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Impact of Governance Quality and Environmental Degradation on Renewable Energy Development: Evidence from Europe

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Since renewable energy is paramount for achieving environmental sustainability, many countries with limited conventional resources, such as those in Europe, have been dealing with various renewable energy development challenges. Thus, this study examines the impact of governance quality and environmental degradation on renewable energy development among 33 European countries in 2022 (the latest available data). In order to analyze the cross-sectional data, principal component analysis (PCA), multivariate linear regression (MLR), and partial least squares structural equation modeling (PLS-SEM) were applied. Based on the results, governance quality and environmental degradation have a significant and positive impact on renewable energy development. Meanwhile, the results of the MLR and PLS-SEM estimation models support one another. The implication of the findings is that European countries should improve political institutions to promote renewable energy and environmental quality. Regarding the catalyst role of environmental degradation in renewable energy development, governments should raise awareness about the negative impact of relying on fossil fuels and other polluting energy sources.

Keywords: Governance Quality, Environmental Degradation, Renewable Energy Development
JEL classification: D72, D73, H11, Q42, Q54

Commitment to renewable energy production and consumption has become the key focus of discussions on sustainable development and climate change mitigation (*Intergovernmental Panel on Climate Change, 2018*). In this regard, renewable energies, such as solar, wind, hydropower, and biomass, are sustainable alternatives to fossil fuels, the main sources of greenhouse gas emissions and global warming (*International Energy Agency, 2020*). Previous research has also demonstrated the beneficial role of renewable energy in enhancing environmental quality by reducing greenhouse gas emissions (*Dogan-Ozturk, 2017; Jebli et al.,*

2016; Li–Shao, 2021). On a larger scale, renewable energy is not only important for reducing carbon emissions and mitigating climate change, but also for improving energy security, reducing dependence on finite resources, and fostering economic growth by creating new industries and jobs (*International Renewable Energy Agency, 2021*).

Despite its many benefits, renewable energy only plays a small role in the world's energy production (*Işik et al., 2017*). For example, in 2022, although renewable power (excluding hydro) increased by 14% to 40.9 exajoules, this was only a 12% share of power generation, with solar recording 25% and wind power showing 13.5% growth in output (*Energy Institute, 2023*). This is primarily because the initial cost of investing in renewable energy remains high, whereas fossil fuels are still heavily subsidized and the full cost of pollution is not factored into the price of such fuels. Meanwhile, the need for energy in developed nations is steadily increasing, and altering the existing energy infrastructure and consumption patterns takes time (*Shahzad et al., 2021*). Thus, it is imperative to determine the drivers of renewable energy development.

Governance is one of the most important determinants that affects renewable energy (*Sarkodie et al., 2020; Kousar et al., 2020*). In this regard, achieving an effective, long-term sustainable renewable energy program requires more than just the advancement of the technologies themselves. Supportive government policies and priorities are also essential, since they establish the institutional framework that enables increased renewable energy production and consumption. On the other hand, a stable, well-designed, and transparent institutional and regulatory framework, coupled with sustained political commitment, are important factors for ensuring continued support for beneficiaries, investors, and developers in the renewable energy sector (*Rahman–Sultana, 2022*). This institutional and political commitment is an essential foundation for realizing the full potential of renewable energy and accelerating the transition to clean energy. In addition, since renewable energy projects are costly and time-consuming, various governance aspects, such as the rule of law, political stability, regulatory quality, corruption control, accountability, and effectiveness, play important roles in creating an environment that is attractive to financial sources and stakeholders (*Belaid et al., 2021*). This is because investors are more likely to commit capital to renewable energy projects in countries with strong, reliable, and transparent governance.

As for fossil energy consumption, such as oil, it causes significant environmental degradation, due to greenhouse gas emissions (*Zhao–Luo, 2017*). In this regard, the rapid growth of the world's population, the rapid globalization of economic relations, and the increased consumption of conventional energy have led to significant increases in CO₂ emissions. While governments are under intense pressure to reduce such emissions through international agreements and shift to a

low-carbon sustainable economy, global CO₂ emissions are continuing to rise (Uzar, 2020). For instance, in 2022, energy-related emissions set a new high of 39.3 billion tons of CO₂ equivalent (or 0.8% more than in 2021), with 87% of all emissions worldwide produced by energy consumption and 11% produced by that in European countries. Moreover, in 2022, global oil consumption reached 97.3 million barrels per day, tripling the amount in 1965. Meanwhile, according to the *Energy Institute (2023)*, oil consumption in Europe reached 14.5% of this figure (or 14.1 million barrels per day). Hence, in order to address the rapid growth in greenhouse gas emissions and the accelerating environmental degradation, replacing fossil fuels with renewable energy sources has become a top priority (Burke–Stephens, 2018; Olanrewaju et al., 2019; Uzar, 2020).

In the literature, the impact of macroeconomic variables on renewable energy consumption and production has been widely investigated (e.g., Sebri–Ben-Salha, 2014; Bamati–Raoofi, 2020; Sahlian et al., 2021; Murshed–Tanha, 2021). However, considerably less attention has been devoted to the combined role of governance quality and environmental degradation, particularly within the European context. Thus, the present study examines the impact of governance quality and environmental degradation on renewable energy development among 33 European countries in 2022 (the latest available data). These countries were selected because they have low energy security and lack conventional and nonrenewable resources. In order to analyze the cross-sectional data, this study used principal component analysis (PCA), multivariate linear regression (MLR), and partial least squares structural equation (PLS-SEM) modeling. This study makes two methodological contributions: by using both variables of renewable energy consumption and generation to analyze renewable energy development; and by creating governance and environmental degradation indexes. The latter utilizes PCA and PLS-SEM to avoid a one-dimensional analysis and provide a macro and comprehensive perspective of the effects on renewable energy development.

The remainder of this study is organized as follows. Section 2 includes a review of previous studies, while Section 3 presents the data and methods. Section 4 discusses the empirical results, while Section 5 presents the conclusions and relevant policy recommendations.

1. Literature Review

1.1 Governance Quality and Renewable Energy

For a successful transition to renewable energy, political decisions must be made and relevant policies must be established (*Cadoreto–Padovano, 2016*). By applying a negative binomial model of Organization for Economic Cooperation and Development countries between 1990 and 2018, *Li and Shao (2021)* identified three key factors as significant driving forces for the adoption/expansion of renewable energy: 1) the legal system and property rights framework; 2) the freedom to trade internationally; and 3) effective regulations. *Shahzad et al. (2021)* used the fully modified ordinary least squares technique and the annual data of 29 developed countries from 1994 to 2018 to examine the impact of the environmental policies index and the performance of institutions on renewable energy generation. According to their analysis, environmental regulation enhances renewable energy production, whereas various factors, such as bureaucratic decision-making, reduces such production. By using autoregressive distributed lag (ARDL) modeling, *Uzar (2020)* examined the relationship between renewable energy consumption and institutional quality across 38 countries from 1990 to 2015. They found that institutional quality has a positive long-term effect on renewable energy consumption in these countries. Similarly, in their study of the determinants of renewable energy consumption in Economic Cooperation Organization (ECO) countries from 1992 to 2011, *Mehrara et al. (2015)* employed Bayesian model averaging and weighted-average least squares methods. According to their results, the most important variables influencing renewable energy use in the ECO economies are institutional quality indexes, urban population, and human capital. *Cadoreto and Padovano (2016)* analyzed how political factors impact of renewable energy sources across 26 European Union countries from 2004 to 2011, and found that standard measures of government quality have a positive effect on renewable energy development. Finally, using panel vector autoregression in 35 high-income countries between 1996 and 2020, *Lin and Okoye (2023)* examined the relationship between governance and renewable energy production. They revealed that governance significantly affects such production. In summary, the common view among researchers is that a positive and meaningful relationship exists between governance and renewable energy development.

2. Environmental Degradation and Renewable Energy

By applying panel co-integration analysis, *Nguyen and Kakinaka (2019)* examined the relationship between renewable energy consumption and carbon emissions across 107 countries from 1990 to 2013, revealing the nuanced differences between low- and high-income country groups. They found that for low-income countries, renewable energy consumption is positively associated with carbon emissions, while for high-income countries, such consumption has a negative relationship with carbon emissions. *Omri and Nguyen (2014)* examined the determinants of renewable energy across 64 countries by using the generalized method of moments technique. They found that CO₂ emissions and trade openness have a favorable impact on the adoption and expansion of renewable energy. The researchers also determined that countries facing greater environmental pressures from greenhouse gas emissions tend to invest more in renewable energy alternatives, as a mitigation strategy.

In related research, *Sebri and Ben-Salha (2014)* used ARDL modeling to study the relationship between renewable energy consumption and CO₂ emissions in BRICS (i.e., Brazil, Russia, India, China, and South Africa) countries from 1971 to 2010. They revealed the positive role of CO₂ emissions in promoting renewable energy consumption. Conversely, using panel ARDL modeling, *Silva et al. (2018)* investigated the drivers of renewable energy in Sub-Saharan Africa between 1990 and 2014, and found that CO₂ emissions have a negative effect on renewable energy. Similarly, in a study on renewable energy consumption in Nigeria, Egypt, Ethiopia, the Democratic Republic of Congo, and South Africa from 1990 to 2015, *Olanrewaju et al. (2019)* used pooled regression analysis to investigate the determinants. Their empirical findings revealed that carbon intensity has a negative effect on renewable energy consumption. Likewise, in their analysis of the relationship between per capita CO₂ emissions and renewable energy production in China from 1980 to 2014, *Chen et al. (2019)* utilized the ARDL approach. Their long-term estimates revealed a negative relationship between renewable energy and CO₂ emissions. However, when *Jebli and Youssef (2015)* applied ARDL modeling to analyze CO₂ emissions and renewable energy consumption in Tunisia from 1980 to 2009, they did not find a statistically significant nexus in the long-term estimation, including the variable of imports. In summary, the literature presents mixed evidence regarding the relationship between CO₂ emissions and renewable energy.

3. Methodology

3.1. Data and Variables Description

Using cross-sectional data for 2022, this study conducted an empirical analysis of 33 European countries, each of which are sensitive to the energy market due to their lack of access to conventional resources (see Table 1). The information regarding the variables was aggregated from the databases of the Energy Institute (EI) and the World Governance Indicators (WGIs). Table 2 contains a list of the variables in this study (described in the following section), while Table 3 presents the descriptive statistics of the dataset, including the number of observations and the minimum, maximum, mean, and standard deviation values of each variable.

3.2 Variables

Renewable energy generation: In this study, electricity generated (in terawatt-hours) from wind, solar, geothermal, biomass, and other sources of renewable energy was used as the indicator of renewable energy generation. This information was extracted from the Energy Institute (EI) database.¹

Renewable energy consumption: In this study, the use of energy generated from renewable sources (in exajoules) was applied for this variable.² This information was obtained from the EI database.

Governance indicators: A total of six governance indicators, i.e., voice and accountability, political stability and violence, government effectiveness, the rule of law, regulatory quality, and corruption control, were applied to illustrate governance quality. Governance scores range from -2.5 (weak governance performance) to $+2.5$ (strong governance performance). This information was extracted from the WGIs database.³

CO₂ emissions: In this study, this variable was used to represent the sum of carbon dioxide emissions (in million tons) through the consumption of oil, gas, and coal for combustion-related activities. This information was obtained from the EI database.

¹ See <https://www.energyinst.org/statistical-review>.

² An exajoule (EJ) is a unit of energy measurement in the International System of Units (SI). It is equal to 1,018 joules.

³ See <https://www.worldbank.org/en/publication/worldwide-governance-indicators>.

Oil consumption: This variable (in thousand barrels per day) included inland demand, international aviation and marine bunkers, and refinery fuel and loss. The consumption of bio gasoline (such as ethanol), biodiesel, and derivatives of coal and natural gas were also included. This information was acquired from the EI database.

Table 1

List of the 33 European countries included in the study

Austria	Estonia	Ireland	Norway	Sweden
Belgium	Finland	Italy	Poland	Switzerland
Bulgaria	France	Latvia	Portugal	Turkey
Croatia	Germany	Lithuania	Romania	Ukraine
Cyprus	Greece	Luxembourg	Slovakia	United Kingdom
Czech Republic	Hungary	Netherlands	Slovenia	
Denmark	Iceland	North Macedonia	Spain	

Source: Author's compilation.

Table 2

Variables and data sources

Variable	Source
Renewable energy generation	EI
Renewable energy consumption	EI
Voice and Accountability	WGI
Political Stability	WGI
Government Effectiveness	WGI
Rule of Law	WGI
Regulatory Quality	WGI
Control of Corruption	WGI
CO ₂ Emissions	EI
Oil Consumption	EI

Notes: EI: Energy Institute; WGIs: Worldwide Governance Indicators.

Source: Author's compilation.

Table 3

Descriptive statistics

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Renewable Energy Generation (Terawatt-hour)	33	0.176	236.500	31.426	48.539
Renewable Energy Consumption (Exajoule)	33	0.001	2.450	0.334	0.504
Voice and Accountability	33	-0.926	1.774	1.012	0.569
Political Stability	33	-1.997	1.262	0.505	0.602
Government Effectiveness	33	-0.496	2.049	0.957	0.695
Rule of Law	33	-0.918	1.958	0.974	0.737
Regulatory Quality	33	-0.331	1.843	1.036	0.597
Control of Corruption	33	-0.633	2.402	0.948	0.875
CO ₂ emissions (carbon dioxide emissions (in million tons))	33	2.502	634.878	110.718	148.072
Oil Consumption (thousand barrels per day)	33	17.066	2075.280	416.102	522.771

Source: Author's calculations.

3.3. Empirical Model Specification and Strategy

Based on the previous literature on renewable energy drivers, this study examined the relationship between governance quality, environmental degradation, and renewable energy development among 33 European countries in 2022. In order to analyze the cross-sectional data, MLR and PLS-SEM techniques were applied.

Regarding the large number of independent variables and the problem of multicollinearity in this study, principal component analysis (PCA) was used to generate the single measure of governance quality from six governance indicators and the single measure of environmental degradation from CO₂ emissions and oil consumption in the MLR model (see Table 4). In this regard, PCA is a statistical technique widely used for dimensionality reduction and data visualization (*Jolliffe–Cadima, 2016*). This method also transforms the original correlated variables into a smaller number of uncorrelated variables called “principal components,” which retain most of the variance in the original dataset (*Jolliffe, 2002*).

Table 4

The variables and principal components derived from the PCA

Variable	Principal Component
Voice and Accountability	
Political Stability	
Government Effectiveness	Governance Quality
Rule of Law	
Regulatory Quality	
Control of Corruption	
CO ₂ Emissions	Environmental Degradation
Oil Consumption	

Source: Author's compilation.

As for the MLR technique, it is used to extend the simple linear regression by incorporating multiple predictors, thereby allowing a more comprehensive analysis of the factors influencing the outcome variables (Rencher, 2005). In this regard, the following models were considered:

$$\text{Renewable Energy Generation}_i = \beta_0 + \beta_1 \text{Governance Quality}_i + \beta_2 \text{Environmental Degradation}_i + u_i \quad (1)$$

$$\text{Renewable Energy Consumption}_i = \beta_0 + \beta_1 \text{Governance Quality}_i + \beta_2 \text{Environmental Degradation}_i + u_i \quad (2)$$

where i represents the country, β_0 is the constant parameter, β_x ($x = 1, 2$) are the elasticity parameters to be estimated, and u is the error term.

Apart from the MLR analysis, this study conducted PLS-SEM for robustness checks. In this case, PLS-SEM is well-suited for exploratory research and predictive applications, since (in contrast to covariance-based SEM) it optimizes the explained variance of endogenous constructs (Henseler et al., 2009; Sarstedt et al., 2021). When working with small sample sizes, this approach is advantageous (Chin, 1998). Specifically, PLS-SEM uses a two-step procedure. First, it estimates the relationships between latent variables and second, it evaluates the validity and reliability of the measurement model (Sarstedt et al., 2021).

For the PLS-SEM in this study, all of the variables used for the multivariate regression models were applied to provide a better perspective of renewable energy development and create a structural model. As Abu-Salih et al. (2022) and Li et al. (2022) pointed out, to provide a complete overview of renewable energy development, attention should be placed on both aspects of renewable energy generation and consumption, which directly impact the improvement of environmental quality. Meanwhile, numerous researchers (e.g., Mehrara et al., 2015; Cadoret-Padovano, 2016; Rahman-Sultana, 2022) have used governance indicators to express political and institutional quality. In this research, governance quality (as the latent variable) represents voice and accountability, political stability,

government effectiveness, the rule of law, regulatory quality, and corruption control. Since oil consumption and CO₂ emissions represent pollution (He et al., 2005; Al-Mulali, 2011; Alkhathlan–Javid, 2015), environmental degradation was used as a proxy. In the hypothetical model, it was also assumed that there is a path from governance quality to environmental degradation, which is in line with Bildirici (2022) and Haseeb (2018), who showed that there is a significant impact between these two aspects. Based on the extant literature and the variables, the latent variables and hypothesised model are presented in Table 5 and Figure 1.

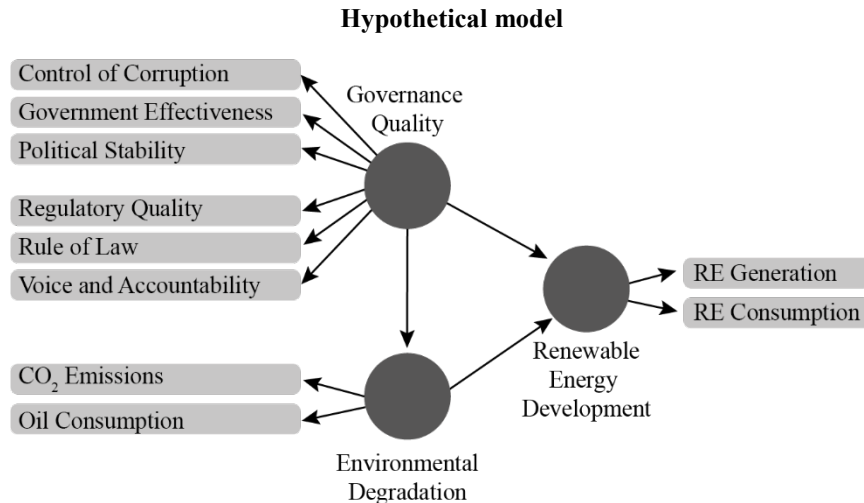
Table 5

The variables and latent variables applied in the PLS-SEM

Variable	Latent Variable
Renewable Energy Generation	Renewable Energy Development
Renewable Energy Consumption	
Voice and Accountability	Governance Quality
Political Stability	
Government Effectiveness	
Rule of Law	
Regulatory Quality	
Control of Corruption	
CO ₂ Emissions	Environmental Degradation
Oil Consumption	

Source: Author’s compilation.

Figure 1



Source: Author’s compilation in SmartPLS 3.

4. Results

4.1. Principal Component Analysis (PCA)

As shown in Table 6, the Kaiser-Meyer-Olkin (KMO) measure (0.814) exceeds the minimum criteria (0.5), indicating that the variables are suitable for PCA. Based on Table 7, the extractions show that each variable's importance is above the required minimum value (>0.4), with components that explain 92.1% of the total variation. Since this is higher than 60%, the minimum required criteria is met (see Table 8). Table 9 presents the components based on the rotated component matrix. In this case, if the correlation coefficient of a variable is higher than 0.5, then this variable is related to the component. Here, the first component consists of the rule of law, government effectiveness, regulatory quality, corruption control, voice and accountability, and political stability, all of which evaluate governance quality. The second component includes oil consumption and CO₂ emissions, demonstrating environmental degradation. Based on Table 10, Cronbach's alpha coefficients for the first component (governance quality = 0.971) and the second component (environmental degradation = 0.666) exceed the minimum criteria (0.60). Thus, both components are reliable.

Table 6

KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.814
Bartlett's Test of Sphericity	Approx. Chi-Square	405.876
	df	28
	Sig.	0.000

Source: Author's calculations.

Table 7

Communalities

Variable	Initial	Extraction
Voice and Accountability	1.000	0.898
Political Stability	1.000	0.729
Government Effectiveness	1.000	0.941
Regulatory Quality	1.000	0.933
Rule of Law	1.000	0.979
Control of Corruption	1.000	0.938
CO ₂ Emissions	1.000	0.977
Oil Consumption	1.000	0.974

Source: Author's calculations.

Table 8

Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	total	% of variance	cumulative %	total	% of variance	cumulative %	total	% of variance	cumulative %
1	5.383	67.285	67.285	5.383	67.285	67.285	5.357	66.964	66.964
2	1.987	24.837	92.122	1.987	24.837	92.122	2.013	25.158	92.122
3	0.338	4.224	96.346						
4	0.134	1.669	98.015						
5	0.079	.984	98.999						
6	0.036	.444	99.443						
7	0.026	.321	99.765						
8	0.019	.235	100.000						

Source: Author's calculations.

Table 9

Total rotated component matrix

Variable	Component	
	1	2
Rule of Law	0.989	-0.023
Government Effectiveness	0.969	-0.036
Regulatory Quality	0.966	-0.006
Control of Corruption	0.963	0.104
Voice and Accountability	0.946	-0.063
Political Stability	0.820	-0.239
Oil Consumption	0.030	0.987
CO2 Emissions	-0.108	0.983

Source: Author's calculations.

Table 10

Reliability statistics

Component	Cronbach's Alpha	N of Items
Governance Quality	0.971	6
Environmental Degradation	0.666	2

Source: Author's calculations.

4.2 Multivariate Regression Models

For both models, the coefficients for determination (R^2) are greater than 80% and acceptable, while 88.9% and 89.6% of the variance of renewable energy generation and consumption are explained by governance quality and environmental degradation, with the remaining 11.1% and 10.4% explained by other factors, respectively. Additionally, the average difference between the observed and estimated values of renewable energy generation is 16.666 terawatt-hours or 0.168 exajoules (see Table 11).

Table 11

Summary of the models

Model	R	R Square	Adjusted R Square	Std. Error
1	0.943	0.889	0.882	16.666
2	0.946	0.896	0.889	0.168

Source: Author's calculations.

According to Tables 12 and 13, since the variance inflation factor values are equal to 1.000 and less than 5, there is no perfect multicollinearity in both models. Thus, the partial effects are interpreted. Based on the coefficients and probability values of the estimations, both explanatory variables have a positive and significant impact on renewable energy generation and consumption at the 5% level of significance. The relations are as follows:

If the governance quality is 0 unit and the environmental degradation is 0 unit, then the estimated renewable energy generation and consumption are 31.426 terawatt-hours and 0.334 exajoules, respectively.

If the governance quality increases by 1 unit, then the estimated renewable energy generation and consumption increase (on average) by 7.184 terawatt-hours and 0.083 exajoules, respectively, assuming that the environmental degradation is constant.

If the environmental degradation increases by 1 unit, then the estimated renewable energy generation and consumption increase (on average) by 45.211 terawatt-hours and 0.470 exajoules, respectively, assuming that the governance quality is constant.

Based on the standard coefficients (beta), the environmental degradation components in both models have stronger effects on renewable energy generation and consumption than the governance quality components. Specifically, their values are 0.931 and 0.932, compared to 0.148 and 0.165 in Models 1 and 2, respectively. Regarding the zero-order correlations and standard coefficients (beta) in Model 1, environmental degradation represents 86.6% of the R^2 , compared to 2.2% for governance quality. Similarly, in Model 2, environmental degradation has the main share of the R^2 , with 86.8%, compared to 2.8% for governance quality.

Table 12

The estimation results of Model 1

Variable	B	Std. Beta	Zero-order	t	Sig	VIF
(Constant)	31.426			10.832	0.000	
Governance Quality	7.184	0.148	0.148	2.438	0.021	1.000
Environmental Degradation	45.211	0.931	0.931	15.345	0.000	1.000

Source: Author's calculations.

Table 13

The estimation results of Model 2

Variable	B	Std. Beta	Zero-order	t	Sig	VIF
(Constant)	0.334			10.832	0.000	
Governance Quality	0.83	0.165	0.165	2.438	0.009	1.000
Environmental Degradation	0.470	0.932	0.932	15.345	0.000	1.000

Source: Author's calculations.

Table 14 indicates that the absolute values of the standardized residuals are less than 3 for Models 1 and 2. Thus, the models do not need to filter out any data because of outliers.

Table 14

Residuals statistics

Model	Minimum	Maximum	N
1	-2.114	2.735	33
2	-1.726	2.682	33

Source: Author's calculations.

4.3 Partial Least Squares Structural Equation Modeling

In order to measure the reliability of the constructs, composite reliability (CR) measures can be used (*Hair et al., 2021*). For the CR measures in this study, the minimum criteria ($CR > 0.7$) were met in all of the latent variables (see Table 15). Meanwhile, convergence validity was examined by average variance extracted ($AVE > 0.5$) and by standardized factor loadings (>0.7). According to the AVE

measures (see Table 15) and the factor loadings (see Table 16), the minimum values (in parentheses) were achieved.

Table 15

Composite reliability and average variance extracted (AVE)

Latent Variable	Cronbach's Alpha	rho-A	CR	AVE
Renewable Energy Development	0.999	0.999	1.000	0.999
Governance Quality	0.975	1.020	0.976	0.871
Environmental Degradation	0.975	0.975	0.988	0.976

Source: Author's calculations.

Table 16

Factor loadings

Indicator	Factor Loading
Renewable Energy Generation	1.000
Renewable Energy Consumption	1.000
Voice and Accountability	0.932
Political Stability	0.731
Government Effectiveness	0.973
Rule of Law	0.982
Regulatory Quality	0.969
Control of Corruption	0.985
CO ₂ Emissions	0.988
Oil Consumption	0.988

Source: Author's calculations.

Tables 17 and 18 show that discriminant validity was also met, based on Fornell and Larcker (1981) criterion and the heterotrait-monotrait ratio of correlations (HTMT < 0.9) (Henseler et al., 2015). Specifically, in Table 17, the main diagonal shows the AVE square root for each construct. Since the AVE square root for each construct is greater than its highest correlation with any other construct, the Fornell-Larcker criterion is met, indicating good discriminant validity.

Table 17

AVE square roots and correlations of the constructs (Fornell-Larcker criterion)

Latent variable	Renewable Energy Development	Governance Quality	Environmental Degradation
Renewable Energy Development	1.000		
Governance Quality	0.174	0.933	
Environmental Degradation	0.927	-0.020	0.988

Source: Author's calculations.

Table 18

HTMT ratio of the correlations

Latent variable	Renewable Energy Development	Governance Quality	Environmental Degradation
Renewable Energy Development			
Governance Quality	0.141		
Environmental Degradation	0.101	0.109	

Source: Author's calculations.

Moreover, the results of the structural model were tested with the bootstrap algorithm, in which all of the paths were significant ($p < 0.05$), except for the governance quality \rightarrow environmental degradation path ($t = 0.069$, $p = 0.945 > 0.05$) (see Table 19). Thus, governance quality has no indirect effect on renewable energy development. After excluding governance quality \rightarrow environmental degradation path from the model, all of the paths are significant (see Table 20).

Table 19

Results of the bootstrap algorithm

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ((O/STDEV))	P Values
Governance Quality \rightarrow RE Development	0.193	0.193	0.074	2.600	0.010
Environmental degradation \rightarrow RE Development	0.931	0.947	0.055	16.789	0.000
Governance Quality \rightarrow Environmental degradation	-0.020	-0.079	0.287	0.069	0.945

Source: Author's calculations.

Table 20

Results of the bootstrap algorithm (excluding the insignificant path from the model)

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ((O/STDEV))	P
Governance Quality \rightarrow RE Development	0.192	0.177	0.075	2.562	0.011
Environmental degradation \rightarrow RE Development	0.928	0.932	0.050	18.625	0.000

Source: Author's calculations.

Based on the standardized path coefficients (i.e., the arrows in Figure 2), the findings are as follows:

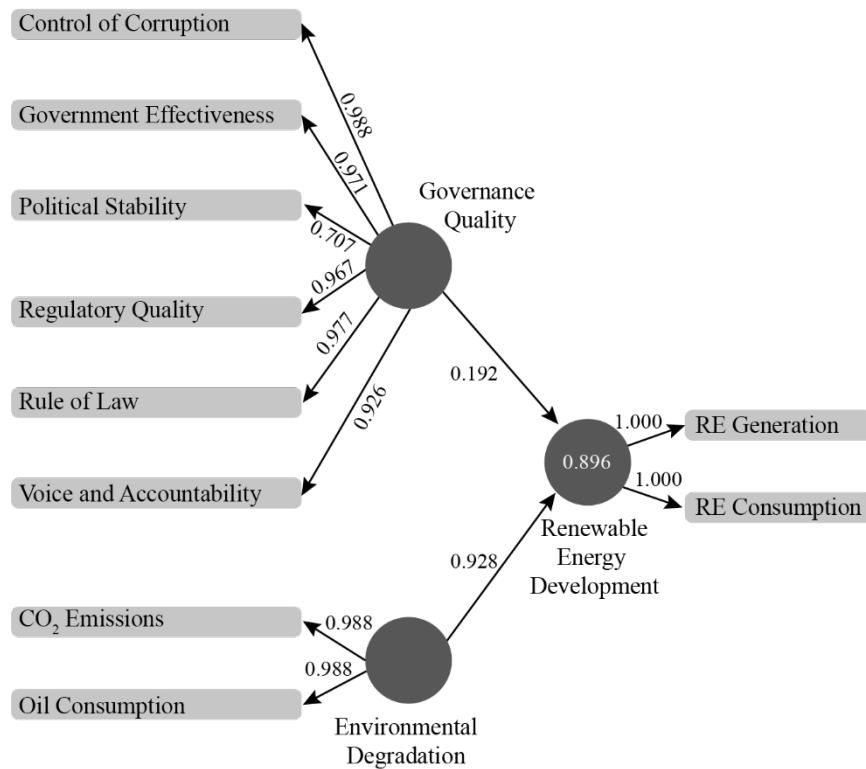
All of the direct effects are positive.

Environmental degradation has a stronger direct effect on renewable energy development ($\beta = 0.928$) than governance quality ($\beta = 0.192$).

The total variance explained ($R^2 = 0.896$, i.e., the ellipse in Figure 2) is considered strong in the case of renewable energy development.

Figure 2

Results of the PLS algorithm (path coefficients and R^2)



Source: Author's compilation in SmartPLS 3.

Finally, it is important to note the effect sizes (f^2), which show “the change in the R^2 value when a specified exogenous construct is omitted from the model and can be used to evaluate whether the omitted construct has a substantive impact on the endogenous constructs” (Hair et al., 2021). In the present study, the path of environmental degradation \rightarrow renewable energy development ($f^2 = 8.257$) is considered to be large, whereas the path of governance quality \rightarrow renewable energy development ($f^2 = 0.354$) is small (see Table 21).

Table 21

Effect sizes

Path	f^2
Governance Quality \rightarrow RE Development	0.354
Environmental degradation \rightarrow RE Development	8.257

Source: Author’s calculations.

5. Conclusion

Renewable energy is vital for achieving environmental sustainability, especially for countries with limited conventional sources. However, these countries face various challenges in renewable energy development. Thus, using the latest available data from 2022, this study examined the impact of governance quality and environmental degradation on renewable energy development among 33 selected European countries. To analyze the cross-sectional data, it used the PCA, MLR, and PLS-SEM techniques. Regarding the PCA, two principal components, i.e., governance quality and environmental degradation emerged from the eight variables. Based on the MLR, the impact of governance quality and environmental degradation on both renewable energy generation and consumption were positive and significant, while environmental degradation had a stronger effect than governance quality. According to the PLS-SEM, governance quality, environmental degradation, and renewable energy development (as the latent variables) were formed by the observed variables to constitute a structural model. Similarly to the MLR results, governance quality and environmental degradation had a positive and significant impact on renewable energy development, whereas governance quality had a weaker effect than environmental degradation.

In general, good governance reflects the existence of effective institutions, policies, and regulatory frameworks that are expected to promote renewable energy development. Meanwhile, investing in renewable energy is facilitated through transparency and efficiency under good governance. Thus, this study suggests that European countries should improve political institutions in order to promote renewable energy and environmental quality. For example, this can be achieved by implementing regulations, such as tax and tariff exemptions, to support renewable energy projects.

The positive impact of environmental degradation on renewable energy development also suggests that higher degrees of environmental deterioration can serve as a catalyst for action toward renewable energy. In this case, as the adverse effects of such degradation become more evident, there is increased public and political pressure to transition toward cleaner energy sources to mitigate these effects. Regarding the catalyst role of environmental degradation, European governments should raise awareness about the negative impact of relying on fossil fuels and other polluting energy sources to stimulate them toward this alternative resource.

Finally, the stronger impact of environmental degradation than governance quality indicates that the decisions and measures in support of the environment and renewable energy are not as serious as the extent of environmental degradation and greenhouse gas emissions. Thus, we can conclude that observing the effects of environmental degradation can further stimulate renewable energy development.

Overall, this study presents several unique research prospects. Specifically, repeating this exercise for developing nations can yield results that either support or contradict the findings of this study. By doing so, researchers can compare the effects of governance quality and environmental degradation on renewable energy in both developed and developing countries.

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