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Exploring the Role of Fossil Fuels and Renewable Energy in Determining Environmental Sustainability: Evidence from OECD Countries

Haitao Hou [1,*], Wei Lu [2], Bing Liu [1], Zeina Hassanein [3], Hamid Mahmood [4] and Samia Khalid [4]

[1] Business School (MBA Education Center), Henan University of Science and Technology, Luoyang 471000, China
[2] Hydrology Bureau of Yellow River Water Conservation Commission, Zhengzhou 471013, China
[3] Business Administration Department, Cyprus International University, Nicosia 99258, Cyprus
[4] School of Economics and Finance, Xi'an Jiaotong University, Xi'an 710049, China
* Correspondence: 9905725@haust.edu.cn

Abstract: Global warming has become a major concern for countries around the world. In this context, developed countries have decided to reduce global emissions to achieve sustainable development. The energy mix of OECD countries consists of 80% fossil fuels and accounts for about 35% of worldwide carbon emissions. Therefore, it is important to analyze how environmental factors affect carbon emissions in OECD countries. This study uses fossil energy, renewable energy (RE), and GDP for the period 1990–2019. Unlike previous studies, we will estimate two separate models for FFE and RE. To evaluate the empirical results, advanced panel data estimation methods using the cointegration test and the CS-ARDL estimation technique are employed to examine the long-run relationship between the variables. The results of the study demonstrate that fossil fuel use and GDP increase carbon emissions both in the short and long term. However, the use of RE hurts carbon emissions and is associated with sustainable development in OECD countries. Therefore, it is assumed that although fossil fuel use degrades the environment, economic growth helps it by reducing carbon emissions. Overall, our study shows that the use of RE is essential for OECD countries to achieve their environmental sustainability goals because it reduces the share of fossil fuels in the overall energy mix. Furthermore, in order to achieve a sustainable environment, OECD countries are recommended to begin long-term planning to reduce carbon emissions.

Keywords: fossil fuels; renewable energy; environmental sustainability; OECD

Citation: Hou, H.; Lu, W.; Liu, B.; Hassanein, Z.; Mahmood, H.; Khalid, S. Exploring the Role of Fossil Fuels and Renewable Energy in Determining Environmental Sustainability: Evidence from OECD Countries. *Sustainability* **2023**, *15*, 2048. https://doi.org/10.3390/su15032048

Academic Editor: Farooq Sher

Received: 8 December 2022
Revised: 14 January 2023
Accepted: 16 January 2023
Published: 20 January 2023

1. Introduction

One of the most important drivers of economic development and prosperity is energy consumption in all its forms, including electricity generation and industrial use. Therefore, fossil fuels are still the primary source of energy in the world [1]. Awareness of the need for energy conservation measures and the use of alternative energy sources, particularly renewable energy (RE), has increased in response to concerns about greenhouse gas emissions and climate change. Numerous scholars have pointed out that while traditional fossil fuels promote economic expansion, they also release carbon dioxide (CO_2) into the atmosphere, which contributes to climate change and accelerates global warming [2–9]. For climate change risk to be reduced, all countries need to act quickly. As concerns grow about energy security and plan to reduce carbon emissions, several countries have decided to support the use of RE.

Studies by [3,4,10,11] have investigated the factors influencing the consumption of RE using a demand modeling technique. This is due to a growing understanding of how RE contributes to the development of a more sustainable energy consumption balance. In these studies, the consumption of RE is modeled specifically in terms of real production, real CO_2

emissions, and real oil prices. However, the findings are contradictory and unclear. For example, [10] claimed that there was no direct causal relationship between the components. Meanwhile, [5] discovered a bidirectional link between them in Central American countries. However, [12] observed causal flows between CO_2 emissions and RE use, which is the exact opposite of the conclusions of most studies. With different geographic regions, countries, and econometric approaches, the empirical results change. Similar evidence for the long-term relationship between RE use and CO_2 emissions was found [13]. Recent studies have also highlighted the use of RE as an alternative to fossil fuels [7,9,14–20].

Global warming, air pollution, and elevated health hazards are just a few of the negative environmental effects of the growing production and usage of fossil fuels in several countries [20]. According to the Organization for Economic Co-operation and Development (OECD), fossil fuels will remain the main source of energy for the foreseeable future due to their higher energy density and slower pace of innovation, but OECD countries have recognized the need to promote alternative energy sources (European Environment Agency, 2019). The International Energy Outlook (2021) projects that overall energy consumption in OECD countries will increase by 15% by 2050. The energy mix of OECD countries is shown in Figure 1. It demonstrates that fossil fuels, including coal, natural gas, and oil, make up 38%, 28%, and 14%, respectively, of the energy utilized in OECD countries. This shows that 80% of the energy mix in OECD countries is fossil fuels. This is because many governments continue to promote the consumption of energy from fossil fuels, especially oil and gas. In this context, OECD countries allocated about USD 108 billion to fossil fuel extraction in 2019 (OECD, 2020). In addition, capital expenditures for fossil fuel production are also fiscally incentivized. This reduces the price of carbon emissions, undermining the efficacy of environmental measures, and prevents the shift to an economy that is more energy-efficient and low-carbon.

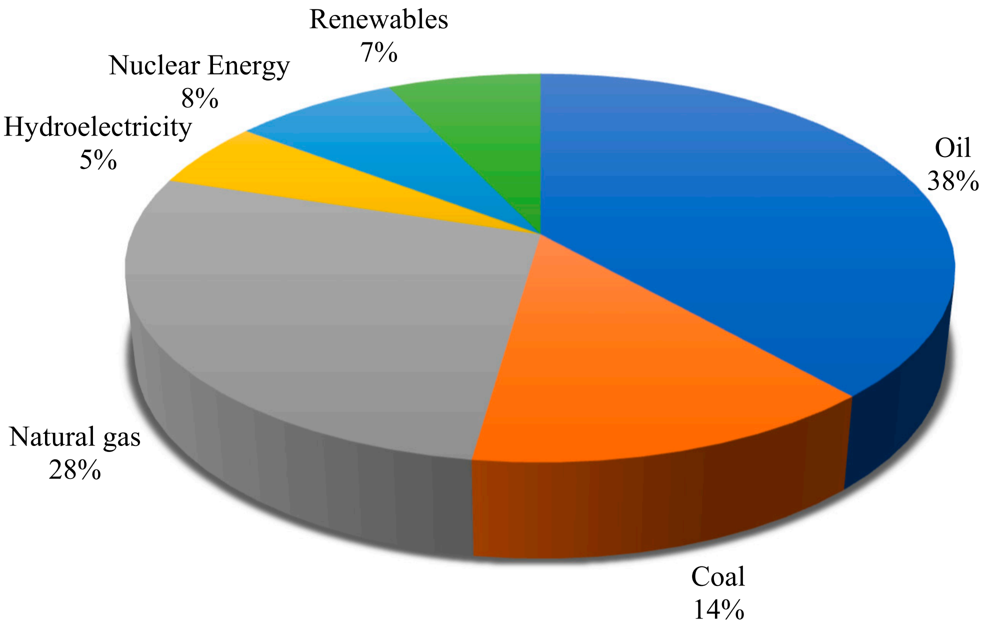

Figure 1. Energy mix in OECD countries (2019).

As shown in Figure 2, carbon emissions in OECD countries have trended upward since 1990. However, OECD countries currently account for 35% of the world's energy-related carbon emissions, down from 50% in 1990 (OECD, 2020). This is due to improvements in energy efficiency in production processes, energy supply adaptation, and the organizational structure of the industrial sector. This largely occurred in the late 2000s, after the 2008 global financial crisis, which led to a decline in economic output in several countries. Nevertheless, OECD countries continue to emit far more CO2 per person than the majority of other regions of the world (OECD, 2020). To increase knowledge of the interrelationships between elements, it is necessary to promote comprehensive policy options for a sustainable environment in OECD countries.

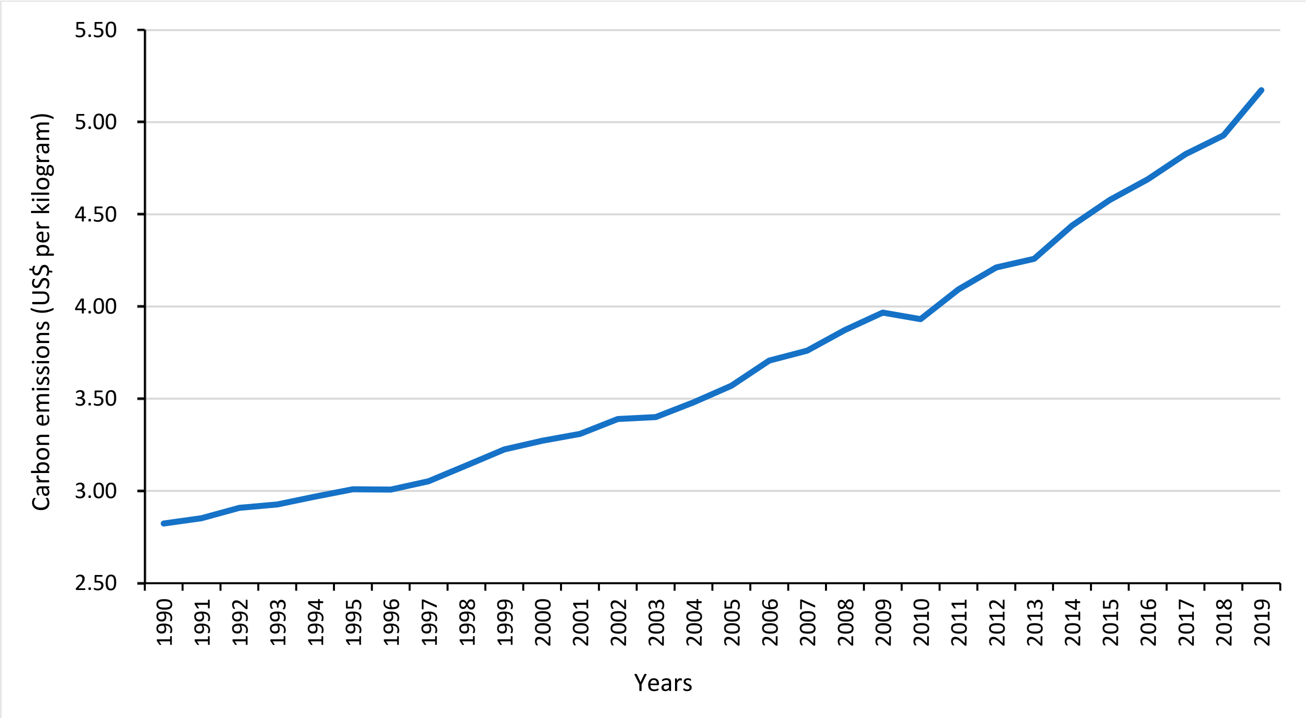

Figure 2. Carbon emissions in OECD countries (1990–2019).

This study contributes to the literature in the following ways: First, compared to previous research, the present study evaluates a panel of OECD countries for the period 1990–2019 to assess a larger group of economies and determine whether there is a long-term relationship between carbon emissions, fossil fuel use, and RE. Secondly, unlike previous studies, we will estimate two separate models for FFE and RE. Because FFE data is almost the equivalent of non-renewable energy, using these simultaneously does not give reliable results. Third, to assess the empirical results, this study uses advanced panel data estimation techniques to avoid inconsistent results due to cross-sectional dependence and structural breaks in the data. In this context, the panel cointegration procedure of [21] and the CS-ARDL model are used to estimate the results. For causality analysis, the heterogeneous panel causality test [22] is used. Last but not least, this study also adds to the body of knowledge on environmental sustainability by examining the current connection between fossil fuel energy and carbon emissions. In addition, the results will help policymakers better understand the factors causing the increase in carbon emissions and adopt energy conservation measures that can have the greatest impact.

The remaining sections of the study are organized as follows: Section 2 discusses previous research in the literature. The methodology is explained in Section 3. The empirical results and discussion are presented in Section 4. Finally, Section 5 presents the conclusions and policy implications.

2. Literature Review

Several studies have been carried out in recent years to look at the potential causes of CO_2 emissions in various countries. In this context, several empirical studies have examined in detail several variables that cause CO_2 emissions. These factors include economic growth [6,15,16,23–25], urbanization [19,26,27], trade [28–30], innovation [31–33], energy use [5,14,18,20,34], financial development [35–37], foreign direct investment (FDI) [38–40], and tourism [41–43].

Several research studies address this relationship, considering the growing need for renewable energy sources to replace fossil fuel use and its associated environmental impacts [4,10]. However, these studies mostly focus on emerging economies. [25] used a structural VAR method to examine the use of RE and economic growth on CO_2 emissions in India. The study found that a shock to GDP has a significant positive impact on CO_2 emissions, and a good shock to the adoption of RE sources increases GDP and reduces CO_2 emissions. [44] found no evidence of a direct correlation between GDP and RE sources in the United States. In addition, they disagreed that burning garbage as fuel would reduce waste and solve the country's disposal problems. Another study by [5] examines the variables affecting the adoption of RE in a group of seven countries in Central America between 1980 and 2010. According to their results, there is a positive and significant long-term relationship between CO_2 emissions, RE consumption, GDP, coal, and oil prices. The empirical investigation of the variables influencing the use of RE in 25 OECD countries between 1980 and 2011 is extended by [5] from the same year. To examine the causal and long-run relationships between the use of RE and economic growth in BRICS countries from 1971 to 2010, [12] used the ARDL model and Vector Error Correction Model (VECM). They found a causal relationship between the use of RE and economic growth in BRICS countries. The empirical results of these studies were confirmed by [45–47].

Ref. [48] employed panel cointegration techniques to identify the long-term relationship between energy use, GDP, carbon dioxide emissions, and oil prices for a panel of 11 South American countries from 1980 to 2010. Causal dynamics and persistent linkages are considered. In another study, [14] used panel data from 42 industrialized countries to look at how CO_2 emissions, the usage of RE and non-RE, and economic development are related. In the case of China, [49] found that rapid economic growth in China was associated with a rapid increase in energy consumption, which resulted in significant GHG emissions. [27] examined the relationship between urbanization, economic growth, environmental degradation, and the use of fossil, solid, and RE sources in sub-Saharan Africa. The results suggest that non-renewable energy consumption hinders economic development in underdeveloped countries. The study used a panel of 34 developing countries from 1995 to 2015 to explain its findings using the Generalized Method of Moments (GMM) approach. The study found a significant negative relationship between urban growth and the use of fossil and solid fuels for cooking and a largely positive relationship between these two factors and carbon dioxide emissions. It also showed an inverted U-shaped relationship between per capita economic growth and carbon dioxide emissions. In addition, this study found that the long-term use of RE promotes economic growth. For the United States and the United Kingdom, [15] employed the NARDL model and discovered an asymmetric association between economic growth and CO_2 emissions.

Based on the studies conducted to date, panel data may have cross-sectional dependence. Therefore, most of the studies conducted recently to explore the factors causing an increase in CO_2 emissions have used advanced econometric estimation techniques for panel data and found that there is a long-term relationship between CO_2 emissions, GDP, international trade, RE, and non-renewable energy [17,18,28,50,51]. However, existing literature found that increasing energy consumption is always associated with increasing CO_2 emissions, and increasing economic growth is always associated with increasing CO_2 emissions in the long and medium terms. However, the main reason for the increase in carbon emissions is energy from fossil fuels. Moreover, these studies have mainly focused on emerging economies or conducted time-series analyses for specific countries. No study has examined fossil fuel energy in the context of OECD countries. Therefore, this study will add to the existing literature by using fossil energy with carbon emissions in OECD countries. This is because OECD countries consume a significant amount of fossil fuels and account for 35% of global carbon emissions. This study will assess how fossil fuels, RE, and GDP may impact the carbon emissions of OECD countries using sophisticated panel data estimation methodologies.

3. Data and Methodology

3.1. Data

The study applies panel data analysis to OECD countries for the period 1990–2019. A panel data set of 25 OECD countries are selected based on fossil fuel energy use and data availability as well (see Appendix A). The study analyzed CO_2 emissions to measure environmental sustainability and examine the impact of fossil fuels and renewable energy on CO_2 emissions. Table 1 provides the details of the data. In the case of panel data, the base models are presented as follows:

$$CE_{it} = \alpha_1 FFE_{it} + \alpha_2 GDP_{it} + \varepsilon_{it} \quad (1)$$

$$CE_{it} = \beta_1 RE_{it} + \beta_2 GDP_{it} + \epsilon_{it} \quad (2)$$

Table 1. Description of Variables and Data.

Variables	Sign	Unit	Source
Carbon emissions	LCE	Kiloton (Kt)	OECD
Fossil fuel energy	LFFE	% of total	EIA
Renewable energy	LRE	quad Btu	EIA [1]
Gross domestic product	LGDP	Constant USD 2010	WDI

[1] Energy Information Administration (EIA) https://www.eia.gov/interntional/data/world (accessed on 10 November 2022).

In the above two equations, CE is carbon emissions, FFE is fossil fuel energy, RE is renewable energy, and GDP represents economic growth. In contrast to existing studies [18,20], we have constructed two separate models to check the impact of FFE and RE. Because FFE data is almost the equivalent of non-renewable energy, RE and FFE are almost perfect functions of each other and using these both simultaneously in the explanatory part of the model is not correct. Secondly, to avoid multicollinearity, RE and FFE should be separately analyzed. Figure 3 below shows methodological diagram of the study.

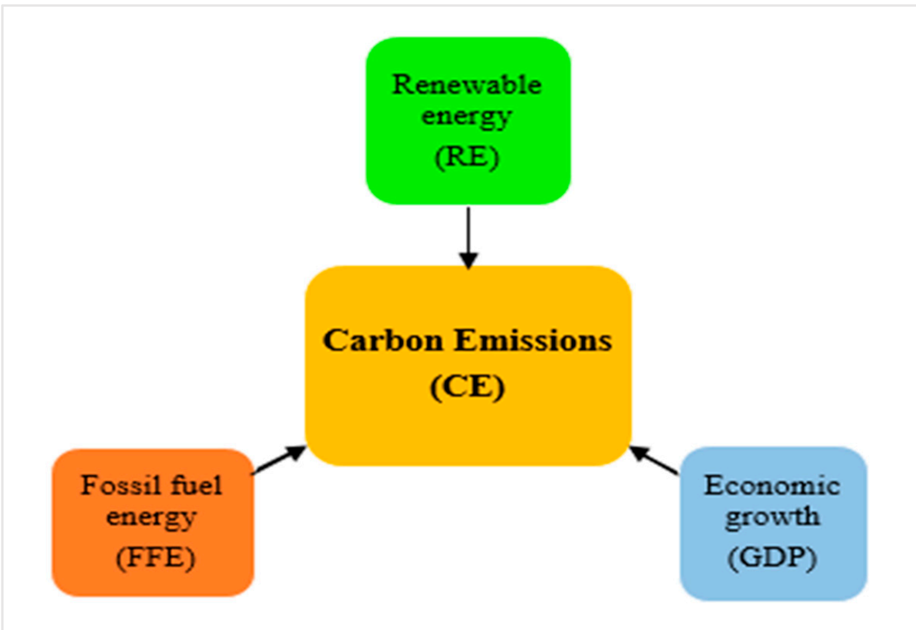

Figure 3. Methodological diagram.

3.2. Estimation Technique

In this study, advanced estimation techniques are used to solve potential methodological problems with panel data. The study uses a panel data set of 25 OECD countries for the period 1990–2019 and the selection of countries is based on fossil fuel energy use and availability of data (see Appendix A). When estimating panel data, there is a possibility of inaccurate empirical results if cross-sectional dependence (CSD) between units is not taken into account [52,53]. Therefore, the study's estimation procedure begins with an examination of cross-unit CSD using the [54] test for CSD. For unit root analysis, the IPS extended cross-sectional test (CIPS) and the Dickey–Fuller extended cross-sectional test (CADF) are used. These unit root tests are superior to conventional tests for dealing with CSD and slope heterogeneity (SH). The long-term relationship is then examined using the test of [55].

3.2.1. Cross-Sectional Dependence

A cross-sectional dependence (CSD) investigation must be performed before applying any approach to measure relationships, especially in studies that use panel data. Therefore, the Lagrange multiplier test (LM) of [56] is used in conjunction with the test of [54]. The legitimacy of the result obtained is the reason why two tests are applied for the same objective. In addition, the purpose of the CSD test is to obtain a reliable result; if this is not the case, ambiguous and unpredictable results may occur. The following Equation (3) illustrates the mathematical representation of [56]:

$$\mathrm{CSD} = \mathrm{T}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2} \tag{3}$$

Furthermore, the following Equation (4) illustrates how the [54] test was represented mathematically:

$$\mathrm{CSD} = \sqrt{\frac{2\mathrm{T}}{\mathrm{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}} \tag{4}$$

In the above equations, T is time, N is the size of the panel data, and ρ_{ij} is the correlation coefficient. In both of these tests, the hypothesis statements assume that if the null hypothesis is accepted, CSD is not present; if the alternative hypothesis is accepted, CSD is present.

3.2.2. Unit Root Tests for Panel Data

Before evaluating the CSD test, the criteria must be taken into consideration to assess the order of integration. The Levin–Lin–Chu test and Im, Pesaran, and Shin (IPS) test are examples of first-generation unit root tests that are insufficient to demonstrate stationarity for the dataset with the CSD [57]. The tests of cross-sectional augmented IPS (CIPS) and cross-sectional augmented Dickey–Fuller (CADF) are therefore utilized in the current investigation since the second generation category is deemed to be appropriate [58]. The mathematical form of the test is provided below:

$$\Delta \mathrm{CA}_{i,t} = \varphi_i + \varphi_i \mathrm{Z}_{i,t-1} + \varphi_i \overline{\mathrm{CA}}_{t-1} + \sum_{I=0}^{p}\varphi_{iI}\Delta\overline{\mathrm{CA}}_{t-1} + \sum_{I=0}^{p}\varphi_{iI}\Delta \mathrm{CA}_{i,\,t-1} + \mu_{it} \tag{5}$$

$$\hat{\mathrm{CIPS}} = \frac{1}{\mathrm{N}}\sum_{i=1}^{n}\mathrm{CDF}_i \tag{6}$$

3.2.3. Panel Cointegration Test

The degree of cointegration among the targeted variables was assessed in the following phase. The ability to identify CSD and structural breaks was a shortcoming of the first generation of cointegration tests [59–62]. Moreover, the common conventional tests tend to produce inaccurate results when the data have heteroscedasticity and CSD characteristics [63]. Therefore, the present study employs the Westerlund and Edgerton

(2008) panel cointegration test. Because this test can jointly address CSD, structural breaks, and autocorrelation [64,65]. The mathematical form of [21] is as follows:

$$LM_{\tau} = \frac{\hat{\Phi}_i}{SE(\hat{\Phi}_i)} \quad (7)$$

$$LM_{\Phi} = T\hat{\Phi}_i\left(\frac{\hat{\omega}_i}{\hat{\sigma}_i}\right) \quad (8)$$

In Equation (7) above, SE ($\hat{\Phi}_i$) is the least square estimator; the reflection of $\hat{\Phi}_i$'s SE is $\hat{\sigma}_i$ where the reflection of $\hat{\Phi}_i$ is $SE(\hat{\Phi}_i)$. With the null hypothesis accepted, the cointegration is missing.

3.2.4. CS-ARDL Estimation

This study investigates the association between fossil fuel energy, RE, and CO_2 emissions for a panel of OECD countries. Due to the presence of cross-section dependence and slope heterogeneity problem the traditional estimation techniques of FMOLS and DOLS can generate unreliable results as these techniques do not consider these issues [66]. The CS-ARDL equation is written as follows:

$$\begin{aligned} CE_{it} = \alpha_i + \varphi_i\left(CE_{it-1} - \beta_i X_{it-1} - \delta_{1i}\overline{CE}_{t-1} - \delta_{2i}\overline{X}_{t-1}\right) + \sum_{j=1}^{p-1}\gamma_{ij}\Delta CE_{it-j} \\ + \sum_{j=1}^{q-1}\gamma_{ij}\Delta X_{it-j} + \varphi_{1i}\overline{\Delta CE}_t + \varphi_{2i}\overline{\Delta X}_t + \varepsilon_{it} \end{aligned} \quad (9)$$

In the above Equation (9), CE is the dependent variable and X denotes the explanatory variables. In the same way, ΔCE_{it-j} and ΔX_{it-j} symbolize dependent and explanatory variables in the short-run.

4. Results and Discussion

It is important to check the CSD before beginning the panel data analysis. Therefore, Table 2 below shows the results that reject the H_0 (null hypothesis) of the test of no CSD at the 1% significance level and confirm that there is CSD in the data. This indicates that these OECD countries are closely related to each other and that the effects of a shock in one country will spill over to the other countries as well.

Table 2. Results of CSD Test.

Variable	CSD Statistic
LCE	19.76 ***
LFFE	25.61 ***
LRE	17.32 ***
LGDP	21.56 ***

Note: Author calculated. *** $p < 0.01$.

Before starting the long-run analysis, it is important to check the order of integration of the variables. To accomplish this, the CIPS and CADF unit root tests were applied. Table 3 displays the results, and the same findings were reached when both tests were applied to the data. All variables (LCE, $LFFE$, LRE, $LGDP$) are integrated of order I (1) in both unit root tests at the 1% level of significance.

The next step is to check the cointegration by using [21] panel cointegration and the results of both models are given in Table 4. The absence of cointegration between the variables is the null hypothesis of the cointegration test. The results show that there is cointegration between the variables at a 1% level of significance in both models, rejecting the null hypothesis.

Table 3. Results of CADF and CIPS Unit Root Test.

Variables	CADF Test		CIPS Test	
	Level	First Diff	Level	First Diff
LCE	−1.376	−5.289 ***	−1.652	−4.345 ***
LFFE	−1.519	−4.672 ***	−1.204	−4.991 ***
LRE	−1.076	−4.219 ***	−1.479	−3.719 ***
LGDP	−1.184	−5.934 ***	−1.567	−5.789 ***

Note: Author calculated. *** $p < 0.01$.

Table 4. Results of Westerlund and Edgerton (2008) Cointegration Test.

	Model 1					
	No Shift		Mean Shift		Regime Shift	
	Statistic	*p*-Value	Statistic	*p*-Value	Statistic	*p*-Value
LM_τ	−6.513 ***	0.00	−7.013 ***	0.00	−6.041 ***	0.00
LM_φ	−9.238 ***	0.00	−7.061 ***	0.00	−7.225 ***	0.00
	Model 2					
LM_τ	−10.21 ***	0.00	−8.091 ***	0.00	−11.06 ***	0.00
LM_φ	−9.249 ***	0.00	−8.349 ***	0.00	−10.05 ***	0.00

Note: Models are run with a maximum of five factors. Null hypothesis: No cointegration exists. *** $p < 0.01$.

Table 5 shows the long-run and short-run estimation results of the CS-ARDL model. The findings of model 1 show that the estimated FFE coefficient is significantly positive in both the short and long run. This indicates that a 1% increase in FFE increases carbon emissions by 0.081% and 0.098%, respectively. These findings are supported by [20,67]. The reason is that most of the OECD countries support the use of fossil fuel energy and provide special incentives to the oil and gas sectors. In addition, investments in fossil fuel infrastructure and tax policies that provide capital expenditures for fossil fuel production merit priority consideration in some of these countries. These regulations are impeding global efforts to reduce greenhouse gas (GHG) emissions. Additionally, energy efficiency regulations might vary greatly between countries, regions, and economic levels. The employment of energy policies that address environmental challenges, particularly the usage of eco-friendly technology, has received increased attention from OECD member countries. For instance, the International Energy Agency (IEA) and the governments of the major countries' forum have committed to expanding public sector expenditures in low-carbon research and development and speeding up the adoption of low-carbon technology (OECD, 2020).

Table 5. Estimation Results of CS-ARDL Model.

	Model 1 (With FFE Use)		Model 2 (With RE Use)	
Variables	Coefficient	Std. Error	Coefficient	Std. Error
(a) Long-run coefficients				
LFFE	0.081 ***	0.025	-	-
LRE	-	-	−0.421 **	0.202
LGDP	0.262 **	0.118	0.639 **	0.231
(b) Short-run coefficients				
ΔLFFE	0.098 ***	0.034	-	-
ΔLRE	-	-	−0.081 *	0.045
ΔLGDP	0.339 ***	0.112	0.569 ***	0.194
C	3.162 ***	0.459	4.513 ***	0.891
ECT	−0.175 **	0.084	−0.233 **	0.102

Source: Author estimation. Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. All tests are two tailed.

In model 2, the calculated coefficient RE is significantly negative, −0.421% for the long-term period and −0.081% for the short-term period. Thus, it can be shown that an increase in RE leads to a 42% and 8.1% reduction in carbon emissions, respectively. The use of RE is seen as a possible means of reducing carbon emissions and improving environmental quality. This is consistent with the findings of [1,3,18,28,50,51]. The explanation is that OECD countries have implemented a variety of measures, such as government subsidies, load management, and consensus-based green power initiatives, to reduce both their dependence on fossil fuels and their harmful effects on the environment. In OECD countries, hydropower has historically been the primary source of RE. However, these resources have largely been depleted. Non-hydroelectric sources, particularly wind energy, are projected to contribute significantly to the increase in RE sources in OECD countries (International Energy Outlook, 2013). This increase in non-hydroelectric sources is primarily the result of energy regulations in several OECD countries.

GDP has a positive impact on carbon emissions in both long-term and short-term models. These findings are similar to those of [15,16,20,23,24]. Economic practices in developed countries often lead to environmental degradation as these economies rely on non-renewable energy sources for energy production and increase carbon emissions. But ecologically friendly forms of energy, including wind, solar, geothermal, biomass, and hydropower, are all available. The environmental problems of OECD countries can be mitigated by investing in RE initiatives. It will be easier to reduce carbon emissions and, more importantly, the long-term costs of climate change as long as the economy remains strong. The error correction term (ECT) is negative and significant in both models, indicating convergence toward equilibrium in the long run.

The panel causality test developed by Dumitrescu and Hurlin (2012) was then used to assess the causal relationship between the variables, and the results are presented in Table 6. Concerning FFE, RE, and GDP, results show unidirectional causality with carbon emissions.

Table 6. Results of Dumitrescu and Hurlin (2012) Heterogeneous Panel Causality Test.

Null Hypothesis	Stats	Prob.	Outcome
FFE does not granger cause CE	12.92 ***	0.000	Unidirectional causality
CE does not granger cause FFE	6.809	0.216	
RE does not granger cause CE	−13.26 ***	0.000	
CE does not granger cause RE	7.543	0.205	
GDP does not granger cause CE	15.87 ***	0.000	
CE does not granger cause GDP	7.189	0.288	

Source: Author estimation. Note: *** $p < 0.01$.

5. Conclusions

The objective of this study was to examine the relationships between carbon emissions, fossil fuel energy, and renewable energy in OECD countries. Advanced panel data estimation techniques such as the cross-sectional dependence test, second-generation unit root tests, the Westerlund and Edgerton (2008) cointegration test, and the CS-ARDL estimation model are used for the econometric estimation. These advanced econometric panel techniques help address the problems of cross-sectional dependence and structural breaks in the data to obtain objective empirical results. According to the results of the study, fossil fuels have a largely positive impact on carbon emissions, unlike renewable energy. The use of renewable energy leads to a significant reduction in carbon emissions while improving environmental quality. Economic growth (GDP) in OECD countries, on the other hand, has been found to increase carbon emissions.

The results of the study contribute to a better knowledge of energy consumption in OECD countries. In addition, fossil fuel energy consumption plays an important role in increasing carbon emissions in OECD countries. Government support for the production and use of fossil fuels has grown, mostly as a result of increasing assistance for the fossil fuel-generating industry. Therefore, it is critical to stabilizing carbon emissions at levels that prevent the dangers associated with environmental degradation. The dependence of domestic production on fossil fuels must be reduced, and the resulting emissions are another way to reduce overall emissions. Otherwise, this will undermine the efficacy of environmental measures and prevent the shift to a low-carbon economy. The use of renewable energy sources, on the other hand, aids OECD countries in lowering their carbon emissions. The development of renewable energy sources needs to be supported, and governments are encouraged to be active in this regard. Authorities must give importance to renewable energy when developing regulations to increase energy efficiency. Therefore, decoupling evidence based on domestic emissions per unit of GDP or per person can only give an incomplete picture.

Based on the results of the study, it is recommended that OECD countries should promote carbon pricing, environmental levies, and the elimination of government subsidies and other forms of support for fossil fuels to secure an optimal balance of market-based mechanisms. This will be crucial in this shift, to say the least. Secondly, OECD countries should modernize their industrial infrastructure to shift energy demand from fossil fuels to renewable sources. They also need to promote the use of environmentally friendly technologies. At last, they should also implement national and international strategies to reduce carbon emissions and further decouple greenhouse gas emissions from economic growth.

The study has only data limitations. Due to data limitations, our sample is restricted to 25 countries. Future research can be conducted in such a way that, instead of using total panel data, country-specific analysis of OECD countries can provide interesting results.

Author Contributions: Conceptualization, B.L.; methodology, H.M.; software, H.M.; formal analysis, Z.H.; investigation, W.L.; resources, B.L.; writing—original draft preparation, S.K.; writing—review and editing, H.M.; supervision, H.H.; project administration, H.H.; funding acquisition, B.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research work was funded by: 1. Henan New Liberal Arts Research and Reform Practice Project: Reform and Practice of Liberal Arts Major Transformation and Upgrading in Local Ordinary Undergraduate Colleges—Taking E-commerce as an example. Grant Recipient: Guoqu Deng. 2. Henan University of Science and Technology 2022 student research and training program (SRTP): "Research on the impact of supply chain integration on enterprise quality performance". Grant Number: 2022357; Grant Recipient: Bing Liu.

Institutional Review Board Statement: The study did not require ethical approval.

Informed Consent Statement: Not applicable.

Data Availability Statement: The is available on OECD database and World Bank.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. List of Selected OECD Countries.

Country	Percentage Share of Fossil Fuels in Total Energy (2021)
Israel	94.66%
Poland	92.24%
Luxembourg	88.91%
Lithuania	88.47%
Australia	87.07%
Netherland	86.63%
Japan	85.34%
Estonia	85.03%
South Korea	84.92%

Table A1. *Cont.*

Country	Percentage Share of Fossil Fuels in Total Energy (2021)
Turkey	83.42%
Italy	81.64%
Ireland	81.44%
United States of America	81.38%
Greece	79.84%
Hungary	77.79%
United Kingdom	76.28%
Germany	75.61%
Latvia	74.19%
Belgium	73.89%
Chile	73.48%
Spain	68.52%
Portugal	67.03%
Canada	64.15%
Austria	62.52%
New Zealand	59.75%

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