Factor Productivity (TFP) (Griliches, 1996). Moreover, Romer (1994) stated that R&D plays an important role in increasing economic growth, productivity, and innovation. Additionally, Kuznets (1955) claimed that income inequality had an impact on the economic growth of countries. As argued by Simon Kuznets (1955), the issue of income inequality has also been the subject of discussion, especially in recent years (Grossman and Helpman, 1994; Brueckner and Lederman, 2018; Aiyar and Ebeke, 2020). Recent empirical research suggests that income inequality can both positively and negatively influence economic growth. For instance, studies show that income inequality could either constrain growth through underinvestment in human capital or incentivize productivity by rewarding skills and innovation, depending on the socioeconomic context of the countries analyzed (Odhiambo, 2022; Espoir and Ngepah, 2021).

Do R&D, productivity and income inequality have an impact on economic growth over time and across countries? So what is the extent of the effects of all these variables on economic growth? To answer these questions, we aim to investigate the effects of productivity, R&D, and income inequality on economic growth in developed and developing countries. For this purpose, panel data obtained from different databases of developed and developing countries between 1998 and 2018 will be used. Furthermore, TFP data will be employed as the productivity indicator of the countries.

This research fills the gap in the literature in some ways. Our analysis covers a wider range of countries in both developing as well as developed countries, and emphasizes on recent period Gini coefficients, R&D expenditures, and productivity, from 1998 to 2018. Furthermore, the results of this research will not only facilitate the economic policymakers of the countries but will also be effective in realizing how important R&D expenditures and productivity are in economic growth. Additionally, similar to the study by Nogueira and Madaleno (2021), this research examines whether advancements in human development and competitiveness, as measured by international indices, are correlated with economic growth, particularly as observed among European Union countries

The rest of our paper is organized as follows. Section 2 presents the empirical model in which we explain the data and methodology. Section 3 summarizes the results of the panel data regression and discusses these results that may give rise to a positive effect of R&D expenditures and TFP on economic growth. Section 4 concludes.

2. DATA, ESTIMATION, METHOD and MODEL

2.1. Data

The analysis is conducted on a sample of 29 developed and developing countries observed between 1998-2018. In this study, emerging and developing countries were randomly selected based on the availability of their data, and the classification of countries was determined according to the World Bank's Atlas methodology. These countries are shown in Table A1 in Appendix. The explanations of the variables used in the model are shown in Table A2 in Appendix.

Real GDP data (annual percent change) is obtained from IMF datasets. TFP data was obtained from the Penn World Table (PWT 9.1) database. In addition, the data is in the form of Total Factor Productivity level (TFP level at current PPPs (USA =1) at current purchasing parity). The R&D variable is the R&D expenditures of developed and developing countries (as billions of dollars), and the data for the variable is obtained from OECD database and GINI coefficient data were obtained from the Standardized World Income Inequality Database (SWIID) published by Harvard University.

Descriptive statistics of Real GDP (%), TFP, R&D (% of GDP) and GINI variables for developed and developing countries between 1998 and 2018 are shown in Table 1.

Table 1. Descriptive statistics of variables (1998-2018)

Variable	*N*	*Mean*	*Std. Deviation*	*Min*	*Max.*
Real GDP (%)	609	2.96	3.28	-14.7	14.5
TFP	609	0.78	0.22	0.25	1.40
R&D (% of GDP)	609	1.61	1.01	0.12	4.95
GINI	609	0.47	0.047	0.32	0.56

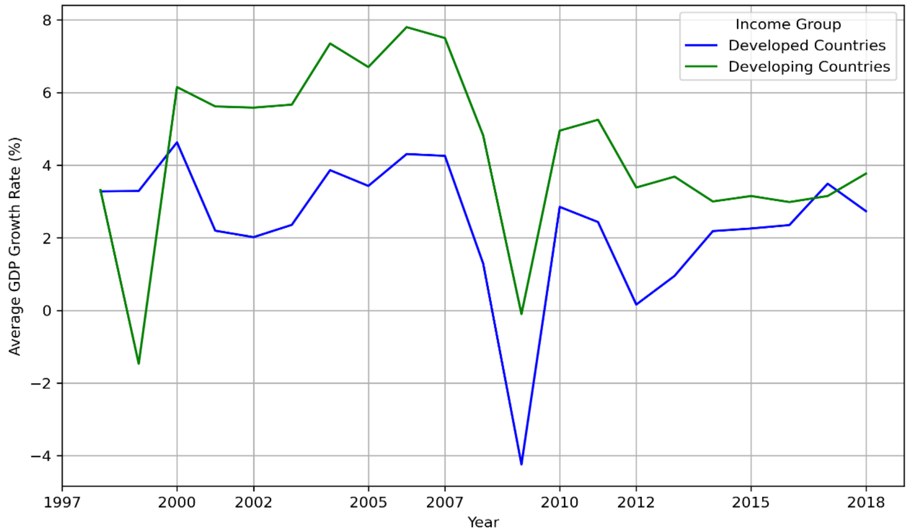

Figure 1. Average GDP growth rate over time by income group

Figure 1 compares the annual average GDP growth rates over time for the samples of developed and developing economies used in this study. In general, developing economies exhibit higher average growth rates, although these rates tend to fluctuate more significantly. Notably, during the 2008–2009 period, both groups experienced negative growth rates, with a particularly pronounced decline in the developing economies group. This downturn is attributed to the global crisis that occurred during this period. After 2009, developing countries demonstrated a faster recovery, whereas developed countries returned to lower, but comparatively more stable, growth rates. After 2010, growth rates in the developing economies group decreased, attaining a more balanced structure. These differences reveal structural distinctions in the approaches of developed and developing economies toward economic growth, as well as the differing responses they exhibit to economic shocks.

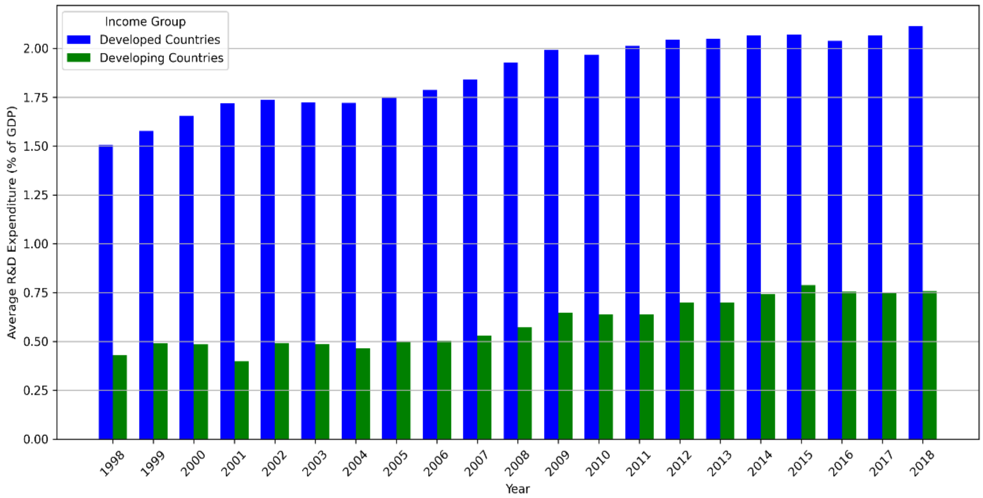

Figure 2. Average R&D expenditure over time by income group

Figure 2 presents a comparison of average R&D expenditures (as a percentage of GDP) over the years for developed and developing countries. Overall, developed countries allocate significantly higher levels of resources to R&D compared to developing countries. This reflects the greater emphasis that advanced economies place on technology- and innovation-driven growth strategies. Over the years, R&D expenditures in the developed countries group have consistently remained above 1.5%, approaching 2% in certain years. In contrast, R&D spending in the developing countries group has averaged around 0.5%, with a noticeable increase in the 2007–2008 period. This rise highlights the potential of developing countries to expand their R&D investments and underscores the importance of these expenditures in fostering technological competitiveness. In conclusion, the high R&D expenditures observed in developed countries can be seen as a strategy aimed at sustainable economic growth.

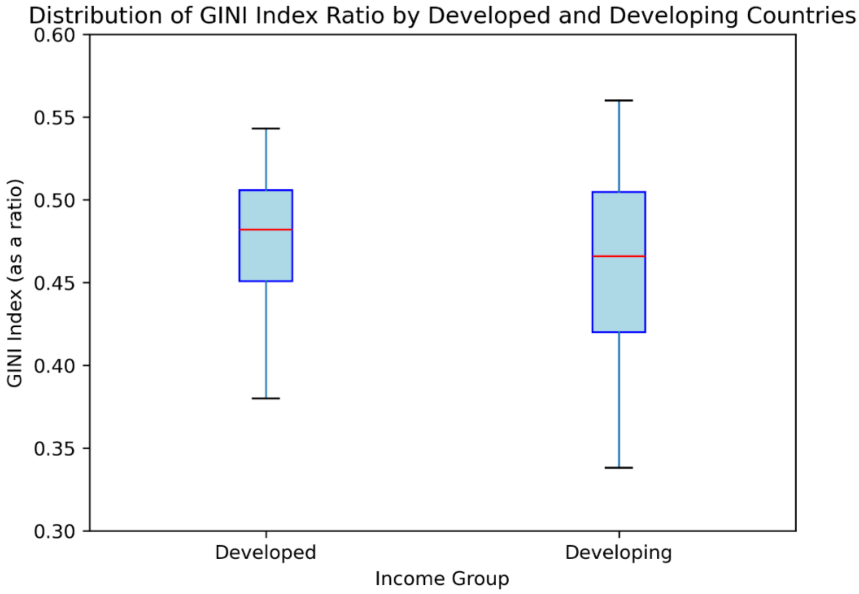

Figure 3. Distribution of GINI index ratio by developed and developing countries

Figure 3 compares income distribution inequality based on the GINI index for the developed countries and developing countries groups. Examination of the GINI index as a ratio reveals a marked difference in income inequality levels between the two groups. The GINI value for the developed countries group has a median of approximately 0.45, with a narrower range between 0.40 and 0.55, indicating a relatively more balanced income distribution in advanced economies. In contrast, the developing countries group has a median GINI index of about 0.48, with a broader distribution range from 0.35 to 0.55. This wider range suggests that income inequality is more pronounced and variable in emerging economies. These differences in the GINI index reflect the divergent socioeconomic structures and income distribution policies of the two country groups.

2.2. Estimation Method and Empirical Model

Following Baltagi (2021), Croissant and Millo (2019), and Wooldridge (2010), we study the effect of TFP, R&D expenditure and GINI on GDP with a panel regression model. Specifically, in this study, static panel data methods were selected over dynamic models due to the specific aim of capturing the contemporaneous effects of R&D, productivity, and income inequality on economic growth. Given our objective, which focuses on immediate rather than lagged impacts, static models provide a more straightforward approach. Additionally, the structural considerations of our dataset limit the feasibility of dynamic panel approaches, as dynamic models often introduce endogeneity concerns and require more complex implementations."The ‘plm’ package (Croissant and Millo, 2008) in the R program is used for all panel data tests. In this study, we consider pooled model (Equation 1), fixed effects (Equation 2), and random effects model (Equation 3) as follows:

$$GDP_{it} = \beta_{0it} + \beta_{1it}TFP_{it} + \beta_{2it}GINI_{it} + \beta_{3it}R\&D_{it} + u_{it} \quad (1)$$

$$GDP_{it} = \beta_{0i} + \beta_{1it}TFP_{it} + \beta_{2it}GINI_{it} + \beta_{3it}R\&D_{it} + \mu_i + u_{it} \quad (2)$$

$$GDP_{it} = \beta_{0it} + \beta_{1it}TFP_{it} + \beta_{2it}GINI_{it} + \beta_{3it}R\&D_{it} + u_{it} \quad (3)$$

where, i denotes countries and i = 1,2,..., 29. t denotes years and t = 1998, 1999,.., 2018. β_{0it} refers to the constant term of the model. β_{kit} stands for the parameters of explanatory variables. Panel data applications often use a one-way error component model for disturbances (Baltagi, 2021: 15). Thus, the error term u_{it} (Equation 4) is as follows:

$$u_{it} = \mu_i + v_{it} \quad (4)$$

where μ_i denotes the unobservable individual specific effect and v_{it} specifies the remainder disturbance. Additionally, it is assumed that the μ_i are the fixed parameters to be estimated and the v_{it} are stochastic error term with identically and independent normally distributed IID (0, σ_v^2) for all countries and for all time periods with zero mean and constant variance. Moreover, for all i and t, all regressors are assumed independent of the v_{it}.

3. RESULT and DISCUSSION

Consistency of stationarity tests for panel data is affected by cross-section dependence. Hence, to determine which of the unit root tests would be more appropriate, it was examined whether there was a cross-sectional dependence on the variables.

Table 2. Cross-sectional dependence test results of variables

Test		*GDP*	*TFP*	*R&D*	*GINI*
Breusch-Pagan LM	Statistic	8.34	17.68	6.96	5.89
	Probability	0.000	0.000	0.000	0.000
Pesaran CD	Statistic	10.81	23.55	23.57	23.65
	Probability	0.000	0.000	0.000	0.000
Scaled LM	Statistic	248.950	116.290	245.640	140.790
	Probability	0.0000	0.000	0.000	0.000

Table 2 demonstrates that the null hypothesis is rejected at the α=0.05 significance level, therefore, it can be concluded that all variables contain cross-sectional dependence. Thus, we decided to conduct the second generation panel unit root tests by using CIPS test (Pesaran, 2007).

Table 3. Pesaran CIPS unit root test results

	Variables			
Models	*GDP*	*TFP*	*R&D*	*GINI*
Intercept	-2.3732	-0.685	-1.9083	-1.6631
Prob.	>0.01	>0.1	>0.1	>0.1
Intercept&Trend	-2.457	-1.557	-2.6283	-1.7438
Prob.	>0.1	>0.1	>0.08	>0.1
No Intercept&Trend	-0.84085	-1.011	-0.23642	-1.6135
Prob.	>0.1	>0.1	>0.1	>0.04

Note: The critical values are 0.05, 0.1, 0.01. When the results of the CIPS unit root tests are analyzed according to all three models (Intercept, intercept&trend, no intercept&trend), the null hypothesis: “There is a unit root across the panel” cannot be rejected.

All variables in Table 3 are nonstationary for the original series because they contain a unit root. In this case, it is essential to investigate whether there exists a long-term equilibrium relationship among the variables. The cointegration test allows us to examine whether the series that move together fluctuate around a certain equilibrium in the long run. This analysis reveals a meaningful long-term relationship between the variables if there is a cointegrated relationship among non-stationary series.

Table 4. Westerlund Cointegration test results

Test Statistic	*Value*	*Z-Value*	*P-Value*
Gt	-1.859	-0.674	0.0681
Ga	-3.212	-0.892	0.3890
Pt	-2.322	-0.567	0.0885
Pa	-4.392	-0.783	0.2970

According to Table 4, the results of the Westerlund cointegration test (Westerlund, 2005; Westerlund, 2007), applied to the data do not provide strong evidence of a long-term relationship among the variables. The Westerlund test, a cointegration test that accounts for cross-sectional dependence in panel data analysis, identified cross-sectional dependence in this study and established that the data are non-stationary. However, the p-values for the Gt, Ga, Pt, and Pa statistics of the Westerlund test all exceed the 5% significance level, specifically 0.0681, 0.3890, 0.885, and 0.2970, respectively. This outcome suggests the absence of a long-term cointegration relationship among the variables. Given the non-stationarity of the data and the presence of cross-sectional dependence, the Westerlund test is expected to provide more reliable results under these conditions.

Under the hypothesis of a unit root in the errors, first differencing the data is a convenient way to revert to a stationary error term. Moreover, Wooldridge (2010: 317) states that if the original errors are thought to exhibit a random walk, then the first differentiation of the data will lead to stationary and uncorrelated errors. Wooldridge's first-difference test for serial correlation shows that there is serial correlation in original errors (F = 5.4888, df1 = 1, df2 = 549, p-value = 0.0195) so that we can consider to disappearing it after first differencing (FD) (Equation 6). Then, we can write the model (Equation 1) in general for the previous period as in Equation 5.

$$GDP_{it-1} = \beta_{0it} + \beta_{1it}TFP_{it-1} + \beta_{2it}GINI_{it-1} + \beta_{3it}R\&D_{it-1} + u_{it-1} \quad (5)$$

Now, if model in Equation 5 is subtracted from model in Equation 1, Equation 6 is obtained.

$$GDP_{it} - GDP_{it-1} = \beta_0 - \beta_0 + \beta_1 TFP_{it} - \beta_1 TFP_{it-1} + \beta_3 GINI_{it} - \beta_3 GINI_{it-1} + \beta_2 R\&D_{it} - \beta_2 R\&D_{it-1} + u_{it} - u_{it-1} \quad (6)$$

Thus, FD model is as in Equation 7.

$$\Delta GDP_{it} = \beta_1 \Delta TFP_{it} + \beta_2 \Delta GINI_{it} + \beta_3 \Delta R\&D_{it} + \Delta v_{it} \quad (7)$$

As seen on the FD model above, all time-constant unobserved variables (μ_i) are purged. After applying the first differencing, we investigated whether there was a multicollinearity problem with assuming Equation 8.

$$rank\ [\sum_{t=2}^{T} E(\Delta X_{it}' \Delta X_{it})] = K \quad (8)$$

Table 4 clearly shows that there is no multicollinearity problem in the FD model. When looking at the unit root test results of the FD model, we found that the variables became stationary (see Table 5).

Table 5. VIF values for explanatory variables

Variables	*VIF*	*1/VIF*
ΔTFP	1.05980	0.94357515
ΔGINI	1.02116	0.97927655
ΔR&D	1.07408	0.93103368
Mean VIF	1.05168	

According to the Table 6, it is possible to say that all differenced variables are stationary at the $\alpha = 0.05$ significance level. Then, the pooled (OLS), fixed effects (FE) and random effects (RE) model outputs of the differentiated variables are given in Table 7.

Table 6. Pesaran CIPS unit root test results of first differenced (FD) variables

	Variables			
Models	*Δ GDP*	*Δ TFV*	*Δ R&D*	*Δ GINI*
Intercept	-2.8207	-3.603	-2.7667	-2.3492
Prob.	<0.01	<0.01	<0.01	<0.01
Intercept&Trend	-2.7012	-3.677	-2.4723	-1.7128
Prob.	0.047	<0.01	0.03	<0.01
No Intercept&Trend	-2.725	-3.311	-2.4723	-1.9947
Prob.	<0.01	<0.01	<0.01	<0.01

Table 7. Estimations of OLS, FE and RE models

	OLS	*FE*	*RE*
(Intercept)	0.00081*	N/A	0.00811 *
	0.00362	N/A	0.00362
ΔTFP	0.22804 ***	0.22804 ***	0.22973 ***
	0.00000	0.00000	0.00000
ΔGINI	0.35620	0.35620	0.40080
	0.44880	1.02212	0.30270
ΔR&D	0.73336 ***	0.73336 ***	0.60142***
	0.00000	0.00000	0.00000
R^2	0.60845	0.60186	0.60845
Adj. R^2	0.60641	0.57933	0.60641
Num. obs.	580	580	580
σ_v^2	N/A	N/A	0.00596
σ_μ^2	N/A	N/A	0.0000
θ	N/A	N/A	0.0000

***, p < 0.00; **, p < 0.01 and *, p < 0.05;

When Table 7 is examined, it is determined that the TFP and R&D variables are significant in all three models, while the GINI variable does not have a significant effect in all models. The standard errors of the models show that the lowest errors are in the pooled model and random effects model. Here, the parameter θ refers to the part of the unit average extracted from each variable (Croissant and Millo, 2019: 49). Theta value is defined as in Equation 9.

$$\hat{\theta} = 1 - \left(\frac{1}{\sqrt{1 + \frac{T\sigma_{\mu}^2}{\sigma_{\nu}^2}}} \right) \qquad (9)$$

In the random effects model results, the θ value was found to be zero. Croissant and Millo (2019: 49) describe the θ value approaching 1 ($\theta \rightarrow 1$) as the convergence of the random effects model estimator Generalized Least Squares (GLS) to the fixed effects model estimator Within, and the θ value approaching 0. They expressed ($\theta \rightarrow 0$) as the convergence of the GLS estimator to the OLS estimator. In the Table 6, if the θ parameter is 0, it means that the random effects model converges to the OLS estimator. Therefore, OLS estimates and random effects model estimates were obtained to be the same.

3.1. Model Selection

Since the stationarity of differenced variables was ensured, model selection was made using differenced variables. The following tests were applied in order to choose between the pooled model, fixed effects model and random effects model. The comparison between of the pooled model and the random effects model with the Breusch-Pagan test, the OLS and FE with the F test, and the RE and FE model with the Hausman (1978) test was performed. Model results are shown in Table 7 below.

Table 8. Model comparison results

	F Test	*Breusch – Pagan Test*	*Hausman Test*
Test value	0.462	4.553	2.266
p-value	0.992	0.033	0.519

Upon examining the results of the model comparison tests, it is observed that according to the F-test, the null hypothesis (H_0) asserting the appropriateness of the pooled model over the fixed effects model cannot be rejected at the α=0.05 significance level. Contrary to the implications of the F-test, which supports the suitability of the pooled model, the Breusch-Pagan test results indicate the rejection of the null hypothesis that advocates for the pooled model being more suitable compared to the random effects model. In pursuit of substantiating the model comparisons, the Hausman test was conducted under the H0 hypothesis indicating the appropriateness of the random effects model, leading to the conclusion that the random effects model is the most fitting. Consequently, when the test results are collectively considered, both the Breusch-Pagan and Hausman tests corroborate the random effects model as the most appropriate.

3.2. Estimation and Test Results of Random Effects Model

Following the model comparison test results, it was indicated that the random effects model is appropriate. At this stage, the random effects model is formulated as follows:

$$\Delta GDP_{it} = \beta_1 \Delta TFP_{it} + \beta_2 \Delta R\&D_{it} + \beta_3 \Delta GINI_{it} + \Delta u_{it} \qquad (9)$$

Table 9. Estimation of the RE model

	Estimate	*Std. Error*	*z-value*	*Pr (>|z|)*
Intercept	0.0081147	0.0036277	2.2369	0.02529 *
diff (TFP)	0.229730	0.42652	48.606	1.17e-06 ***
diff (GINI)	0.4008	1.3413	-0.9949	0.3027
diff (R&D)	0.60142	0.03885	28.5846	2.2e-16 ***

Note: Signif. codes: 0 '***', 0.001 '**', 0.01 '*' , R^2: 0.60845, Chi-sq: 895.069, p-value: < 2.22e-16

Upon examination of the estimation results derived from the random effects model, it is observed that at the significance level of α=0.05, the model's intercept, Total Factor Productivity, and R&D variable have a significant impact on GDP. Conversely, the GINI variable is not statistically significant. The R2 value of the model is approximately 0.61. Furthermore, considering the overall significance of the model, it is discernible that the value of the F-statistic is significant.

3.3. Random Effects Model Fundamental Assumption Tests

According to the random effects model, tests for assumptions of autocorrelation, heteroscedasticity, and cross-sectional dependence required for panel regression have been conducted. For the detection of serial correlation in the errors of the random effects model, Breusch-Godfrey/Wooldridge and Durbin-Watson tests have been applied. Herein, the value of the Breusch-Godfrey/Wooldridge test is obtained as 27.326 (p-value: 0.1263), while the Durbin-Watson statistic is determined to be 2.2119 (p-value: 0.9941). According to these results, the null hypothesis (H_0) indicating the absence of autocorrelation in the error terms is not rejected in either test. Consequently, it is found that the error terms do not possess serial correlation.

One of the important assumptions of panel data analysis is the homoscedasticity as well as no serial correlation in residuals. Hence, we conduct the Breusch-Pagan test. The test results show that there is heteroscedasticity in residuals (BP = 1793.1, df= 3, p-value < 2.2e-16). The residuals plot showing the presence of heteroscedasticity is shown in Figure 1.

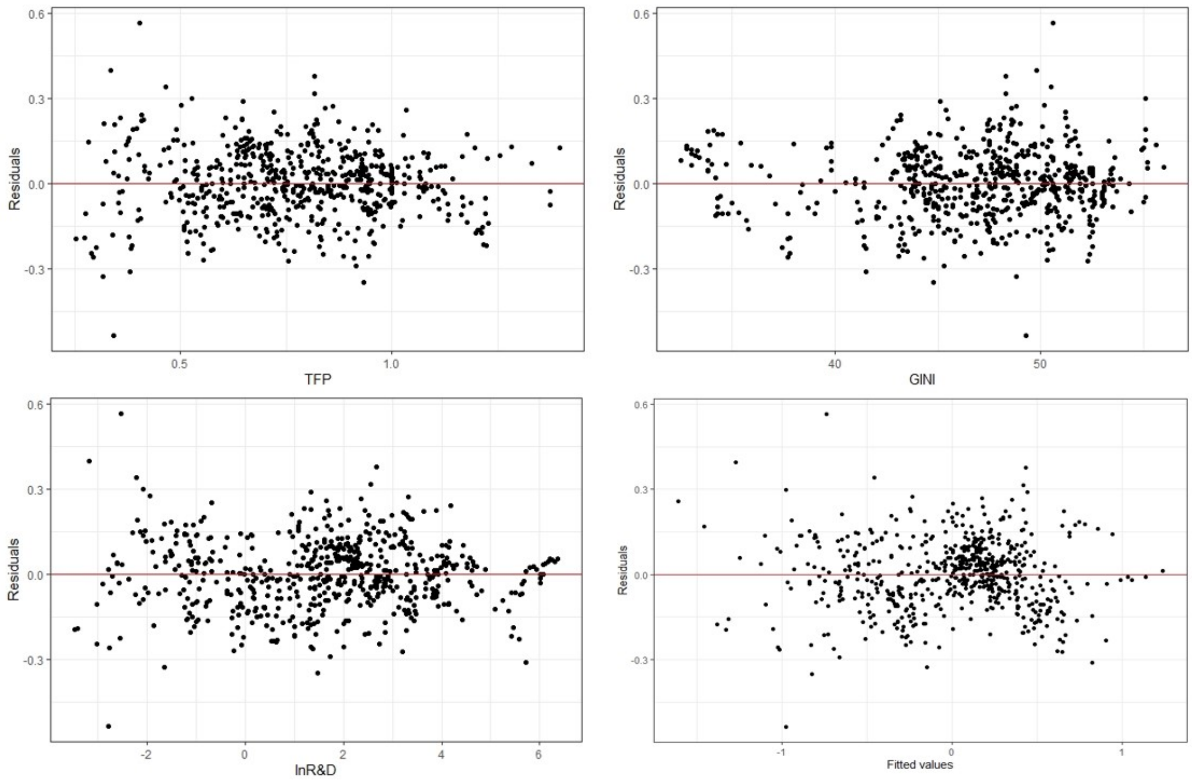

Figure 1. Heteroscedasticity in residuals

Cross-sectional dependence tests for the random effects model errors, including Breusch-Pagan LM, Pesaran CD, and Scaled LM, have been conducted. These tests examined the following hypotheses:

H_0: There is no cross-sectional dependence in the error terms of the random effects model.

H_1: There is cross-sectional dependence in the error terms of the random effects model.

The test results are as follows: Breusch-Pagan LM test (Breusch and Pagan, 1980) yielded a result of 1622.60, with a p-value of 0.000; the Pesaran CD test resulted in 31.386, with a p-value of 0.000; and the Scaled LM test resulted in 42.695, with a p-value of 0.000. Based on all these outcomes, the null hypothesis, which states that there is no cross-sectional dependence in the error terms, is rejected. Thus, it has been identified that the error terms of the model exhibit cross-sectional dependence.

On reviewing the assumptions of the random effects panel data model, it has been found that although there is no autocorrelation in the error terms of the model, issues of heteroscedasticity and cross-sectional dependence in the error terms do exist. Observing that these two assumptions are not met, robust estimators, which are typically employed in the presence of such assumption violations, have been applied to the model.

Table 10. Results of Arellano's robust estimator

	Estimate	*Std. Error*	*z-value*	*Pr (>|z|)*
Intercept	0.0081147	0.0056427	1.4381	0.02529
diff (TFP)	0.229730	0.54830	4.1161	3.853e-05 ***
diff (GINI)	0.4008	1.5622	-1.0769	0.2815
diff (R&D)	0.60142	0.15622	9.2905	2.2e-16 ***

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. R-squared: 0.60845, Chisq: 101.784, p-value: < 2.22e-16

In Table 10, the model estimation results have indicated that the chi-square (χ^2) statistic value of 101.78 is significant. It has been determined that both explanatory variables, Total Factor Productivity (TFP) and R&D, are significant within the model. Additionally, the coefficient of determination (R-squared) of the model is approximately 0.61. Since the dependent variable of the model is the annual percetange of real GDP, a one-unit increase in TFP will result in an approximate increase of 0.2297 units in GDP. On the contrary, a one-unit increase in the R&D ratio increases the GDP growth rate by approximately 0.601 units. This positive coefficient indicates that R&D investments have a serious effect on the growth rate within the model.

When examining the primary drivers of economic growth, the role of productivity in the literature is quite significant (Mankiw, 2021: 508). Lee and Xuan (2019) have found that an increase in TFP in China positively affects growth in the long term by increasing total output. Kamacı et al. (2019) have stated for 15 OECD countries that a one-unit increase in TFP results in an increase of 1.19 units in growth. Bosworth and Collins (2003), in their study investigating the sources of growth in 84 countries including Turkiye, found that TFP's effect on growth is 0.90%. Similarly, Han et al. (2004), in their analysis of 45 countries in 5-year periods, particularly noted that for Turkiye, the effect of TFP on growth is 1%. However, this study finds that a one-unit increase in TFP leads to an increase of 1.62 units in growth. Thus, the findings for the TFP variable in this study are in line with the literature.

When evaluating the relationship between R&D and economic growth, it would not be incorrect to say that we encounter findings similar to those in the literature (Göçer, 2013; Inekwe, 2014; Sokolov-Mladenović et al., 2016; Ali et al., 2021). However, in the study conducted by Samimi and Alerasoul (2009) covering the 2000-2006 period on 30 developing countries, they did not find that R&D expenditures directly affected economic growth. They have suggested that this might be due to the low budgets allocated to R&D expenditures by the countries included in the analysis. Contrary to their findings, our results show that a one-unit increase in R&D expenditures will increase growth by 0.60 units. There is considerable literature that supports our findings. For example, Göçer (2013) investigated the relationship between R&D expenditures and growth in 11 developing Asian countries between 1996-2012 and claimed that R&D expenditures positively affected growth. Moreover, the study indicated that a 1% increase in R&D expenditures accelerates growth by 0.43%. Similarly, Inekwe (2014), in his study covering the 2000-2009 period on developing countries, found the coefficient of the R&D variable statistically significant at 1% level, indicating its robustness at traditional probability levels. According to the model estimations used in the study, a 1% increase in R&D expenditures improved economic growth by 0.06%. Another study supporting our findings was conducted by Sokolov-Mladenović, Cvetanović, Mladenović, (2016). In their study for 28 European countries covering the 2002-2012 periods, multiple regression estimations showed that a 1% increase in R&D expenditures, while holding all other variables constant, would increase growth by 2.2%. Additionally, the study reported that the R-squared value of the model estimated using the within estimator was approximately 0.60.

When examining the relationship between income distribution inequality and economic growth, based on the findings of this research, it has been determined that the GINI coefficient does not have a significant effect in explaining economic growth. This finding is supported by Barro (2000) but contradicts the study conducted by Forbes (2000). Considering the relationship between these two variables in the literature, it's evident that scholars hold different views on this matter. While some studies significantly highlight the negative effect of income inequality on growth (Alesina and Rodrik, 1994; Persson and Tabellini, 1994; Clarke, 1995), more recent studies with improved datasets and the introduction of panel data analysis, such as those by Forbes (2000) and Barro (2000), have argued that an increase in income inequality has a positive effect on growth. However, distinct from Forbes (2000), Barro (2000) has not found a significant effect across the entire sample; he noted that this relationship is positive for developed countries and negative for underdeveloped countries.

Considering all these disparities, it may be thought that they arise from the choice of data sources and the use of different inequality indicators. Moreover, the contradiction might also be attributed to the quality of data used for income distribution inequality, different estimation methods employed, and various models used. These factors collectively suggest that the relationship between income inequality and economic growth is complex and influenced by multiple variables, requiring careful consideration of methodological approaches and the context of the studied countries.

4. CONCLUSION

In this study, the effects of Total Factor Productivity (TFP), R&D, and income distribution inequality on economic growth in developed and developing countries have been investigated. Generally, the literature suggests that R&D and TFP have positive effects on growth, whereas consensus is lacking regarding the relationship between income distribution inequality and growth.

The results of this study have demonstrated positive effects of TFP and R&D on economic growth. Just as the research of Barro (2000), this study also found the effects of income distribution inequality, as represented by the GINI coefficient, to be non-significant on growth. However, this finding contradicts Forbes (2000), who argued that income distribution inequality positively affects growth. The differences between this study's findings and the literature may stem from the use of different time series, cross-sectional dimensions, data quality, and methodologies.

Unlike some studies that solely rely on time series or crosssectional analysis, this research employs panel data analysis, which accounts for unobserved effects, contributing to the literature. The analysis encompasses a broad panel of both developed and developing countries and focuses on recent periods from 1998 to 2018, looking at GINI coefficients, R&D expenditures, and productivity.

The findings indicate that a one-unit increase in TFP leads to an increase of 0.229 unit in economic growth. Similarly, a one-unit increase in R&D results in a 0.60 unit increase in growth. This suggests that countries should place considerable emphasis on these two variables to boost GDP, welfare, and competitiveness, especially in developing countries where increasing budgets for R&D and technology transfers are critical. Furthermore, providing various supports and incentives to firms to increase total factor productivity is another way to enhance growth. This study has certain limitations that should be acknowledged. First, data after 2018 were not included in the analysis due to limited availability and consistency of key variables such as R&D expenditures and Total Factor Productivity (TFP) across a broad range of developed and developing countries. Restricting the timeframe to 1998-2018 ensures a more reliable and comparable dataset, but it may not capture recent economic developments. Additionally, while the study incorporates TFP, R&D, and income inequality, other potentially influential factors such as: human capital, institutional quality, and infrastructure were not included. These limitations suggest that future research could extend the analysis with more recent data and additional variables to further enhance our understanding of the factors affecting economic growth. Future studies could build on this research by incorporating more recent data, extending the analysis beyond 2018 to capture recent economic changes that may impact productivity, R&D, and income inequality. Additionally, future research could benefit from examining other variables such as human capital, institutional quality, and infrastructure, which also play significant roles in economic growth. Exploring alternative measures of income inequality, like wealth inequality or regional disparity indicators, could provide a more nuanced understanding of how income distribution affects growth. Comparative studies focusing on specific regions or income groups within countries may also shed light on context-specific factors that influence growth dynamics.

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

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APPENDIX

Table A1. Countries and their codes

Country Code	*Countries*	*Country Code*	*Countries*	*Country Code*	*Countries*
1	USA	11	South Korea	21	Lithuania
2	Germany	12	Norway	22	Turkiye
3	UK	13	Czech Rep.	23	China
4	France	14	Denmark	24	Russia
5	Italy	15	Finland	25	Kazakhstan
6	Canada	16	Portugal	26	Mexico
7	Spain	17	Austria	27	Serbia
8	Israel	18	Hungary	28	Bulgaria
9	Netherland	19	Poland	29	Colombia
10	Singapore	20	Slovenia		

Table A2. Descriptions of variables

Variables	*Description*	*Source*
GDP	Real Gross Domestic Product (annual %)	IMF
TFP	Total Factor Productivity	Penn World Table (PWT 9.1)
R&D	R&D expenditures of countries	OECD
GINI	Income Inequality of countries	The Standardized World Income Inequality Database (SWIID)