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Financial Development, ICT Use, Renewable Energy Consumption and Foreign Direct Investment Impacts on Environmental Degradation in OIC Countries

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ABSTRACT

This article examines the influence of financial development, ICT use, FDI and renewable energy on environmental degradation in 38 OIC countries using panel data from 2003 to 2021. For data estimation, the authors employed the CD test, slope homogeneity test, CIPS and CADF test, FGLS model, PCSE model and Dumitrescu Hurlin panel causality test. It is found that the variables have cross-sectional dependence, slope heterogeneity, heteroskedasticity, and autocorrelation in a model. The Westerlund test of cointegration also ensures the cointegration among variables in a model while panel unit root tests found the mixed integration order of variables. The FGLS model shows that FD and renewable energy consumption negatively and significantly influence CO2 emissions in OIC countries. The outcomes also show that the use of ICT and FDI inflows in OIC countries are positively related to CO2 emissions. The PCSEs model is used as a robustness estimation technique which also confirms the estimates of the FGLS model. The authors suggested that financial development should be promoted to finance green energy projects, design regulatory policies to prevent polluted technology from the FDI inflows and to prevent the harmful effects of ICT on the environment, the use of green energy resources in ICT use should be promoted.

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1. Introduction

The attainment of sustainable development has become very challenging due to the world's continually worsening environmental conditions. Controlling environmental degradation to achieve sustainable development has become a key concern for policymakers and academics. On the one hand, human activities promote economic activities and lead to severely polluting the atmosphere and warming the planet (Rani, Wang, Rauf, Ain, & Ali, 2023). Several factors affect the environmental quality, such as, financial development (FD) supports financing facilities for technological advances and efficient industrial operations, which in turn promote environmental development. Menegaki, Ahmad, Aghdam, and Naz (2021) proposed that FD broadens access to credit and promotes investment in the local business (Shah et al., 2020). Financial development can also have negative impacts on environmental degradation (ED). This implies that ED is caused by loan availability for industrial development that ignores environmental concerns (Rong & Qamruzzaman, 2022). Similarly, information and communication technology (ICT) is another imperative aspect that transforms human society however it also has environmental implications. Furthermore, ICT has significantly aided in the development of countries (Kirikkaleli & Adebayo, 2021; Palvia, Baqir, & Nemati, 2018). ICT is widely used in developed countries, therefore its contribution to economic growth cannot be overstated; nonetheless, its consequences on the environment are debatable (Danish, Khan, Baloch, Saud, & Fatima, 2018). The development of the ICT industry can contribute to the CO_2 emissions. Increased use of cell phones, computers and other devices enhances the energy demand and contributes to CO_2 emissions (Adebayo, Agyekum, Altuntaş, Khudoyqulov, Zawbaa, & Kamel, 2022; Charfeddine & Kahia, 2021). In contrast, the positive effect of ICT use on environmental protection can be attributed to efficient use of ICT can increase energy sector efficiency and lead to lower CO_2 emissions (X. Liu, Latif, Latif, & Mahmood, 2021; Majeed, 2018; Usman, Ozturk, Ullah, & Hassan, 2021).

Conversely, foreign direct investment (FDI) can also have environmental implications. Certain foreign investors introduce technologies to their host countries that have significant environmental implications (To, Ha, Nguyen, & Vo, 2019). The FDI inflows positively related to the ED when foreign businesses may be exempted from the same environmental laws that apply to domestic businesses, allowing them to emit more pollutants than would otherwise be allowed (Sarkodie & Strezov, 2019). Pollution of the air and water may result from this, which could have detrimental effects on the health of nearby ecosystems and people. Deforestation caused by FDI can also result in environmental deterioration. Large areas of land are cleared by several foreign corporations for industrial or agricultural uses, which destroys natural habitats and displaces local fauna (Lawson & Nguyen-Van, 2020). The pollution haven hypothesis advocates that industrialized nations invest in host economies with the cheapest technologies due to the lenient environmental regulations. The reason for this is that there is a greater financial burden in the home nation to comply with environmental standards than there is in the host country to do so (Sarkodie & Strezov, 2019). In contrast, the pollution halo hypothesis recommends that multinational organizations transfer energy-efficient technology or pollution reduction or control strategies, including energy-conserving and renewable energy-related technologies in the host countries. Consequently, these nations experience a decrease in emissions, which eventually results in a cleaner environment (Chiriluș & Costea, 2023). Lastly, energy consumption is crucial for boosting economic activities, but it also contributes to environmental issues including carbon emissions and resource depletion (Osobajo, Otitoju, Otitoju, & Oke, 2020).

Although, there are several potential advantages to using more renewable energy, such as a decrease in greenhouse gas emissions, diversity of energy sources, and less reliance on fossil fuels. Furthermore, the substitution of carbon-intensive energy sources is made possible by renewable energy initiatives. Because the renewable energy sector employs a higher labor force, escalating the availability of renewable energy could lead to job growth in the "green" technology sector (Belaïd & Zrelli, 2019). The key attempt of this paper is to examine the influence of FD, ICT usage, FDI and renewable energy on environmental degradation. For empirical estimation, we have chosen the Organization of Islamic Countries (OIC), a global organization with 57 member nations. The OIC faces serious environmental problems including deforestation, desertification, and pollution of the air and water. Concern over climate change is also growing as a consequence of rising sea levels, more frequent and severe weather events, and rising temperatures in several OIC member states (S. M. Khan & Saif-ur-Rehman, 2024). Over the past 20 years, the rate of deforestation worldwide has somewhat decreased; however, among OIC member countries, the rate has increased, rising from 0.27% to 0.44% annually. The average annual growth rate of greenhouse gas (GHG) emissions per person is greater than the global average. OIC GHG emissions climbed by 91% to 9.2 Gt-CO_2 equivalent between 1990 and 2019, whereas global GHG emissions increased by 53% during the same period (SESRIC). This shows that in OIC countries the environmental problem is continually increasing. Therefore, it is vital to analyze the influence of FD, ICT use, renewable energy and FDI on environmental degradation in OIC countries.

1.1. Contribution of the Study

This research contributes to the body of literature in different ways. First, it analyzes the influence of FD, ICT usage, FDI and renewable energy on ED in OIC countries from 2003 to 2022. Second, the data properties have been examined using different techniques such as descriptive statistics, correlation matrix, slope heterogeneity test, cross-sectional dependence test, CIPS and CADF test of unit root, Westerlund test of cointegration, modified Wald test of heteroskedasticity and Wooldridge test of autocorrelation. Third, the study examines the coefficient of variables using the FGLS approach and the PCSEs model is employed for the robustness estimation. Lastly, this study provides fresh insights into how FD, ICT usage, FDI and renewable energy influence CO_2 emissions in OIC countries. Consequently, by considering the outcomes, suitable policy suggestions are given to reduce the CO_2 emissions in OIC countries.

2. Literature Review

This section deals with a literature review of the studies on the impact of financial development (FD), ICT use, renewable energy consumption (REC) and FDI on environmental degradation (ED) that is given as follows:

2.1. Financial Development and Environmental Degradation

Several studies examined the relationship between FD and ED such as Rani, Amjad, Asghar, and Rehman (2022) probed the influence of FD on ED in South Asia during 1990 to 2020. The results indicated that the association between FD, economic expansion and ED was U-shaped. Additionally, labor, industrialization, globalization and membership in educational institutions all considerably raise economic growth and ED. Utilizing data from 1990 to 2018, G. Liu, Khan, Haider, and Uddin (2022) explored the effect of institutional quality and FD on the ecological footprints of emerging economies. The results displayed that increasing the ecological footprints causes ecological quality to be degraded by FD. Their study also showed that institutional quality and human capital lower the ecological footprints. Additionally, financial development uses human capital as a conduit to promote environmental sustainability. The influence of Pakistan's financial sector development between 1974 and 2018 on environmental degradation was assessed by Inamullah and Rehman (2022). It was found that ED was adversely impacted by financial development. Over time, the influence of FDI, energy usage and population increase were all favorable and statistically significant. Trade has an adverse and considerable influence on ED. Zaidi, Hussain, and Zaman (2021) observed the relationships between ED, energy usage and financial inclusion in OECD economies during 2004 to 2017. The direct link between energy use, ED and financial inclusion was found in a study. Similarly, Shoaib, Rafique, Nadeem, and Huang (2020) discovered the linkage between FD and ED in D8 and G8 countries between 1990 and 2013. The outcomes showed that FD has a positive association with ED. Energy efficiency and trade openness was found to reduce carbon emissions. Lastly, Bui (2020) used data from 100 nations between 1990 and 2012 to assess the effect of FD on ED. Empirical results found the positive influence of FD on ED. The financial system's growth also raises energy consumption, which raises pollution emissions. It was also found that financial development benefits a greater proportion of the population and reduces economic inequality. Therefore, considering the literature review, the following hypothesis is formulated:

H_o: Financial development is significantly related to environmental degradation in OIC countries

2.2. ICT Use and Environmental Degradation

The association between ICT use and ED is investigated by different authors such as Nghiem, Bakry, Al-Malkawi, and Farouk (2023) determined the influence of ICT on ED in the OECD nations from 1990 to 2018. The results found that internet use and cell phone subscriptions had different effects on CO_2 emissions. The use of mobile phones declines CO_2 emissions while using the internet tends to raise emissions. Results also indicated that economic progress had an adverse influence on the environment whereas REC leads to improvement in the environment. Using data from 1995 to 2019, Damrah, Satrovic, and Shawtari (2022) discovered the influence of ICT on ED for six oil-exporting nations. This study provided evidence in favor of the EKC phenomenon as a relationship between carbon intensity and the HDI. The energy usage greatly raises the carbon intensity. The outcomes also exhibited that ICT use is directly related to environmental preservation. Similarly, Zafar, Zaidi, Mansoor, Sinha, and Qin (2022) considered the effect of education and ICT on the quality of environment in Asian nations by employing data from 1990 to 2018. Their study showed that economic growth was correlated with rising energy demand and use. According to this study, education promotes ICT innovation growth, however, when green energy is lacking, ICT growth degrades the environment in Asia. The study suggested that utilizing green energy to expand ICT could help Asian nations reduce their carbon emissions. Another study that explored the association between ICT and ED in developing countries by Haldar and Sethi (2022) used data from 2000 to 2018. According to the study, there was a considerable difference in CO_2 emissions between rising internet use, trade, REC and NREC. The study showed that ED reduced when the use of the internet and innovations were jointly taken. Similarly, the rising usage of mobile devices lowers ED via innovation, trade, FD, and REC. The study suggested that these countries should urge the telecom industry to utilize more renewable sources of energy and green innovation solutions to decrease their detrimental environmental impacts. The study accompanied by Weili, Khan, Khan, and Han (2022) analyzed how the BRI countries' energy consumption, ICT, FD and economic progress affected CO_2 emissions between 2000 and 2019. The findings showed that trade and REC lower CO_2 emissions while ICT, FD and growth of the economy leads to a rise the CO_2 emissions. Lastly, Shobande and Ogbeifun (2022) explored the influence of ICT on the sustainability of the environment in OECD countries during 1980 to 2019. The results emphasized how critical it is to use ICT to advance environmental sustainability. The study also determined how ICT might impact the environment, including FDI, education, transportation, regulatory quality, and institutional quality. Therefore, the subsequent hypothesis is formulated in light of the literature review:

H_1: ICT usage is significantly associated with environmental degradation in OIC countries

2.3. Renewable Energy and Environmental Degradation

Renewable energy resources are vital in influencing environmental degradation. Different studies analyzed the relationship between REC and ED such as during 1989 to 2021, Kartal, Kılıç Depren, Ayhan, and Depren (2022) explored the association between the use of energy and ED in the USA. The outcomes exhibited that energy use has a substantial influence on ED. The outcomes highlighted how important it is to use renewable energy to decrease ED both overall and in specific categories to improve the environment. The results suggested that US officials must concentrate on reducing their dependency on fossil fuels and boosting the REC by converting their energy systems to produce less carbon dioxide. Similarly, Magazzino, Toma, Fusco, Valente, and Petrosillo (2022) evaluated the causality link between REC, CO_2 emissions and GDP using a dataset covering five Scandinavian nations from 1990 to 2018. The results exhibited that using REC was a good way to lower ED without harming GDP. For the years 1985 to 2018, H. Khan, Weili, Khan, and Khamphengxay (2021) considered the influence of tourism, REC, trade and FDI on ED. The findings showed that REC has an adverse influence on ED. FDI has an adverse influence on ED in developing nations; however, it has an optimistic influence in developed nations. In the case of Mediterranean nations, Belaïd and Zrelli (2019) explored the association between ED, GDP and REC and NREC from 1980 to 2014. The outcomes suggested that the association between NREC and ED was bidirectional. Evidence of unidirectional causal links was found between GDP and ED, NREC and ED, and REC and ED. Similarly, Karasoy and Akçay (2019) investigated how trade and energy use affected Turkey's environmental pollution between 1965 and 2016. The outcomes showed that the REC lowers CO_2 emissions and increases in trade and NREC increase them over time. Lastly, using data from 1985 to 2011, Dogan and Seker (2016) explored the impacts of income, trade, NREC, REC and FD on ED. The study discovered that NREC raises the amount of emissions while REC, trade and FD reduces the CO_2 emissions. Therefore, the subsequent hypothesis is formulated in light of the literature review:

H_2: Renewable energy consumption is significantly linked to environmental degradation in OIC countries

2.4. Foreign Direct Investment and Environmental Degradation

The influence of FDI and institutional quality on ED was analyzed by Bouchoucha (2024) in 17 MENA economies utilizing data from 1996 to 2018. The outcomes demonstrated that FDI raises CO_2 emissions. The presence of effective institutions can reduce the harmful effects of FDI on ED. The negative consequences of CO_2 emissions in MENA nations could be mitigated by FDI combined with sound governance. Similarly, Huang, Chen, Wei, Xiang, Xu, and Akram (2022) used data of G20 countries from 1996 to 2018 to examine the effects of FDI on ED. The study showed that FDI inflows positively related to the ED. Similarly, Wang, Wang, and Sun (2020) employed panel data of 29 provinces of China from 1994 to 2015 to observe the effect of FDI and corruption on environmental pollution. The study exhibited that FDI deteriorates the environment while corruption by allowing low-quality FDI to enter the market reduces the impact of FDI's spillover effect, and indirectly contributes to additional environmental pollution. Another study examined the link between FDI and ED was investigated by Jugurnath and Emrith (2018) in developing states during 2004 to 2014. The analysis exhibited that FDI and ED were inversely associated. Therefore, the subsequent hypothesis is formulated in light of the literature review:

H_3: FDI significantly influence the environmental degradation in OIC countries

3. Material and Methods

3.1. Data and Model Description

To analyze the influence of FD, ICT use, renewable energy and FDI on environmental degradation, we have used the data of 38 OIC countries from 2003 to 2021. The data of all the variables is taken from WDI dataset. To make our experimental tests more effective and reliable we have taken the natural log to improve the distribution of the variables and it will help to eliminate autocorrelation issues between the variables (Amer et al., 2022; Hakimi & Hamdi, 2016). The following model is developed for the empirical estimation:

$$ED_{it} = \beta_o + \beta_1 FD_{it} + \beta_2 FDI_{it} + \beta_3 REC_{it} + \beta_4 ICT_{it} + v_{it} \tag{1}$$

Where ED indicates environmental degradation, FD represents financial development, FDI indicates foreign direct investment inflows, REC is the consumption of renewable energy, ICT is information and communication technology use, and v_{it} is the error term. β_1, β_2, β_3, and β_4 are the coefficients of the FD, FDI, REC, and ICT respectively. β_o is the intercept term.

Table 1: Description of Variables

Variables	Description of Variables		Source
Dependent Variable			
ED	Environmental degradation	CO_2 emissions (kt)	WDI
Independent Variables			
FD	Financial development	Domestic credit to the private sector as a percentage of GDP	WDI
FDI	Foreign direct investment	Current US dollars	WDI
REC	Renewable energy consumption	Percent of total energy consumption	WDI
ICT	Information and communication technology usage	Fixed broadband subscriptions	WDI

3.2. Data Estimation Techniques

3.2.1. Cross-Sectional Dependence

In this study, the Lagrange Multiplier (LM) developed by Breusch and Pagan (1980) and the CD test developed by Pesaran (2007) is utilized to evaluate the cross-sectional dependence (CD) in panel data. CD is known to exist when nations are connected on a regional or global scale. To avoid erroneous, biased, and inconsistent panel data analysis results, CD must be evaluated. The equations of LM and CD test are given as follows:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} {h_{ij}}^2 \rightarrow x^2 \frac{N(N-1)}{2} \tag{2}$$

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \sqrt{T_{ij} {h_{ij}}^2} \right) \tag{3}$$

Where h indicates correlation coefficient, x^2 is asymptotic circulation for fixed, N represents cross-section size, and T indicates the period. The following hypotheses are tested to evaluate the CD:

H_o: No cross-sectional dependence
H_1: Cross-sectional dependence

3.2.2. Slope Homogeneity Test

Slope homogeneity is crucial when employing panel data in econometrics. There is an association between cross-sectional units and slope homogeneity among countries (Pesaran & Yamagata, 2008; Sadorsky, 2009). The following hypotheses are formulated to test the slope homogeneity:

H_o: Slope coefficients are homogeneous
H_1: Slope coefficients are heterogeneous

3.2.3. Panel Unit Root Test

The ability of second-generation panel unit root tests to handle the CD issue in documenting the variables' integration order has led to their implementation over conventional ones. We used the framework provided by Pesaran and Yamagata (2008), also referred to as CIPS and CADF, for stationary tests. In the existence of heterogeneity and CD among the examined nations, the 2nd generation tests provide reliable results.

$$\Delta x_{it} = \alpha_{it} + \beta_i x_{it-1} + \partial_i T + \sum_{j=1}^{N} \theta_{it} \Delta x_{i,t-j} + \nu_{it} \quad (4)$$

Where Δ represents a differenced function, x_{it} indicates variables under investigation with cross-section and time series, $x_{i,t-j}$ is the lag 1st difference managing serial correlation among the errors, ɑ indicates divergent intercept, T means time and ν_{it} indicates error term.

3.2.4. FGLS Model

Feasible generalized least square method (FGLS) is applied in panel data analysis to determine a linear regression model's parameters. Heteroskedasticity and autocorrelation are two problems that might occur in panel data analysis, and FGLS can produce better results in the presence of these issues. This technique is also useful when panel data have more time series than cross-sectional units (Alharthi & Hanif, 2020).

3.2.5. Robustness Estimation

To assess the stability of the outcomes of the model in the investigation, we employed the Panel Corrected Standard Errors (PCSEs) technique, which was presented by Beck, Katz, and Science (1995). The traditional OLS estimations are inefficient and lead to biased standard errors due to autocorrelation, cross-sectional dependency, and heteroskedasticity issues (Adekoya, 2019). This model is also employed to adjust heteroskedasticity, CD and autocorrelation problems to improve parameter efficiency (Sundjo & Aziseh, 2018).

4. Data Analysis

4.1. Descriptive Statistics

The characteristics of variables in terms of mean, minimum and maximum value, SD, skewness and kurtosis are shown in Table 2. The mean values of ED, FD, FDI, REC and ICT are 9.786, 3.256, 20.520, 2.221 and 19.038 respectively. The maximum values of ED, FD, FDI, REC and ICT are 13.384, 4.933, 24.398, 4.540 and 27.068 respectively. Similarly, the minimum values of ED, FD, FDI, REC and ICT are 4.717, -0.303, 13.234, -4.605 and 9.739 respectively. The skewness value of all the variables is negative indicating a negatively skewed distribution. The kurtosis value of ED and FD is less than 3 indicating platykurtic distributions while the kurtosis value of FDI, REC and ICT is greater than 3 indicating leptokurtic distributions.

Table 2: Descriptive Statistics

Variables	ED	FD	FDI	REC	ICT
Mean	9.786	3.256	20.520	2.221	19.038
Maximum	13.384	4.933	24.398	4.540	27.068
Minimum	4.717	-0.303	13.234	-4.605	9.739
Std. Dev.	2.231	0.829	1.972	2.463	2.451
Skewness	-0.302	-0.241	-0.747	-1.286	-1.002
Kurtosis	2.098	2.864	3.555	3.814	5.142

4.2. Correlation Matrix

The degree of association is analyzed using the correlation coefficient. Table 3 shows that environmental degradation is positively correlated to financial development, foreign direct investment and ICT use while negatively correlated to renewable energy consumption.

Table 3: Correlation Matrix

Variables	ED	FD	FDI	REC	ICT
ED	1.000				
FD	0.526	1.000			
FDI	0.832	0.580	1.000		

REC	-0.516	-0.464	-0.403	1.000	
ICT	0.757	0.372	0.672	-0.354	1.000

4.3. CD and Slope Homogeneity Test

In this paper, different tests are utilized to evaluate the cross-sectional dependence (CD). Table 4 exhibits that all the tests have significant values; therefore, the null hypothesis of no CD is rejected. It is concluded that the variables ED, FD, FDI, REC and ICT are cross-sectional dependent indicating that shocks in any factor in a country impact the economy of other countries. The slope homogeneity test estimates show that the values of delta and delta adjectives are significant at a 1 percent level, therefore, we reject the null hypothesis of no heterogeneity. These outcomes confirm the existence of heterogeneity in a model.

Table 4: CD and Slope Homogeneity Test Estimates

Variable	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
ED	8263.99***	201.64***	74.67***
FD	5630.41***	131.41***	15.21***
FDI	2487.25***	47.58***	27.82***
REC	3855.00***	84.06***	16.27***
ICT	2189.58***	39.65***	17.91***
Slope Homogeneity Test			
Test		Statistic	
Δ		20.438***	
Δadj		24.709***	

Note: ****, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

4.4. Panel Unit Root Test

We have applied 2nd generation panel unit root tests that produce reliable results in case of CD and heterogeneity in data. Hence, CIPS and CADF tests are utilized to calculate the integration order of variables. Table 5 shows that ED, financial development, FDI and ICT use are integrated at the level whereas the variable renewable energy consumption is integrated at 1st difference. These results found the mixed integration order of variables in a model.

Table 5: CIPS and CADF Test Estimates

Variables	CIPS		CADF		Outcomes
	I(0)	I(1)	I(0)	I(1)	
ED	-2.419***	--	-2.474***	--	I(0)
FD	-2.034*	--	-2.057**	--	I(0)
FDI	-2.201**	--	-3.006***	--	I(0)
REC	--	-4.097***		-2.859***	I(1)
ICT	-2.697***	--	-2.366***	--	I(0)

*Note: ***, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

4.5. Cointegration, Heteroskedasticity and Autocorrelation Test

Table 6 exhibits that the test statistic value of the Westerlund test of cointegration is significant at the 1 percent significance level, therefore, it is proposed that there is a presence of cointegration among variables in a model. The heteroskedasticity in a model is checked using a modified Wald test and autocorrelation is assessed using the Wooldridge test. The estimate of both these tests implies the incidence of heteroskedasticity and autocorrelation in a model.

Table 6: Cointegration, Heteroskedasticity and Autocorrelation Test Estimates

Westerlund test for cointegration	Modified Wald test	Wooldridge test
2.5893***	2561.62***	69.704***
(0.0048)	(0.000)	(0.000)

*Note: ***, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

4.6. FGLS Test Estimates

To get reliable results in the occurrence of CD, autocorrelation and heteroskedasticity in a model, this study used the FGLS model for model estimation. The FGLS model is proven to be effective in addressing autocorrelation, heteroskedasticity and CD and provides reliable estimates (Amer et al., 2022; Yuliadi & Yudhi, 2021). The FGLS estimates are shown in Table 7. The outcomes exhibit that FD is negatively and significantly (at 1 percent level) linked to ED.

An increase in FD at the rate of one percent leads to a decline in the ED by 0.2675 percent. It implies that FD provides credit facilities to promote investment in environmentally suitable technologies that assist in reducing CO_2 emissions (Shobande & Enemona, 2021). Comparable, outcomes were also confirmed by Javaid, Ximei, Irfan, Sibt-e-Ali, and Shams (2023); Rani et al. (2022). The variable FDI is found to be positively and significantly linked to the ED. An increase in FDI at the rate of one percent leads to enhance the ED by 0.6126 percent. It suggests that FDI brings polluted technology in OIC countries which leads to deteriorate the environment. These outcomes were also found by Pavlović et al. (2021); Shahbaz, Nasir, and Roubaud (2018); Solarin and Al-Mulali (2018). REC is vital to improve the quality of the environment. The analysis shows that REC is negatively and considerably associated with the ED. An increase in REC at the rate of one percent leads to a decline in the ED by 0.1849 percent. It implies that renewable energy assists in maintaining a clean environment due to the substitution effect, which occurs when renewable energy replaces traditional technologies that depend on fossil fuels (Bilgili, Koçak, & Bulut, 2016). Similarly, it also guarantees energy security (Prandecki, 2014) and has spillover effects because of its simple deployment and inexpensive maintenance (Majeed & Luni, 2019). Similar outcomes were also verified by Hailiang, Iqbal, Yin Chau, Raza Shah, Ahmad, and Hua (2023); Hossain, Eleais, Urbee, Hasan, and Tahrim (2024); Ji, Sibt-e-Ali, Amin, and Ayub (2023). Lastly, the use of ICT is found to be optimistically and significantly related to the ED. An increase in ICT use at the rate of one percent leads to enhance the ED by 0.2570 percent. It indicates that, in OIC countries, ICT equipment enhances the energy demand and leads to the deterioration of the environment. These outcomes were also found by (Charfeddine & Kahia, 2021; Danish et al., 2018; Gyamfi, Ampomah, Bekun, & Asongu, 2022).

Table 7: FGLS Estimates

Variables	Coefficient	S.E.	Z-Statistic	Prob.
FD	-0.2675***	0.0640	-4.17	0.000
FDI	0.6126***	0.0315	19.39	0.000
REC	-0.1849***	0.0183	-10.10	0.000
ICT	0.2570***	0.0211	12.15	0.000
C	-4.3581***	0.5179	-8.42	0.000

*Note: ***, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

4.7. Robustness Estimation

For the robustness estimation, we have applied the PCSEs model. Similar to the FGLS model, the PCSEs model also provides reliable estimates of the occurrence of autocorrelation, heteroskedasticity and CD (Sundjo & Aziseh, 2018). Table 8 shows that the estimates of the PCSEs model are consistent with the outcomes of the FGLS model.

Table 8: Panel Correlated Standard Errors Estimates

Variables	Coefficient	S.E.	Z-Statistic	Prob.
FD	-0.2675***	0.0732	-3.65	0.000
FDI	0.6126***	0.0382	16.03	0.000
REC	-0.1849***	0.0153	-12.06	0.000
ICT	0.2570***	0.0492	5.22	0.000
C	-4.3581***	0.6618	-6.59	0.000

*Note: ***, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

4.8. Causality Analysis

Lastly, we have applied the Dumitrescu Hurlin panel causality test for causality analysis. Table 9 exhibits that there is bidirectional causality between FD and ED, REC and ED. The outcomes also exhibit unidirectional causality between environmental degradation and FDI and no causality between ICT use and ED.

Table 9: Causality Test Estimates

Null Hypothesis	Statistic	Prob.	Outcomes
FD ↛ ED	3.6260	0.0003	Bidirectional
ED ↛ FD	6.3879	0.0000	
FDI ↛ ED	0.9386	0.3479	Unidirectional
ED ↛ FDI	3.4625	0.0005	
REC ↛ ED	23.002	0.0000	Bidirectional
ED ↛ REC	3.6609	0.0003	

ICT ↛ ED	1.0618	0.2883	No-Causality
ED ↛ ICT	1.5549	0.1200	

Note: ****, **, and * specifies the p-values at 1%, 5% and 10% level respectively*

5. Conclusions and Policy Implications

This analysis used the data of 38 OIC countries from 2003 to 2021 to analyze the influence of financial development, ICT use, renewable energy, and FDI on environmental degradation. We have employed the CD test, slope homogeneity test, CIPS and CADF test, FGLS model, PCSE model and panel causality tests for data estimation. It is found that the variables have CD indicating that shocks in any factor in a country affect the economy of other countries. The results also found slope heterogeneity, heteroskedasticity, and autocorrelation in a model. The Westerlund test of cointegration also ensures the cointegration among variables in a model while the CIPS and CADF estimates found the mixed integration order of variables. The FGLS model shows that FD and REC negatively and significantly impact environmental degradation in OIC countries. The outcomes also found that ICT use and FDI inflows in OIC countries positively related to CO_2 emissions. The PCSEs model is used as a robustness estimation technique which also confirms the findings of the FGLS model. Lastly, the causality analysis demonstrates the bidirectional causality between FD and ED, REC and ED. The outcomes also exhibit unidirectional causality between ED and FDI and no causality between ICT use and ED.

These outcomes suggest significant policy implications for the OIC countries. First, financial development should be promoted to finance the green energy projects. Secondly, the OIC countries should design regulatory policies to prevent polluted technology from the FDI inflows that contribute to environmental degradation. These countries should promote FDI inflows that bring green technology into a country. Thirdly, the government of OIC countries should provide credit and subsidies to promote renewable resources of energy such as solar, wind and thermal in a country. Fourthly, to prevent the harmful effects of ICT on the environment, the use of green energy should be promoted. Lastly, creating favorable conditions for green financing and investment in renewable energy infrastructure should be the main focus of policymakers. The study has also some limitations. First, this paper used the panel dataset of OIC countries however; other studies can use the data of developing countries to analyze the influence of ICT use, FD, FDI and REC on environmental degradation. Second, the moderating role of renewable energy resources can be analyzed to see the influence of ICT use on ED. Lastly, other factors such as digitalization, green energy investment, and technological innovation can be incorporated into a model to see the influence on environmental protection.

References

Adebayo, T. S., Agyekum, E. B., Altuntaş, M., Khudoyqulov, S., Zawbaa, H. M., & Kamel, S. (2022). Does information and communication technology impede environmental degradation? fresh insights from non-parametric approaches. *Heliyon, 8*(3).

Adekoya, A. F. (2019). Income inequality and violent crime in Nigeria: A panel corrected standard error approach. *IBADAN JOURNAL FOR PEACE AND DEVELOPMENT, 9*(2).

Alharthi, M., & Hanif, I. (2020). Impact of blue economy factors on economic growth in the SAARC countries. *Maritime Business Review, 5*(3), 253-269.

Amer, E. A. A. A., Meyad, E. M. A., Gao, Y., Niu, X., Chen, N., Xu, H., & Zhang, D. (2022). Exploring the link between natural resources, urbanization, human capital, and ecological footprint: A case of GCC countries. *Ecological Indicators, 144*, 109556. doi:https://doi.org/10.1016/j.ecolind.2022.109556

Beck, N., Katz, J. N., & Science, P. (1995). Time-series (with not to do) to do (and what cross-section). *Polit Sci, 89*(3), 634-647.

Belaïd, F., & Zrelli, M. H. (2019). Renewable and non-renewable electricity consumption, environmental degradation and economic development: evidence from Mediterranean countries. *Energy Policy, 133*, 110929. doi:https://doi.org/10.1016/j.enpol.2019.110929

Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews, 54*, 838-845. doi:https://doi.org/10.1016/j.rser.2015.10.080

Bouchoucha, N. (2024). Does Institutional Quality Mitigate the Effect of Foreign Direct Investment on Environnemental Quality: Evidence of MENA Countries. *Journal of the Knowledge Economy*, 1-19. doi:https://doi.org/10.1007/s13132-023-01606-0

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The review of economic studies, 47*(1), 239-253. doi:https://doi.org/10.2307/2297111

Bui, D. T. (2020). Transmission channels between financial development and CO2 emissions: A global perspective. *Heliyon, 6*(11). doi:https://doi.org/10.1016/j.heliyon.2020.e05509

Charfeddine, L., & Kahia, M. (2021). Do information and communication technology and renewable energy use matter for carbon dioxide emissions reduction? Evidence from the Middle East and North Africa region. *Journal of Cleaner Production, 327*, 129410. doi:https://doi.org/10.1016/j.jclepro.2021.129410

Chiriluș, A., & Costea, A. (2023). The effect of FDI on environmental degradation in Romania: Testing the pollution Haven hypothesis. *Sustainability, 15*(13), 10733. doi:https://doi.org/10.3390/su151310733

Damrah, S., Satrovic, E., & Shawtari, F. A. (2022). How does financial inclusion affect environmental degradation in the six oil exporting countries? The moderating role of information and communication technology. *Frontiers in Environmental Science, 10*, 1013326. doi:https://doi.org/10.3389/fenvs.2022.1013326

Danish, Khan, N., Baloch, M. A., Saud, S., & Fatima, T. (2018). The effect of ICT on CO 2 emissions in emerging economies: does the level of income matters? *Environmental Science and Pollution Research, 25*, 22850-22860. doi:https://doi.org/10.1007/s11356-018-2379-2

Dogan, E., & Seker, F. (2016). The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. *Renewable and Sustainable Energy Reviews, 60*, 1074-1085. doi:https://doi.org/10.1016/j.rser.2016.02.006

Gyamfi, B. A., Ampomah, A. B., Bekun, F. V., & Asongu, S. A. (2022). Can information and communication technology and institutional quality help mitigate climate change in E7 economies? An environmental Kuznets curve extension. *Journal of Economic Structures, 11*(1), 14. doi:https://doi.org/10.1186/s40008-022-00273-9

Hailiang, Z., Iqbal, W., Yin Chau, K., Raza Shah, S. A., Ahmad, W., & Hua, H. (2023). Green finance, renewable energy investment, and environmental protection: empirical evidence from BRICS countries. *Economic research-Ekonomska istraživanja, 36*(2).

Hakimi, A., & Hamdi, H. (2016). Trade liberalization, FDI inflows, environmental quality and economic growth: a comparative analysis between Tunisia and Morocco. *Renewable and Sustainable Energy Reviews, 58*, 1445-1456. doi:https://doi.org/10.1080/1331677X.2022.2125032

Haldar, A., & Sethi, N. (2022). Environmental effects of Information and Communication Technology-Exploring the roles of renewable energy, innovation, trade and financial development. *Renewable and Sustainable Energy Reviews, 153*, 111754. doi:https://doi.org/10.1016/j.rser.2021.111754

Hossain, M. A., Eleais, M., Urbee, A. J., Hasan, M. A., & Tahrim, F. (2024). Assessing the Intensity of Economic Progress, Industrialization, Energy Use on Environmental Degradation. *South Asian Journal of Social Sciences and Humanities, 5*(1), 23-42. doi:https://doi.org/10.48165/sajssh.2024.5102

Huang, Y., Chen, F., Wei, H., Xiang, J., Xu, Z., & Akram, R. (2022). The impacts of FDI inflows on carbon emissions: Economic development and regulatory quality as moderators. *Frontiers in Energy Research, 9*, 820596. doi:https://doi.org/10.3389/fenrg.2021.820596

Inamullah, M., & Rehman, A. (2022). The Impact of Financial Sector Development on Environmental Degradation (Carbon Dioxide Emission) in Pakistan. *Journal of Economic Impact, 4*(3), 244-251. doi:https://doi.org/10.52223/jei4032211

Javaid, M. Q., Ximei, K., Irfan, M., Sibt-e-Ali, M., & Shams, T. (2023). Exploring the nonlinear relationship among financial development, human capital and CO2 emissions: a comparative study of South and East Asian emerging economies. *Environmental Science and Pollution Research, 30*(37), 87274-87285. doi:https://doi.org/10.1007/s11356-023-28512-x

Ji, D., Sibt-e-Ali, M., Amin, A., & Ayub, B. (2023). The determinants of carbon emissions in Belt and Road Initiative countries: analyzing the interactive role of information and

communication technologies. *Environmental Science and Pollution Research, 30*(46), 103198-103211. doi:https://doi.org/10.1007/s11356-023-29719-8
Jugurnath, B., & Emrith, A. (2018). Impact of foreign direct investment on environment degradation: evidence from SIDS countries. *The Journal of Developing Areas, 52*(2), 13-26.
Karasoy, A., & Akçay, S. (2019). Effects of renewable energy consumption and trade on environmental pollution: The Turkish case. *Management of Environmental Quality: An International Journal, 30*(2), 437-455.
Kartal, M. T., Kılıç Depren, S., Ayhan, F., & Depren, Ö. (2022). Impact of renewable and fossil fuel energy consumption on environmental degradation: evidence from USA by nonlinear approaches. *International Journal of Sustainable Development & World Ecology, 29*(8), 738-755. doi:https://doi.org/10.1080/13504509.2022.2087115
Khan, H., Weili, L., Khan, I., & Khamphengxay, S. (2021). Renewable energy consumption, trade openness, and environmental degradation: a panel data analysis of developing and developed countries. *Mathematical Problems in Engineering, 2021*, 1-13. doi:https://doi.org/10.1155/2021/6691046
Khan, S. M., & Saif-ur-Rehman, S. F. (2024). Impact of Foreign Direct Investment (FDI), Institutional Performance and Scientific Innovations on Environmental Degradation: Evidence from OIC Countries.
Kirikkaleli, D., & Adebayo, T. S. (2021). Do renewable energy consumption and financial development matter for environmental sustainability? New global evidence. *Sustainable Development, 29*(4), 583-594. doi:https://doi.org/10.1002/sd.2159
Lawson, L. A., & Nguyen-Van, P. (2020). Is there a peaceful cohabitation between human and natural habitats? Assessing global patterns of species loss. *Global Ecology and Conservation, 23*, e01043. doi:https://doi.org/10.1016/j.gecco.2020.e01043
Liu, G., Khan, M. A., Haider, A., & Uddin, M. (2022). Financial development and environmental degradation: promoting low-carbon competitiveness in E7 economies' industries. *International Journal of Environmental Research and Public Health, 19*(23), 16336. doi:https://doi.org/10.3390/ijerph192316336
Liu, X., Latif, Z., Latif, S., & Mahmood, N. (2021). The corruption-emissions nexus: do information and communication technologies make a difference? *Utilities Policy, 72*, 101244. doi:https://doi.org/10.1016/j.jup.2021.101244
Magazzino, C., Toma, P., Fusco, G., Valente, D., & Petrosillo, I. (2022). Renewable energy consumption, environmental degradation and economic growth: the greener the richer? *Ecological Indicators, 139*, 108912. doi:https://doi.org/10.1016/j.ecolind.2022.108912
Majeed, M. T. (2018). Information and communication technology (ICT) and environmental sustainability in developed and developing countries. *Pakistan Journal of Commerce and Social Sciences, 12*(3), 758-783.
Majeed, M. T., & Luni, T. (2019). Renewable energy, water, and environmental degradation: a global panel data approach. *Pakistan Journal of Commerce and Social Sciences (PJCSS), 13*(3), 749-778.
Menegaki, A. N., Ahmad, N., Aghdam, R. F., & Naz, A. (2021). The convergence in various dimensions of energy-economy-environment linkages: A comprehensive citation-based systematic literature review. *Energy Economics, 104*, 105653. doi:https://doi.org/10.1016/j.eneco.2021.105653
Nghiem, X.-H., Bakry, W., Al-Malkawi, H.-A. N., & Farouk, S. (2023). Does technological progress make OECD countries greener? New evidence from panel CS-ARDL. *Management of Environmental Quality: An International Journal, 34*(6), 1555-1579.
Osobajo, O. A., Otitoju, A., Otitoju, M. A., & Oke, A. (2020). The impact of energy consumption and economic growth on carbon dioxide emissions. *Sustainability, 12*(19), 7965. doi:https://doi.org/10.3390/su12197965
Palvia, P., Baqir, N., & Nemati, H. (2018). ICT for socio-economic development: A citizens' perspective. *Information & Management, 55*(2), 160-176. doi:https://doi.org/10.1016/j.im.2017.05.003
Pavlović, A., Njegovan, M., Ivanišević, A., Radišić, M., Takači, A., Lošonc, A., & Kot, S. (2021). The impact of foreign direct investments and economic growth on environmental degradation: the case of the Balkans. *Energies, 14*(3), 566. doi:https://doi.org/10.3390/en14030566
Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of applied econometrics, 22*(2), 265-312. doi:https://doi.org/10.1002/jae.951

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics, 142*(1), 50-93. doi:https://doi.org/10.1016/j.jeconom.2007.05.010
Prandecki, K. (2014). Theoretical aspects of sustainable energy. *Energy and Environmental Engineering, 2*(4), 83-90.
Rani, T., Amjad, M. A., Asghar, N., & Rehman, H. U. (2022). Revisiting the environmental impact of financial development on economic growth and carbon emissions: evidence from South Asian economies. *Clean Technologies and Environmental Policy, 24*(9), 2957-2965. doi:https://doi.org/10.1007/s10098-022-02360-8
Rani, T., Wang, F., Rauf, F., Ain, Q. u., & Ali, H. (2023). Linking personal remittance and fossil fuels energy consumption to environmental degradation: evidence from all SAARC countries. *Environment, Development and Sustainability, 25*(8), 8447-8468. doi:https://doi.org/10.1007/s10668-022-02407-2
Rong, G., & Qamruzzaman, M. (2022). Symmetric and asymmetric nexus between economic policy uncertainty, oil price, and renewable energy consumption in the United States, China, India, Japan, and South Korea: Does technological innovation influence? *Frontiers in Energy Research, 10*, 973557. doi:https://doi.org/10.3389/fenrg.2022.973557
Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics, 31*(3), 456-462. doi:https://doi.org/10.1016/j.eneco.2008.12.010
Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the total environment, 646*, 862-871. doi:https://doi.org/10.1016/j.scitotenv.2018.07.365
SESRIC. *OIC Environment Report*. Retrieved from https://sesricdiag.blob.core.windows.net/sesric-site-blob/files/article/848.pdf
Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: the effects of FDI, financial development, and energy innovations. *Energy Economics, 74*, 843-857. doi:https://doi.org/10.1016/j.eneco.2018.07.020
Shoaib, H. M., Rafique, M. Z., Nadeem, A. M., & Huang, S. (2020). Impact of financial development on CO 2 emissions: A comparative analysis of developing countries (D 8) and developed countries (G 8). *Environmental Science and Pollution Research, 27*, 12461-12475. doi:https://doi.org/10.1007/s11356-019-06680-z
Shobande, O. A., & Enemona, J. O. (2021). A multivariate VAR model for evaluating sustainable finance and natural resource curse in West Africa: evidence from Nigeria and Ghana. *Sustainability, 13*(5), 2847. doi:https://doi.org/10.3390/su13052847
Shobande, O. A., & Ogbeifun, L. (2022). Has information and communication technology improved environmental quality in the OECD?—a dynamic panel analysis. *International Journal of Sustainable Development & World Ecology, 29*(1), 39-49. doi:https://doi.org/10.1080/13504509.2021.1909172
Solarin, S. A., & Al-Mulali, U. (2018). Influence of foreign direct investment on indicators of environmental degradation. *Environmental Science and Pollution Research, 25*, 24845-24859. doi:https://doi.org/10.1007/s11356-018-2562-5
Sundjo, F., & Aziseh, F. (2018). An empirical investigation into the key drivers of economic performance in the CEMAC zone: A panel corrected standard errors approach. *International Journal of Business, Economics and Management, 5*(6), 189-200. doi:https://doi.org/10.18488/journal.62.2018.56.189.200
To, A. H., Ha, D. T.-T., Nguyen, H. M., & Vo, D. H. (2019). The impact of foreign direct investment on environment degradation: evidence from emerging markets in Asia. *International Journal of Environmental Research and Public Health, 16*(9), 1636. doi:https://doi.org/10.3390/ijerph16091636
Usman, A., Ozturk, I., Ullah, S., & Hassan, A. (2021). Does ICT have symmetric or asymmetric effects on CO2 emissions? Evidence from selected Asian economies. *Technology in Society, 67*, 101692. doi:https://doi.org/10.1016/j.techsoc.2021.101692
Wang, S., Wang, H., & Sun, Q. (2020). The impact of foreign direct investment on environmental pollution in China: Corruption matters. *International Journal of Environmental Research and Public Health, 17*(18), 6477. doi:https://doi.org/10.3390/ijerph17186477
Weili, L., Khan, H., Khan, I., & Han, L. (2022). The impact of information and communication technology, financial development, and energy consumption on carbon dioxide

emission: evidence from the Belt and Road countries. *Environmental Science and Pollution Research*, 1-16. doi:https://doi.org/10.1007/s11356-021-18448-5

Yuliadi, I., & Yudhi, W. S. A. (2021). *Economic Growth Determinants of Asean Economic Community: Feasible Generalized Least Square Approach.* Paper presented at the E3S Web of Conferences.

Zafar, M. W., Zaidi, S. A. H., Mansoor, S., Sinha, A., & Qin, Q. (2022). ICT and education as determinants of environmental quality: The role of financial development in selected Asian countries. *Technological Forecasting and Social Change, 177*, 121547. doi:https://doi.org/10.1016/j.techfore.2022.121547

Zaidi, S. A. H., Hussain, M., & Zaman, Q. U. (2021). Dynamic linkages between financial inclusion and carbon emissions: evidence from selected OECD countries. *Resources, Environment and Sustainability, 4*, 100022. doi:https://doi.org/10.1016/j.resenv.2021.100022