Economics

Re-investigating the Impact of Economic Growth, Energy Consumption, Financial Development, Institutional Quality, and Globalization on Environmental Degradation in OECD Countries

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Abstract

This study attempts to quantify various macroeconomic variables' influences on environmental quality. Being significantly negative in character, the impacts of economic growth, energy consumption levels, financial development tools, changes in institutional qualities, and globalization on environmental degradation are regarded worthy of research. The dynamic panel model reports robust results using quantile regression and Generalized Moment Method (GMM) approaches. Renewable energy consumption, globalization, and institutional quality significantly reduce the negative impacts on the natural environment across all quantiles. In contrast, electricity consumption has a significant deleterious impact across all quantiles, except at the 95% level, where the impact is not detrimental. Economic growth and financial development produce significantly positive injurious effects on the environment across all quantiles. Our findings reveal that callous indifference to global environmental degradation should not be tolerated for economic and ethical reasons, and it falls on the OECD countries to show leadership and take the initiative. OECD countries can mitigate environmental degradation by sharing knowledge and experience of balancing growth to promote sustainable development and responsible consumption globally.

Keywords: Economic Growth, Energy Consumption, Financial Development, Institutional Quality, Globalization, Environmental Degradation, OECD.

1. Introduction

The recent deterioration in global climatic conditions, caused by an increasing concentration of greenhouse gases (GHGs), has been posing increasingly severe threats to human life and significant concerns for biodiversity. Because of the issue of environmental degradation (Bilgili & Ulucak, 2020), regulators, policymakers, and environmentalists have constantly been searching for the most feasible solutions to the problem of how to achieve the long-term objective of sustainable economic development (ED). Climate change and natural-environment problems such as global warming, deforestation, and desertification have started exerting adverse economic and social consequences for societies. The disruptions in the balance of our ecosystems due to unfavorable climate change can cause climatic disasters and pollution (Charfeddine & ben Khediri, 2016).

The causes and effects of environmental degradation have been extensively analyzed empirically for the last three decades. According to Rehman et al. (2019), economic growth (EG) and energy consumption (EC) has been cited as the most significant factors impacting the environment. An important issue in environmental arguments worldwide is the rise in GHGs, which are seen as a price to pay for economic progress and the use of fossil fuels (Dong et al., 2018). In the existing literature, environmental degradation has also been examined from several angles; among them, one of the most widely used ways is the Environmental Kuznets Curve (EKC) hypothesis Aydoğan & Vardar (2020). Aydin (2019) analyzed using a newly-built panel smooth-transition regression model showing that EKC does not hold for most of the 26 European nations studied over a 1990–2013 time period.

Destek et al. (2018) reported the existence of the traditional EKC nexus between ecological footprint (ECF) and national income in the context of E.U. economies. Extant research has rarely analyzed these dynamics, particularly from the perspective of institutional quality, to examine their effects on the degradation of the environment. Figure

1 shows various primary sources of energy usage by OECD and non-OECD countries in the last decade and the projected usage to 2050 (in quadrillion British thermal units on the Y axis[1]).

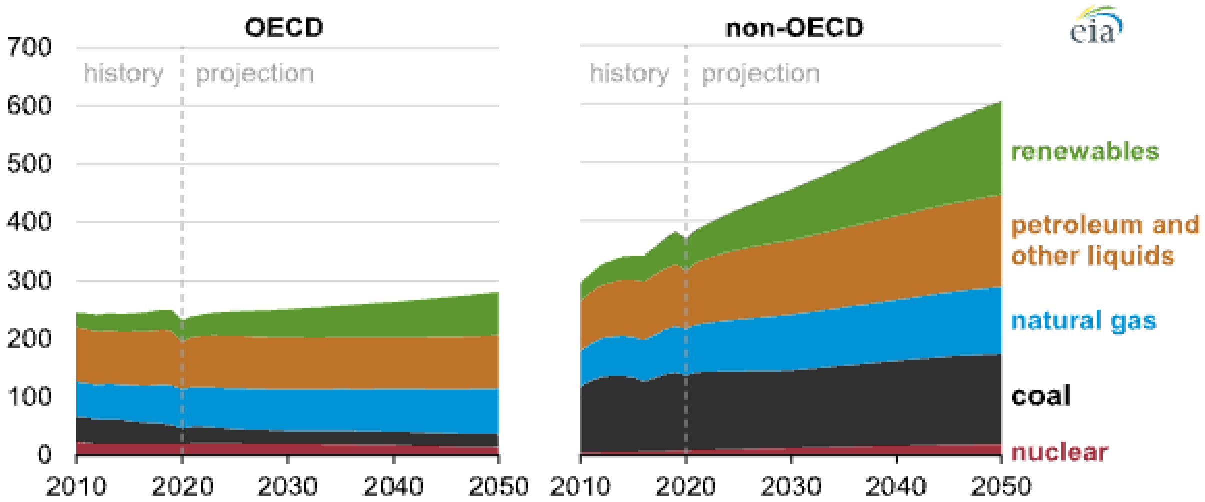

Figure 1: *The usage of primary energy sources*

Source: *U.S. Energy Information Administration, International Energy Outlook 2021*

Figure 2 shows the actual and projected carbon-based emissions caused by the energy usage in OECD and non-OECD countries (in quadrillion British thermal units on the Y axis[2]).

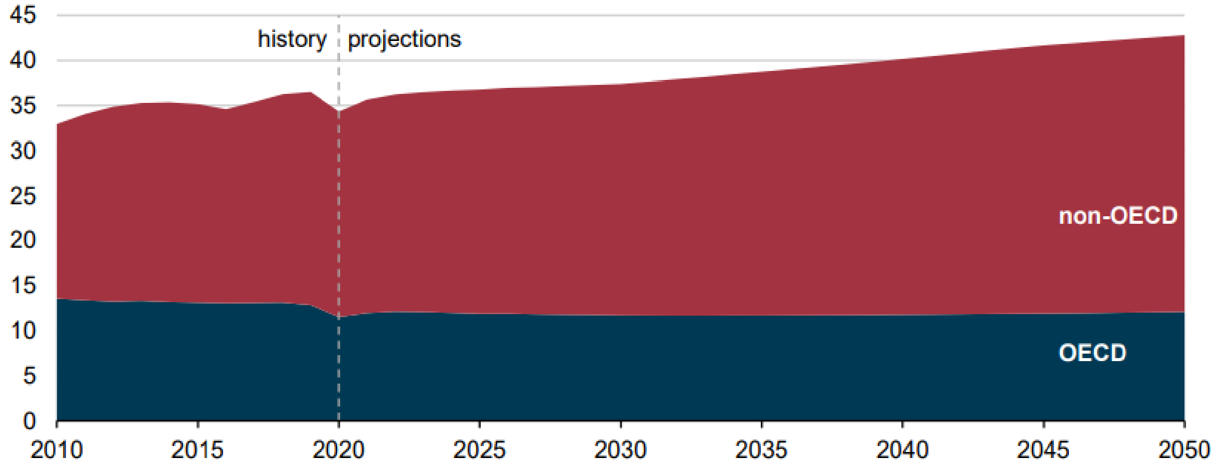

Figure 2: *Energy-based CO2 Emissions*

Source: U.S. Energy Information Administration, International Energy Outlook 2021

[1] https://www.eia.gov/todayinenergy/detail.php?id=49876

[2] https://www.eia.gov/todayinenergy/detail.php?id=49876

The current research article attempts to analyze the impact of institutional quality (IQU), financial development (FD), globalization (GLO), usage of renewable energy sources (REC), EC, and EG on environmental degradation in the context of OECD economies for the period from 1972 to 2016. (Note: these acronyms are used throughout this paper for purposes of parsimony.)

This research relies on dynamic panel-data models, i.e., system GMM and difference GMM, for analysis. Moreover, further robustness was checked with quantile regression modelling. For the first time, this study combines IQU and GLO with other macroeconomic variables to examine their impacts on environmental degradation in OECD countries. The economies of OECD countries are developing very rapidly. They extensively use energy resources for industrial usage and are hubs of production and consumption. Therefore, the current pattern of economic activities and the ambition to maintain high growth are severe threats to the natural environment in OECD countries.

2. Literature Review

Climate changes has become an alarming issue in recent years (Shahbaz et al., 2019). Climate change badly affects both human lives and property. Though a number of factors contribute to climate change, CO_2 emissions have received much attention in the literature (Tiba & Omri, 2017). Extensive use of fossil fuels to maintain EG and achieve new highs in development is considered one of the main contributors to climate change (Shahbaz et al., 2019). Zhan et al. (2021) employed a Quantile Auto-Regressive Distributed Lag Parameter (QARDL) approach with quarterly data from 1995 to 2018 and found that IQU and GDP can affect CO_2-based emissions. Their findings suggest that CO_2 emission increases with an increase in IQU. On the other hand, information communication technology (ICT) and FD negatively impact CO_2 emissions. This shows that the CO_2 emission level decreases with growth in the ICT and ED.

Islam et al. (2021) analyzed Bangladesh's growth and attributed it to the contributions and influences of different factors such as IQU, innovation, EC, urbanization, EG, trade volume, FDI, and GLO that also impact its natural environment. Their results show that innovation, FD, and GLO affect the levels of CO2 emissions negatively, thereby helping in improving the quality of environmental indicators, while urbanization, EC, trade volume, and EG increase CO2-based emissions, thereby hastening the degradation of environmental indicators both in the short and long-run. The study also reported positive impacts of IQU, measured in terms of the political terror scale (PTS), on CO2-based emissions in the short and long run. Godil et al. (2021) suggested policy implications to encourage innovation, FD, and GLO and carefully utilize institutions' strengths, urbanization, trade potential, income growth, and EC to ensure optimum quality of environmental indicators amongst the OECD nations.

According to Khan et al. (2021), environmental degradation has posed serious challenges for most developing countries that use energy primarily from sources such as fossil fuels. Consumption of renewable energy (REC) is now highly recommended to mitigate the problem and effects of environmental degradation; however, these economies need the desired policies and efforts to switch towards REC and ensure environmental quality. Khan et al. (2021) used data from 1970 to 2018 and examined the relevance of FD. They found that different energy sources improve environmental quality. Since their findings show that economic expansion degrades environmental quality, governments are encouraged to safeguard environmental quality while pursuing EG using environmentally friendly tactics, proper equipment, and the REC (Khan et al., 2020).

In another environmental study by Le & Ozturk (2020), the changes in environmental indicators were analyzed under the influence of IQU, FD, government spending, and GLO. Researchers incorporated GDP per capita and EC into the EKC model for the 47 emerging markets and developing economies (EMDEs) from 1990 to 2014. They used dynamic common correlated effects (DCCE), Mean Group (MG), and the Common Correlated Effects Mean Group estimator (CCEMG) models for their analyses. According to their findings, FD, energy use, government oversight, financial accruals, and GLO enhanced the levels of CO2-based emissions, supporting the EKC theory. In the context of EMDEs, the study revealed the nature of the trade-off between EG and environmental quality. They also proposed vital policy implications for balancing FD, EG, and EC, viz a viz the environmental sustainability in a globalized world.

The nexuses amongst the CO2-based emissions, EG and EC, have garnered considerable research during the last few decades. Yilanci & Pata (2020) used an endogenous structural break to examine the impact of globalization and FD on environmental deterioration and reported that while FD helps curtail the pollution levels in Japan, it significantly improves the ecological footprint in Italy and Canada. EC and GLO increase environmental deterioration, and compared to FD, GLO appears to be a more influential factor in managing environmental footprints in the G-7 countries. However, in the U.K., Japan, and France, EG worsens the country's environmental impact. While EC is critical for economic progress, it also contributes to environmental damage (Owusu et al., 2021). EC continues to degrade the environment in a variety of countries (Ahmad et al., 2016), and therefore, GLO opportunities should be exploited to solve environmental problems.

2.1 Economic Growth and CO2-based emissions

Using the EKC idea, the literature sheds light on the link between environmental contamination and economic expansion. According to the EKC, the environment deteriorates as output increases till a definite level of EG is reached, at which point pollution decreases as per capita and gross domestic product increase, generating an inverted U-shaped relationship (Grossman & Krueger,1995).

This occurs when citizens demand that governments enact strict environmental rules to promote a healthy environment. Individuals with higher incomes become more worried about their health. Hence typically demand a quality environment, which results in policy actions to reduce radiation and encourage a healthy environment. At a more outstanding mark of development, the economic structure is generally changed away from highly polluting industries toward creative and service-oriented output that is largely pollution-free. Since that time, several further studies have been conducted to determine the existence or absence of the EKC, utilizing various contaminants and approaches. Environmental degradation was initially associated with economic expansion, but ecological degradation declined after a specific threshold was reached. Numerous research studies have found contradictory associations between CO2-based emissions and EG (Haseeb et al., 2018) and (Khan et al., 2021). In light of the above discussion, we formulate the following hypothesis:

H1: *EG causes the CO_2-based emissions to reduce.*

2.2 The Linkage between REC and CO2-based emissions

Global CO2-based emissions are linked to several different aspects of the economy. Assessment of growth-energy-emissions pollution has moved beyond looking at the link between EG and pollution. When it comes to climate change, REC helps reduce CO2-based emissions while also creating a friendlier environment (Charfeddine & Kahia, 2019). REC is now at the forefront of fighting environmental deterioration, being amongst the environmental policies incorporated into the strict environmental policy index, a composite measure of relative policy stringency (Gielen et al., 2019). Increased renewable energy supply reduces CO2-based emissions in the BRICS (Chen et al., 2019), but according to Sebri & Ben-Salha (2014), the evidence is different as increased CO_2 emissions diminish the REC in South Africa and India. In Turkey, Bölük & Mert (2015) observed that REC reduces CO2-based emissions; however, Pat (2018) reported a piece of evidence to the contrary. In Turkey, Salim & Rafiq (2012) demonstrated that power generation from RE reduces CO_2-based emissions significantly and favorably; in Indonesia, Sugiawan & Managi (2016) discovered the same. For Brazil, China, Russia, and India, Danish et al. (2019) reported a significantly negative nexus between REC and CO2-based emissions but a positive and insignificant relationship in the context of South Africa. In addition, (Acheampong et al., 2019) discovered that increasing REC reduces CO2 emissions for a group of forty-six African countries. Because of the discussions mentioned above, we formulated the following hypothesis:

H2: REC *causes the CO_2-based emissions to be reduced*.

2.3 Financial development and CO2-based emissions

The link between FD, EG, and CO2-based emissions has been a hot topic in energy economics research during the last few years. Foreign direct investment is critical because it provides the financial resources necessary for EG and ecological quality (Khan et al., 2019c). However, it is unknown if FD has a detrimental effect on ecosystems or a beneficial impact. There are no censuses in the previous studies; some researchers (Khan et al., 2019b) assert that FD encourages EG but results in CO2-based emissions. GLO facilitates institutional development and changes that encourage further FD and economic progress. Without question, FD furthers and enables countries to utilize their finite resources more efficiently and boost their EG by increasing overall investment (Li & Ramanathan (2020). As such, the globalization regime encourages both emerging and developed countries to reform their financial sectors, promoting economic advancement (Khan et al., 2019a). Customers might also get more convenient loans as a result of FD. However, no single country can effectively solve energy, and environmental concerns on its own (Kohl, 2019) GLO harms environmental quality via a variety of networks (Xu et al., 2018).

Different nations have unique chances to lead the world in contributing to the growth of new energy technologies. The indication presented above is abundantly evident that FD is critical for advancing further innovation in energy usage and related strategies. Given the discussion above, we formulate the following hypothesis:

H3: An increase in FD *causes the CO_2-based emissions to reduce*.

2.4 Electricity Consumption and CO2

Energy is utilized as an input in manufacturing products and services, and it is vital for the economy's growth and development. As emerging economies develop, energy demand rises, posing a threat to environmental quality. FD is essential for EG and is seen as a significant force behind increased energy demand. FD decreases financial risk and borrowing costs, improves transparency, and stimulates energy demand as a source of investment and FD (Sadorsky, 2010).

Chen et al., (2016) examined the nexuses amongst the economy, GDP, and carbon-based emissions for the period between 1993 and 2010 for 188 nations. The results demonstrated a one-way causality between economy and carbon emission when the vector error correction model (VECM) was used. EC was also linked to the CO2-based emissions in thirty-four nations. Consequent to their findings, the researchers concluded that EC contributes significantly to carbon dioxide emissions. India's long and short-term relationships between EC, GDP, and CO2-based emissions have been examined. At both aggregated and disaggregated levels, the presence of EKC was validated using the ARDL approach. EC also contributes to greenhouse gas emissions. Thus, Riti et al. (2018) examined the effect of EC and F.C. on CO2-based emissions in ninety countries.

According to the dynamic ordinary least squares (DOLS) study, environmental degradation is primarily caused by the EC and GDP. Some researchers have also studied the relationship between EC and carbon emissions; they concluded that EC is the primary cause of CO2-based emissions. Because of the discussions mentioned above, we formulate the following hypothesis:

H4: An increase in electricity consumption *causes the* CO_2*-based emissions to* increase.

2.5 Globalization and CO2 Emissions

EG is promoted through GLO, which connects countries and economies worldwide through commerce, investment, and financial transactions. Working together to close innovation gaps, exchange best practices, and extend access to sustainable energy solutions allows countries to speed up the innovation process (Shahbaz et al., 2018). Globalization is good for many countries on a macro level. However, there may be pockets of workers who suffer from the competitive pressures from other countries with comparative advantages in their industries. Investment opportunities, capital flows, trade, and cultural linkages worldwide help drive EG and integration. It also aids countries in speeding up the innovation process by emphasizing shared issues and goals, collaborating to close innovation gaps, exchanging best practices, and making clean energy technologies more widely available (Shahbaz et al., 2018).

As a result of globalization, institutions are being reformed, resulting in financial progress and increased economic output. With financial development, nations may use their limited resources more efficiently, encourage investment, and increase EG. Apart from the studies mentioned above, the EKC proposition in the Chinese economy was evaluated and found that the globalization regime index and the sub-indices lower the level of CO2-based emissions, thereby increasing environmental quality (Shahbaz et al., 2017). Research on the trade-CO2-based emissions nexus focuses primarily on "trade openness" (Hasanov et al., 2018). Following the discussions above, we formulate the following hypothesis:

H5: GLO *causes the* CO_2*-based emissions to reduce*.

2.6 Institutional Quality and CO_2

Lau et al. (2014) suggested that competent and unbiased domestic organizations are critical for economic success and carbon release mitigation. Abid (2017) incorporated IQU into the growth emission model for the forty-one E.U. and 58 of the economies sampled from Africa and Middle East countries using a 1990–2011 dataset. He found IQU a critical factor in many economies for lowering CO2-based emissions and raising the targeted EG.

Additionally, according to Sarkodie & Adams (2018), IQU reduced CO2-based emissions by 0.1 percent in South Africa. Further, Salman et al. (2019) discovered that national institutions contribute significantly to EG and CO2-based emissions reduction. This shows that sound and effective environmental regulations are likely to be a significant determinant. Thus, state institutions must ensure the development and implementation of sound environmental regulation regimes and rules, which, if appropriately applied, will address the global economy's ecological concerns. Because of the discussions mentioned above, we formulated the following hypothesis:

H5: IQU *causes the CO_2-based emissions to reduce*.

3 Methodology

We employ various panel co-integration test equations. The primary function and model equations for the variables considered with the GMM-System estimator in this empirical study are as follows:

Variables (All except the first are independent)	Description	Data Source
CO2-based emissions (dependent)	Metric tons/capita	OECD
Consumption of Renewable Energy (REC)	Total, percentage of primary energy	OECD
Consumption of Electricity (EC)	Total Gigawatt-hours	OECD
Growth of economy (EG)	GDP (constant 2010 USD)	WDI
Financial Development (FD)	The volume of domestic credit extended by the formal sector (% of GDP)	WDI
Institutional Quality (IQU)	The law-and-order situation, corruption, the quality of the bureaucracy framework, the accountability of democratic institutions, and government stability.	ICRG
Globalization regime (GLO)	KOFI Globalization Index	KOFI

$$CO2 = f\,(REC, EC, FD, EG, GLO, IQU) \qquad (1)$$

$$lnCO2_{it} = \beta_{0it} + \beta_1 lnREC_{it} + \beta_2 lnEC_{it} + \beta_3 lnFD_{it} + \beta_4 EG_{it} + \beta_5 GLO_{it} + \beta_6 IQU_{it} + \varepsilon_{it} \qquad (1.1)$$

We have to verify whether co-integration exists among these variables with differences I (1). Employing the methodology of Phillips–Perron (Phillips & Perron, 1988), Fisher Chi-square, and Augment Dickey-Fuller (ADF), a panel unit root test was conducted to check if the variables are stationary at level. The Westerlund (2007) co-integration test, Kao residual co-integration test (Kao, 1999), and Pedroni co-integration (Pedroni, 2001, 2004) were employed before the long-run analysis. The econometric model was used to estimate the GMM model equations for one-step difference GMM, one-step system GMM, and two-step system GMM.

In the case of the between-dimension (mean panel), the group ADF-statistic, group PP-statistic, and the rho-statistics are considered for the testing of the residuals. The system estimator (GMM, one-step system) proposed by Blundell & Bond (1998) and Arellano & Bover (1995) serves as an alternative to GMM-DIF and helps resolve the problems of endogeneity of the independent variables and serial correlation.

The econometric model based on the system GMM approach used in the analysis is as follows:

$$Log\ CO2_{it} = \alpha_0 + \alpha_1 LogEC_{it} + \alpha_2 LogREC_{it} + \beta_3 LogFD_{it} + \beta_4 LogEG_{it} + \beta_5 LogGLO_{it} + \alpha_6 LogIQU_{it} + \delta_t + \eta_{it} + ''_{it} \quad (2)$$

3.1. Pedroni and Kao Test Equations

This research study uses the logarithm of CO2-based emissions in total metric tons/capita as the dependent variable to assess environmental degradation. The data were sourced from the online sources of the World Development Indicators, while "i" represents the number of OECD economies sampled in the analysis, and t represents the time framework. The explanatory variables are given and explained in the table above.

Pedroni (1999) and Kao (1999) co-integration estimators estimate the variables' long-run relationship. Pedroni's (1999) test is appropriate for variables with a panel unit root or heterogeneous panels. The study applies the Pedroni (1999) test to determine the long-run relationships between CO2, REC, EC, FD, EG, GLO, and IQU. The Kao test is a complementary test that helps analyze whether or not co-integration exists in the residuals' data series. The Pedroni (1999) test model equation is as follows:

$$co2_{it} = \varphi_i + \varphi_t + \beta_i \sum_{i=1}^{i=6} P_{ji} + \epsilon_{it} \quad (1)$$

$$\text{Where } \epsilon_{it} = \sum_{j=1}^{s_i} \theta_{it}\, \epsilon_{it} + \mu_{it} \quad (2)$$

Where; s_i denotes the sum of lags in the amplified 'Dickey-Fuller regression.' The CO2 signifies the dependent variable; P denotes the vector of explanatory variables.

Pedroni's (1999) test contains seven statistics. Four statistics are within a dimension (panel V, Q, P.P., and ADF), and three are between the dimensions (Panel ADF-static, panel PP-statistic, panel-rho statistics), and panel v-statistic (nonparametric for variance ratio). These statistics are constructed based on residuals from equation (2).

The Kao (1999) test is concerned with the cross-section of unique intercepts and homogenous coefficients in the first stage of the explanatory variables. The following equation (3) presents the Kao (1999) regression test:

$$y = \alpha_{\ i} + \beta x_{it} + e_{it}\ , i = 1,2,3, \ldots .N;\ t = 1,2,3, \ldots, T \quad (3)$$

$$y_{\ it} = y_{it-1} + u_{it} \quad (4)$$

$$x_{\ it} = x_{it-1} + \varepsilon_{it} \quad (5)$$

$\alpha_{\ i}$ represents fixed effects varying across the cross- section observations; β represents the slope parameter, and yit and xit are independent random walks for all i.

For the Augmented Dickey- Fuller test, estimated residuals are constructed from the equation (6)

$$\hat{e}_{it} = \rho \hat{e}_{it-1} + \sum_{j=1}^{p} \varphi_j\, \Delta \hat{e}_{it-j} + \nu_{iip} \quad (6)$$

There is no co-integration, and the ADF test is constructed as presented in the following equation (7):

$$\text{ADF} = \frac{t_{\hat{\rho}} + \sqrt{6\,N}\,\hat{\sigma}_r / (2\hat{\sigma}_{0r}}{\text{SQRT}(\hat{\sigma}^2{}_{0r}/(2\hat{\sigma}^2{}_r) + (3\hat{\sigma} r^2{}_r/(10\hat{\sigma}^2{}_{0r}))} \quad (7)$$

and the covariance of $\omega_{it} = \begin{bmatrix} \mu_{it} \\ \epsilon_{it} \end{bmatrix}$ is constructed as presented in the equation (8)

$$\Sigma \begin{bmatrix} \hat{\sigma}^2{}_{\mu} & \hat{\sigma}^2{}_{\mu e} \\ \hat{\sigma}^2{}_{0\mu\epsilon} & \hat{\sigma}^2{}_{\epsilon} \end{bmatrix} = \frac{1}{NT} \sum_{i=1}^{N} \sum_{i=1}^{T} \hat{\omega}_{it} \hat{\omega}_{it} \quad (8)$$

We determine the long-run covariance by using the Kernel estimator as from the equation (9)

$$\widehat{\Omega} = \sum \begin{bmatrix} \widehat{\sigma}^2{}_{0\mu} & \widehat{\sigma}^2{}_{0\mu e} \\ \widehat{\sigma}^2{}_{0\mu\epsilon} & \widehat{\sigma}^2{}_{0\epsilon} \end{bmatrix} = \frac{1}{N} \Sigma_{i=1}^{N} \left[\frac{1}{T} \Sigma_{i=1}^{T} \widehat{\omega}_{it}\widehat{\omega}_{it} + \frac{1}{T} \Sigma_{\tau=1}^{\infty} K\left(\frac{\tau}{b}\right) x \ \Sigma_{t=\tau+1}^{T} \widehat{\omega}_{it}\widehat{\omega}_{it-1} + \widehat{\omega}_{it-\tau}\widehat{\omega}_{it} \quad (9)$$

K represents the supported kernel function, and "b" represents the bandwidth.

3.1 GMM model equations

Difference and system GMM estimators are appropriate for the dynamic panel data. These models perform better in the presence of endogeneity, autocorrelation, and heteroskedasticity.

The difference model equation is:

$$Y_{it} = \alpha y_{i,t-1} + x_{it}^{/}\beta + \epsilon_{it} \qquad (10)$$

where;

$$\epsilon_{it} = \mu_i + v_{it}$$

ϵ_{it} contains two orthogonal components: for fixed effects "μ_i" and for idiosyncratic shocks "v_{it}"

We can rewrite the equation (9) as:

$$\Delta Y_{it} = (\alpha - 1)y_{i,t-1} + x_{it}^{/}\beta + \epsilon_{it} \qquad (10)$$

where x/ is a set of explanatory variables.

SYS-GMM MODEL

$$CO2_{it} = \alpha_0 + (1-\beta_1)CO2_{it-1} + \beta_2 REC_{it} + \beta_3 EC_{it} + \beta_4 FD_{it} + \beta_5 EG_{it} + \beta_6 GLO_{it} + \beta_7 IQU_{it} + v_t + \varepsilon_{i,t} \qquad (11)$$

where $vt = ut - (1 - \beta 1)\ ut - 1$

3.2 Panel quantile regression equation (PQRE)

The PQRE accounts for the panel data's unobserved heterogeneity and heterogeneous covariate effects. It is estimated from the following equation (12)

$$CO2_{it}(\tau \ || \ X_{it}) = \alpha_0(\tau) + X_{it}^{/}\beta_i(\tau), \qquad (12)$$

where $X_{it}^{/}$ is a vector of explanatory variables.

3.3 Westerlund co-integration test:

The Westerlund test is appropriate for data that has cross-dependency. It investigates the presence of an error correction for an individual panel or the entire panel. It can be computed from the following equation (13)

$$\Delta z_{i,t} = a'_i d_i + \xi_i\left(Z_{i(t-1)} + \zeta_i' \ y_{i(t-1)}\right) + \textstyle\sum_{j=1}^{m}.\phi_{i.f}\Delta z_{i(t-1)} + \sum_{j=0}^{m}.\phi_{i.j}\Delta y_{i(t-1)} + \omega_{i,t} \quad (13)$$

where ξi is the adjustment term, di is a vector of deterministic components, including constant and linear time trends, $zi, t = (\ xi, t, yi, t)$ is the k+1 panel unit dimensioned vector of integrated variables. At the same time, other parameters introduce a nuisance in the variable of interest. The panel-mean statistics, which test the cross-sections in all panel units, can be calculated as follows:

$$P_\tau = \frac{\xi_i}{SE\xi_i}$$

$$P_a = T\xi_i$$

For the panel-mean statistics, the rejection of the null hypothesis signifies no co-integration for the entire panel. On the other hand, the Westerlund group mean statistics can be calculated as follows:

$$G_\tau = N^{-1}\Sigma_{i=1}^{N} \frac{\hat{\xi}i}{SE(\xi i)}$$

$$G_a = N^{-1}\Sigma_{i=1}^{N} \frac{T\hat{\xi}i}{SE(\xi i)}$$

where $G\tau$ *and* G_a are the groups' mean statistics which test the null hypothesis of no co-integration in the cross-sectional panel. The rejection of this hypothesis means the existence of co-integration for at least one cross-sectional unit in the panel.

3.4 Cross-sectional dependence test

This test is imperative in the empirical investigation involving panel data, especially in countries with similar economic characteristics like transition, development, and emerging economies. Since widespread globalization may make any economy subject to shock in other countries, testing the cross-sectional dependency is required with four widely used tests. For example, the Lagrange multiplier (LM) test is proposed in a situation when the cross-section (N) is smaller than time (T).

4 Results and Discussion

The values for each variable with minimum and maximum values are given as follows in Table 1.

Table 1: Mean, Std. Dev, Min, and Max Statistics

Variable	Obs.	Mean	Std.Dev.	Min.	Max.
CO2 Emission	684	8.301	4.084	2.800	24.700
REC	684	15.421	16.069	0.400	89.750
EC	684	4.930	0.674	3.054	6.622
EG	684	2.536	3.189	-14.814	25.163
IQU	684	0.110	1.636	0.205	2.089
GLO	684	1.908	0.037	1.774	1.961
FD	684	96.018	46.039	0.186	304.575

The matrix of correlation shows the link amongst the variables. Referring to Table 2, a negative as the well insignificant relation has become evident between REC, IQU, and GLO with the emissions of CO2. On the other hand, a positive and insignificant link occurs among EC, EG, and FD with the emissions of CO2. However, the value of the correlation coefficients is relatively low for predictors that are less than 0.70, which indicates that there is no issue of multicollinearity, and this finding is further endorsed by the results of VIF which are lower than the cutoff value of 10, as suggested by an author like Wooldridge (2014). The VIF results are shown in Table 3. Panel unit root (PUR) tests were run with the outcomes of the Levin-Lin-Chu unit root (Bornhorst & Baum, 2006) and Harris-Tzavalis unit root (Harris & Tzavalis, 1999) tests, respectively. Results show that the variables employed in our study at the level are not stationary, even though they become stationary when inspecting their first difference, therefore assimilated at I (1).

Table 2: Correlations Matrix

Variables of the Study	(CO2 Emission)	(REC)	(EC)	(EG)	(IQU)	(GLO)	(FD)
CO2 Emission	1.000						
REC	-0.284	1.000					
EC	0.169	-0.293	1.000				
EG	0.014	-0.003	-0.150	1.000			
IQU	-0.301	0.306	-0.030	-0.111	1.000		
GLO	-0.213	-0.058	0.058	-0.221	0.534	1.000	
FD	0.234	0.186	0.351	-0.233	0.390	0.290	1.000

Thus, all variables in the study are integrated at the level for the common unit root and also for Levin-Lin-Chu and Harris Tzavalis tests, except for the emissions of CO2 and REC. This means that at the level in the PUR test, the null hypothesis cannot be precluded.

Table 3: Variance inflation factor (VIF)

Study Variables	VIF	1/VIF
REC	1.390	0.720
EC	1.370	0.729
EG	1.100	0.911
IQU	1.770	0.565
GLO	1.590	0.627
FD	1.530	0.655
Mean VIF	1.460	

Therefore, the variables of the study have a non-stationary unit root. In our study, we have taken the difference at a significance level of 1%, where they all are static. Then, the null hypothesis is precluded.

Table 4: Panel Unit Root Tests

	Levin-Lin-Chu		Harris-Tzavalis	
	At Level	At Difference	At Level	At Difference
CO2 Emission	1.2672	-9.7707***	3.1093	-35.9044***
REC	4.2016	-8.7335***	2.2541	-40.8294***
EC	-4.5495***	-12.6984***	0.3378	-31.2775***
EG	-9.6771***	-18.4656***	-20.1397***	-38.5611***
IQU	-11.3454***	-20.0433***	-5.1844***	-26.9416***
GLO	-4.1790***	-13.6999***	1.3502	-30.9600***
FD	-4.2565***	-7.1406***	-2.5345**	-28.4731***

Where * p = <0.05; ** p = <0.01; *** p = <0.001

As time-series data were employed, it is helpful to assess the cross-sectional dependency (CSD) using the Pesaran (2004) test. The results are given in Table 5. The null hypothesis is not accepted. Accordingly, among the units, there is a presence of CSD at the CS level.

Table 5: CSD Test

Study Variables	CD-test	p-value	Corr	abs(corr)
CO2 Emission	39.33	0.000	0.360	0.662
REC	63.80	0.000	0.583	0.729
EC	27.23	0.000	0.249	0.515
EG	64.94	0.000	0.594	0.595
IQU	12.33	0.000	0.113	0.428
GLO	86.17	0.000	0.788	0.814
FD	16.35	0.000	0.149	0.444

As the issue of stationarity has been examined, we now proceed to employ the cointegration tests like Kao (1999), Pedroni (1999) as well as Westerlund & Edgerton (2008) tests. Based on the application of the test results, there is cointegration among the study variables, and the null hypothesis is rejected.

Table 6: Panel Cointegration Tests

Kao Cointegration Test		
	Statistic	P-Value
Modified Dickey-Fuller t	1.5822	0.0568
Dickey-Fuller t	1.543	0.0650
Augmented Dickey-Fuller t	3.5243	0.0002
Unadjusted modified Dickey-Fuller t	-0.4471	0.3274
Unadjusted Dickey-Fuller t	-0.1980	0.4215
Pedroni Cointegration Test		
	Statistic	P-Value
Modified Phillips-Perron t	5.4598	0.0000
Phillips-Perron t	-8.0410	0.0000
Augmented Dickey-Fuller t	-8.0129	0.0000
Westerlund Cointegration Test		
	Statistic	P-Value
Variance Ratio	-1.4114	0.0791

Dynamic panel model outcomes are shown in Table 7. This study used one-step difference GMM, one-step and two-step systems GMM respectively, to examine the impact of the independent variables on the dependent variable. The lagged dependent coefficient variable is linked positively with CO2 emission at a 1% significance level in all steps of GMM. In the one-step difference, the REC, as well as GLO, has a significant negative coefficient, whereas EC, EG, and IQU have a meaningful and positive influence on CO2 emissions at the 1% significance level. Further, in the one-step system GMM, the REC, GLO, and IQU have negative significant coefficients at the 5% and 10% levels, respectively, whereas EG, FD, and EC have a substantial and meaningful influence on CO2 emissions at the significance levels of 1% and 10% respectively.

Moreover, in the GMM two-step system, the REC has a significant negative coefficient at a 5% significance level. Thus, the REC contributes to lessening the emissions of CO2. In addition, the results are compatible with the studies of Aydoğan & Vardar (2020); Bilgili et al. (2016), and Shafiei & Salim (2014), but the analyses of Jamel & Derbali (2016) and Ozcan et al. (2020) disagree with the conclusions of our study, as they said that EC produces a positive influence on degradation in the environment. Furthermore, GLO has a significant harmful coefficient at a 5% significance level. As per our study results, GLO can lead to decreasing CO2 emissions. These outcomes are consistent with Muhammad & Khan (2021) and Sahu & Kumar (2020), while the results are not in accord with the findings of the Nathaniel et al. (2021), Nguyen & Le (2020), and Sethi et al. (2020) studies.

EC, EG, IQU, and FD have a meaningful impact on the emission of CO2 at a 1% significance level. Accordingly, built on the results, it can be said that EC, EG, and IQU can lead to an increase in the emissions of CO2, and the outcomes agree with the results of Le & Ozturk (2020); Shahbaz et al. (2020) and Usman et al. (2020). FD has a substantial positive impact on the emission of CO2 at a 5% significance level. Thus, FD contributes to higher emissions of CO2. Therefore, the results of Sehrawat et al. (2015) and Shahbaz et al. (2020) are compatible with our study results. Thus, it can be suggested that the effects are strong, based on the dynamic panel model with quantile estimations at the 10, 25, 50, 75, and 90 percent levels for the study variables for REC, EC, EG, IQU, GLO, and FD.

Table 7: Dynamic Panel Model Results

	One-Step Difference GMM CO2	One-Step System GMM CO2	Two-step System GMM CO2
L. CO2 Emission	0.731***	0.999***	0.978***
	(23.60)	(174.29)	(175.94)
REC	-0.580***	-0.764**	-0.179**
	(-4.88)	(-3.47)	(-4.16)
EC	3.295***	1.326*	0.228***
	(6.78)	(2.41)	(11.40)
EG	0.0452***	0.0393***	0.0378***
	(6.87)	(5.81)	(21.68)
IQU	0.198***	-0.166*	0.222***
	(4.95)	(-2.07)	(-5.50)
GLO	-14.63***	-0.760**	-1.367**
	(-5.68)	(-3.45)	(-2.84)
FD	0.202**	0.499***	0.191***
	(4.69)	(15.35)	(5.96)
_cons		1.164*	2.570**
		(2.56)	(2.70)
N	612	648	648

Table 8 shows the quantile regression results, which indicate that all variables in the study substantially influence the environment across the varying quantiles. For instance, REC produces adverse significant effects on the environment across all quantiles, and the outcomes are consistent with the results of the Mbarek et al. (2018) and Zaman et al. (2021) studies but not in accord with the outcomes of the studies by Ozcan et al. (2020), Raza et al. (2019) and Saboori & Sulaiman (2013). Further, across all quantiles, GLO shows adverse significant effects on the environment in terms of emissions of CO2. However, these results are not in accord with the (Adebayo & Acheampong, 2022) and Sethi et al. (2020) studies.

IQU showed a negative and noteworthy influence on CO2 emissions across all quantiles. This means that IQU does add to the reduction of CO2 emissions, and the results are in accord with Salman et al. (2019) studies but not consistent with the findings of studies like Azam et al. (2021) and Teng et al.(2021). EC has a significant positive impact across the quantiles of 25, 50, and 75, but the 95th quantile returned a negative impact. This means that EC generally leads to an increase in the emissions of CO2. This finding agrees with the studies of (Al-Mulali and Che Sab 2018; Lean and Smyth, 2010; Shahbaz et al. 2014).

Moreover, EG and FD produce positive and significant environmental effects across all quantiles. This means that the major contributors to CO2 emissions are EG and FD. The results are in line with the findings of Sehrawat et al. (2015) for both variables, and, for EG alone, the results are in line with Alam et al. (2007), Khan et al. (2019b) and Saboori & Sulaiman (2013). However, the results of our study on FD and CO2 emissions are not in accord with those of Khan et al. (2019a).

Table 8: Robustness checks Quantile Regression Results

	Simultaneous quantile regression				QRPD
	Q25	Q50	Q75	Q95	
REC	-0.8832**	-0.0740***	-0.1040***	-0.152***	-0.0553***
	(-3.99)	(-11.14)	(-3.00)	(-11.39)	(-26.95)
EC	0.5812**	0.6020*	1.5420***	-1.095)**	0.5973***
	(3.72)	(2.38)	(7.07)	(-2.31)	(23.85)
EG	0.8123**	0.2343***	0.1600**	0.2350***	0.0460***
	(3.69)	(5.21)	(2.25)	(3.58)	(5.09)
IQU	-1.255***	-1.1920***	-0.9130*	-1.1290***	-1.0528***

	(-7.84)	(9.75)	(-1.87)	(-10.60)	(-74.68)
GLO	-5.3010***	-4.582**	-25.9260*	-12.5090***	-6.9866***
	(-5.12)	(-3.98)	(-2.38)	(-4.41)	(-13.46)
FD	1.0020*	1.7212***	0.0330**	0.054***	0.0035***
	(1.98)	(4.25)	(2.21)	(7.80)	(5.52)
_cons	17.5790*	14.2560***	54.8600*	-6.6490***	
	(2.13)	(7.71)	(2.36)	(-15.98)	
Pseudo R2	0.1895	0.1593	0.1110	0.3158	
N	684				684

t statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The graphical representation of the variables in the quantile regression is shown in Figure 3.

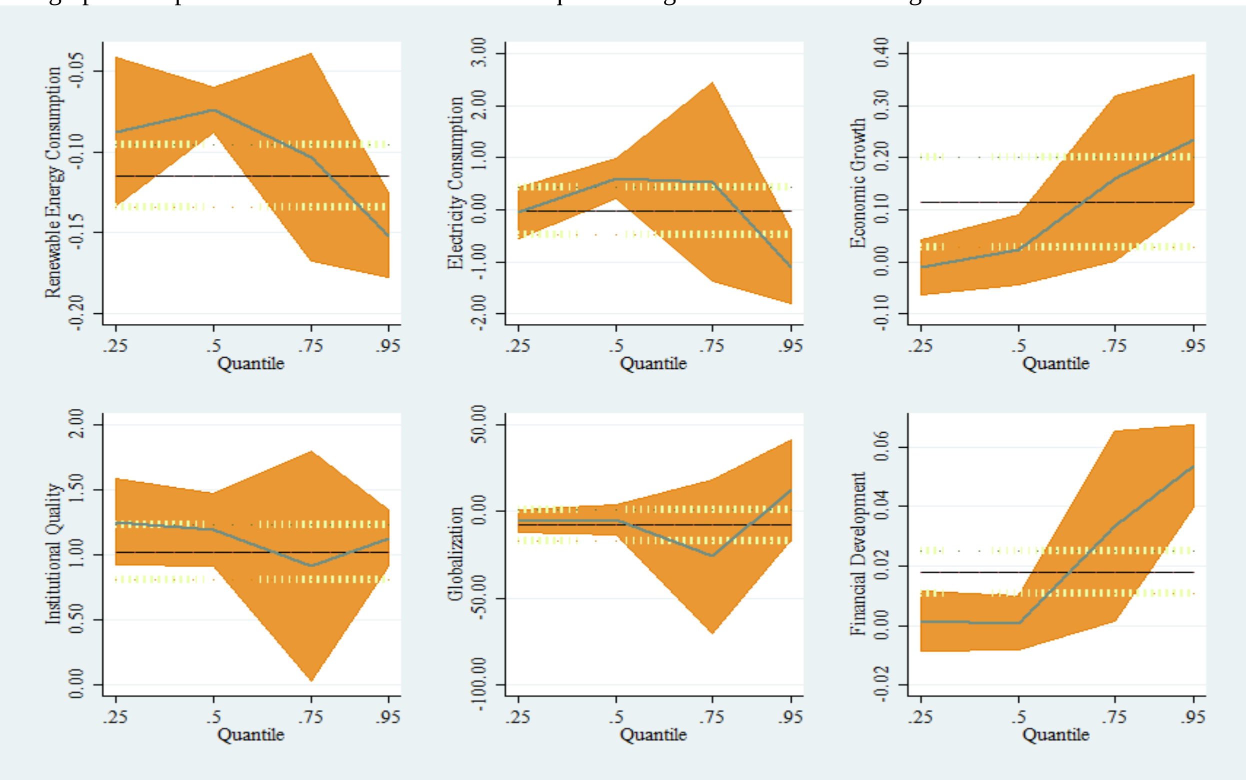

Figure 3: *Quantiles Regression Graphs*

5 Conclusion and Implications

Environmental concern is increasing due to the effects of economic activities involved in producing and exchanging goods and services at national and international levels. This study has attempted to assess the ways in which EG, EC, REC, FD, IQU, and GLO make a significant contribution to the degradation of the environment in OECD countries from 1996 to 2019 via quantile regression and the GMM approach. All the models in this study support the findings that REC, GLO, and IQU reduce emissions of CO_2, while EG, EC, and FD tend to lead to increases in CO_2 emissions and injurious impacts on the natural environment.

Therefore, based on the results of our study, the following policy recommendations are proposed: the production of electricity with fossil fuels must be replaced with the use of renewable energy sources, which eventually pose less harm to the environment. Liberalizing trade may be one way to support economic growth during the transition period. Maximizing REC can safeguard economic development yet also protect environmental quality. In addition, pertinent policies must be framed to link FD to facilitate technological advances in low-carbon machinery and batteries. As a result of this, the emissions of CO_2 will be reduced in OECD countries. This study has opened up prospects that can be augmented by future researchers through examining the proposed link with the other proxy of environmental degradation, that is, the ecological footprint.

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