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RETRACTED: Towards Sustainable Environment in G7 Nations: The Role of Renewable Energy Consumption, Eco-innovation and Trade Openness

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Some of the globe's most economically advanced nations make up the G7 (Canada, Japan, France, Germany, Italy, United States and United Kingdom). Nevertheless, in tandem with such strong economic growth, the environmental conditions in these nations have deteriorated, raising serious issues among stakeholders. Therefore, we examine the effect of eco-innovation and trade openness on CO_2 emissions in G7 nations. We also take into account the role of renewable energy, economic growth and nonrenewable energy use using a dataset covering the period from 1990–2019. We employed recent econometric techniques such as slope heterogeneity (SH) and cross-sectional dependence (CSD), Westerlund cointegration, fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS), panel quantile regression and panel causality tests to assess these associations. The outcomes of the CSD and SH tests disclosed that using a first-generation unit root test will produce biase outcomes. Furthermore, the outcomes of the Westerlund cointegration disclosed support long-run association between CO_2 and its drivers. In addition, the results of the long-run estimators (FMOLS and DOLS) unveiled that nonrenewable energy and trade openness contribute to the damage to the environment while economic expansion, renewable energy and eco-innovation enhance the quality of the environment. Furthermore, the outcomes of GDP, REC and ECO curb CO_2 while NREC energy and TO surge CO_2. Finally, the outcomes of the panel causality test unveiled that CO_2 emissions can be predicted by all the exogenous variables.

Keywords: CO2 emissions, trade openness, eco-innovation, renewable energy consumption, panel quantile regression

INTRODUCTION

Despite the fact that the Middle East has more than two-thirds of the world's oil reserves, energy-importing nations are attempting to secure adequate energy supply in order to maintain their distinct economic development rates. Nevertheless, providing energy security should typically be achieved by increasing the availability of greener energy resources, as the combustion of filthy fossil fuels has negative environmental consequences (Adebayo, 2022a; Agyekum et al., 2022; Akram et al., 2021; Rehman et al., 2021). As a result, current international ecological development treaties, including the Paris Agreement, attempt to minimize emissions resulting from the use of filthy fossil fuels (Fareed et al., 2021a; Shahzad et al., 2021). Furthermore, the 7th goal of the United Nations' SDGs declaration intends to increase access to reliable, inexpensive and green sources of energy in order to curb CO_2 emissions and guarantee global growth (Adebayo, 2022b; He et al., 2021). As a result, global economies are attempting to identify routes that will lead to clean energy transitions within worldwide energy systems (Xu et al., 2022; Altuntaş et al., 2022).

Likewise, the G7 nations (Canada, United Kingdom, Germany, France, Italy, the United States and Japan) are dedicated to lowering CO_2 emissions through diversification of their portfolios of energy, particularly by including green energy sources into their conventional energy packages (Murshed, 2020). These countries are responsible for around 30 and 25% of global energy use and CO_2, correspondingly (Ahmad et al., 2021). Furthermore, the G7 countries rely heavily on foreign and indigenous nonrenewable energy supplies. Interestingly, the majority of G7 nations rely on non-renewable energy imports to meet their energy needs. Japan, Italy, and Germany import around 96 percent, 84 percent, and 64 percent of their total primary energy supply, correspondingly (EIA, 2022). As a consequence, these figures highlight the G7 nations' dilemma of dirty fuel reliance. These figures explain why, regardless of their economic prosperity, these countries have mainly failed to limit the degradation of their environmental protection.

Growth in the economy results in amplified energy consumption and, as a result, greater CO2 emissions. The EKC is a hypothetical curve that may be visually depicted as an inverted U-curve and is often used to propose and quantify the interrelationship between CO2 and GDP per capita. The EKC is also utilized to look at how factors like alternative energies, fossil fuel use, exports, and eco-innovation impact CO_2. Regardless of the fact that the findings of such research can only give scant details, the results obtained are nevertheless useful in presenting policy-relevant conclusions.

Trade openness is critical for boosting the movement of products and services and raising economic production, however, the significance of possible CO_2 emission sources is still debated (Ali et al., 2020; Destek and Sinha, 2020). In the G7 economies, trade is a major source of CO_2 emissions from production, and CO_2 is embedded in the final domestic demand for imported goods. Despite the fact that nations are switching their resources to focus on project efficiency and utilize numerous environmental technologies to balance trade and CO_2, ensuring greener and more efficient production remains an essential problem in this world, with international trade and growth being the principal drivers.

Through their attempts to optimize their use of renewable resources, technological breakthroughs have assisted the expansion of renewable energy and benefited nations in reducing pollution levels and altering the quality of their ecosystems. There is a strong link between renewable energy sources and innovation, as well as their final commitment to environmental and economic developments, according to a large body of literature(Cheng et al., 2021; Anwar Khan et al., 2021). The use of REC can help to minimize CO2. This is accomplished by switching from a nonrenewable source of energy that puts a massive strain on the environment to a more source of renewable energy. Economic structures are transitioning to renewable energy derivatives such as renewable energies, according to (Lin and Zhu, 2019). These countries choose ecological protection skills and environmentally relevant technological advancements that help to improve ecological protection initiatives to a certain extent. In addition, technological improvements have been identified to assist in the decrease of contaminants and the enhancement of environmental protection initiatives (Jahanger et al., 2022; Vural, 2021).

Based on the above information, the present research assesses the effect of trade openness, on CO2 emissions for the period 1990 to 2019. In a departure from previous research, our work adds to the current literature in several ways. First and foremost, we want to offer a more thorough answer to the issue of whether renewable energy can help the G7 nations reduce ecological damage. For the G7 economies, various previous research has cast light on the implications of renewable energy utilization on CO_2. Nevertheless, in the case of these nations, nothing is documented about the ecological consequences of eco-innovation. Second, over the period 1990–2019, this is the first effort to assess the impact of trade openness, economic growth, nonrenewable energy eco-innovation, and REC on CO_2 in G7 nations. Existing research has mostly focused on assessing the ecological consequences of economic growth in the G7 nations. Evaluating the consequences of eco-innovation and trade openness, on the other hand, is crucial since it contributes a holistic component to the economic expansion-environmental quality research. Finally, in order to meet the study's goals, we used robust panel econometric methodologies that account for CSD as well as slope heterogeneity issues in the data. Several current research have mainly avoided the issue of diverse slope coefficients while adjusting for cross-sectional dependency; as a result, the results published in those investigations are liable to be contradictory and biased. **Table 1** presents the summary of the literature.

The next section presents data and methods which are followed by findings and discussion in *Findings and Discussion Section*. *Conclusion and Policy Directions Section* concludes the empirical analysis.

MATERIALS AND METHOD

Data and Model

In this study, we explore the effect of trade openness, economic growth, and eco-innovation on CO2 emissions in G7 nations. We

TABLE 1 | Synopsis of Related Studies.

Authors	Nation(s)	Period	Techniques	Outcomes
Xu et al. (2022)	BRICS	1990–2018	Panel Quantile Regression	GDP and NREC increase CO_2 while REC curb CO_2
Adebayo and Kirikkaleli, (2021)	Japan	1990Q-2015Q4	Wavelet Coherence	GDP, ECO, and NREC increase CO_2 while REC curbs CO_2
Gyamfi et al. (2022a)	Mediterranean Nations	1990–2016	MMQR	GDP and URB increase CO_2 while REC curb CO_2
Tony Odu et al. (2022)	India	1990–2018	Quantile Approach	GDP, and TO, TOR increase CO_2
Adebayo, (2022a)	Spain	1990–2018	Wavelet Tools	GDP, ECI and NREC increase CO_2 while FDI and mitigate CO_2
Oladipupo et al. (2021)	Portugal	1980–2018	NARDL	GDP and TO increase CO_2 while ECO mitigates CO_2
Murshed, (2020)	South Asia	2000–2015	ARDL	ECO and REC mitigate CO_2
Ahmad et al. (2021)	G7 countries	1980–2016	CS-ARDL	EKC is valid while ECO curb CO_2
Ahmed and Le, (2021)	ASEAN	1995–2015	CUP-FM	GDP and TO increase CO_2 while ECO mitigates CO_2
Ahmed et al. (2019)	Indonesia	1971 to 2014	ARDL	GDP, URB, and TO increase CO_2 while ECO mitigates CO_2
Fan and Hossain, (2018)	India	1974–2016	ARDL	ECO and TO increase GDP
Sohag et al. (2015)	Malaysia	1985–2012	ARDL	GDP and TO increase CO_2 while ECO and REC mitigate CO_2
Anwar et al. (2021)	India	1985–2017	VECM	GDP, and FDI increase CO_2 while ECO and REC mitigate CO_2
Dauda et al. (2021)	Africa	1990–2016	Panel Techniques	GDP, HC and URB increase CO_2 while ECO and REC mitigate CO_2
Rafique et al. (2021)	BRICS countries	1990 to 2017	AMG	GDP, and TO increase CO_2 while ECO and REC mitigate CO_2

TABLE 2 | Data source and Description.

Sign	Variable	Measurement	Source
CO_2	Carbon Emissions	Metric Tonnes Per Capita	BP
GDP	Economic Growth	GDP per Capita Constant US$2010	WDI
ECO	Eco-innovation	% of total technological innovation	OECD
REC	Renewable Energy Consumption	million tonnes of oil equivalent	BP
NREC	Nonrenewable Energy Consumption	million tonnes of oil equivalent	BP
TO	Trade Openness	Trade % of GDP	WDI

also incorporate energy (nonrenewable and renewable) as a driver of CO_2 emissions using a dataset from the period from 1990–2019. **Table 2** lists the measurement of the variables gathered and the unit of measurement used, as well as the sources of all the data used to generate the econometric outcomes shown in the sub-sections below. All series correspond to yearly observations from 1990 to 2019, which were selected based on available data.

We put up an econometric model, as indicated in **Eq. 1**, predicated on the topic under investigation and the data obtained, which are evaluated using robust panel econometric approaches.

$$CO_2 = f\,(GDP, ECO, REC, NREC, TO) \qquad (1)$$

Where; CO_2 denotes CO_2 emissions, ECO stands for eco-innovation, REC represents renewable energy consumption, NREC denotes nonrenewable energy and TO represents trade openness.

Estimation Strategy

We commenced by utilizing the FMOLS and DOLS to catch the effect of GDP, TO, NREC, REC and ECO) on the endogenous variable (CO_2). Furthermore, we utilized the quantile regression to identify the effect of GDP, TO, NREC, REC and ECO on varied quantiles of CO_2 emissions. As previously stated, fixed-effect panel quantile regression was used to analyze the influence of the regressors (NREC, ECO, GDP, TO, and NREC) on CO_2 emissions in this study. Unlike previous estimators, quantile regression provides a clearer picture of the relationship between the parameters by enabling for substantially more flexibility in empirical evaluation at different quantiles of the response parameter distribution. Additionally, outliers in the result variables have little effect on the estimated regressors. As a consequence, the panel quantile regression approach is utilized to evaluate the influence of NREC, ECO, GDP, TO, and NREC on different quantiles of CO emissions. The application of the generalized version of the median regression analysis is shown below:

$$Q_{yi}\left(\tau_k / x_i\right) = x_i^{\tau}\beta_{\tau} \qquad (2)$$

Furthermore, unlike traditional panel quantile regression, fixed effects quantile regression is utilized to capture possible cross-sectional variability, as evidenced by cross-sectional dependency tests.

$$Q_{yi}\left(\tau_k / \alpha_i x_{it}\right) = \alpha_i + x_{it}^{\prime}(\tau_k) \qquad (3)$$

Where: Υ represent CO_2 emissions and X represents the exogenous variables (REC, NREC, TO, ECO and GDP). In panel quantile regression analysis, the presence of a large

TABLE 3 | CSD and CIPS Tests Outcomes.

Tests	CSD Test Outcomes					
	GDP	REC	ECO	TO	NREC	CO_2
Breusch-Pagan LM	485.65*	306.00*	598.25*	365.36*	220.64	358.17*
Pesaran scaled LM	71.698*	43.977*	89.072*	53.137*	30.805	52.027*
Bias-corrected scaled LM	71.577*	43.857*	88.951*	53.016*	30.684	51.906*
Pesaran CD	21.664*	8.6660*	24.457*	17.076*	7.7289	18.076*

Note: *p < 0.01.

number of fixed factors poses a considerable barrier. There will be unpredictability when individuals reach infinite, but each cross-section will have fixed measurements. The goal of using fixed effects is to get rid of any unintended fixed effects. Estimates are linear in this approach, which is why provisional quantiles are utilized. To deal with these problems, (Koenker, 2004) proposed a process which deals with unobservable fixed effects, given as parameters to assess, as well as covariate influences for several quantiles. The computing concerns with this approach have been addressed by using a penalty term for assessing variables, which allows the variable estimate to be obtained as follows;

$$Min_q \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{i=1}^{N} w_k P_{\tau k}\left(y_{it} - \alpha_i - x_{it}^{\tau}\beta(\tau_k)\right) + \lambda \sum_{l}^{N} \mathrm{I}\alpha_i \mathrm{I} \quad (4)$$

Moreover, the function of the quantile for τ for the present research variables is illustrated below:

$$Q_{yi}(\tau_k \mathrm{I}\alpha_i, \xi_t, x_{it}) = \alpha_i + \xi_t + \vartheta_0 + \vartheta_{1\tau} GDP_{it} + \vartheta_{2\tau} NREC_{it} + \vartheta_{3\tau} REC_{it} + \vartheta_4 \tau ECO_{it} + \vartheta_{5\tau} TO_{it} \quad (5)$$

TABLE 4 | Slope Heterogeneity Test.

$\hat{\Delta}$	*p*-value	$\hat{\Delta}_{Adj}$	*p*-value
9.708*	0.000	10.901*	0.000

*Note:**p < 0.01.

TABLE 5 | CIPS Test Outcomes.

	GDP	REC	ECO	TO	NREC	CO_2
Level	−1.211	−1.048	−1.570	−1.730	−0.863	−2.1305
First difference	−3.613*	−5.20*	−4.852*	−3.944*	−5.798*	−5.352*

Note: *p < 0.01.

TABLE 6 | Cointegration Outcomes.

Statistics	Gt	Ga	Pt	Pa
Value	−3.43	−7.021	−7.923	−8.885
p-value	0.009**	0.833	0.002*	0.339

*Note:**p < 0.01 and **p < 0.05.*

FINDINGS AND DISCUSSIONS

The econometric study begins by examining the data for crosssectional dependency (CSD) and slope heterogeneity (SH). **Table 3** shows the findings of the CSD analysis, which demonstrate the occurrence of CSD in the data. The test statistics have statistical significance at the 1% level, rejecting the null hypothesis of CSD and confirming the CSD concerns. This discovery is significant in light of the fact that the G7 nations are all industrialized nations that are intertwined, specifically in terms of financial and trade flows. As a result, a single macroeconomic disruption is likely to have similar effects on these nations. The SH test comes after the CSD analysis. The results of the SH test are presented in **Table 4**. The test results for the model are significant statistically, according to the estimations. To validate the existence of slope heterogeneity concerns in the data, the null hypothesis of slope homogeneity is discarded at a 1% level of significance. Even though the G7 nations are highly comparable in many ways, there are some economic contrasts between them. As a result, slope heterogeneity is warranted in this context.

The cointegration and unit root analyses are performed after the CSD and SH problems in the data have been confirmed. The 1st-generation tests are no longer appropriate because the CSD problems have been discovered. As a result, the stationarity qualities are determined using the second-generation CIPS test. **Table 5** summarizes the findings of the unit root analyses. At level, the series are non-stationary, but stationary at first difference, according to the estimations. At 1% and 5% levels of significance, the statistical significance of the anticipated test statistics rejects the null hypothesis of non-stationarity, confirming these assertions. As a result, the variables examined in this research have a common order of integration. The analysis of cointegration comes after the unit root analysis is ascertained.

Table 6 summarizes the Westerlund (2007) cointegration outcomes. The existence of cointegration in the model is confirmed by the statistically significant of the test statistics. As a result, in the framework of the G7 nations, CO_2 has long-run interrelationship with GDP, TO, NREC, ECO, and REC. The presence of long-run associations makes estimating long-run elasticity estimates straightforward.

After confirming the cointegration between CO_2 and the regressors, we proceed by examining the effect of GDP, ECO, TO, REC and NREC on CO_2 using long-run estimators (FMOLS

TABLE 7 | FMOLS and DOLS.

	FMOLS		DOLS	
	Coefficients	T-statistics	Coefficients	T-statistics
GDP	−0.4154	−6.3069*	−0.4504	−6.5966*
ECO	−0.0851	−5.2526*	−0.0683	−4.0206*
REC	−0.0378	−2.1080**	−0.0395	−2.1414**
NREC	1.0606	21.181*	1.0308	20.973*
TO	0.1663	5.5655*	0.1317	4.2226*
R^2	0.99		0.97	
Adj R^2	0.98		0.96	
S.E. of reg	0.0317		0.031338	

and DOLS). **Table 7** presents the DOLS and FMOLS outcomes. The effect of GDP on CO_2 is negative which demonstrates that a 1% upsurge in GDP caused CO_2 emissions to fall by 0.4154% (FMOLS) and 0.4505% (DOLS) respectively. Furthermore, ECO mitigates emissions of CO_2 as revealed by both FMOLS and DOLS. This implies that a 0.08% (FMOLS) and 0.068% (DOLS) decrease in CO_2 is a result of a 1% upsurge in ECO keeping other factors constant. Moreover, the effect of REC on CO_2 is negative which demonstrates that a 1% upsurge in REC caused CO_2 emissions to decline by 0.0374% (FMOLS) and 0.03955% (DOLS) respectively. Furthermore, NREC contributes to emissions of CO_2 as revealed by both FMOLS and DOLS. This implies that a 1.060% (FMOLS) and 1.0308% (DOLS) increase in CO_2 is a result of a 1% upsurge in NREC keeping other factors constant. Lastly, we observed a positive TO and CO_2 emissions association which implies that holding other factors constant, 0.1663% (FMOLS) and 0.1317% (DOLS) growth in CO2 is caused by 1% growth in TO.

The long-run estimators (FMOLS and DOLS) cannot capture the relationship between CO2 and the regressors in each quantile. As a consequence, the current paper employed panel quantile regression (PQR). The PQR outcomes are depicted in **Table 8**. In the lower and middle tails (0.1–0.60), the presence of a negative interrelationship between CO_2 and GDP is evident; however, in the higher tails (0.70–0.90), there is no significant association between CO_2 and GDP. In summary, a surge in GDP boosts the quality of the environment in the lower and middle tails (0.1–0.60). Furthermore, in each quantile (0.1–0.90), we established a negative and significant association between CO_2 and ECO. This implies that ECO curb CO_2 emissions in each tail (0.1–0.90). Moreover, REC mitigates CO_2 in the lower and middle tails (0.1–0.60); however, an insignificant association between CO_2 and ECO is evident in the upper tail (0.70–0.90). Furthermore, a surge in CO_2 is caused by a surge in NREC in each tail (0.1–0.90); though the positive effect is more pronounced in the middle and upper tails (0.35–0.90). Lastly, trade contributes to a surge in CO_2 across all quantiles (0.1–0.90) which implies that trade openness is a major driver of emissions of CO_2 in the G7 nations. These outcomes are consistent with the long-run estimators' outcomes. **Figure 1** presents the graphical outcomes of the PQR.

The results of the (Dumitrescu and Hurlin, 2012) causality test are presented in **Table 9**. There is evidence of feedback causal association between ECO and CO_2 suggesting that both ECO and CO_2 can forecast each other. Furthermore, NREC and CO_2 can forecast each other which supports the proof of bidirectional causal linkage. In addition, REC and CO_2 can significantly predict each other as reported in **Table 8**. This demonstrates that any policy towards REC will impact CO_2 and vice-versa. Furthermore, feedback causality exists between TO and CO_2 suggesting that they can forecast each other Lastly, GDP can predict CO_2; however, no evidence of causality from CO_2 to GDP affirms unidirectional causality from GDP to CO_2. **Figure 2** presents the empirical findings from FMOLS, DOLS and Panel Quantile Regression.

Discussion of Findings

We established that surge in economic expansion mitigates CO2 emissions. This outcome is as anticipated given the fact that the G7 nations are all developed nations. This implies that they are at the technique and composition phases of growth where countries becomes more aware of their environment. At this stage, they consider environmental sustainability when formulating growth agenda. This outcome complies with the research of (Irfan Khan et al., 2021), (Dingru et al., 2021), and (Usman et al., 2020) who reported that GDP growth augments the quality of the ecosystem. Nevertheless, the studies of (Adebayo, 2022a) for Spain, (Awosus et al., 2022a), and (Güngör et al., 2021) refuted this outcome.

Furthermore, we established that renewable energy use curbs damage of the ecosystem. This demonstrates that the utilization of renewable energy perform a significant role in abating the environmental deterioration in the G7 nations. The study outcome agrees with the study of (Miao et al., 2022) for BRICS nations using a dataset from the period 1990–2018 which reported that a surge in green energy abate CO_2.

TABLE 8 | Panel quantile Regression Outcomes.

	Lower Quantile				Middle Quantile			Higher Quantile	
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
GDP	−0.5218*	−0.7316*	−0.5959**	−0.4795**	−0.4149***	−0.2308***	0.1728	0.0961	0.2570
ECO	−0.0307*	−0.0349*	−0.0303*	−0.0420*	−0.0461*	−0.1645*	−0.1595*	0.1368*	−0.1434*
REC	−0.0263*	−0.0287*	−0.0249**	−0.0238**	−0.0259**	−0.0920**	0.2272	0.2309	0.1656
NREC	0.5099*	0.5924*	0.5590*	0.5703*	0.5606*	0.3135*	0.2838*	0.2721*	0.3174*
TO	0.0443*	0.3070*	0.2834*	0.3013*	0.2802*	0.2199*	0.2271*	0.3008*	0.3397*
C	3.7490	4.3965	3.3132	2.0171	1.5521	−3.5436	−2.8798	−2.3829	−4.0666
Pseudo R^2	0.5844	0.5760	0.5709	0.5497	0.5208	0.5361	0.5942	0.5869	0.5882

*Note: *p < 0.01, **p < 0.05 and ***p < 0.10.*

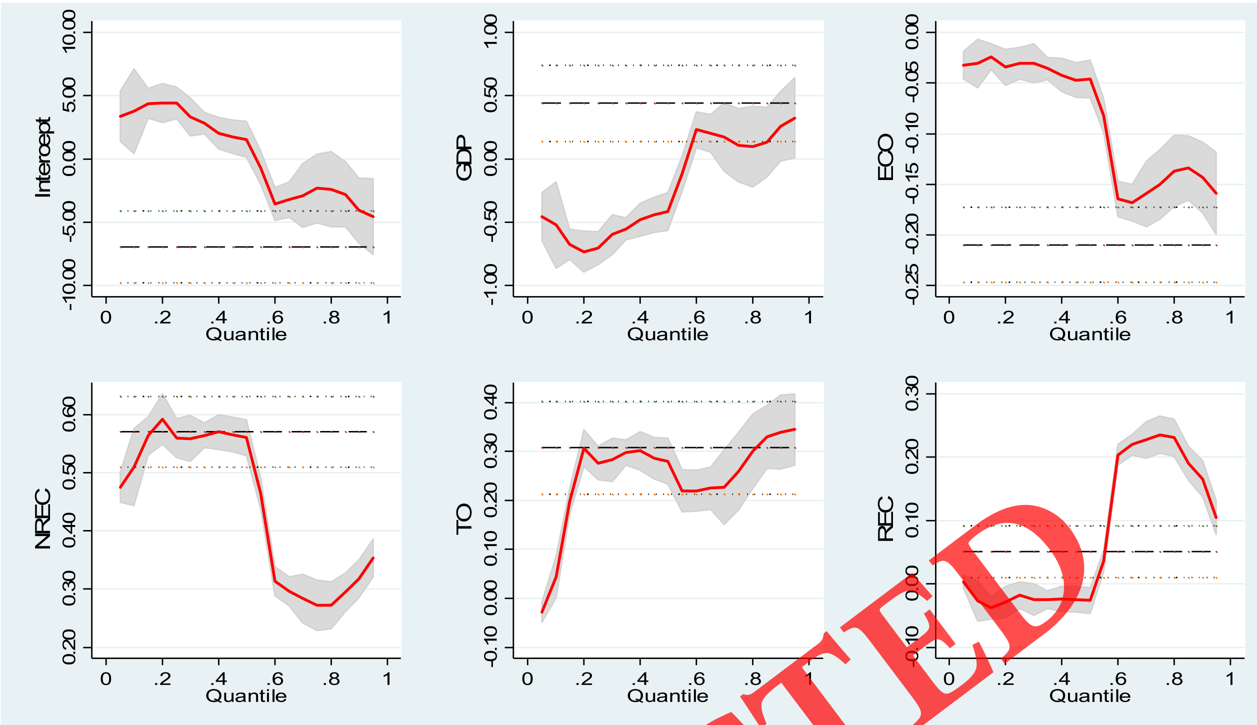

FIGURE 1 | Graphical outcomes of Panel Regression.

TABLE 9 | Panel causality Outcomes.

Path of Causality	W-stat.	Zbar-stat.	Probability	Decision
ECO →CO_2	3.72654	4.28197	0.0000	Feedback Causality
CO2 →ECO	4.14483	4.95960	0.0000	
NREC →CO_2	3.60727	4.08876	0.0000	Feedback Causality
CO_2→NREC	3.48886	3.89694	0.0001	
REC →LCO_2	3.59553	4.06974	0.0000	Feedback Causality
CO_2 →REC	3.73596	4.29725	0.0000	
TO →CO_2	4.32106	5.24510	0.0000	Feedback Causality
CO_2 →TO	2.16141	1.74649	0.0807	
GDP →CO_2	5.30687	6.84210	0.0000	Unidirectional Causality
CO_2 →GDP	0.58998	−.79922	0.4242	

Likewise, the studies of (Adebayo et al., 2022) and (Kirikkaleli and Adebayo, 2020) reported that green energy promotes ecological sustainability.

Moreover, we uncovered that eco-innovation stimulates sustainability of the environment. This means that investments in environmental-related technological innovation, particularly the replacement of older equipment with newer technologies, cut emissions of CO_2 in G7 countries. Low-carbon technical innovation, for instance, can be used on both the supply and demand sides in buildings, transportation and industry. Furthermore, encouraging eco-innovation in these nations decreases energy intensity, lowering dependency on fossil fuels and, as a result, lowering CO_2. This result is in line with the studies of (Kihombo et al., 2021), (Su et al., 2021), (Agyekum et al., 2022), (Awosusi et al., 2022b), (Akadiri et al., 2021) and (Fareed et al., 2021b).

Furthermore, there is proof of positive interconnection between TO and CO_2 in G7 nations. This demonstrates that a surge in trade openness contributes to the deterioration of the G7's ecosystem. Based on this finding, the G7 nations need to re-strategize their trade policies to be more eco-friendly. The study of (Oladipupo et al., 2021) for Portugal and (Soylu et al., 2021) for China complies with this outcome.

Moreover, the research discovered that nonrenewable energy stimulates the deterioration of the environment. This result is to be anticipated, given that energy is understood as a crucial part of the

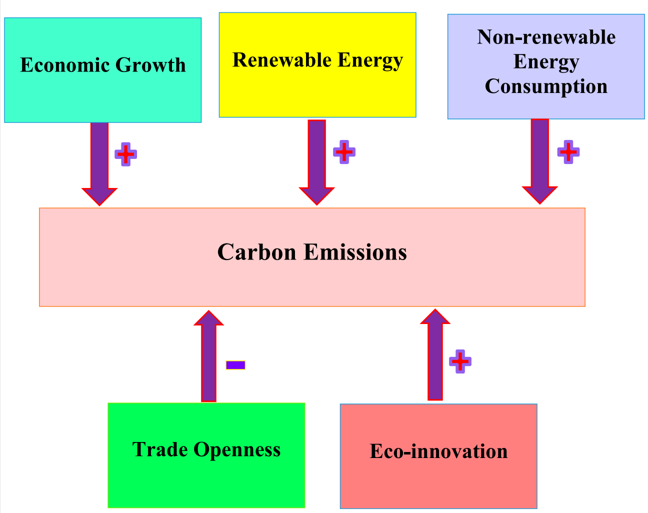

FIGURE 2 | Empirical findings from FMOLS, DOLS and panel quantile regression.

production, and an increase in energy use is assumed to raise economic productivity (Adebayo et al., 2022). Higher energy consumption, on the other hand, can have an effect on the quality of the environment since the burning of energy resources, particularly fossil fuels, results in the release of GHG; hence, energy utilization can be said to be harmful to the environment. This outcome complies with the research of (Yuping et al., 2021) for Argentina, (Shahbaz et al., 2021), and (Gyamfi et al., 2022b).

Finally, the results of the panel causality test unveiled that CO_2 emissions can be predicted by all its drivers ECO, GDP, NREC, TO and REC in the G7 economies. Therefore, policy initiatives directed at any of the CO_2 emissions drivers in the G7 nations will have a substantial influence on CO_2 emissions.

CONCLUSION AND POLICY DIRECTIONS

Conclusion

In this empirical investigation, we examine the effect of eco-innovation and trade openness on CO_2 emissions in G7 nations. We consider the role of renewable energy, economic growth and nonrenewable energy use using a dataset covering the period from 1990–2019. We employed recent econometric techniques such as SH and CSD, Westerlund cointegration, FMOLS, DOLS, panel quantile regression and panel causality tests to assess these associations. The outcomes of the CSD and SH tests disclosed that using a first-generation unit root test will produce bias outcomes. Furthermore, the outcome of the Westerlund cointegration was disclosed to support the long-run association between CO_2 and its drivers. In addition, the results of the long-run estimators (FMOLS and DOLS) unveiled that NREC and TO contribute to the damage to the environment while ECO, REC and GDP enhance the quality of the environment. Furthermore, the outcomes of the panel quantile regression unveiled that in the majority of the quartiles, economic expansion, renewable energy, and eco-innovation enhance the quality of the environment while nonrenewable energy and trade openness contribute to the damage to the environment. Finally, the outcomes of the panel causality test unveiled that CO_2 emissions can be predicted by all its drivers (eco-innovation, economic growth, renewable energy, trade openness and nonrenewable energy use) in the G7 economies. Therefore, policy initiatives directed at any of the CO_2 emissions drivers in the G7 nations will have a substantial influence on CO_2 emissions.

Policy Suggestions

The results of the selected techniques specifically point to ECO, REC, and GDP as potential best practices for reducing G7 emissions. As a result, it is critical for the governments of the G7 economies to focus more on energy transition (from fossil fuels to more sustainable energy sources). As per empirical evidence, economic growth promotes environmental sustainability in G7 countries. This suggests that the growth trajectory of the G7 economies remains stable. The study backs up this need by claiming that renewable energy decreases CO_2 emissions and hence improves the quality of the environment. This demonstrates that the G7 economies are on the right track in terms of reducing environmental deterioration. Nevertheless, in order to attain environmental sustainability, she needs to make further efforts to include other alternative and greener sources of energy into her energy mix.

Furthermore, G7 nations' policymakers should develop liberalization and privatization policies that would encourage both public and private parties to participate in renewable energy. In addition, as previously stated, policymakers or governments should undertake strategies to support ecological integrity by enforcing more carbon taxes on production and assisting sectors in transitioning from conventional high CO_2 emitter technologies to cleaner technologies in order to preserve ecological integrity. Furthermore, because trade openness promotes the destruction of the environment, officials in these nations should reduce trade openness to prevent environmental damage from dirty products trade.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

VO, MI, and MA contributed to conception and design of the study. EA organized the database. SK and ME performed the statistical analysis. MA wrote the first draft of the manuscript. VO, MI, EA, and MF wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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