İşletme | The Business Journal 2024, 5(1), 65-79
https://doi.org/10.57116/isletme.1432746 e-ISSN: 2757-9433

The Impact of Renewable Energy Consumption on Economic Growth in BRIC-T Countries: Panel Data Analysis

(BRIC-T Ülkelerinde Yenilenebilir Enerji Tüketiminin Ekonomik Büyüme Üzerindeki Etkisi: Panel Veri Analizi)

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Abstract

The aim of this study is to examine the impact of renewable energy consumption on economic growth in BRIC-T countries (Brazil, Russia, India, China and Turkiye). In doing that, we consider gross fixed capital formation, trade openess, and foreignd direct investment as control variables. The Driscoll & Kraay estimator is used in the study in which both panel-wide and country-based analysis is performed using data for the period 1990-2020. According to the panel results, renewable energy consumption, trade openness and FDI variables are statistically insignificant. When countries are analyzed separately, the impact of renewable energy consumption on economic growth varies. Accordingly, it has a negative effect in China, India, Russia and a positive effect in Brazil and Turkiye. However, it is statistically significant only in India and Turkiye. In all countries, the increase in gross fixed capital formation has a positive effect on growth and is statistically significant. The effect of trade openness on growth is statistically significant in Brazil (positive), China (positive) and India (negative). FDI is statistically significant only in China and Turkiye. FDI affects growth negatively in China and positively in Turkiye.

Keywords:
Renewable Energy, Growth, Panel Data Analysis

Paper type:
Research

Öz

Bu araştırmanın amacı BRIC-T (Brezilya, Rusya, Hindistan, Çin ve Türkiye) ülkelerinde brüt sabit sermaye oluşumu, ticari açıklık, doğrudan yabancı yatırımları kontrol değişkeni olarak dikkate alarak yenilenebilir enerji tüketiminin ekonomik büyüme üzerindeki etkisini incelemektir. 1990-2020 dönemine ait veriler kullanılarak hem panel geneli hem de ülke bazlı olarak analizin yapıldığı çalışmada Driscoll & Kraay tahmincisi kullanılmıştır. Panel sonuçlarına göre yenilenebilir enerji tüketimi, ticari açıklık ve doğrudan yabancı yatırımlar değişkenleri istatistiksel olarak anlamsızdır. Ülkeler ayrı ayrı değerlendirildiğinde, yenilenebilir enerji tüketiminin ekonomik büyüme üzerindeki etkisi farklılık arz etmektedir. Buna göre Çin, Hindistan, rusya'da negatif etki, Brezilya ve türkiye'de ise pozitif etkilemektedir. Ancak sadece Hindistan ve türkiye'de istatistiksel olarak anlamlıdır. Bütün ülkelerde brüt sabit sermaye oluşumundaki artış büyümeyi pozitif etkilemektedir ve istatisiksel olarak anlamlıdır. Ticari açıklığın büyümeye etkisi Brezilya (pozitif), Çin (pozitif) ve Hindistan'da (negatif) istatistiksel olarak anlamlıdır. Doğrudan yabancı yatırımlar sadece Çin ve Türkiye'de istatistiksel olarak anlamlıdır. Doğrudan yabancı yatırımlar büyümeyi Çin'de olumsuz, Türkiye'de olumlu etkilemektedir.

Anahtar Kelimeler:
Yenilenebilir Enerji, Büyüme, Panel Veri Analizi

Makale türü:
Araştırma

Başvuru/Received: 06.02.2024 | Kabul/Accepted: 22.03.2024 , iThenticate benzerlik oranı/similarity report: %17

Atıf/Citation: Soyu Yıldırım, E., Tuğlu Dur, D. (2024). The Impact of Renewable Energy Consumption on Economic Growth in BRIC-T Countries: Panel Data Analysis, *İşletme*, 5(1), 65-79.

Introduction

Energy plays a crucial part in attaining the objective of sustainable development (Sadorsky, 2009). Energy is a crucial and essential power source for driving economic development (Wang, Dong, Li & Wang, 2022). Additionally, it serves as the primary factor in the manufacturing procedure. Energy resources are crucial for attaining economic growth ambitions. Economic growth and energy usage are positively related.

The meaning that as economic growth increases, so does the degree of energy use (Menegaki & Tugcu, 2017). Simultaneously, energy serves as the fundamental support for the industrial sector. In recent years, the global community has observed a surge in development and economic growth, driven by the significant role of energy in industrialization. This has led to a substantial increase in commerce, income, and energy consumption worldwide (Hassine & Harrathi, 2017).

The demand for energy is steadily kept rising as a result of the swift progress of industrialization, population expansion, advancements in technology, and the proliferation of machines and automobiles (Koç & Kaplan, 2008). Renewable energy sources have arisen as potential substitutes for conventional fuels, especially during the times when energy crises have emerged such as in 1980s, and the unpredictable fluctuations in oil prices. In the 1990s, renewables were associated with sustainable development and became a component of global efforts to combat climate change (Gan, Eskel& and Kolshus, 2007).

Energy is acknowledged as a crucial determinant for economic expansion (Sadorsky, 2009). Historically, coal, natural gas, and oil have been recognized as the most efficient and influential energy sources, therefore playing a crucial role in driving economic progress (Ellabban, Abu-Rub & Blaabjerg, 2014). According to projections, the global population is expected to increase from 7.8 billion in 2021 to 8.5 billion in 2030 and 9.7 billion in 2050, representing a growth of about 25% over a span of 29 years. The global population is experiencing a constant rise, which leads to increase in demand for and use of energy increasingly through the world (IEA, 2022). The rise in energy consumption gives rise to two significant issues: the exhaustion of readily available energy resources and the escalation of global warming due to the rapid surge in greenhouse gas emissions (Karhan, 2019). It is now commonly acknowledged that without taking significant actions to reduce global warming, the world may face not only a decrease in economic growth but, more crucially, a severe environmental disaster (Adamantiades & Kessides, 2009; Reddy & Assenza, 2009). The recognition of non-renewable energy as the primary catalyst for global warming and climate change gives rise to environmental apprehensions and volatility in fossil fuel costs, which detrimentally impact investment choices (Destek & Aslan, 2017). These challenges have prompted society and institutions to investigate alternative energy sources as substitutes for conventional non-renewable energy sources (Öztürk & Bilgili, 2015). The resolution for these issues entails a shift towards an enduring worldwide energy framework that can offer broader electricity accessibility, a more pristine environment, augmented utilization of renewable energy, amplified investments in eco-friendly technology, and enhancements in energy efficiency (Bhattacharya, Paramati, Ozturk and Bhattacharya, 2016).

Over the past few years, there has been an increment in efforts to decrease greenhouse gas (GHG) emissions, which are nevertheless linked to the growing use of non-renewable energy sources. Subsequent to this advancement, there has been a notable increase in attention from many stakeholders, including as policymakers, policy analysts, energy dealers, consumers, and academics. Consequently, numerous nations have substantially augmented their investments in the production of renewable energy in order to satisfy the escalating need for renewable energy (Al-Mulali, Fereidouni, Lee & Sab, 2013).

Renewable energy pertains to harnessing natural environmental cycles to generate an inexhaustible energy source that is environmentally non-polluting (Radhi, 2012; Shah et al., 2011). Renewable energy is different from non-renewable energy sources since it can replenish itself as it is used. Non-renewable energy sources, on the other hand, cannot regenerate themselves and there is a risk of running out of these resources in the future (Koç & Kaya, 2015). Renewable energy include solar energy, hydroelectric power, wind power, marine energy, geothermal power, hydrogen power, and biomass energy. They are referred to as "green energies" by certain researchers (Tsaiba et al., 2017). Renewable energy sources address the dual requirement for reliable and limitless energy sources, while also ensuring the production of various types of energy without causing harm to the environment, particularly by avoiding the release of greenhouse gas emissions (Saidia & Omrib, 2020). These energy sources are considered clean, safe, and inexhaustible, in contrast to conventional energy sources (Apergis & Danuletiu, 2014).

Therefore, governments and academic scholars have prioritized the crucial significance of renewable energy in fostering economic development (Adewuyi & Awodumi, 2017). Therefore, in addition to an extensive literature on the link between overall energy consumption and economic growth (Francis et al., 2007; Hondroyiannis et al., 2002; Ozturk et al., 2010; Sinha et al., 2017), there is also research about relationship between renewable energy and economic growth (Apergis & Payne, 2010; Sadorsky, 2009; Sarı & Soytaş, 2004). The majority of studies prove that renewable energy increases economic growth (Adams et al., 2018; Arain et al., 2020; Bhattacharya et al., 2016; Inglesi-Lotz, 2015; Ito, 2017; Saidia & Omrib, 2020; Tugcu et al., 2012; Wang et al., 2022; Zafar et al., 2019).

This study aims to examine the relationship between REC and GDP from the perspective of the BRIC-T countries. The selection of BRICS countries was based on their economic composition and significant global impact. These countries possess not just strong economic growth but also abundant natural resources and substantial energy reserves. The BRICS economies are dedicated to enhancing energy efficiency and preserving resources. China is the foremost country in terms of enhancing energy efficiency among these nations. In this study, Türkiye was included in the BRICS[1]

[1] South Africa was not included in the analysis due to missing data.

countries, and both the panel and the countries were assessed individually. The research revealed that the fixed effects model was suitable for the given data set. The model is subjected to testing in order to see if it meets the assumptions. Additionally, the Driscoll-Kraay robust standard estimator is calculated to account for any departures from these assumptions.

The literature on the research is included in the study's second section. The model and data set are presented in the third part; the approach and results are shown in the fourth. The conclusion and evaluation are contained in the fifth part.

1. Literature Review and Conceptual Background

There are four opinions that can be used to examine the relationship between economic growth and energy use. According to the growth hypothesis, there is a unidirectional causal relationship between energy consumption and economic growth, and energy consumption has a significant influence on the process of economic growth. In this case, putting energy conservation policies into practice will hurt economic growth. According to the conservation hypothesis, energy consumption and economic growth are causally related. The adoption of conservation measures won't impede economic growth in these circumstances. According to the feedback hypothesis, energy consumption and economic development are correlated, meaning that changes in one variable has an equivalent impact on the other. According to this theory, every change in energy use will have a negative impact on economic growth. The neutrality hypothesis asserts that energy consumption and economic growth are independent of each other and do not influence each others (Bhattacharya et al., 2016).

The objective of this part is to critically examine the existing body of research that explores the impact of renewable energy on sustainable economic growth. This literature is presented in Table 1.

Table 1. Selected studies on the relationship between REC and GDP

Author(s)	Technique	Region/sample period	Findings
Apergis and Payne (2010)	Panel Cointegration	13 Eurasian Countries/ 1992-2017	REC ←→GDP
Apergis and Payne (2011)	Panel Cointegration	Central America / 1980-2006	REC ←→GDP
Apergis and Payne (2012)	Panel Cointegration	80 Countries /1990-2007	REC ←→GDP
Bakırtaş and Çetin (2015)	Pedroni Panel Cointegration	G-20/1992-2010	GDP ↑ REC ↑
Büyükyılmaz and Mert (2015)	MS-VAR	Türkiye/1960-2010	REC ←→GDP
Chang et al. (2015)	Panel Granger Causality	G-7/1990-2011	REC ←→GDP
Bhattacharya et al. (2016).	Panel Cointegration	38 Countries /1991-2012	REC ↑ GDP ↑
Ito (2017)	Panel	42 Countries /2002-2011	FOSSİL ↑ GDP↓ (developing countries)

			REC ↑ GDP ↑ (long term)
Adams et al. (2018)	Panel Cointegration	30 Sub-Saharan African Countries/1980-2012	NON-REC ↑ GDP ↑ REC ↑ GDP ↑
Bulut and Muratoglu (2018)	Panel Cointegration / Causality	Türkiye/1990-2015	REC ≠ GDP
Alper (2018)	Bayer-Hanck Cointegration, Toda-Yamamoto	Türkiye /1990-2017	REC ↑ GDP ↑ GDP → REC
Durğun and Durğun (2018)	ARDL Toda-Yamamoto	Türkiye /1980-2015	REC →GDP
Erdoğan et al. (2018)	Johansen Cointegration, VECM	Türkiye /1998-2015	REC →GDP (long term)
Apaydın et al. (2019)	NARDL	Türkiye /1965-2017	REC and GDP (long term: Asymmetric relationship)
Bayar and Gavriletea (2019)	Panel Cointegration, Panel Causality	Developing Countries / 1992-2014	REC→ GDP
Can and Korkmaz (2019)	Toda Yamamato, ARDL	Bulgaria /1990-2016	REC→ GDP
Arain et al. (2020)	Partial and multiple wavelet coherence	China/1979-2017	REC ↑ GDP ↑
Rahman and Velayutham (2020)	Panel FMOLs, Panel DOLS	Five South Asian countries/1990-2014	REC ↑ GDP ↑ GDP → REC
Wang and Wang (2020)	Panel	34 Countries/2005-2016	REC ↑ GDP ↑
Shahbaz et al. (2020)	FMOLS DOLS	38 Countries / 1990-2018	REC ↑ GDP ↑ NON- REC ↑ GDP ↑
Akram et al. (2021)	Dumitrescu-Hurlin Heterogeneous Panel Causality Test	BRICS/ 1990-2014	REC ↑ GDP↓ REC ←→GDP
Eygü (2022)	ARDL Toda-Yamamoto	Türkiye / 1995-2020	REC →GDP
Muazu et al. (2023)	Panel	54 African Countries/ 1990-2018.	REC ↑ GDP↓
Hieu and Mai (2023)	Movement Quantile Regression (MMQR)	80 Developing Countries/ 1990 to 2020	REC ↑ GDP ↑ NON- REC ↑ GDP ↑ (developing countries)

These experiments yielded disparate outcomes. The findings can be succinctly described as follows:

i) In general, most of the studies in the literature find a positive impact of REC on GDP (Adams et al., 2018; Alper, 2018; Arain et al., 2020; Bakırtaş & Çetin, 2015; Bhattacharya et al., 2016; Büyükyılmaz & Mert, 2015; Hieu & Mai, 2023; Ito, 2017; Rahman & Velayutham, 2020; Shahbaz et al., 2020; Wang & Wang, 2020).

ii) In the reviewed literature, only a few studies (Akram et al., 2021; Muazu et al., 2023) concluded that REC reduces GDP. One study (Apaydın, Güngör & Taşdoğan, 2019) also found an asymmetric relationship.

iii) Some studies in the literature show a bidirectional relationship between REC and GDP (Apergis & Payne, 2010, 2011, 2012; Chang et al., 2015); some studies (Bayar & Gavriletea, 2019; Can & Korkmaz, 2019; Durun & Durun, 2018; Erdoğan et al., 2018; Eygü, 2022) found a unidirectional relationship from GDP to REC; and some studies (Alper, 2018; Rahman & Velayutham, 2020) found a unidirectional relationship from GDP to REC. One study (Bulut & Muratoglu, 2018) found no relationship between REC and GDP.

2. Dataset and Model

The study analyzes the impact of REC on GDP in BRIC-T for the period 1990–2020. The variables used in the study and their explanations are given in Table 2.

Table 2. Variables and Explanations

Abbreviations	Variables	Source
GDP	Per capita GDP	WB
REC	Renewable energy consumption (% of total final energy consumption)	WB
GFC	Gross fixed capital formation (current US$)	WB
TRADE	Trade (% of GDP)	WB
FDI	Foreign direct investment, net inflows (% of GDP)	WB

Note: In order to obtain more robust results, GDP and GFC variables have been converted to natural logarithmic form.

This study uses panel data analysis to observe the growth and consumption of renewable energy in the BRIC-T countries between 1990 and 2020. The variables to be used in the analysis are REC, GDP, GFC, TRADE, and FDI. The data were obtained from the World Bank's database.

The impact of REC on GDP in five countries in the period 1990–2020 is analyzed via following functional relationship:

Model: $lnGDP = \beta_{0it} + \beta_{1it}REC + \beta_{2it}GFC + \beta_{3it}TRADE + \beta_{4it}FDI + \varepsilon_{it}$

In the equations, i = 1, 2, 3,...N denotes horizontal cross-section units, t = 1, 2, 3,...T denotes the time dimension, and Ɛ denotes the panel error term. The variables in the model were tested by the panel data analysis method using the STATA 15.0 program.

3. Methods and Findings

The empirical results obtained by analyzing BRIC-T countries within the framework of panel data analysis between 1990 and 2020 were reported below. First of all, summary statistics of the variables used in the study are presented in Table 3.

Table 3. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	155	3.6283	.3938	2.7233	4.0856
REC	155	25.9178	16.8451	3.18	52.95
GFC	155	10.7401	1.5305	7.7349	12.7952
TRADE	155	40.3328	14.889	15.1556	110.5771
FDI	153	2.0367	1.4275	.02722	6.1868

The panel data analysis method was used to test the data in the model that was constructed to investigate the correlation between growth and renewable energy usage. The issue of multicollinearity may arise in panel regression models due to the strong linear correlation among independent variables. Calculating the parameters became challenging due to the strong connection among the independent variables (Gujarati, 1999). Hence, prior to estimating the model, it is imperative to assess whether there exists a multicollinearity issue among the independent variables. The variance inflation factor (VIF) test is employed to identify this issue. This test allows for the quantification of the level of multicollinearity in parameter estimations and variances. Hence, the extent of its deviation from the actual value is ascertained. When multicollinearity occurs, the variances of parameter estimations tend to grow. The VIF criterion is employed to ascertain if this rise is a result of multicollinearity and if its impact is statistically significant. A multicollinearity problem arises when the VIF value is 10 or above. If the number is below 10, it signifies the absence of multicollinearity issues among the variables (Hair et al., 1998; Salkin & Rasmussen, 2007). The corresponding outcomes are displayed in Table 4.

Table 4. VIF Statistics

		REC	GFC	TRADE	FDI	
Model	VIF	2.58	1.09	2.58	1.08	
	1/ VIF	0.3874	0.9150	0.3872	0.9247	
	Mean VIF	1.83	1.83	1.83	1.83	

If we look at the VIF values in Table 4, it is seen that the VIF values of the variables are less than 10, which indicates that there is no multicollinearity problem.

After that, unit root tests were conducted for the variables. According to the unit root test results, GDP I(0) and REC I(0) are stationary at level, while GFC I(1) and TRADE I(1) variables are stationary at difference 1. Therefore, techniques such as cointegration tests and panel ARDL cannot be used. Therefore, Driscoll kray estimator is used.

Following the assessment of potential multicollinearity, we then proceeded to select the appropriate estimation method for the panel data analysis. The pertinent test results done in this context are displayed in Table 5.

Tablo 5. Results of F test, LM, and Hausman Test

	Tests	Type	Statis.	Decision	
All Countries	F-Test	Pooled	F-sta.	570.10	FE
		FE	Prob	0.000	
	LM Test	Pooled	χ^2 sta.	0.00	Pooled
		RE	Prob> χ^2	1.0000	
	H-Test	FE	χ^2 sta.	141.60	FE
		RE	Prob	0.0000	

In determining the efficient estimator, we used the F-Test (for FE and pooled) in the first stage, the LM test (for RE and pooled) in the second stage, and the Hausman test (for FE and RE) in the last stage. According to the test results in Table 5, the FE model is the most efficient estimator for the countries.

In panel data analyses, in the presence of at least one of the problems of autocorrelation, heteroscedasticity, or inter-unit correlation, efficient but inconsistent estimates are obtained. For this reason, robust standard errors should be calculated without changing the coefficient values of the variables, or estimators that may be appropriate for this situation (Yerdelen Tatoğlu, 2012). In the panel where the efficient estimator is the RE model, the M-Wald test is used to detect heteroscedasticity, Durbin-Watson and Baltagi-Wu LBI tests are used to detect autocorrelation, and Pesaran tests are used for cross-sectional dependence.

Table 6. Heteroscedasticity, Autocorrelation, and CD Test Results

			Model	
		Tests	**Test statis.**	**Decision**
All Countries	HC	M-Wald	274.46	+
			0.000	
	AC	D-W and Baltagi-Wu LBI	.15044225	
			.25673729	+
	CD	Pesaran	2.338	+
			0.0194	

AC, Autocorrelation; HC, Heteroscedasticity; +, Available.

In the model presented in Table 6, the first step is to determine whether there is a problem of varying variance. For this purpose, the M-Wald test was used. According to the results of the test, the null hypothesis H_0, which states "Variances between units are equal," is rejected. In other words, there is a problem of variance in the model. In the second stage, the Durbin-Watson and Baltagi-Wu tests were used to determine whether there was an autocorrelation problem. Since the results of the test are less than the critical value of 2, the null hypothesis H_0, "There is no correlation between error terms," is rejected. In other words, it is seen that there is an autocorrelation problem. When the results are analyzed, it is found that the relevant model has both variance and autocorrelation problems, and there is also cross-sectional dependence between units in the panel data set.

Table 7. Estimation Results

Dependent variable (lnGDP)	C	REC	GFC	TRADE	FDI	R^2
Panel (All countries)	-.91394 (.436767)	-.002233 (.001161)	.431861* (.038568)	-.000993 (.0008)	.006284 (.005083)	0.8457
Brazil	1.6833* (0.06211)	.000095 (.000755)	.184568* (.005590)	.004158* (.000387)	.0016513 (.001368)	0.9812
China	1.523849* (.266554)	-.0014089 (.0009353)	.2148085* (.02236)	.001443*** (.0008376)	-.030018* (.007307)	0.9529
India	-1.3034 (.97112)	-.009613* (.003420)	.426912* (.074955)	-.0046495* (.00085)	-.000878 (.004923)	0.9884
Russia	-2.782577* (.374434)	-.041256 (.040722)	.540564* (.021673)	-.000377 (.00023)	.000538 (.004832)	0.9915
Türkiye	-18.7950* (.2.3287)	.009635* (.003073)	2.87791* (.29901)	-.00088 (.00142)	.014742** (.00634)	0.9542

Note: *, **, *** indicate the significance level of %1, %5, %10, respectively.

Table 7 presents the estimation results. These results are evaluated on a panel and country basis. According to the panel results, renewable energy consumption, which is the main subject of the study, is statistically insignificant. Trade openness and FDI are also insignificant. Only GFC is significant. According to a 1% increase in gross fixed capital formation increases growth by 0.43%. In addition to the panel results, country-specific results are also obtained to examine the impact of renewable energy consumption on economic growth.

When we evaluate countries separately, the following results emerge:

- Renewable energy consumption and foreign direct investments are statistically insignificant in Brazil. While gross fixed capital formation and trade openness variables are significant, a 1% increase in gross fixed capital formation increases growth by 0.18% and a 1% increase in trade openness increases growth by 0.004%.
- Renewable energy consumption in China is statistically insignificant. However, a 1% increase in gross fixed capital formation and trade openness increases growth by 0.21% and 0.001% respectively, while an increase in FDI decreases growth by -0.030%.
- In India, a 1% increase in renewable energy consumption reduces growth by -0.009%. A 1% increase in gross fixed capital formation increases growth by 0.426%, while a 1% increase in trade openness decreases growth by -0.004%. In addition, the foreign direct investment variable is insignificant.
- In Russia, a 1% increase in gross fixed capital formation increases growth by 0.540%. Other variables are insignificant.
- In Turkiye, a 1% increase in renewable energy consumption increases growth by 0.009%, a 1% increase in gross fixed capital formation increases growth by 2.87% and a 1% increase in foreign direct investment increases growth by 0.014%. The trade openness variable is statistically insignificant.

In general, when we evaluate the findings both panel-wise and country-wise, the effect of renewable energy consumption on growth is negative effect in China, India, Russia and a positive effect in Brazil and Turkiye. However, it is statistically significant only in India and Turkiye. In all countries, the increase in gross fixed capital formation has a positive effect on growth and is statistically significant. The effect of trade openness on growth is statistically significant in Brazil (positive), China (positive) and India (negative). FDI is statistically significant only in China and Turkiye. FDI affects growth negatively in China and positively in Turkiye.

4. Conclusion

It is often known that energy plays a significant role in determining economic development and progress. Energy is essential for most countries' advancement in social and economic spheres as well as raising living standards. Concurrently with the global population growth and economic development, there is a tremendous increase in the consumption of energy resources. Furthermore, energy has emerged as a significant area of study due to the growing recognition of the gravity of global climate change and the need for environmental preservation. Studies have determined that energy can be categorized into two distinct types: renewable and non-renewable. Renewable energy possesses the capacity to progressively supplant traditional energy sources. An increasing body of research has concentrated on the correlation between the utilization of renewable energy and the advancement of the economy.

This study examines the impact of renewable energy consumption on economic growth in BRIC-T countries. Driscoll & Kraay estimator is used for this study. According to the panel results, renewable energy consumption, trade openness and foreign direct investment variables are statistically insignificant. Only the increase in gross fixed capital formation increases growth. When countries are analyzed separately, the increase in gross fixed capital formation has a positive effect on growth in all countries, but it is statistically significant only in India and Turkiye. The effect of trade openness on growth is statistically significant in Brazil (positive), China (positive) and India (negative). FDI is statistically significant only in China and Turkiye. FDI affects growth negatively in China and positively in Turkiye.

The study shows that renewable energy consumption has a negative impact on economic growth (except for Brazil and Turkiye). However, it is statistically significant in India and Turkiye. While renewable energy consumption has a negative effect on growth in India, it has a positive effect in Turkiye. These two results can be interpreted as follows.

(i) The negative impact of renewable energy consumption on economic growth in India is consistent with Akram et al. (2021) and Muazu et al. (2023). The use of renewable energy contributes to energy diversity and security, nature, environment and public health. However, it does not contribute positively to economic growth, especially due to the high initial installation costs of the facilities to be established for renewable energy production, and on the contrary, it may negatively affect growth. In order to reduce the negative impact of renewable energy consumption on economic growth and turn it into a positive impact, it is necessary to continue energy production by using existing energy resources. While this process continues, renewable energy potential can be utilized and costs can be reduced. There is also a need to allocate more financial resources and funds to small, medium and large enterprises in the renewable energy sector.

(ii) The positive effect of renewable energy consumption on growth in Turkiye is a remarkable finding. In the literature reviewed in general, the effect of renewable energy consumption on growth is positive (Adams et al., 2018; Alper, 2018; Arain et al., 2020; Bakırtaş & Çetin, 2015; Bhattacharya et al., 2016; Büyükyılmaz & Mert, 2015; Hieu & Mai, 2023; Ito, 2017; Rahman & Velayutham, 2020; Shahbaz et al., 2020; Wang & Wang, 2020). In terms of the Turkish sample, the current study is consistent with Alper's (2018) study. It is very important that the use of renewable energy is beneficial in terms of its environmental impact. However, more importantly, increasing the use of renewable energy can provide significant benefits in terms of Turkiye's potential to reduce energy imports. As the share of renewable energy in Turkiye's energy use increases, the current account deficit due to energy imports will decrease and the resources paid for energy imports can be used in different areas.

Contribution Rate and Conflict of Interest Statement

All stages of the study were designed by the author(s) and contributed equally. There is no conflict of interest in this article.

Ethics Statement and Financial Support

Ethics committee principles were followed in the study. Ethics Committee Report is not required in the study. There has been no situation requiring permission within the framework of intellectual property and copyrights.

References

Adamantiades, A. & Kessides, I. (2009). Nuclear power for sustainable development: Current status and future prospects. *Energy Policy*, 37, 5149-5166. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421509005436

Adams, S., Klobodu, E. K. M. & Apio, A. (2018). Renewable and non-renewable energy, regime type and economic growth. *Renewable Energy,* 125, 755-767. doi: https://doi.org/10.1016/j.renene.2018.02.135

Adewuyi, A. O. & Awodumi, O. B. (2017). Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. *Renewable and Sustainable Energy Reviews,* 69, 275-291. doi: https://doi.org/10.1016/j.rser.2016.11.178

Akram, R., Chen, F., Khalid, F., Huang, G. & Irfan, M. (2021). Heterogeneous effects of energy efficiency and renewable energy on economic growth of BRICS countries: A fixed effect panel quantile regression analysis. *Energy,* 215, 119019.doi: https://doi.org/10.1016/j.energy.2020.119019

Alper, F. Ö. (2018). Yenilenebilir enerji ve ekonomik büyüme arasındaki ilişki: 1990-2017 Türkiye örneği [The relationship between renewable energy and economic growth: 1990-2017 the case of

Turkey. *Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 8(2), 223-242. doi: https://doi.org/10.18074/ckuiibfd.466782

Al-mulali U, Fereidouni, H.G., Lee, J. Y. & Sab, C. N. B. C. (2013). Examining the bi-directional long-run relationship between renewable energy consumption and GDP growth. *Renewable Sustainable Energy Review,* 22, 209-222. doi: https://doi.org/10.1016/j.rser.2013.02.005

Apaydın, Ş., Güngör, A., & Taşdoğan, C. (2019). Türkiye'de yenilenebilir enerji tüketiminin ekonomik büyüme üzerindeki asimetrik etkileri [The effects of renewable energy consumptıon on economıc growth and health expendıtures ın Turkey]. *Mehmet Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 6(1), 117-134. doi: https://doi.org/10.30794/pausbed.846221

Apergis, N. & Payne, J.E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy,* 38, 656-660. doi: https://doi.org/10.1016/j.enpol.2009.09.002

Apergis, N. & Payne, J. E. (2011). The renewable energy consumption–growth nexus in Central America. *Applied Energy,* 88, 343-347. doi: https://doi.org/10.1016/j.apenergy.2010.07.013

Apergis, N. & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics,* 34, 733-738. doi: https://doi.org/10.1016/j.eneco.2011.04.007

Apergis, N. & Danuletiu, D.C. (2014). Renewable energy and economic growth: Evidence from the sign of panel long-run causality. *International Journal of Energy Economics and Policy,* 4(4), 578-587. Retrieved from https://dergipark.org.tr/tr/download/article-file/361344

Arain, H., Sharif, A., Akbar, B. & Younis, Y. (2020). Dynamic connection between inward foreign direct investment, renewable energy, economic growth and carbon emission in China: Evidence from partial and multiple wavelet coherence. *Environmental Science and Pollution Research,* 27, 40456-40474. doi: 10.1007/s11356-020-08836-8

Bakırtaş, İ., & Çetin, M. A. (2016). Yenilenebilir enerji tüketimi ile ekonomik büyüme arasındaki ilişki: G-20 ülkeleri [The Relationship between Renewable Energy Consumption and Economic Growth: G-20 Countries]. *Sosyoekonomi,* 24(28), 131-145. doi: https://doi.org/10.17233/se.43089

Bayar, Y. & Gavriletea, M. D. (2019). Energy efciency, renewable energy, economic growth: evidence from emerging market economies. *Quality & Quantity,* 53, 2221-2234. doi: 10.1007/s11135-019-00867-9

Bhattacharya, M., Paramati, S. R., Ozturk, I. & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy,* 162, 733-741. doi: https://doi.org/10.1016/j.apenergy.2015.10.104

Bulut, U. & Muratoglu, G. (2018). Renewable energy in Turkey: Great potential, low but increasing utilization, and an empirical analysis on renewable energy-growth nexus. *Energy Policy,* 123, 240-250. doi: https://doi.org/10.1016/j.enpol.2018.08.057

Büyükyılmaz, A., & Mert, M. (2015). CO2 emisyonu, yenilenebilir enerji tüketimi ve ekonomik büyüme arasındaki ilişkinin MS-VAR yaklaşımı ile modellenmesi: Türkiye örneği [Relatıonshıp among CO2 emıssıons, renewable and economıc growth wıth modelıng ms-var approach: The case of Turkey]. *Journal of World of Turks,* 7(3), 103-117. Retrieved from https://www.dieweltdertuerken.org/index.php/ZfWT/article/view/719

Can, H. & Korkmaz, Ö. (2018). The relationship between renewable energy consumption and economic growth. *International Journal of Energy Sector Management,* 13(3), 573-589. doi: 10.1108/IJESM-11-2017-0005

Chang, T., Gupta, R., Inglesi-Lotz, R., Simo-Kengne, B., Smithers, D. & Trembling, A. (2015). Renewable energy and growth: Evidence from heterogeneous panel of G7 countries using Granger causality. *Renewable and Sustainable Energy Reviews,* 52, 1405-1412. doi: https://doi.org/10.1016/j.rser.2015.08.022

Destek, M. A. & Aslan, A. (2017). Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renewable Energy,* 111, 757-763. doi: https://doi.org/10.1016/j.renene.2017.05.008

Durğun, B., & Durğun, F. (2018). Yenilenebilir enerji tüketimi ile ekonomik büyüme arasında nedensellik ilişkisi: Türkiye örneği [The causalıty relatıonshıp between renewable energy consumptıon and economıc growth: Evıdence from Turkey]. *International Review of Economics and Management,* 6 (1), 1-27. doi: 10.18825/iremjournal.347200

Ellabban, O., Abu-Rub, H. & Blaabjerg, F. (2014). Renewable energy resources: current status, future prospects and their enabling technology. *Renewable and Sustainabla Energy Reviews,* 39, 748-764. doi: https://doi.org/10.1016/j.rser.2014.07.113

Erdoğan, S., Dücan, E., Şentürk, M., & Şentürk, A. (2018). Türkiye'de yenilenebilir enerji üretimi ve ekonomik büyüme ilişkisi üzerine ampirik bulgular [Empırıcal results on renewable energy productıon and economıc growth relatıons ın Turkey]. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 11(2), 233-246. doi: 10.25287/ohuiibf.382686

Eygü, H. (2022). Yenilenebilir enerji kaynaklarının kullanımı ve ekonomik büyüme ilişkisi: 1995–2020 Türkiye örneği [The relationship between the use of renewable energy sources and economic growth: Case of Turkey between the years 1995–2020]. *Gazi İktisat ve İşletme Dergisi,* 8(2), 387-397. doi: : https://doi.org/10.30855/gjeb.2022.8.2.012

Francis, B.M., Moseley, L. & Iyare, S.O. (2007). Energy consumption and projected growth in selected Caribbean countries. *Energy Economics,* 29, 1224-1232. doi: https://doi.org/10.1016/j.eneco.2007.01.009

Gan, L., Eskeland, G.S. & Kolshus, H.H. (2007). Green electricity market development: lessons from Europe and the US. *Energy Policy,* 35, 144-155. doi: https://doi.org/10.1016/j.enpol.2005.10.008

Gujarati, D. N. (1999). *Temel ekonometri,* (G. Ş. Ü. Şenesen, Çev.), İstanbul: Literatür Yayınları.

Hair, J., Anderson, R., Tatham, R. & William, B. (1998). *Multivariate data analysis.* New Jersey: Prentice-Hall.

Hassine, M.B. & Harrathi, N. (2017), The causal links between economic growth, renewable energy, financial development and foreign trade in gulf cooperation council countries. *International Journal of Energy Economics and Policy,* 7(2), 76-85. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/3976/2657

Hieu, V. M. & Mai, N. H. (2023). Impact of renewable energy on economic growth? Novel evidence from developing countries through MMQR estimations. *Environmental Science and Pollution Research,* 30(1), 578-593. doi: 10.1007/s11356-022-21956-7

Hondroyiannis, G., Lolos, S. & Papapetrou, E. (2002). Energy consumption and economic growth: assessing the evidence from Greece. *Energy Economics,* 24, 319-336. doi: https://doi.org/10.1016/S0140-9883(02)00006-3

Inglesi-Lotz, R. (2015). The impact of renewable energy consumption to economic growth: A panel data application. *Energy Economics,* 53, 58-63. doi: https://doi.org/10.1016/j.eneco.2015.01.003

International Energy Agency (2022). *Energy access outlook. From poverty to prosperity: world energy outlook special report 2022.* Retrieved from https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf.

Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics,* 151, 1-6. doi: https://doi.org/10.1016/j.inteco.2017.02.001

Karhan, G. (2019). Does renewable energy ıncrease growth? Evidence from EU-19 countries. *International Journal of Energy Economics and Policy,* 9(2), 341-346.doi: https://doi.org/10.32479/ijeep.758

Koç, E., & Kaplan, E. (2008, Mart). Dünya'da ve Türkiye'de genel enerji durumu 1.bölüm: Dünya değerlendirilmesi. *Termodinamik*. Retrieved from https://www.termodinamik.info/bilimsel/dunya-da-ve-turkiye-de-genelenerjidurumu-1-bolum-dunya-degerlendirmesi.

Koç, E. ve Kaya, K. (2015). Enerji kaynakları–yenilenebilir enerji durumu [Energy resources–state of renewable energy]. *Mühendis ve Makina,* 56(668), 36-47. Retrieved from https://dergipark.org.tr/tr/download/article-file/1099827

Menegaki, A.N. & Tugcu, C.T. (2017). Energy consumption and sustainable economic welfare in G7 countries; A comparison with the conventional nexus. *Renewable and Sustainable Energy Reviews,* 69, 892-901. doi: https://doi.org/10.1016/j.rser.2016.11.133

Muazu, A., Yu, Q. & Liu, Q. (2023). Does renewable energy consumption promote economic growth? An empirical analysis of panel threshold based on 54 African countries. *International Journal of Energy Sector Management,* 17(1), 106-127.doi: 10.1108/IJESM-09-2021-0003

Ozturk, I. & Bilgili, F. (2015). Economic growth and biomass consumption nexus: dynamic panel analysis for Sub-Sahara African countries. *Applied Energy,* 137, 110-116. doi: https://doi.org/10.1016/j.apenergy.2014.10.017

Ozturk, I., Aslan, A. & Kalyoncu, H. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. *Energy Policy,* 38, 4422-4428. doi: https://doi.org/10.1016/j.enpol.2010.03.071

Radhi, H. (2012). Trade-off between environmental and economic implications of PV systems integrated into the UAE residential sector. *Renewable Sustainable Energy Review,* 16(5), 2468-2474. doi: https://doi.org/10.1016/j.rser.2012.01.048

Rahman, M. M. & Velayutham, E. (2020). Renewable and non-renewable energy consumption-economic growth nexus: new evidence from South Asia. *Renewable Energy,* 147, 399-408. doi: https://doi.org/10.1016/j.renene.2019.09.007

Reddy, B.S. & Assenza, G.B. (2009). The great climate debate. *Energy Policy,* 37, 2997-3008. doi: https://doi.org/10.1016/j.enpol.2009.03.064

Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economy,* 31(3), 456-462.doi: https://doi.org/10.1016/j.eneco.2008.12.010

Saidia, K. & Omrib, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research,* 186(3), 1-11. doi: https://doi.org/10.1016/j.envres.2020.109567

Salkin, N. J. & Rasmussen, K. (2007). *Encyclopedia of measurements and statistics.* California: Volume 1.

Sari, R. & Soytas, U. (2004). Disaggregate energy consumption, employment, and income in Turkey. *Energy Economics*, 26, 335-344. doi: https://doi.org/10.1016/j.eneco.2004.04.014

Shah, A. A, Rashidi, R. S, Bhutto, A. & Shah, A. (2011). The real life scenario for diffusion of renewable energy technologies (RETs) in Pakistan – lessons learned through the pilot field study under physical community. *Renewable and Sustainable Energy Review,* 15(5), 2210-2213. doi: https://doi.org/10.1016/j.rser.2011.01.017

Shahbaz, M., Raghutla, C., Chittedi, K. R., Jiao, Z. & Vo, X. V. (2020). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. *Energy,* 207, 118162. doi: https://doi.org/10.1016/j.energy.2020.118162

Sinha, A., Shahbaz, M. & Balsalobre, D. (2017). Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. *Journal of Cleaner Production,* 168, 1217-1229. doi: https://doi.org/10.1016/j.jclepro.2017.09.071

Tsaiba, S. B., Xuec, Y., Zhange, J., Chena, Q., Liuf, Y. & Zhoug, J. (2017). Models for forecasting growth trends in renewable energy. *Renewable and Sustainable Energy Reviews,* 77, 1169-1178. doi: https://doi.org/10.1016/j.rser.2016.06.001

Tugcu, C. T., Ozturk, I. & Aslan, A. (2012). Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. *Energy Economics,* 34, 1942-1950. doi: https://doi.org/10.1016/j.eneco.2012.08.021

Wang, G., Sadiq, M., Bashir, T.,Jain, V., Ali, S. A. & Shabbir, M. S. (2022). The dynamic association between different strategies of renewable energy sources and sustainable economic growth under SDGs. *Energy Strategy Reviews,* 42, 1-6. doi: https://doi.org/10.1016/j.esr.2022.100886

Wang, Q. & Wang, L. (2020). Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. *Energy*, 207, 118200. doi: https://doi.org/10.1016/j.energy.2020.118200

Wang, Q., Dong, Z., Li, R. & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. *Energy*, 238, 122018. doi: https://doi.org/10.1016/j.energy.2021.122018

Yerdelen Tatoğlu, F. (2012). *Panel veri ekonometrisi.* İstanbul: Beta Yayınevi.

Zafar, M. W., Shahbaz, M., Huo, F. & Sinha, A. (2019). From nonrenewable to renewable energy and its impact on economic growth: The role of research & development expenditures in Asia-Pacific Economic Cooperation countries. *Journal of Cleaner Production*, 212, 1166-1178. doi: https://doi.org/10.1016/j.jclepro.2018.12.081.