Yıldız Social Science Review, Vol. 11, No. 1, pp. 1–11, 2025

Yıldız Social Science Review
Web site information: https://yssr.yildiz.edu.tr
DOI: 10.51803/yssr.1544004

Original Article / Orijinal Makale

Determining the Relationship Between Economic Growth, Carbon Emission and Energy Consumption: Panel Cointegration and Causality Approach in G20 Countries

Ekonomik Büyüme, Karbon Salımı ve Enerji Tüketimi Arasındaki İlişkinin Belirlenmesi: G20 Ülkelerinde Panel Eşbütünleşme ve Nedensellik Yaklaşımı

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ARTICLE INFO

Article history
Received: 5 September, 2024
Accepted: 7 October, 2024

Keywords:
AMG, Economic growth, G-20, global warming, granger causality, panel data

ABSTRACT

As it is known, CO_2 is a greenhouse gas. Greenhouse gases contained in fossil fuels mix with the atmosphere and cause global warming on earth. Global warming causes many negative situations such as irregular rainfall, drought, difficulties in accessing fresh water, and changes in living biology. Thus, life on earth is becoming increasingly threatened. In this study, the relationship between CO_2 emissions and renewable and fossil-based energy use, which are among the factors affecting economic growth, was applied in G-20 countries with panel data analysis. The data of the study were collected from the World Bank. A total of 589 data were studied in 19 countries and 31 time dimensions. AMG method was used for long-term estimation of the data by performing cross-section dependence, unit root tests and homogeneity tests. Granger causality test was performed between the variables. A positive relationship was found between GDP growth and CO_2, and it was found that a one-unit increase in CO_2 use would cause a 0.88-unit increase in GDP growth. Additionally, the study found that there is a unidirectional causality from renewable energy, fossil energy consumption and CO_2 usage to GDP growth.

Cite this article as: Göktolga, Z. G. (2024). Determining the Relationship Between Economic Growth, Carbon Emission and Energy Consumption: Panel Cointegration and Causality Approach in G20 Countries. *Yıldız Social Science Review, 11*(1), 1–11.

MAKALE BİLGİSİ

Makale Hakkında
Geliş tarihi: 5 Eylül 2024
Kabul tarihi: 7 Ekim 2024

Anahtar kelimeler:
AMG, ekonomik büyüme, küresel ısınma, G-20, granger nedensellik, panel veri

ÖZ

Bilindiği gibi CO_2 bir sera gazıdır. Fosil yakıtların içerdiği sera gazları atmosfere karışarak yeryüzünde küresel ısınmaya neden olmaktadır. Küresel ısınma, düzensiz yağışlar, kuraklık, tatlı suya erişimde zorluklar, canlı biyolojisinde değişiklikler gibi birçok olumsuz duruma neden olmaktadır. Bu yüzden yeryüzündeki yaşam giderek daha fazla tehdit altına girmektedir. Bu çalışmada ekonomik büyümeyi etkileyen faktörler arasında yer alan CO_2 emisyonları ile yenilenebilir ve fosil bazlı enerji kullanımı arasındaki ilişki G-20 ülkelerinde panel veri ana-

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lizi ile incelenmiştir. Araştırmanın verileri Dünya Bankası'ndan toplanmıştır. 19 ülkede ve 31 zaman boyutunda toplam 589 veri incelenmiştir. Yatay kesit bağımlılığı, birim kök testleri ve homojenlik testleri yapılarak verilerin uzun vadeli tahmininde AMG yöntemi kullanılarak, değişkenler arasında Granger nedensellik testi yapılmıştır. GSYİH büyümesi ile CO_2 arasında pozitif bir ilişki bulunmuş ve CO_2 kullanımındaki bir birimlik artışın GSYİH büyümesinde 0,88 birimlik bir artışa neden olacağı bulunmuştur. Ayrıca çalışma, yenilenebilir enerji, fosil enerji tüketimi ve CO_2 kullanımından GSYİH büyümesine doğru tek yönlü bir nedensellik olduğunu ortaya çıkarmıştır.

Atıf için yazım şekli: Göktolga, Z. G. (2024). Determining the Relationship Between Economic Growth, Carbon Emission and Energy Consumption: Panel Cointegration and Causality Approach in G20 Countries. *Yıldız Social Science Review, 11*(1), 1−11.

1. INTRODUCTION

The G20 is a group of 20 of the world's leading countries in economic terms representing more than 80% of total gross domestic product (GDP), 80% of global investment, 75% of world trade and 66% of the world's population (Paratama, 2023). 77% of the world's total CO_2 emissions (kt) are produced by G20 countries (World bank, 2024). Today's increasing energy demand also gradually increases CO_2 emissions which a greenhouse gas. Energy use and CO_2 emissions in G20 countries, which have an important place in the world economy, naturally contribute to global warming. Therefore, it is important to investigate CO_2 emissions and energy use in G20 countries.

There are two ways to meet increasing energy demand. Either using fossil-based energy or using renewable energy sources. For this reason, countries' energy production preferences may be based on fossil-based or renewable energy, sometimes out of necessity and sometimes to avoid costs. It is important to see the change over the years in countries' use of both fossil-based and renewable energy. It is also important to see the substitution of these energy types with each other over the years. Another issue is determining how these energy resources move with economic growth.

The following graphs have been prepared to see the change in data on a country basis (Wold Bank, 2024). Figure 1 shows CO_2 emissions (kt) in G20 countries. The highest CO_2 emission belong to China. It is also noteworthy that CO_2 emission are increasing in China. The country that produces the second highest CO_2 emissions is the USA. However, US emission figures have not increased over the years examined have even started to decrease slightly in recent years. There is no significant change in the emission figures of other countries.

Renewable energy consumption rates are shown in Figure 2. When consumption rates are examined, it is seen that renewable energy consumption has decreased

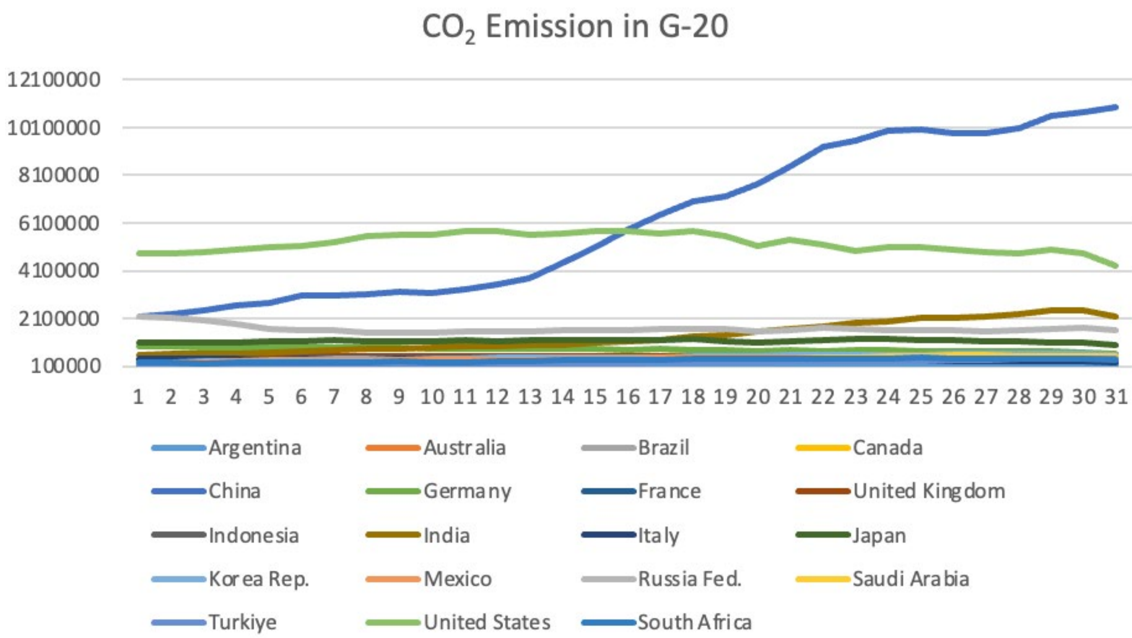

Figure 1. CO_2 emission (kt).

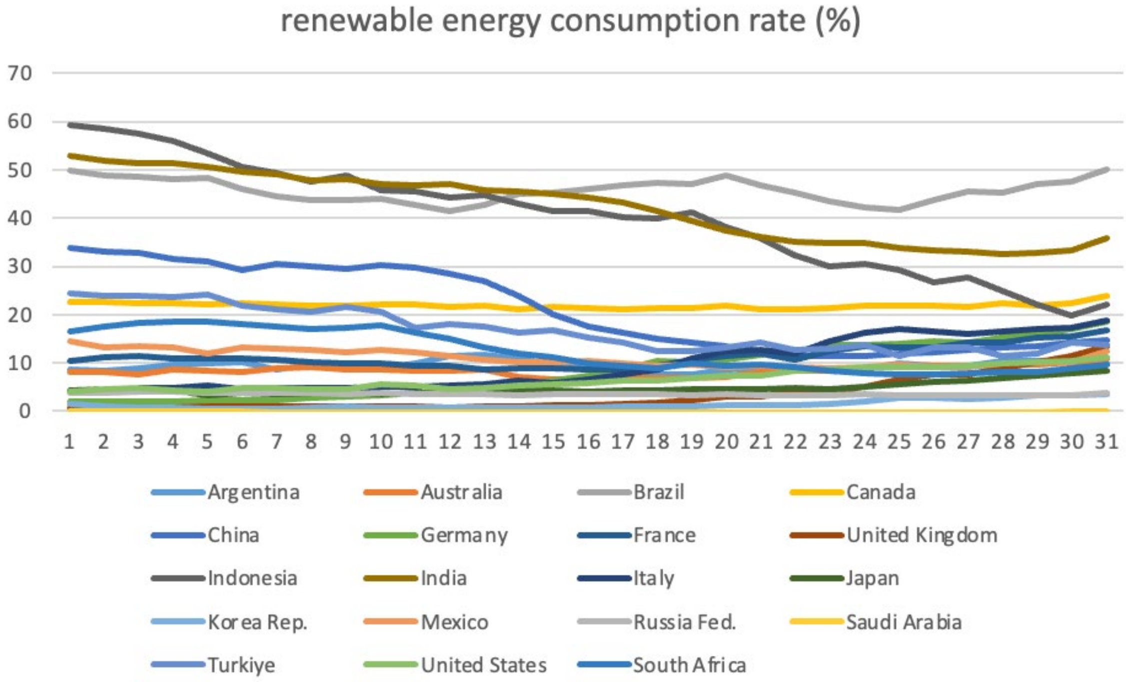

Figure 2. Renewable energy consumption rate (%).

significantly in Indonesia, India and China. Fluctuations in other countries do not appear to be very significant.

The fossil fuel consumption rate is shown in Figure 3. When the rates are examined, it is seen that fossil fuel use has increased significantly in India and Indonesia between the years examined. Additionally, it is seen that there have been significant increases in Brazil and Japan after 2015.

Figure 4 shows the GDP growth rates of G20 countries between years of 1990 and 2020. According to the figure, 1998, 2002, 2009 and 2020 are the years when serious declines occurred. These years generally represent crisis years whose effects appear with a one-year delay. These; The Asian crisis centered on Thailand in 1997 (Lane, 1999), the financial crisis centered on Turkey in 2001(Turan, 2011), the global economic crisis centered on the USA in 2008 (El-Erian, 2008), and the global contraction caused by Covid-19 in 2020.

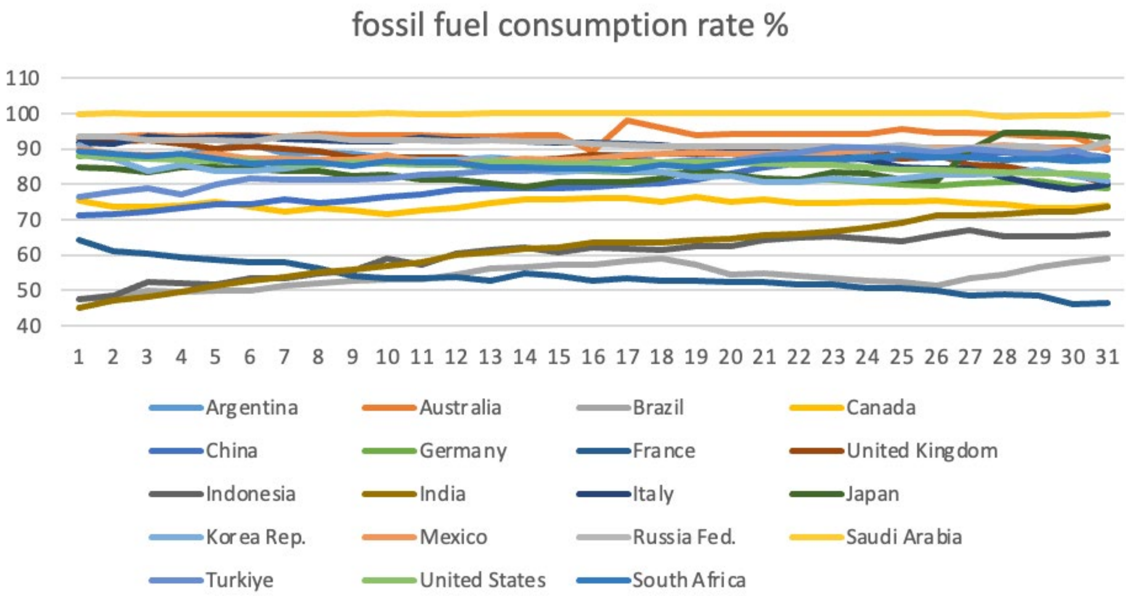

Figure 3. Fossil fuel consumption rate %.

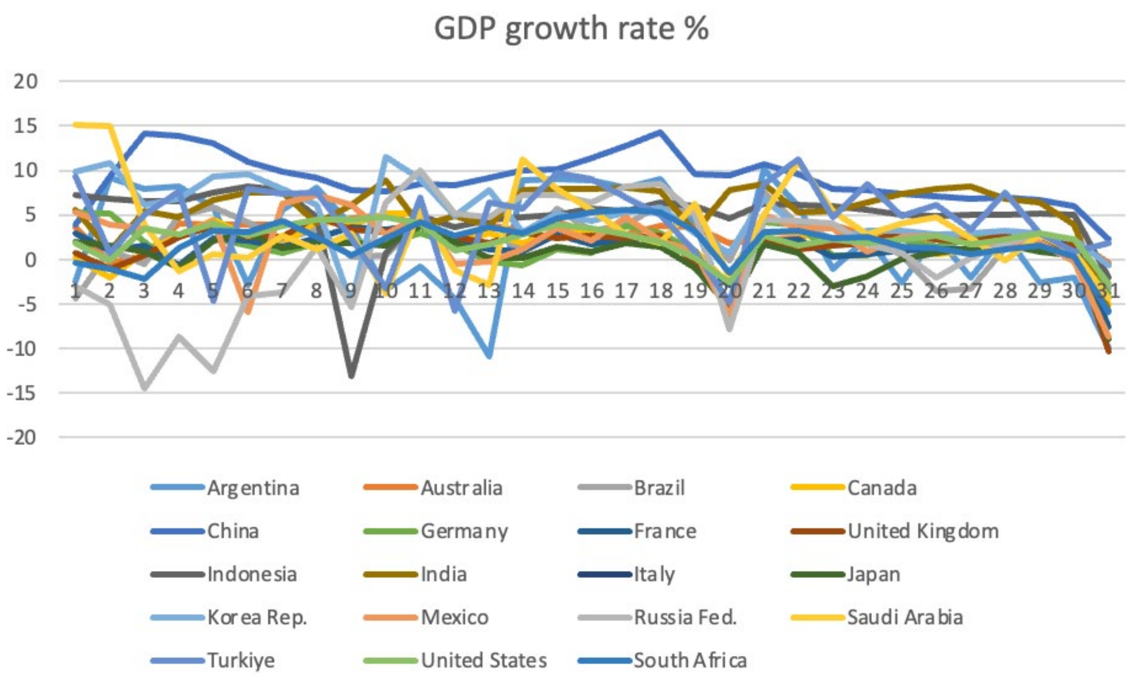

Figure 4. GDP growth rate in G20.

2. BACKGROUND AND LITERATURE REVIEW SECTIONS

One of the aims of this study is to determine whether there is a relationship between the economic growth of countries and carbon dioxide emissions. To achieve this goal, G20 countries were chosen as the study area. In the literature, studies have been conducted to determine the relationship between carbon dioxide emissions and economic growth in various countries or groups of countries. Esso and Keho (2017) conducted energy consumption, economic growth and carbon emissions in selected African countries. The relationships between CO_2 emissions, energy consumption and income were studied by Ajmi et al. (2015). In the article conducted by Zhang and Cheng (2009) energy consumption, carbon emissions and economic growth have been studied in China. Ang (2008.) examined economic development, pollutant emissions and energy consumption in Malaysia.

Another aim of this study is to determine the direction and degree of the relationship between economic growth and energy consumption in G20 countries. To achieve this goal, the energy variable has been divided into renewable and fossil fuel energies. Thus, it has been possible to see the change in the consumption of renewable energies and fossil-based energies over the years. Many studies have been conducted in the literature on the relationship between energy variables and economic growth. The first article examining the causality relationship between energy consumption and GDP using data between 1947 and 1974 was written by Kraft and Kraft (1978). Energy imports are also primarily responsible for environmental degradation. In this context, renewable energy resources are considered as an alternative to non-renewable resources in order to protect the natural environment (Yadav and Mahalik, 2024). The relationship between energy consumption and GDP is crucial for realizing their future development and growth objectives (Mishra et al., 2009). Economic growth is among the most significant issue to be considered in projecting changes in world energy consumption. Therefore, the investigation of the relationship between energy consumption and economic growth has received a great deal of attention during the past years (Omri et al., 2015). Bozoklu and Yilanci (2013) conducted a causal relationship between energy consumption and economic growth for 20 OECD countries.

It was also aimed to determine whether there is cointegration between the variables in the study. For this aim, comments were made with the Augmented Average Group (AMG) results developed by (Eberhardt and Teal, 2010) and (Eberhardt and Bond, 2009) which show long-term relationships. It was also aimed in the study to determine the causality results developed by Dumitrescu and Hurlin (2012). Causality between variables was examined bidirectionally.

Lee (2005) studied energy consumption and GDP in developing countries a cointegrated panel analysis. The impact of GDP growth, industrialization, energy use and urbanization on CO_2 emissions in developing countries was revealed by Sikder et al. (2022) through the panel ARDL approach. The relationship between energy saving and sustainable economic growth was examined by Chang and Carbello (2011) in the example of Latin America and the Caribbean. Mozumder and Marathe (2007) studied causality relationship between electricity consumption and GDP in Bangladesh. Huang et al. (2008) examined the causal relationship between energy consumption and GDP growth with a dynamic panel data approach. Oh and Lee (2004) The causal relationship between energy consumption and GDP was re-examined for Korea between 1970 and 1999. Soytaş and Sarı (2009) in her article examined the long-term Granger causality relationship between economic growth, carbon dioxide emissions and energy consumption in Turkey by controlling for gross fixed capital formation and labor. Soytaş at al (2007) in their article they investigated the impact of energy consumption and production on carbon emissions in the United States. Relationship between Electrical Energy Consumption and GDP, causal link Researched for 17 countries in Latin America, Canada and USA. Rodríguez-Caballeroa and Ventosa-Santaulàriab (2016). Relationships between GDP and electricity consumption in 10 developing Asian countries are estimated using panel data procedures. Empirical results from a single data set show that there is a unidirectional short-term causality from economic growth to electricity consumption (Chen et al., 2007). Chu and Chang (2012) conducted nuclear energy consumption, oil consumption and economic growth in G-6 countries.

Heil and Selden (1999) studied panel stationarity with structural breaks for carbon emissions and GDP. The relationships between energy consumption, pollution emission and economic growth in Nepal were studied by Bastola and Sapkota (2015). Temporal analysis of cross-country distribution patterns of carbon dioxide emissions and income was made by Coondoo and Dinda (2008). In the article written by Friedl and Getzner (2003), the relationship between economic development and carbon dioxide (CO_2) emissions was investigated for Austria, a small, open and industrialized country. Halıcıoğlu (2009) conducted an econometric study on CO_2 emissions, energy consumption, income and foreign trade in Turkey.

3. DATA AND METHODOLOGY

3.1. Data

The data of the research consists of G20 countries which are Argentina, Australia, Brazil, Canada, China, Germany, France, Indonesia, India, Italy, Japan, Korea Rep., Mexico, Russia Fed., Saudi Arabia, Turkiye, South Africa, United Kingdom, United States. The European Union is a G20 member but is not included in the data because it is not a country. Cross-sectional data were collected from these countries (N = 19). Annual data between 1990 and 2020 were used as the time period in the study (T=31). The analysis of the data was run in Stata and Eviews programs.

Table 1 shows the names, explanations and sources of the variables.

In this study, GDPG was added as a dependent variable, thus it is possible to estimate the direction and degree of the relationship between CO_2 emissions and the growth of countries. In addition, renewable energy and fossil fuel energy were added to the model and the model was established as follows equation (1).

$$GDPG_{it} = \alpha_{0i} + \beta_{1i}\, CO2_{it} + \beta_{2i}\, REC_{it} + \beta_{3i}\, FFEC_{it} + \varepsilon_{it} \quad (1)$$

The data of the variables in the model were converted to natural logarithms and the model was reconstructed as in equation (2).

$$lnGDPG_{it} = \alpha_{0i} + \beta_{1i} lnCO2_{it} + \beta_{2i} lnREC_{it} + \beta_{3i} lnFFEC_{it} + \varepsilon_{it} \quad (2)$$

In the formulas, $\beta_i(i=1,2,3)$ represents the coefficient of the independent variables, α is the constant term, ε is the stochastic term. Additionally, i refers to the cross section and t refers to time.

Descriptive statistics are shown in Table 2. A total of 589 panel data were studied for 19 countries and 31 years between 1990-2020. The mean, standard deviation, minimum and maximum values of the data are shown in Table 2.

Table 1. Variable descriptions and data sources

Variables	Explanation	Source
GDPG	GDP growth (annual %).	World Bank
	Annual percentage growth rate of gross domestic product (GDP) at market prices based on constant local currency.	
CO_2	CO_2 emissions (kt).	World Bank
	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	
REC	Renewable energy consumption (% of total final energy consumption).	World Bank
	Renewable energy consumption is the share of renewable energy in total final energy consumption.	
FFEC	Fossil fuel energy consumption (% of total).	World Bank
	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	

Table 2. Descriptive statistic

Variable	Obs	Mean	Std. dev.	Min	Max
GDPG	589	2.8545	4.020373	-14.53107	15.19343
CO_2	589	1117140	1794583	100313.9	1.09e+07
REC	589	14.65886	14.19053	0.01	59.18
FFEC	589	80.68233	13.69432	45.17457	99.99678

Table 3. Correlation matrix

	GDPG	CO_2	REC	FFEC
GDPG	1.0000			
CO_2	0.1982	1.0000		
REC	0.1733	-0.0688	1.0000	
FFEC	-0.0811	0.0991	-0.7858	1.0000

The correlation matrix is shown in Table 3 to reveal the direction and degree of the relationship between the variables. When looking at the relationship between the dependent variable (GDPG) and the independent variables, it is seen that there is a positive relationship with CO_2 use and renewable energy consumption (REC), but a negative relationship with fossil fuel consumption. CO_2, as the independent variable, shows the strongest relationship with the dependent variable. As expected, a negative relationship was found between renewable energy consumption and CO_2 use. In addition, it has been determined that there is a negative relationship between renewable energy consumption and fossil fuel consumption, which are independent variables. Fossil fuel consumption is gradually decreasing as renewable energy replaces fossil fuel.

3.2. Methodology

Before running long-term coefficient estimates, it is important to find the results of cross-section test, homogeny test and unit root tests. The cross-section test is selected based on the Slope Homogeneity test results.

3.2.1. Homogeneity test and cross-section dependency test methodology

In this study, the slope heterogeneity and homogeneity test developed by (Pesaran and Yamagata, 2008) (Blomquist and Westerlund, 2013) was used. Cross-section dependency tests were performed according to the slope heterogeneity and homogeneity test results (Li et al., 2020) investigated the estimation and inference issues of heterogeneous coefficients in panel data models with common shocks. (Pesaran and Yamagata, 2008) purposed a test for large panel but the test cannot deal with the practically relevant case of heteroskedastic and/serially correlated errors. The study proposes a generalized test that accommodates both features. (Blomquist and Westerlund, 2013).

Breusch-Pagan LM, Pesaran scaled LM and Pesaran CD were used as cross-section dependency tests. While the Breusch-Pagan LM test was developed by Breusch and Pagan (1980), the Pesaran scaled LM test and the Pesaran CD test were developed by Pesaran (2021) and Pesaran and Yamagata (2008).

3.2.2. Unit root test methodology

Before performing the panel cointegration test, the stationarity of the variables must be tested. If there is cross-sectional dependence in the data, the second generation unit root test should be used. In this study, the CIPS test developed by Pesaran (2007), one of the second generation unit root tests, was used.

CIPS test proposed a simple alternative to standard augmented Dickey-Fuller (ADF) regressions, in which the lagged levels and first differences of the individual series are augmented with cross-sectional averages. New asymptotic results are obtained for both individual cross-sectionally augmented ADF (CADF) statistics and their simple averages (Pesaran, 2007: 266-267). Based on cross-sectional augmented Dickey-Fuller (CADF) statistics, the CIPS unit root test statistic is shown as follows;

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \overline{y}_{t-1} + d_i \Delta \overline{y}_t + e_{it} \quad (3)$$

$$CIPS = \frac{1}{N} \sum_{i=1}^{n} CADF_i \quad (4)$$

3.2.3. Panel cointegration test methodology

Before determining the Augmented Mean Group (AMG) estimators, the error correction model (ECM) test was performed to determine whether there was cointegration among the variables. Panel ECM test was developed by Westerlund (2007). The results obtained by Westerlund (2007) showed that the tests have good small sample properties with small size distortions and high power compared to other popular residual-based panel cointegration tests. Panel ECM test produces more consistent results in the presence of cross-sectional dependence and slope heterogeneity (Jalil, 2014). While Gt and Ga statistics show the existence of cointegration for the group averages, Pt and Pa statistics show whether there is cointegration for the entire panel. In the ECM test, the null hypothesis is no cointegration. The alternative hypothesis is that cointegration exists.

3.2.4. Cointegration estimators' methodology

After determining the existence of cointegration between variables, the next step is to estimate this relationship. This study uses the second-generation estimation technique of AMG to estimate the long-run coefficients. Augmented Mean Group (AMG) estimates panel time series models with heterogeneous slopes (Stata 17). Augmented Mean Group estimator introduced in Eberhardt and Teal (2010) and Eberhardt and Bond (2009). In this method, the degrees of cointegration of the variables in the model do not have the same feature, the relationships between the over-sections are monitored and different coefficients can be estimated for the cross-section equations (Acaravcı et al, 2015). The AMG estimator provides robust estimates of the CSD and allows for country-specific heterogeneity and stationary deliveries of the series (Saqib and Benhmad, 2021; Cengiz and Manga, 2023).

Mean Group approach is a related approach which we term the Augmented Mean Group (AMG) estimator accounts for cross-section dependence by inclusion of a "common dynamic process" in the country regression. This process is extracted from the year dummy coefficients of a pooled regression in first differences (FD-OLS) and represents the levels-equivalent mean evolution of unobserved common factors across all countries. Provided the unobserved common factors form part of the country-specific cointegrating relation (Pedroni, 2007), the augmented country regression model encompasses the cointegrating relationship, which is allowed to differ across i.(Eberhardt and Teal, 2010: 7-8): In the second stage, the □□ variable is added to each of the regressions of N standard units. It is estimated by the following equations;

Stage 1 $\Delta y_{it} = b'\Delta x_{it} + \sum_{t=2}^{T} c_t \Delta D_t + e_{it} \Rightarrow \hat{c}_t \equiv d_i \hat{\mu}_t^{\cdot}$ (5)

Stage 2 $y_{it} = a_i + b' x_{it} + c_i t + d_i \hat{\mu}_t^{\cdot} + e_{it} \quad \hat{b}_{AMG} = N^{-1} \sum_{i=1} \hat{b}_i$ (6)

3.2.5. Causality test methodology

In this study, the granger causality test was used. Granger causality test was developed by Dumitrescu and Hurlin (2012). Regression model using panel causality test. It takes into account the heterogeneity and heterogeneity of causal relationships (Pehlivan, at al., 2020).

Let us denote by x and y, two stationary variables observed for N individuals on T periods. For each individual i= 1,..,N, at time t= 1,..,T, we consider the following linear model (Dumitrescu and Hurlin, 2012: 1451):

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} y_i^{(k)} y_{i,t-k+} \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k+} e_{i,t} \qquad (7)$$

with K ∈ N and $\beta i = (\beta i^{(1)},\dots,\beta i^{(K)})'$. For simplicity, the individual effects αi are supposed to be fixed in the time dimension. Initial conditions $(y_{i,-K},\dots,yi, 0)$ and $(x_{i,-K},\dots,xi, 0)$ of both individual processes $y_{i,t}$ and $x_{i,t}$ are given and observable. The null hypothesis and alternative hypothesis are as follows:

H_0: x does not Granger-cause y.

H_1: y does Granger-cause x for at least one panelvar.

4. RESULT AND DISCUSSION

Table 4 shows the results of (Pesaran and Yamagata. 2008) slope heterogeneity and homogeneity test. The null hypothesis in the test is that the slope coefficients are homogeneous. According to the test results, the homogeneity of the slope coefficients was rejected at the 0.01 significance level and it was concluded that the slope coefficients were heterogeneous across all cross-sections.

Breusch-Pagan LM, Pesaran scaled LM and Pesaran CD cross-section tests results are shown in Table 5 These tests developed by Breusch and Pagan (1980), Pesaran (2021). The null hypothesis that cross-sectional independence was rejected significance level at 0,01 for all variables. Test results show that there is cross-sectional dependence for all variables.

CIPS unit root test (Pesaran, 2007) results are shown in the table 6. In the CIPS test, the null hypothesis is that it contains a unit root. The results were tested for models with constant and with constant and trend. Since the CIPS

Table 4. Testing for slope heterogeneity and homogeneity

Delta	p-value
5.191*	0.0000
Adj. 5.668*	0.0000

* denotes significance at the 1% level.

Table 5. Cross-section dependence test

Variables	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
LnGDPG	1254.529* (0,000)	58.59053* (0,000)	29.02011* (0,000)
$LnCO_2$	2866.133* (0,000)	145.7361* (0,000)	15.31514* (0,000)
LnREC	2129.402* (0,000)	105.8982* (0,000)	4.640941* (0,000)
LnFFEC	1565.166* (0,000)	75.38784 (0,000)	-2.512366* (0,012)

* indicate significance level at 1%. parentheses indicate P value.

Table 6. CIPS unit root test

	Constant			Constant and trend		
	Level	**First difference**	**Inferences**	**Level**	**First difference**	**Inferences**
LnGDPG	-1,631	-1,505	I(1)	-1,937	-1,929	I(1)
$LnCO_2$	-1,949	-2,132	I(1)	-2,081	-2,257	I(1)
LnREC	-0,533	-0,457	I(1)	-2,373	-2,454	I(1)
LnFFEC	-1,792	-1,67	I(1)	-2,197	-2,111	I(1)

statistical values were found to be lower than the critical values given at the bottom of the Table 6, the null hypothesis was accepted for all variables. It was found to be I(1) in all variables, both in constant and constant and trend models.

Critical values at the 5% level are 2,21 for level and first difference with constant. Critical values at the 5% level are 2,73 for level and first difference with constant and trend.

ECM test results are shown in Table 7. According to the results, the null hypothesis is rejected and it is decided that there is cointegration in all groups (Gt, Ga) and the entire panel (Pt, Pa). Once the existence of panel cointegration is determined, the panel estimators stage can be started. The results of Augmented Mean Group (AMG), the panel cointegration estimator, are as follows:

Augmented Mean Group (AMG) results are shown in Table 8. According to Augmented Mean Group estimator (AMG) results, the existence of a positive relationship between CO_2 use and growth in GDP is at the 0.001 significance level. The increase in CO_2 use increases the growth in GDP. One unit increase in CO_2 use causes a 0.88 unit increase in GDP growth. Sikder et al. (2022) stated by the short-term estimate found a positive relationship between GDP growth, CO_2 emission.

Table 7. Error correction model (ECM) panel cointegration tests

Statistic	Value	Z-value	P-value
Gt	-3.332	-6.908	0.000
Ga	-14.924	-4.964	0.000
Pt	-15.515	-7.458	0.000
Pa	-16.346	-8.335	0.000

According to AMG results, there is no significant relationship between renewable energy consumption and GDP growth. In the research conducted by Demir and Görür (2020) in OECD countries, the following conclusion was reached; A one unit increase in renewable energy consumption created a 0.529 unit increase in GDP. In the panel results by Omri et al. (2015), the GDP variable was found to be significant at the 5% significance level and was determined to have a positive slope. It was determined that a 0.227% growth in the economy caused an increase in additional energy demand of 0.23%.

According to AMG results, there is no significant relationship between fossil fuel energy consumption and GDP growth. Rahman and Velayutham (2020) indicated positive effects of capital on economic growth, which ultimately supports for having more capital stock in Pakistan and Sri Lanka. Economic growth also encouraged non-renewable energy usage in Pakistan.

Table 9 shows the granger causality results. When the causality results are examined, it is seen that there is a Granger causality relationship from the independent variables to the dependent variable. Carbon dioxide use, renewable energy consumption and fossil fuel energy consumption are the causes of gross domestic product. In the study conducted by Chien and Hu (2008), the relationship

Table 8. Augmented mean group estimator (AMG) results

	Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
$LnCO_2$	.8897584*	.2569262	3.46	0.001	.3861922	1.393325
LnREC	.1287838	.1138162	1.13	0.258	-.0942918	.3518594
LnFFEC	-.3368855	.7537817	-0.45	0.655	-1.814271	1.1405
00000R_c	.9094467*	.1035154	8.79	0.000	.7065603	1.112333
cons	-.2863932	4.725237	-0.06	0.952	-9.547687	8.9749
Number of obs = 589						
Wald chi2(3) = 13.47						
Prob > chi2 = 0.0037						

* indicate significance level at 1%. Variable 00000R_c refers to the common dynamic process

Table 9. Causality test results

Null hypothesis (H_0): no causality	W-bar	Z-bar	Z-bar tilde	Decision of null hypothesis
$LnCO_2 \nrightarrow LnGDPG$	3.7973*	8.6219*	7.2938*	Reject
$LnGDPG \nrightarrow LnCO_2$	1.3883	1.1969	0.8276	Accept
$LnREC \nrightarrow LnGDPG$	2.3605*	4.1934*	3.4372*	Reject
$LnGDPG \nrightarrow LnREC$	1.5625	1.7338	1.2952	Accept
$LnFFEC \nrightarrow LnGDPG$	2.6602*	5.1170*	4.2415*	Reject
$LnGDPG \nrightarrow LnFFEC$	1.0903	0.2783	0.0276	Accept

* indicate significance level at 1%. H_0: x does not Granger-cause y. H_1: x does Granger-cause y for at least one panelvar.

between economic growth and renewable energy may make renewable energy more economical in the countries examined. In the mentioned studies, the existence of a causal relationship between energy use and economic growth was found to be important (Asafu-Adjaye, 2000; Akinlo, 2008; Adewuyi, 2016). There is no Granger causality relationship from the dependent variable to the independent variables. Growth in GDP is not a cause of carbon dioxide use, renewable energy consumption and fossil fuel consumption.

5. CONCLUSION

In the study, GDP growth was taken into the model as the dependent variable. CO_2 usage, renewable energy consumption and fossil fuel energy consumption were included in the model as independent variables. According to AMG results in the study, a positive relationship was found between CO_2 use and GDP growth. According to the Granger causality results in the study, a unidirectional causality relationship was found from CO_2 use to GDP growth. A unidirectional causality relationship was also found from renewable energy consumption and fossil fuel energy consumption to GDP growth.) The effect of CO_2 emissions and energy consumption on social and economic variables was examined by Pehlivan, at al. (2020). Unidirectional causality was determined from CO_2 emissions to health expenditures and GDP per capita.

CO_2 production is actually associated with growth in agriculture, industry and services sectors. There is a very strong relationship between energy use and agricultural productivity (Karkacier et, al., 2006). The increasing number of facilities in the industry both fuels energy demand and increases CO_2 emissions along with production. As it is known, CO_2 is a greenhouse gas. Greenhouse gases contained in fossil fuels mix with the atmosphere and cause global warming on earth. Global warming causes many negative situations such as irregular rainfall, drought, difficulties in accessing fresh water, and changes in living biology. Thus, life on earth is becoming increasingly threatened.

With such studies, variables related to economic growth can be determined. These variables can be considered separately and useful suggestions can be made to policy makers. Nowadays, countries want to have better economic and environmental living conditions. The best way to achieve this is to grow economically while also protecting the environment. These concepts are not rivals to each other. So there is no need to give up one to choose the other. The way to achieve balanced development is to protect both the environment we live in and the environment where future generations will live, without damaging the environmental structure along with economic growth. Policy makers have important duties in this regard.

As stated in the introduction of the article, the two countries with the highest CO_2 usage are the USA and China. This situation is due to both the dense population of these countries and the intense production demand. Policies should be implemented to guide all countries in the world, especially these countries, to meet their energy demands in their production and consumption with renewable energy sources instead of fossil fuels. Production with renewable energy sources will both reduce CO_2 emissions and contribute to correcting the economic current balance of countries that are especially dependent on fossil fuel consumption by reducing the consumption of energy resources such as oil and natural gas.

Authors' Contributions: The authors contributed to the study equally.

Declaration of Conflict of Interest: The authors declare that there is no conflict of interest.

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