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CO_2 Emissions from Renewable and Non-Renewable Electricity Generation Sources in the G7 Countries: Static and Dynamic Panel Assessment

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Abstract: The threat of global warming has increased due to industrialization, urbanization, population expansion, and changes in lifestyle among the Group of Seven(G7) Carbon dioxide emissions (CO_2) directly affect how much electricity can be generated from various sources. This research aims to identify environmental hazards associated with various energy sources. Analyzing the impact of various energy sources on CO_2 emissions from electricity and heat production using data from the G7. The data is analyzed using quantile regression (QR), generalized method of moments (GMM), random effects (RE), and fixed effects (FE). Our results indicate a substantial positive impact on CO_2 emissions regardless of the technology used to generate coal and gas power. Coal-fired power plants have a larger impact on the environment than other sources of emissions. Also, all coal and gas coefficients are significant in FE, RE, GMM, and QR. Oil coefficients have a negative impact on environmental degradation and are significant for FE, RE, and D-GMM regressions. Hydroelectric and renewable energy production can reduce CO_2 emissions in all regression models. Nuclear energy has a beneficial impact on the environment, but the coefficients are only significant for S-GMM and the last quantile. However, the most significant result of this study is the identification of a cause-and-effect relationship between CO_2 emissions and energy production. Carbon dioxide (CO_2) emissions can be lowered by shifting away from fossil fuels and toward renewable and hydroelectric sources. The research also suggests several renewable and alternative electricity production policies for sustainable energy.

Keywords: G7; climate change; CO_2 emissions; electricity production sources; energy consumption

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Citation: Voumik, L.C.; Islam, M.A.; Ray, S.; Mohamed Yusop, N.Y.; Ridzuan, A.R. CO_2 Emissions from Renewable and Non-Renewable Electricity Generation Sources in the G7 Countries: Static and Dynamic Panel Assessment. *Energies* **2023**, *16*, 1044. https://doi.org/10.3390/en16031044

Academic Editor: Wen-Hsien Tsai

Received: 24 December 2022
Revised: 10 January 2023
Accepted: 12 January 2023
Published: 17 January 2023

1. Introduction

Since Thomas Alva Edison invented the earlier version of the electric light bulb, the impact of electricity consumption has become more apparent in every sphere of our life. The train was once driven by steam, now fully operating on electricity, and a large proportion of vehicles are switching to electric models. Cell phones today are used to recharge and operate home appliances and heavy machinery or big industries are booming. Electricity is the main driving force of this modern times. As the nation's transform from agrarian to industrialised, electricity production and consumption demands surmount. Production methods have changed in manifolds like burning fossil fuels (coal, gas, oil.), renewable (solar), hydropower, and nuclear power plant to meet the demand [1].

The G7 countries represent the most well-developed industrialized nations. Group of Seven (G7) members comprise the United States, Canada, France, Germany, Italy, Japan, and the United Kingdom. Roughly 770 million individuals make up G7, roughly 10% of the global population. As of 2021, Crédit Suisse reports that the G7 represents around 53% of the global net wealth. Historically, G7 was formed to advocate major global issues and climate change was on the agenda from its inception. Addressing climate change was the focus of 2015, and an Accord was reached in Paris by the Group of Seven. The G7 nations pledged to create a green, low-carbon society that guarantees environmental sustainability (Paris Climate Agreement, signed at COP21 in 2015). However, the G7 economies have failed to mitigate CO_2 emissions and are far behind in reaching the decarbonized goal within 2035. As of 2020, the G7 nations were responsible for around 23.2% of global CO_2 emissions, according to Dale [2]. Other nations regularly mirror the policies and activities of the world's biggest industrialized economies. Since using fossil fuels to generate electricity accounts for 75% of all GHG emissions, it is clear that this sector is a major contributor to air pollution worldwide.

The trend in Figure 1 senses that their economic expansion begets their need for more power. With more need for power, rising pressure is placed on upstream energy resources, including crude oil, coal, and natural gas, hence the gruelling availability of non-renewable energy. Due to heavy reliance on cheaper energy sources such as fossil fuels, mainly generated from power, the energy sector has also become accountable towards the greenhouse gases impact, climate change, and other environmental miseries [3–6]. The diagram shows that six G7 countries, namely Italy, Japan, the US, the UK, Germany, and Canada, fit the above elaboration where more carbon emissions have been produced to produce fuel-based electricity. Meanwhile, there is a clear downward trend for carbon emissions released from the fuel burned for France. The French energy sector has since the 1970s been dominated by nuclear energy, and in the 2010s, nuclear has provided at most over 75% of the country's electricity. Because of this internationally exceptional feature, France is relatively advanced in transitioning from fossil fuels. In recent news, the country aims to clear its electricity production of fossil fuels and focus on nuclear energy.

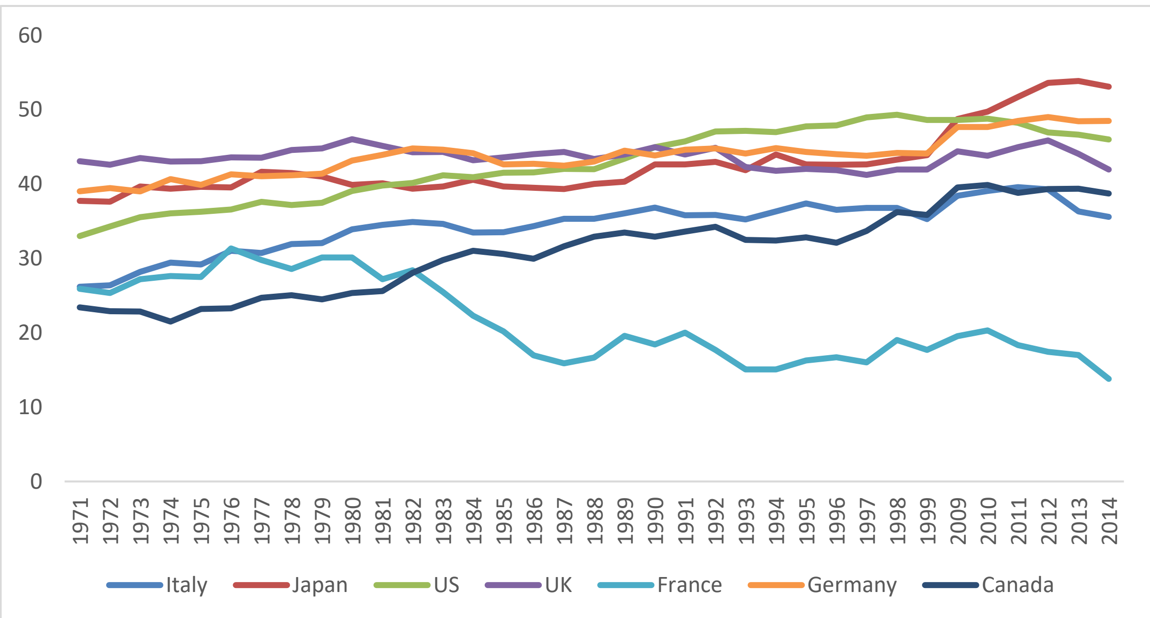

Figure 1. The Trend of CO_2 emissions from the production of electricity and heat as a whole (% of total fuel burned) for G7 countries from 1971 to 2014.

Sadly, this is not the case for the remaining G7 countries, as their electricity is produced from fossil fuels, emitting CO_2 as a major by-product. CO_2 is the major source of air pollution and the primary contributor to greenhouse gases (GHGs), severely affecting human health and the habitable environment. Electricity production can be devised in numerous ways, with different degrees of detrimental effects on the surrounding habitat. Renewable energy sources like solar and hydroelectric power demonstrate a negative correlation with CO_2 production and stay coherently with the environment. Nuclear power plants are also a non-CO_2 emitter process but have a huge risk. Another huge issue in nuclear power is nuclear waste management. Using fossil fuels by burning coal, gas, and oil remains the most popular and overwhelmingly practised method of electricity production; incrementing the percentage of CO_2 in the air contributes to overall global warming. Coal usage has the highest positive correlation with CO_2 production and the most harmful environmental impact. Environmentalists, researchers, and climate activists forecast a formidable fate regarding global warming for our planet earth. Suppose we cannot leash the reign of increasing CO_2 levels; the vital signs of the planet earth, like average temperature level, ecological balance, and animal population's habitat, could be at risk.

In this article, we introspect the production of power from coal, oil, and gas while at the same time examining the quantity of carbon dioxide emissions from the sources. This research also summarizes prior work on the correlation between renewable energy and carbon dioxide emissions. On a global level, electricity production by renewable sources has not been expanded as climate activists expected in recent years. Around sixty per cent of the world's power is still generated by coal and natural gas [7]. Therefore, diversifying the electrical portfolio toward non-CO_2-emitting energy sources like nuclear, hydroelectricity, and renewables like wind and solar power may be an effective strategy. The G7 promised to achieve the milestone of "predominantly decarbonized" electricity sectors by 2035, a major step to counteract the impending threat of climate change [8].

The objectives of this research to find out which electricity production from different sources impact on environment. G7 is one of the most electricity consumption areas and it is high time to find out which electricity production sources are beneficial for environment and which are detrimental. The hypothesis is that using hydropower, nuclear, and other renewable energy sources may help reduce greenhouse gas emissions and pollutants in the atmosphere. We anticipate that the information gleaned from this research will aid us in recommending the following environmental policy not just for the G7 but also for other nations. Therefore, it is critical to include CO_2 in our model, as studies have shown a correlation between energy generation and CO_2 emissions. Further, we found that, from a scholarly and research standpoint, only a small number of studies used GMM and quantile regression techniques [1,9]. Panel data research employing GMM and QR methods appears to be uncommon in the G7 region, based on our current understanding of the matter. The article continues with the following structure: The literature review is presented in Section 2. Section 3 presents the specifics of our methodology and data collection. Results from the regression analyses were analyzed in Section 4. In Section 5, we focus on the discussion of the main results. Next, Section 6 portray the conclusion and policy recommendations. Lastly, Section 7 contains limitations and future research.

2. Literature Review

The world's energy markets target to net zero emissions by 2050, and the G7 is setting the pace by leading the way. They also pledged to "lead a technology-driven transition to net zero, backed by applicable policies" and to achieve "net zero no later than 2050."[7]. These pledges were made in an impressive show of political leadership just before the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change. In 2020, the gross domestic product, energy consumption, and carbon dioxide emissions of the G7 countries combined for approximately 40% of the world total [8]. Achieving net zero emissions safely and economically in the G7 is essential to speeding up people-centred transitions elsewhere. This goal can be achieved by implementing the policies, demonstrating the technologies, and taking the measures required.

Decarbonising electricity must be prioritised to achieve net zero emissions since it targets the sector with the largest emissions today and paves the way for the decarbonisation of other sectors. Since cleaner sources are replacing coal, the electrical sector's proportion of G7 energy-related emissions has decreased from 40% in 2007 to just over 30%. Governments in the G7 are working to reshape the electrical policy environment with net zero in mind, and this movement is gaining traction. A major component of zero emissions is the broad adoption of low-carbon technologies, such as the tripling of wind and solar PV capacity increases from around 75 GW in 2020 to 230 GW by 2030. One of the almost 400 sector-specific and technology-specific goals outlined in the IEA's Net Zero by 2050: A Roadmap for the Global Energy Sector is reaching zero emissions from electricity in the G7. Spending on NZE energy production is expected to increase within the next decade within the G7 before levelling at around double the present level in the 2030s and 2040s [10]. In the G7, the need for hour-to-hour flexibility is expected to triple between 2020 and 2050 due to the increasing proportion of electricity in total energy consumption and the increasing proportion of wind and solar PV. An integrated strategy is necessary to address NZE power and energy security threats. The global community is urging the G7 to accelerate its energy transition, and as the world's most developed nations, the G7 must listen.

Nearly 30 gigatons of carbon dioxide were released into the atmosphere in 2010. Coal, oil, and natural gas generate heat for steam-driven turbines, accounting for around 12 Gt (40%) of the power generation sector's emissions. Carbon dioxide (CO_2), the major "greenhouse gas" responsible for global warming, is produced when these fuels are burned, along with additional sulphur and nitrogen oxides, all of which have a variety of negative effects on the environment [11]. In 2021, power and heat generation had the largest increase in CO_2 emissions per sector, with a rise of more than 900 Mt. Since an increase in the usage of all fossil fuels is necessary to help meet the expansion in power demand, this accounted for 46% of the worldwide increase in emissions. With emissions approaching 14.6 Gt, a new record was set, and almost 500 Mt more carbon dioxide was released into the atmosphere than in 2019. Nearly all of the projected worldwide rise in emissions from the power and heat sectors between 2019 and 2021 may be attributed to the People's Republic of China (henceforth, 'China'). Unfortunately, the rest of the world's collapse did not make up for China's rise [11].

Both developed and developing countries contributed to a return to 2019 levels of global CO_2 emissions from the industrial and construction sectors from the upcoming year. Except for China, industrial CO_2 emissions fell for the second year in 2020 due to decreased coal consumption. The transportation industry is the only one in which global CO2 emissions stay well below 2019. Sales of electric cars hit a record high in 2021, but the simultaneous rise in demand for SUVs more than offset the positive effect on carbon reductions. Dantama et al. [12] state that electricity influences economic, social, and even first-world living standards in various ways. Data from 72 nations shows that between 1990 and 2012, worldwide CO_2 emissions rose from 67 million to 134 million metric tons. Consequently, environmental pollution is responsible for more than 150,000 deaths annually [13]. In ASEAN countries, electricity production from renewable sources reduces CO_2 emission, on the other hand, electricity production from fossil fuels increases CO_2 emission [1]. Another study was done by Voumik et al in BRICS. They showed that coal and gas power generating significantly increased CO_2 emissions. Coal-fired power plants have a bigger effect on the environment than other types of pollution. Hydroelectric and renewable energy generating may cut CO_2 in all regression models in BRICS. Ozturk [14] also established a correlation between other forms of energy consumption and economic growth, including the consumption of electricity from diverse sources. Increases in worldwide CO_2 emissions have been attributed to several causes, including rising populations, increased use of nuclear power, fossil fuels, and carbon-intensive energy sources, rapid urbanisation, and exposure to dangerous air pollutants [15,16]. Their research elucidated the effect of these variables on the worldwide CO_2 emission level. In addition, due to the high temperatures required by geothermal plants (between 300- and 700 degrees Fahrenheit), carbon dioxide is released into the atmosphere, impacting the environment. Although fossil fuel power plants have more environmental repercussions, the relationship between energy consumption, economic growth, and CO_2 emissions was examined using Granger causality and panel cointegration tests [17]. Data from 70 nations were examined from 1994 to 2013. Research using the Granger causality technique demonstrates a bidirectional relationship between energy usage and carbon dioxide emissions. The cointegration tests also established long-term connections between the study's focus areas (energy use and economic growth) and CO_2 emissions. However, consistent approaches proved that rising energy use and expanding economies cut CO_2 emissions [18]. Economy size, electricity intensity (effort put forward by demand policy), heat generation fraction (effort put forth by supply policy), and carbon emission coefficient are the four variables used in this method to dissect CO_2 emissions (demand policy effort). EU nations lowered CO_2 emissions more than non-EU nations overall. Reducing the proportion of thermal power and boosting energy efficiency were the primary drivers of the policy. However, as proven by scientists, these increases may be attributable to a shift in the generation mix or an increase in electricity consumption [19].

The extensive use of alternative energy sources and the resulting CO_2 emissions seriously threaten future generations through droughts, melting glaciers, rising sea levels, global warming, and heat waves. The ecosystem is in jeopardy due to these negative environmental effects. The impact of biomass energy consumption on the ecological footprints of the G7 nations between 1992 and 2018 was analysed by Awosusi et al. [20]. Nonetheless, environmental deterioration is a problem for all quantiles, and this is due to economic development, natural resource extraction, and the build-up of gross capital (10th to 90th). Research conducted by Aydin [21] made use of G7 data collected between 1992 and 2013, emphasising the importance of biomass energy on economic progress. Diverse nations reaped the benefits of the outcomes of the heterogeneous panel data study. The study advocated biomass as an alternative energy source to foster economic growth and lessen reliance on volatile international energy markets. To estimate the sources of CO_2 emissions, Panel quantile regression was employed by Shisong et al. [22]. According to their findings, non-renewable energy sources are the most effective in reducing carbon emissions but reiterating that countries with high emissions can do to help develop renewable energy that might help reduce their emissions. Energy output's effect on industrialisation and long-term economic growth was studied by Yu et al. [23], who zeroed attention on the countries with the greatest increases in electricity generation between 2000 and 2018. From 1991 to 2018, electricity production in G7 nations aided industrial output and sustained economic growth.

In addition, past studies discovered a correlation between electrification and the amounts of dangerous gas emissions in the environment [24,25]. Since 1990, the increased size and significance of China's leading sectors have significantly increased the country's energy consumption. The manufacturing sector, raw materials, mining, and chemicals are all part of this sector. In addition, during the last three decades, it has helped greatly expand the electrification of all commercial and residential buildings [16]. However, the causal relationship between energy generation sources and carbon dioxide emissions has not been investigated in the G7 countries we are aware of. Thus, this study seeks to bridge a gap in the existing body of information. In addition, no other researcher has used system GMM and Difference GMM and the Quantile regression approach to learn about CO_2 emissions from various power production sources in G7 countries.

3. Methodology

3.1. Data and Variables of the Study

The annual panel data came from the World Bank's World Development Indicators [26] database for five major economies from 1971 to 2019. Unfortunately, the research omitted data for 2020 and 2021 due to COVID-19, which may affect the data to be highly biased and inaccurate. The missing observation was treated by the mean value of the variable. Table 1 lists the considered factors for this study.

Table 1. Introduction of Selected Variables.

Name of the Variables	Variables in Log Form	Elaboration of the Variables
$EHCO_2$	$L(EHCO_2)$	CO_2 emissions from the production of electricity and heat as a whole (% of total fuel burned)
Coal	L(Coal)	Coal-generated power (% of total electricity output)
Gas	L(Gas)	Gas-generated electricity (% of total power output)
Nuc	L(Nuc)	Nuclear power output (% of total electricity generation)
Hydro	L(Hydro)	Hydroelectricity generation (% of total power production)
Oil	L(Oil)	Oil-generated electricity (% of total power output)
Renew	L(Renew)	Renewable power generation (% of total electricity output)

Source: WDI [26].

3.2. Theoretical Framework and Marshallian Demand Function (MDF)

Energy creation is thought to be directly linked to releasing carbon dioxide from electricity production. Therefore, CO_2 emissions from energy generation are a function of power generation from diverse sources, assuming the market clearing condition holds. Using the framework of the classic Marshallian demand function [27], we get the following at time t. From the MDF market clearing condition, we can write Equation (1):

$$CO_2 \text{ emission from electricity and heat} = F \text{ (electricity production from different sources)} \quad (1)$$

Electricity-generated sources from coal, natural gas, nuclear, hydropower, oil, and renewable energy sources (except hydroelectric) were all included as independent variables, and we employed the well-established methodological procedure. Using the following Equation (2), the influence of dependent and independent factors may be determined:

$$EHCO_2 = f(Coal, Gas, Oil, Renew, Hydroelectric, Nuclear) \quad (2)$$

The dependent variable is CO_2 emissions from electricity and heat production ($EHCO_2$). On the other hand, independent variables are major electricity production sources. Here, the multivariate econometric model was defined in Equation (3):

$$EHCO_{2it} = \beta_0 + \beta_1 Coal_{it} + \beta_2 Gas_{it} + \beta_3 Oil_{it} + \beta_4 Renewable_{it} + \beta_5 Hydroelectric_{it} + \beta_6 Nuclear_{it} + \varepsilon_{it} \quad (3)$$

In Equation (4), we use a logarithmic transformation.

$$L(EHCO_2)_{it} = \beta_0 + \beta_1 L(Coal)_{it} + \beta_2 L(Gas)_{it} + \beta_3 L(Oil)_{it} + \beta_4 L(Renew)_{it} + \beta_5 L(Hydro)_{it} + \beta_6 L(Nuc)_{it} + \varepsilon_{it} \quad (4)$$

where β_0 is the intercept term. β_1 to β_6 are the slope coefficients. The ε presents the error term, i presents the cross-section country, and t presents the time.

3.3. Econometric Methodology

Our choice to employ this approach was motivated by several considerations. To select the most appropriate method for analysis, we employed a multi-method approach, combining fixed effect (FE) regression, random effect (RE) regression, the generalised method of moment [28,29], and the quantile regression model for a sample of seven countries from the Group of Seven (G7). While we incorporated alternative approaches for comparison, we emphasised the differenced and system GMM approach as it provides efficient and impartial results. Our analysis of the prior research was conducted using both fixed and random effects. We also acknowledged that the results might be subject to bias and unpredictability due to the omitted variables bias and the endogeneity problem, which cannot be resolved using this methodology. The coefficient sign of differenced GMM agrees with the results of system GMM, verifying their validity, and thus allows us to employ difference GMM for comparison and robustness purposes. We use this model as it better comprehends outcomes that are not normally distributed and have nonlinear associations with regression models. The quantile regression approach allows analyzing interactions between variables outside the mean of the data. By expanding methods of moments (MM) to include cases where more moment conditions exist than parameters, GMM generalizes the approach. Since MM does not take advantage of these additional moment circumstances, GMM is more productive. The estimator is considered overidentified when there are more moment conditions than parameters. On the other hand, the fundamental benefit of quantile regression is that it has the potential to better understand outcomes that are not normally distributed and that have nonlinear associations with predictor variables, both of which are outside the realm of traditional linear regression. These models combinedly applied in many researches [1].

3.3.1. Fixed and Random Effects

The following Equation (5) is the fixed effect format of Equation (4)

$$L(EHCO_2)_{it} = \beta_1 L(Coal)_{it} + \beta_2 L(Gas)_{it} + \beta_3 L(Oil)_{it} + \beta_4 L(Renew)_{it} + \beta_5 L(Hydro)_{it} + \beta_6 L(Nuc)_{it} + Cj + \varepsilon_{it} \quad (5)$$

Cj is here group specific intercept.

Equation (6) is the random effect model of Equation (4)

$$L(EHCO_2)_{it} = \beta_1 L(Coal)_{it} + \beta_2 L(Gas)_{it} + \beta_3 L(Oil)_{it} + \beta_4 L(Renew)_{it} + \beta_5 L(Hydro)_{it} + \beta_6 L(Nuc)_{it} + Cj + \alpha + (\mu_i + \varepsilon_{it}) \quad (6)$$

α is here constant value of all unit specific effects. μ_i is the unit specific variance.

3.3.2. GMM Approach

The purpose of a study can be attained through the application of several distinct econometric approaches. To determine if using numerous energy sources significantly impacts CO_2 emissions, we employed a rigorous strategy that would reveal an obvious path to adopt in this investigation. In this study, we used the generalised technique of moments to estimate dynamic panel estimators (GMM). Specifically, we used the GMM for detecting differences between two sets of data that Arollana and Bond [28] created, as well as the GMM for detecting changes in a single step in a system that Arellano and Bover [29] and Blundell and Bond [30] constructed. Arellano and Bond [28] created both of these generalised estimating models. We also employed the dynamic panel model system generalised method of moments to address the unbalanced panel bias and the possible endogeneity of explanatory variables, which was first presented by Arellano and Bover [29] and afterwards by Blundell and Bond [30]. The system GMM yields more stable and time-efficient parameter estimations than panel OLS regressions. Exogeneity can come in many forms, and this model accommodates a wide variety of them for independent variables. Correlations exist between the current and historic errors and the independent variables that need not be exogenous. There is likely to be autocorrelation and heteroscedasticity in each group [31]. This model outperforms the alternative dynamic panel model in terms of both adaptability and results in reliability. Since this dynamic panel model is so effective at dealing with endogeneity and over-identification of independent variables, it has become one of the most widely used in the field.

The following Equations (7) and (8) are the specification for the system GMM technique in the level and different form formats:

$$\begin{aligned} L(EHCO_2)_{it} = \beta_0 + \beta_1 L(CO_2)_{it-1} + \beta_2 L(Coal)_{it} + \beta_3 L(Gas)_{it} + \beta_4 L(Oil)_{it} + \beta_5 L(Renew)_{it} \\ + \beta_6 L(Hydro)_{it} + \beta_6 L(Nuc)_{it} + \varepsilon_{it} \end{aligned} \quad (7)$$

Differences GMM:

$$L(EHCO_2)_{it} - (EHCO_2)_{it-1} = \beta_0 + \beta_1(L(EHCO_2)_{it-1} - L(EHCO_2)_{it-2}) + \beta_2(L(Coal)it - L(Coal)_{it-1}) + \beta_3(L(Gas)_{it} - L(Gas)_{it-1}) + \beta_4(L(Oil)_{it} - L(Oil)_{it-1}) + \beta_5(L(Renew)_{it} - L(Renew)_{it-1}) + \beta_6(L(Hydro)_{it} - L(Hydro)_{it-1}) + \beta_7(L(Nuc)_{it} - L(Nuc)_{it-1}) + (\eta_t - \eta_{t-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad (8)$$

η_t and η_{t-1} are here time-invariant terms.

3.3.3. Quantile Regression (QR)

An important application of the quantile regression methodology is studying non-normally distributed and nonlinearly correlated outcomes and their nonlinear interactions with predictor factors. Buchinsky [32] points out that, to describe the feasible heterogeneous impacts, we identify the q^{th}-quantile ($0 < q < 1$) of the dependent variable as impermanent distribution, given a set of X_i variables, as follows in Equation (9):

$$Q_q(y_{it}|\beta_0, \varepsilon_{it}, x_{it}) = \beta_0 + \varepsilon_{it}^q + \beta_i^q x_{it} \quad (9)$$

where y_t the CO_2 emission through time is, u_t signifies unobservable factors. Separately provided is a vector of explanatory variables (X_{it}). Inference from the q^{th} quantile regression, as established by Cameron and Trivedi [33], necessitates minimising the absolute value of the residual, as shown by the following objective function in Equation (10).

$$Q\left(\beta_i^q\right) = \min\beta \sum_{q,i,t=1}^{n} ||y_{it} - x_{it}\beta_i^q|| = \min\left[\sum_{i:y_{it} \geq x_{it}\beta} q\left|y_{it} - x_{it}\beta_i^q\right| + \sum_{i:y_{it} < x_{it}\beta} (1-q)\left|y_{it} - x_{it}\beta_i^q\right|\right] \quad (10)$$

There are two parts to Canay's [34] assessment approach. In the first step, the mean of u_t was calculated. Quantile regression is then used to evaluate this component after subtracting it from its original dependent variable.

4. Result and Discussion

Table 2 summarizes the data for all of the variables. Descriptive analysis can be used to do a preliminary investigation of the variables. Statistical information such as the mean, number of observations, and standard deviation are shown alongside the lowest and maximum values. The mean value of L(EHCO2) is higher than other variables.

Table 2. Synopsis of Descriptive Statistics.

Variables	N	Mean	sd	Min	Max
$L(EHCO_2)$	256	3.666	0.339	2.624	4.174
L(Coal)	264	3.095	0.761	0.769	4.275
L(Gas)	264	2.403	1.225	−0.599	4.026
L(Oil)	264	1.344	1.221	−0.978	3.953
L(Hydro)	264	2.248	1.092	−0.203	4.198
L(Renew)	261	−0.0504	2.014	−8.028	3.268
L(Nuc)	234	3.057	0.778	−2.433	4.376

Results of the Panel Unit Root Test

Using the panel unit root test, it is crucial to seek if the dependent and independent variables are stationary in a panel data analysis. In the current literature, there are several panel unit root tests. In Table 3, we can see the results of conducting clinical trials for unit roots at the level of data and the first difference of both dependent and independent variables. While H_0 is a non-stationary process with a unit root, H_1 is stationary with no unit root. The table reveals that all of our variables are stationary at I_1. However, all are stationarily at the first difference level when data was changed from one period to the previous period. Both level and first difference, 5% significance level, were applied, and the result reveals that the null hypothesis is rejected at the first difference for all variables. Our expected p-values are 0.00; hence, at the first difference, data for all variables are classified as stationary variables, and there is no unit root. At I_1, all series are stationary variables, and now it is easy to predict the data. All *p* values less than 0.01 mean score were all signed with a 1% significance level because it is less than alpha (=0.01).

Table 3. Unit Root Test Result.

	At Level			At 1st Difference		
Variables	**Harris-Tzavalis**	**Im-Pesaran-Shin**	**Levin, Lin &Chut**	**Harris-Tzavalis**	**Im-Pesaran-Shin**	**Levin, Lin &Chut**
L(EHCO$_2$)	0.462	0.546	−0.471	−22.35 ***	−10.765 ***	−5.613 ***
L(Coal)	1.847	2.294	4.70	−20.44 ***	−9.13 ***	−7.29 ***
L(Gas)	−0.94	1.145	0.362	−19.10 ***	−8.956 ***	−5.15 ***
L(Oil)	−1.236	−0.863	−0.073	−38.19 ***	−9.33 ***	−7.88 ***
L(Renew)	−0.98	−0.736	−0.559	−31.83 ***	−9.177 ***	−7.82 ***
L(Hydro)	−1.11	0.617	0.545	−39.52 ***	−9.769 ***	−7.72 ***
L(Nuc)	−2.18	−1.054	−1.028	−44.82 ***	−10.75 ***	−9.687 ***

Note: 1% significance levels are denoted by ***. Presume as trend and intercept.

The unit root method is what we anticipate would happen between all the model variables. When the *p*-value is less than or equal to the level of significance set for the study, the null hypothesis should be rejected, often 0.1 (10%) or 0.05 (5%). The high significance level is the first difference of 1% or less. For example, because our calculated *p*-value is less than 0.01, we might confidently reject the null hypothesis at the 5% level of significance.

Models 3 and 4 in Table 4 have a positive and highly significant lag value for CO_2 emissions L(L(EHCO$_2$), i,t − 1), indicating a link between the previous year's L(EHCO$_2$) emissions and present levels.

Table 4. Dynamic and Static Panel Regression Result (L(EHCO$_2$)).

VARIABLES	FE	RE	S-GMM	D-GMM
L.L(EHCO$_2$)			0.583 *** (0.182)	0.672 *** (0.170)
L(Coal)	0.214 *** (0.017)	0.212 *** (0.017)	0.097 * (0.054)	0.095 ** (0.040)
L(Gas)	0.065 *** (0.009)	0.0745 *** (0.010)	0.031 (0.020)	0.056 * (0.031)
L(Oil)	0.022 ** (0.009)	0.018 ** (0.009)	0.018 (0.011)	0.020 * (0.012)
L(Renew)	−0.009 ** (0.004)	−0.005 (0.004)	−0.007 (0.005)	−0.0004 (0.003)
L(Hydro)	−0.105 *** (0.024)	−0.076 *** (0.022)	−0.073 ** (0.031)	0.010 (0.014)
L(Nuc)	−0.011 (0.010)	−0.012 (0.010)	−0.008 * (0.005)	−0.018 (0.014)
Constant	3.089 *** (0.093)	3.025 *** (0.108)	1.324 *** (0.497)	0.785 * (0.456)
Observations	225	225	209	218
R-squared	0.542			
Countries		7		

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4 shows the log-log model for estimating both static and dynamic panels. Our CO_2 emissions and power generation from various sources are shown, together with their fixed and random effects, in the model represented by the coefficient of columns 1 and 2. For every per cent change in the independent variables, there is a corresponding per cent change in the CO_2 emissions represented by the coefficient. Columns 3 and 4 show the dynamic panel regression of our model. This estimate is positive and statistically significant in both the fixed and random effect models, where the coefficients of L(EHCO$_2$) explained

L(Coal) as 0.214 *** and 0.212 ***, respectively. CO_2 emissions increase by 0.098 for the Differenced GMM model and by 0.096 for the System GMM model for every 1% increase in L(Coal). The coefficients of fossil fuels are similar with previous several findings [8,9]. In the second phase, when L(Coal), L(Gas), and L(Oil) significantly contribute to increasing CO_2 in a specific panel study area, the expected output is calculated using the dynamic GMM model. In both the fixed and random effect models, L(Renew) significantly and negatively affects L($EHCO_2$) with respective coefficient weights of -0.0099^{***} and -0.0058. For the Difference GMM and System GMM models, a 1% rise in L(Renew) declines to CO_2 emissions of 0.008 and 0.000, respectively. Similarly, in Differenced GMM models, a 1% rise in L(Hydro) reduces CO_2 emissions by 0.07. The coefficients of renewable energy sources are similar with previous researchers' findings.

Table 5 shows Regression quantiles in columns 1–3. There are Q25, Q50, and Q75 in the QR model. Evidence suggests that coal and natural gas use for power generation increases carbon emissions from heat and electrical sources. The Q25, Q50, and Q75 values are all taken into account in the QR model. Carbon emissions increase with the generation of electricity from coal, hydro, and natural gas. In the QR models for Q25, Q50, and Q75, the coefficients of L(Coal) to explain L(EHCO2) are 0.250, 0.266, and 0.244, respectively. Both L(Renew) and L(Nuc) have a negative and significant impact on L(EHCO2) when considering carbon emissions. Quantile-specific L(EHCO2) barriers of 0.03%, 0.04%, and 0.04 % may be achieved by increasing L(Renew) sources by 1%. The corresponding L(Renew) coefficients are −0.03, −0.04, and −0.04. Notably, there is a statistically significant inverse relationship between carbon emissions and power generation from renewable and nuclear sources. Research shows that the coefficients for renewable energy sources are consistent with those found by other researchers. Carbon emissions are reduced due to the increased use of renewable and nuclear energy to generate electricity, improving environmental quality. Less carbon dioxide is released into the air when there is more power-generating integration.

Table 5. Quantile Regression Output Result (L($EHCO_2$)).

Quantile Regression			
Variables	**QR_{25}**	**QR_{50}**	**QR_{75}**
L(Coal)	0.250 *** (0.015)	0.266 *** (0.012)	0.244 *** (0.021)
L(Gas)	0.231 *** (0.008)	0.204 *** (0.006)	0.189 *** (0.011)
L(Oil)	0.00259 (0.008)	0.00817 (0.007)	0.00178 (0.012)
L(Renew)	−0.0337 *** (0.004)	−0.0399 *** (0.003)	−0.0423 *** (0.006)
L(Hydro)	0.103 *** (0.010)	0.0791 *** (0.008)	0.0508 *** (0.014)
L(Nuc)	−0.0145 (0.015)	−0.0179 (0.012)	−0.0997 *** (0.022)
Constant	2.106 *** (0.109)	2.221 *** (0.090)	2.719 *** (0.154)
Observations	225	225	225

Standard errors in parentheses *** $p < 0.01$.

5. Discussion

The environment suffers when fossil fuels like coal, gas, and oil are used to produce power. Findings from this article indicate that coal is the most polluting alternative for generating electricity. Coal mining and burning in power plants create massive quantities of toxic air pollution, harming human health, releasing enormous quantities of pollutants, and speeding up the rate at which the planet warms. In addition, coal burning for power generation may emit several harmful substances into the environment, such as benzene, carbon monoxide, formaldehyde, and polycyclic aromatic hydrocarbons. In this research coefficients of coal have detrimental impact on environment. The findings similar with some previous studies [1]. The foregoing investigation proves a connection between CO_2 discharges and coal-based power generation. Both methane (CH4) and carbon monoxide (CO) are produced as by-products of the combustion process used to generate electricity from oil and natural gas. Greenhouse gas emissions are reduced by burning oil rather than natural gas or coal, but oil combustion remains detrimental. When oil is burnt to create energy, it releases several smog-causing particles, airborne contaminants, and poisonous compounds. These factors significantly contribute to the release of CO_2 and other greenhouse gases. Accordingly, the primary cause of air pollution is the combustion of fossil fuels, which releases harmful chemicals into the atmosphere. Renewable energy sources (excluding hydroelectricity) and nuclear can have a beneficial impact on the planet. Considering the impact of hydroelectricity, only the quantile regression coefficient is positive, while the FE, RE, and system GMM coefficients are all negative. The renewable energy coefficients are significantly negative and statistically significant when using either FE or quantile regression. Though all coefficients are negative, only the last quantile and for the GMM system, the nuclear energy coefficients are statistically significant. Comparatively, the emissions from renewable energy generation are far lower than those from the combustion of fossil fuels. The transition from fossil fuels, which account for the vast bulk of emissions today, to renewable energy sources is essential to averting a climate catastrophe. The research shows that most of the coefficients of renewable energy, hydro, and nuclear energy are negative. That means electricity production from renewable energy sources are beneficial from environment. Compared to the emissions produced by burning coal or other fossil fuels, renewable energy's carbon footprint is far less. To mitigate the effects of global warming, switching to renewable energy sources is recommended. Green energy, sometimes called clean energy and related to renewable energy, is advantageous to the natural world. Renewable energy sources benefit the planet by decreasing carbon footprint, cheaper utility bills, greater stability and resilience, an effectively infinite supply of usable energy, the creation of new employment, and enhanced sustainability. We support hydro sources over fossil fuels even though hydroelectricity coefficients are disadvantageous for the environment in quantile regression but favorable in FE, RE, and GMM. The most tried-and-true technique of creating hydroelectricity is using the potential energy of rivers and oceans. Nine of the world's ten largest power plants are hydroelectricity generators, with dams on rivers providing the most energy. Since nuclear power plants do not release any toxic by-products, they are seen as environmentally friendly. There are challenges in maintaining nuclear reactor control, but the G7 countries have cutting-edge technology and robust research and development sectors. This reactor generates energy through the process of fission, which involves the splitting of uranium atoms. The fission process may create energy by boiling water and driving a turbine, which is a safer alternative to burning fossil fuels.

6. Conclusions and Policy Recommendation

We discovered a positive and negative link between energy output and CO_2 emissions during our research. As a result, governments should concentrate on developing energy and economic policies that minimize CO_2 emissions while enhancing the environment and supporting sustainable energy sources. However, this regulation must also be implemented without severely hurting power consumption or the general economics of the community. For example, sustainable environment investment is commonly viewed as a critical step in mitigating the environmental repercussions of CO_2 emissions. Furthermore, if these principles are followed, there should be no detrimental influence on energy consumption or economic development. Climate financing, for example, has been seen as a vital step in addressing the environmental consequences of global CO_2 emissions.

- A nation may do this by investing in renewable, climate-friendly energy sources. According to the research, a strategy to avoid environmental deterioration should include renewable and environmentally friendly energy sectors. Increased investments and the application of new technologies are predicted in the electrical industry, both of which are favorable developments. Clean energy will be available for business and personal usage in both developed and developing nations as a result of this. As a result, environmental damage is reduced, and economic growth in nations is limited. Consequently, future efforts should raise knowledge of renewable energy sources and

encourage investment. With approximately 45% of the world's economy, G7 accounts for roughly 60% of the total geographical area. As a result, the influence of these large growing economies has a significant impact on all other regions of the Earth.
- G7 countries should take steps to reduce fossil fuels. The ongoing use of coal, oil, and gas is a major contributor to global warming and is generating profits for fossil fuel companies. It is time for the G7 to implement a high tax on fossil fuels and subsidize alternative energy sources. In the event that the use of fossil fuels is absolutely necessary, the G7 should employ environmentally friendly technology to reduce the amount of carbon dioxide (CO_2) released.
- However, the G7 countries should raise their spending on R&D. Because of their vast economies, G7 countries can easily afford to raise their research budget. Findings from recent studies will provide the best approach to increasing renewable energy and confirming a sustainable environment.
- Given the importance of economic development and expansion, authorities should consider their energy strategy to combat environmental pollution, such as CO_2 emissions, which is the topic of this article. Because of geography, this sector has no landlocked nations, ensuring extensive coastline expanses. A vast geographical area is covered by innumerable crisscrossing rivers that run from hills and mountains to the sea. G7 countries have a lot of rough terrain and even deserts. This implies that establishing a nuclear, hydropower, solar panel, or bigger windmill project should not be difficult regarding space, security, scope, and overall feasibility. To minimize carbon emissions, the G7 nations must boost energy efficiency and invest in renewable energy research and development.
- G7 is pivotal in leading the global energy markets, achieving net zero emissions (NZE) by 2050. This effort should be spearheaded using technologies to drive the transition and outlining and practicing policies advocating green and renewable energy. Enforcing good policies, evidencing technologies and practicing other good strategies among the G7 can help them formulate actions toward net zero emissions securely and affordably. Subsequently, G7 can lead global-level, people-centered transitions. The decarbonizing policy is also crucial in achieving net zero emissions as decarbonization targets the highest emitting sectors and other offending sectors, grounding the global average temperature rise at 1.5 °C maximum. All G7 members pledged to reach zero emissions by reducing coal-fired power and upping renewable energy use. G7 members have also continuously initiated carbon pricing mechanisms to support electricity decarbonization. The government must eliminate barriers and produce effective policies, actions and frameworks to chart a path to net zero electricity. Low-emissions electric supply is possible by using low-carbon hydrogen and ammonia, nuclear and planting vegetation for carbon capture. Lastly, rapid electrification of end-uses is crucial for net zero emissions by 2050, as energy efficiency moderate's electricity demand growth. Electric vehicles, public transport and hydrogen production, have a major impact, and heat pumps are buildings' most popular heating method. The electricity and wider energy security tasks in the NZE require a whole systems approach, outspreading narrow operational problems to encompass systems resilience to face climate change, power failures, natural disasters, and cyber-attacks. To accomplish this, G7 members must collaborate and share their most effective practices and ensure that climate resilience is prioritized in their energy security policies. The NZE sees a prominent decrease in dependency on net energy imports over time for importing countries in the G7, which is a positive from an energy security perspective. However, as new alarms arise, the supply chains for critical minerals are required for clean energy technologies.

7. Limitations and Future Research

The fact that there is little data to work with is a limitation of the study. Yearly data means that most observations are rather small. There is a lack of data regarding nuclear energy. In addition, no information about the amount of electricity produced from sun, ocean, or wind sources was gathered for this study. More panels can be included and more recent information on the study variables used in future investigations on the same issue. There were first-generation unit root tests, quantile regression, fixed- and random-effects analyses, and a generalized method of moments (GMM) used. Second-generation unit roots, cointegration tests, and cross-sectional dependencies will all be part of the upcoming research. Also, future studies will apply fresh panel models.

Author Contributions: L.C.V.: conceived and designed the study; contributed reagents, materials, analysis tools, or data; wrote the paper; supervised. M.A.I.: Collected, analyzed, and interpreted the data; wrote the paper. S.R.: wrote the literature review; draft the methodology. A.R.R.: write the introduction, refine, revise the overall manuscript and handle the submission. N.Y.M.Y.: contributes the conclusion and policy recommendations besides being the funder for this manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are grateful to the Institute of Energy Policy and Research (IEPRe), University Tenaga Nasional, Malaysia for the financial support under the UNITEN-Suruhanjaya Tenaga Malaysia Grant of Chair Energy Economics (Grant number 2022001KETST).

Data Availability Statement: The data can be available on request.

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

Abbreviations

G7	Group of Seven
CO_2	Carbon dioxide emissions
GMM	Generalized Methods of Moments
S-GMM	System GMM
D-GMM	Dynamic GMM
QR	Quantile Regression
RE	Random effects
FE	Fixed effects

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