Analysis Report

This report is structured as follows.

Contents

Sample Characteristics

The purpose of this analysis was to examine the impact of economic and environmental factors on renewable energy consumption (RE) in selected Latin American countries. Data was sourced from the World Development Indicators for Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Panama, Peru, and Uruguay, covering the years 2000 to 2022. The dependent variable was renewable energy consumption as a percentage of total energy consumption, with independent variables including foreign direct investment (FDI) as a percentage of GDP, CO2 emissions per capita, urban population growth (UP) as an annual percentage, trade openness (TO), and GDP growth. Due to the longitudinal nature of the data, mixed-effects modeling was implemented to account for country-specific effects and temporal correlations. The results of standard regression analyses were also examined to support the assumption testing process and model selection.

Data Collection and Preparation

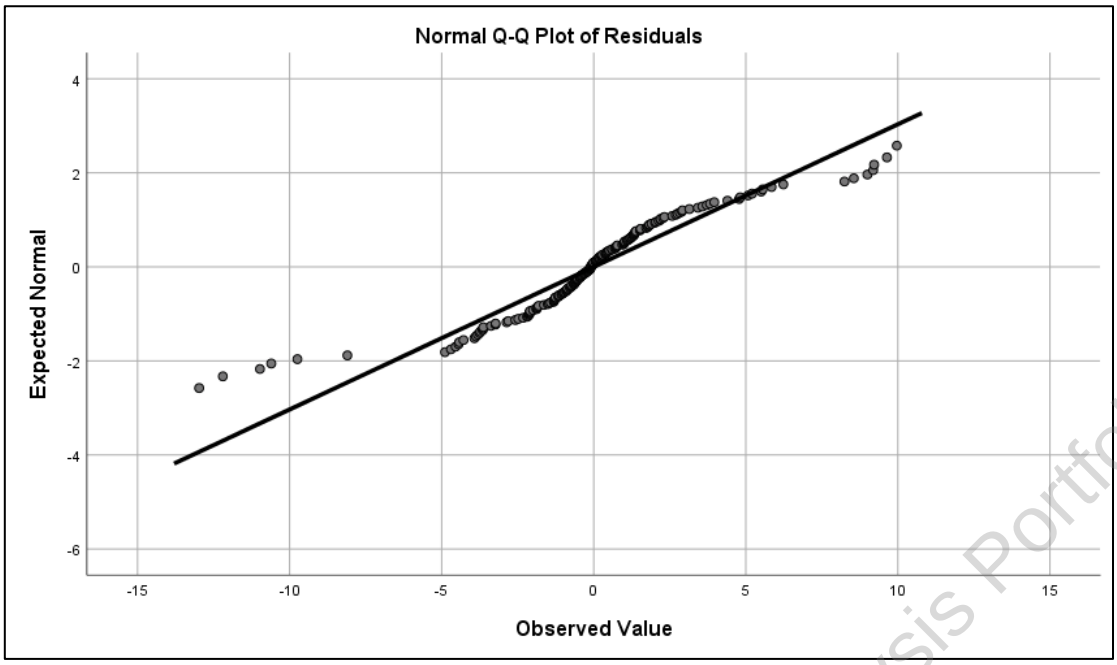
The dataset was obtained using the `WDI` package in R, and indicators were specified using World Bank codes for each variable of interest. Each variable was inspected for completeness, and missing values were addressed appropriately. The variables were sorted by `country` and `year`, and lagged variables were created for FDI to capture potential delayed effects on renewable energy consumption.

Preliminary diagnostics revealed non-normality in residuals, as evidenced by the table below ($p < 0.001$) and the QQ-plot of residuals.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Residuals	.120	200	.000	.905	200	.000
Residuals	.120	200	.000	.904	200	.000
Residuals	.121	200	.000	.908	200	.000

a. Lilliefors Significance Correction



Log-transformations were used on CO2, FDI, UP, TO, GDP, and RE, with constants added to ensure positive values for transformation. This transformation enhanced normality ($p > 0.01$ in the Kolmogorov-Smirnov test) and stabilized variance, satisfying model assumptions (table and QQ plot below).

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Residuals	.064	199	.047	.978	199	.003
Residuals	.066	199	.036	.976	199	.002
Residuals	.063	199	.056	.978	199	.003

a. Lilliefors Significance Correction

Mixed-Effects Model Specification

The analysis involved fitting a series of mixed-effects models with various structures, accounting for both fixed and random effects. The primary model and several alternative specifications were assessed for model fit, and the impact of each predictor on renewable energy consumption was evaluated.

Collinearity and Autocorrelation Diagnostics: Initially, standard linear regression was used to examine collinearity and identify any potential autocorrelation in residuals. Variance Inflation Factor (VIF) results indicated that collinearity was not a concern among the predictors, with all VIF values remaining below the conventional threshold of 10. The Durbin-Watson statistic was notably low at 0.367, indicating strong positive autocorrelation in residuals. These findings justified the use of a mixed-effects model with autoregressive structures to account for the temporal dependencies in the data.

Coefficients[a]

		Collinearity Statistics	
Model		Tolerance	VIF
1	CO2	.916	1.091
	FDI	.609	1.642
	UP	.747	1.338
	TO	.533	1.878
	GDP	.843	1.186

a. Dependent Variable: RE

Mixed Model with Year and Country Random Effects: Initially, random intercepts for both `year` and `country` were specified to control for unobserved heterogeneity and autocorrelation. However, the model's fit statistics revealed that the variance associated with `year` was close to zero, suggesting that treating `year` as a random effect did not add significant value to the model. This finding led to the exclusion of `year` as a random effect, resulting in a model with only random intercepts for `country`.

Mixed Model with Country Random Effects: A model with random intercepts for `country` alone was subsequently tested to capture between-country variability. This model yielded a poorer fit than a fixed-effects approach using dummy variables for each country, as indicated by higher -2 log-likelihood (1112.36 versus 1040.46) and Akaike Information Criterion (AIC) values. Consequently, a fixed-effects model with country-specific dummies was favored due to its superior model fit. Log-transformation has further improved model fit (-2LL = -623.47, AIC = -621.47, BIC = -618.26).

Final Model with Fixed Effects for Country: The final model specification included log-transformed predictors and dummy variables for each country to control for country-specific differences. An autoregressive (AR1) covariance structure was specified for `year` within each country to address the observed autocorrelation in residuals. The syntax implemented in SPSS was as follows:

```
plaintext
Copy code
MIXED LOG_RE WITH LOG_CO2 LOG_FDI LOG_UP LOG_TO LOG_GDP countryArgentina
countryBrazil countryChile countryColombia countryCostaRica countryEcuador
countryMexico countryPanama countryPeru countryUruguay
  /CRITERIA=CIN(95) MXITER(100) MXSTEP(10) SCORING(1)
SINGULAR(0.000000000001)
  /FIXED= LOG_CO2 LOG_FDI LOG_UP LOG_TO LOG_GDP countryArgentina
countryBrazil countryChile countryColombia countryCostaRica countryEcuador
countryMexico countryPanama countryPeru countryUruguay | SSTYPE(3)
  /METHOD=REML
  /PRINT=SOLUTION TESTCOV
  /RANDOM INTERCEPT | SUBJECT(country) COVTYPE(VC)
  /REPEATED=year | SUBJECT(country) COVTYPE(AR1).
```

Models with Lagged FDI Variables: Additional models were estimated with 1-year and 2-year lagged FDI terms, replacing the current-year FDI, to evaluate potential delayed effects. The structure remained consistent, with country-level fixed effects and an AR1 structure for temporal correlation.

Model Results

These mixed-effects models incorporated fixed effects for each country, with CO2 emissions, foreign direct investment (FDI), urban population growth (UP), trade openness (TO), and GDP growth (GDP) as predictors, along with country-specific dummy variables. Three models were evaluated: the main log-transformed model, a model with a one-year lag for FDI, and a model with a two-year lag for FDI.

Across all models, CO2 was consistently a significant predictor of renewable energy consumption. In the main log-transformed model, the coefficient for CO2 was negative, **b = -0.50**, **SE = 0.06**, **t(185) = -8.64**, **p < .001**, indicating that higher CO2 emissions were associated with lower renewable energy consumption. Urban population growth (UP) also significantly predicted renewable energy consumption, **b = -0.13**, **SE = 0.03**, **t(185) = -4.24**, **p < .001**, suggesting that as urban populations increase, renewable energy consumption tends to decrease.

Trade openness (TO) was another significant predictor, **b = -0.15**, **SE = 0.05**, **t(185) = -3.06**, **p = .003**, indicating that higher trade openness correlates with lower renewable energy consumption. However, GDP growth and FDI were not significant predictors. For instance, in the log-transformed model, FDI had a non-significant effect, **b = 0.02**, **SE = 0.03**, **t(185) = 0.73**, **p = .466**, implying that FDI does not play a substantial role in explaining renewable energy consumption in this context.

Models incorporating lagged FDI terms showed similar results, with FDI remaining non-significant. For the one-year lag model, FDI lagged by one year did not predict renewable energy consumption, **b = 0.01**, **SE = 0.02**, **t(184) = 0.87**, **p = .388**, and similarly, in the two-year lag model, FDI lagged by two years was not significant, **b = 0.01**, **SE = 0.02**, **t(185) = 0.62**, **p = .534**. This suggests no delayed or lagged effect of FDI on renewable energy consumption.

Country dummy variables were significant across all models, reflecting the different levels of renewable energy consumption between countries. Argentina, for example, had a substantial negative coefficient in the main model, **b = -0.54**, **SE = 0.03**, **t(185) = -19.36**, **p < .001**, indicating lower renewable energy consumption compared to other countries. Colombia and Ecuador also had significant negative estimates, **b = -0.20**, **SE = 0.02**, **t(185) = -8.10**, **p < .001**, and **b = -0.39**, **SE = 0.03**, **t(185) = -14.93**, **p < .001**, respectively, highlighting country-level differences. The tables below show the model coefficients.

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	2.084	.080	185.000	25.991	1.165E-63	1.926	2.242

LOG_CO2	-.495	.057	185.000	-8.639	2.625E-15	-.608	-.382
LOG_FDI	.021	.029	185.000	.730	.466	-.036	.078
LOG_UP	-.135	.032	185.000	-4.240	3.533E-5	-.197	-.072
LOG_TO	-.146	.048	185.000	-3.060	.003	-.240	-.052
LOG_GDP	-.033	.028	185.000	-1.196	.233	-.088	.022
countryArgentina	-.537	.028	185.000	-19.356	2.420E-46	-.592	-.483
countryBrazil	.006	.024	185.000	.242	.809	-.041	.053
countryChile	-.006	.030	185.000	-.212	.832	-.064	.052
countryColombia	-.199	.025	185.000	-8.095	7.455E-14	-.248	-.151
countryCostaRica	-.048	.029	185.000	-1.647	.101	-.106	.010
countryEcuador	-.392	.026	185.000	-14.926	1.403E-33	-.443	-.340
countryMexico	-.457	.031	185.000	-14.762	4.280E-33	-.518	-.396
countryPanama	-.153	.033	185.000	-4.570	8.910E-6	-.218	-.087
countryPeru	-.186	.022	185.000	-8.427	9.781E-15	-.230	-.142
countryUruguay	0[b]	0	.	.	.	.	.

a. Dependent Variable: LOG_RE.

b. This parameter is set to zero because it is redundant.

Estimates of Fixed Effects[a]

						95% Confidence Interval	
Parameter	Estimate	Std. Error	df	t	Sig.	Lower Bound	Upper Bound
Intercept	2.051	.080	184.000	25.717	7.875E-63	1.894	2.209
LOG_CO2	-.499	.058	184.000	-8.644	2.602E-15	-.613	-.385
LOG_FDI_lag1	.014	.016	184.000	.865	.388	-.018	.047
LOG_UP	-.132	.032	184.000	-4.156	4.953E-5	-.195	-.069
LOG_TO	-.125	.049	184.000	-2.581	.011	-.221	-.030
LOG_GDP	-.025	.020	184.000	-1.278	.203	-.064	.014
countryArgentina	-.534	.028	184.000	-19.037	2.344E-45	-.589	-.478
countryBrazil	.010	.024	184.000	.402	.688	-.037	.056
countryChile	-.010	.029	184.000	-.332	.740	-.068	.048
countryColombia	-.200	.025	184.000	-8.143	5.680E-14	-.248	-.151
countryCostaRica	-.055	.029	184.000	-1.874	.063	-.113	.003
countryEcuador	-.394	.026	184.000	-14.869	2.331E-33	-.446	-.341
countryMexico	-.459	.031	184.000	-14.716	6.596E-33	-.521	-.398
countryPanama	-.168	.034	184.000	-4.918	1.932E-6	-.236	-.101
countryPeru	-.188	.022	184.000	-8.567	4.198E-15	-.232	-.145
countryUruguay	0[b]	0	.	.	.	.	.

a. Dependent Variable: LOG_RE.

b. This parameter is set to zero because it is redundant.

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval

						Lower Bound	Upper Bound
Intercept	2.075	.079	185.000	26.303	2.044E-64	1.919	2.230
LOG_CO2	-.499	.058	185.000	-8.542	4.799E-15	-.615	-.384
LOG_FDI_lag2	.010	.017	185.000	.623	.534	-.023	.043
LOG_UP	-.136	.032	185.000	-4.274	3.066E-5	-.199	-.073
LOG_TO	-.144	.047	185.000	-3.033	.003	-.237	-.050
LOG_GDP	-.018	.019	185.000	-.936	.351	-.057	.020
countryArgentina	-.536	.028	185.000	-18.980	2.722E-45	-.591	-.480
countryBrazil	.006	.024	185.000	.256	.798	-.041	.053
countryChile	-.005	.030	185.000	-.181	.857	-.064	.053
countryColombia	-.200	.025	185.000	-8.090	7.690E-14	-.249	-.151
countryCostaRica	-.049	.030	185.000	-1.664	.098	-.107	.009
countryEcuador	-.392	.027	185.000	-14.748	4.687E-33	-.444	-.339
countryMexico	-.456	.031	185.000	-14.547	1.847E-32	-.517	-.394
countryPanama	-.154	.033	185.000	-4.612	7.424E-6	-.220	-.088
countryPeru	-.187	.022	185.000	-8.447	8.643E-15	-.231	-.143
countryUruguay	0[b]	0	.	.	.	.	.

a. Dependent Variable: LOG_RE.

b. This parameter is set to zero because it is redundant.

In summary, the log-transformed models provided better fit and addressed some of the issues identified in the untransformed models. CO2, urban population growth, and trade openness were significant predictors of renewable energy consumption, while GDP and FDI were not. The lagged FDI models also revealed no significant delayed effect of FDI on renewable energy consumption. Country-level effects remained strong, emphasizing the importance of regional differences in renewable energy consumption patterns.