# Impact of Political, Institutional and Economic aspects on Renewable Energy Penetration in Asian and Pacific Countries

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Supervisor: Dr. Syed Ali Abbas Kazmi

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## LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| $CO_2$ | Carbon Dioxide |
| RE | Renewable energy |
| IQ | Institutional quality |
| GDP | Annual GDP growth |
| Mt | Mega Tones |
| Fig | Figure |
| ARDL | Auto Regressive Distributed Lag |
| Eq | Equation |
| IPCC | International Panel for Climate Change |
| CADF | Cross sectional Augmented Dicky Fuller |
| GMM | Generalized model of moments |
| ICRG | International Country Risk Guide |
| OCED | Organization for Economic Co-operation and Development |
| MG | Mean group estimation |
| BP | British petroleum |

| | |
|---|---|
| ECM | Error Correction Method |
| PMG | Pool Mean group |
| CSD | Cross-sectional dependence |
| FMLOS | Fully Modified Ordinary Least Squares |

# ABSTRACT

The escalating global environmental degradation has attracted significant attention in global discourse and imposed substantial imperatives on policymakers, regulators, and individuals. The utilization of fossil fuels in energy generation has led to the emission of greenhouse gases, prompting a shift towards green and more sustainable energy sources, such as renewable energy. Despite the considerable contribution of renewable energy for the mitigation of environmental crises, there exist certain constraints that hinder an in-depth understanding of the determinants influencing its adoption. To fill this gap, this research analyzes the relationship among quality of institutions, economic growth, carbon dioxide emissions and renewable energy in 15 states spanning from 1984 to 2020 using panel ARDL-PMG methodology. The results of this study conclude that better institutional quality has a long run positive impact on the penetration of renewable energy. Additionally, GDP growth is a significant and favorable factor that determines renewable energy penetration. However, $CO_2$ emissions negatively impact renewable energy penetration. Within this framework, the significance of institutional quality measured by the reliability and performance of political as well as regulatory frameworks becomes a critical and deliberate determinant impacting the implementation of renewable energy and mitigates environmental issue.

**Keywords:** Institutional Quality, Renewable energy, Political Framework, Greenhouse gas emissions, Autoregressive Distributed Lag, Economic growth.

# CHAPTER 1: INTRODUCTION

## 1.1 Motivation

Power network is an essential component in facilitating economic development [1], the need for electricity can be fulfilled through two distinct power generation methods: renewable and conventional energy sources. Renewable energy sources are becoming more prominent in energy generation due to the significant negative environme ntal consequences of electricity produced from fossil fuels. Globally, the adoption of renewable power generation is steadily increasing. At global level , renewables' share of primary energy was 12% in 2019 which will rise to 35-64% by 2050 [2]. The International Energy Outlook 2023 states that the share of coal-fired power in new global capacity additions peaked at 45% in 2006 and has since gradually declined to 11% in 2022 [3]. The annual addition to coal capacity crossed 100 GW in 2012 which has been reduced to 50 GW by 2022, as large investments in coal fade and solar PV and wind power increasingly dominate system expansion. In accordance with IPPC report the mean surface temperature of earth increased by 1.1°C between 2011 and 2020 relative to the 1850-1900 average. Human activities, particularly the utilization of fossil fuels, are the most significant factor contributing to global warming. Global warming results in changes such as altered rainfa ll patterns, melting glaciers, permafrost and increasing sea levels. This not only endangers natural ecosystems but also poses threats to human life [4] .In the context of global warming, rising temperature and modifying the electrical supply structure within power sector is critical.

Enhancing the proportion of clean energy sources is crucial for the power industry to make the switch to an environmentally friendly energy supply structure. The growing importance of clean energy sources for energy generation demands a comprehensive analysis of the determinants that drive the adoption of renewables in energy mix. This possesses significant importance in terms of expanding the integration of renewable power as an instrument for mitigating $CO_2$ emissions and combat climate crisis. Countries are implementing fundamental regulations and plans in energy markets to foster renewable energy adoption, including initiatives such as public financing, direct payments for energy, and competitive auctions. Incentives such as monetary subsidies, investment grants, and tax incentives for investments are critical in emerging economies, Caucasus, the Central Asian region, and Eastern and Central European countries [5]. However, the literature predominantly focused on environmental and macroeconomic parameters such as economic development, carbon dioxide emission, regulation, employment, green growth, urbanization, financial development, and exports have evolved as main factors impacting the integration of renewable energy [6]–[11] .With little attention to political and institutional aspects of renewable energy penetration, restricting the deployment of RE with only environmental and economic factors leads to significant analytical problems. Ignoring the impact of institutional and political variables, particularly bureaucratic excellence, stability of the government, corruption, law enforcement, and democratic levels in this context will lead to an inadequate comprehension of renewable energy. Initia lly, renewable energy utilization is mainly a matter of political will [12]. Secondly, certain government-backed policies hinder investments in renewable energy, leading to policy failures. Consequently, ineffective voluntary measures are implemented to meet individuals demands for eco-friendly investments [13]. On the other side, the establishme nt of an effective government may raise people's regard for environmental quality and clean energy adaptation. Moreover, fossil fuels are inexpensive than renewables governments should implement policies to minimize dependency on fossil fuels, either by increasing their cost through emissions-related taxes or by subsidizing renewable energy [14]. Although, environmental and economic impacts of renewable energy are majorly studied in previous studies, political variables are frequently overlooked. In recent years, the association within political and political and institutional factors such as democratic level and governance has become significantly important. However, thorough comprehension of the political and economic landscape of renewable energy presents several obstacles. For instance, the impact of renewable energy and democracy on $CO_2$ emissions has been examined by [15] . The outcomes indicate that RE and democracy reduce $CO_2$ emissions. Similarly [16] examined the consequences of income and democracy on energy mix. These investigations have studied the effects of a restricted number of political variables;

however, these studies have made substantial contributions to comprehending the political variables influencing renewable energy.

As it is apparent, there exists a research gap in understanding political factors influencing renewable energy. This research primarily aims to determine the impact of government stability, rule of law, democratic systems, corruption, and bureaucratic excellence on the penetration of renewable energy. To deal with this issue, the present study investigates the impact of institutional quality on renewable energy penetration across 15 Asian nations during 1984 to 2020 using institutional quality as a political metric. In addition, the model includes GDP per capita (annual %) and carbon dioxide emissions per capita as independent variables to evaluate the economic and environmental aspects. This research enriches literature in several ways. Firstly, this research seeks to address the void in previous literature by examining the political factors influencing renewable energy. As a result, the policy recommendations derived from this research could potentially aid in reducing emissions and encourage renewable energy penetration. If it is confirmed that institutional quality has a favorable influence on renewable energy, in such cases these nations can achieve political and environmental benefits. Secondly, numerous institutional indicators sourced from ICRG are used to indicate institutional quality. These metrics are effective for representing institutional quality and can contribute to strategic policy formulations for renewable energy penetration. This study differs from [12] and [17] that utilizes wider variety of institutional indicators, whereas others utilize a more constrained set. Thirdly, as a methodological contribution this research presents certain methodological benefits compared to previous studies, particularly incorporation of panel interdependence improves both the number of samples and the accuracy of the tests. Failure to include cross-sectional dependency result in skewed and imprecise result in skewed [18].

Consequently, this study utilizes Breusch-Pagan, LM Pesaran scaled, CD Bias-corrected scaled LM and Pesaran CD tests that considers cross-sectional dependency. Consequently, the outcomes exhibit greater precision and robustness as compared to prior studies. Finally, the long-run estimation critically examines the macroeconomic and institutional parameters. These results will contribute to a greater comprehension of the institutional frameworks and mechanisms that are vital for renewable energy generation in the case of emerging economies.

### 1.2 Aims and Objectives

Previous research in the field of renewable energy has primarily emphasized investiga t ing macro-economic and environmental factors that influence renewable energy penetration such as GDP growth, income, FDI, trade liberalization and so on. While these studies have provided valuable insights related to specific aspects of renewable energy penetration, there has been a noticeable gap in the research when it comes to studying the repercussions of political and economic factors on renewable energy penetration mainly in Asian states. In contrast to previous work, the primary objective of this work aims to analyze the long run and short run impact of IQ on renewable energy penetration. Additionally, GDP per capita and $CO_2$ emissions are incorporated as independent variables. The statistica l estimation tests as well as the data acquisition system's information are described in the thesis. The research gap observed in previous studies is that the existing studies primarily emphasize the implications of economic and ecological variables, neglecting the influe nce of political/institutional factors.

### 1.3 Scope

The primary goals of this research are listed as follows:

- Econometric analysis of the parameters influencing renewable energy using validated simulation results.
- Analyzing the long-term and short-term influence of institutional quality on the penetration of renewable energy
- Highlight the impact of GDP growth and carbon dioxide on renewable energy.
- A comprehensive 1984–2020 panel ARDL-PMG study can provide periodic changes and trends in the 15 states.

### 1.4 Outline of thesis report

**Chapter 2** presents the literature about different studies mainly macro-economic and environmental factors influencing renewable energy penetration and impact of $CO_2$ emission on RE penetration. Moreover, the consequences of democracy and politica l ideology on renewable energy are also discussed.

**Chapter 3** provides a thorough description of the data and model specifications. It includes the list of dependent and explanatory variables that are selected to examine the relations hip between them. It also includes the descriptive statistics of the data and the status of highest and lowest institutional quality and renewable energy generation across countries.

**Chapter 4** provides a thorough description of the methodology employed to investigate the long run and short run impact of institutional quality on renewable energy penetration. It encompasses a range of tests utilized for evaluating non-stationarity of variables and co-integration among the variables, offering insights into the estimation conducted, and presenting output data obtained from the data acquisition system**.**

**Chapter 5** explains the outcomes of the investigated variables' correlated errors. Moreover, advanced unit root tests are conducted to check the stationarity of the variables. Additionally, second generation cointegration tests including Pedroni and Westlund are conducted. Finally, the long run and short impact is presented and the casual relations hip between the variables.

**Chapter 6** presents the explanation of this research, including a summary of the findings and recommendations for future investigations.

# CHAPTER 2: LITERATURE REVIEW

There is significant research addressing the question of how economic activities and environmental factors impact renewable energy. The components exerting influence on renewable energy penetration have been explored via a variety of time intervals, factors, and methods in diverse countries and regions. Prior research has investigated the factors influence the adoption of renewable energy has frequently utilized economic and environmental indicators, including energy prices, $CO_2$ emissions, economic growth, trade openness, employment, income level, trade globalization and technological innovat ions advancement. Additionally, there exist studies investigating certain political factors that influence and determine environmental issues, the lack of research related to institutio nal catalysts for renewable energy development is particularly diminutive. The presence of this research gap in the existing literature requires a more thorough examination of the politica l variables influencing renewable energy.

## 2.1 Impact of macro-economic and environmental factors on renewable energy penetration

As stated earlier, a substantial portion of studies investigate the linkage between renewable energy and wider economic and environmental variables. M. M. Alam and M. W. Murad [19] examined that trade liberalization, technological advancement, and economic expansion have a considerable impact on the adoption of renewable energy sources in the long run among 25 developed countries with mixed short-term effects. Similarly [20] studied the variables driving the utilization of renewable energy within six developing economies from 1980 to 2006 by applying FMOLS, Dynamic Ordinary Least Squares and Granger causality techniques. This study reveals that income levels and pollutant emissio ns significantly influence renewable energy usage in Brazil, China, India, and the US. In the Philippines and Turkey, income levels are the key determinant. The study also found bidirectional casual connection between income and renewable energy consumption, as well as between the utilization of renewable energy and pollutant emissions in the short term. The factors impacting renewable energy production in 27 countries from 1990-2014 have been investigated by [13]. The findings indicate that a boost in economic growth, along with a rise in unemployment and government debt served as catalysts for the expansion of renewable energy generation. The causal relationship connection between GDP expansion and renewable electricity of 20 OECD countries from 1990 to 2008 using panel error correction model have been analyzed by [21]. The findings pointed out that renewable energy generation and GDP are bidirectionally correlated, with biomass, hydropower, and waste electricity significantly impacting GDP in the long term.

Similarly as in [22], an econometric analysis with in 50 nations during 1995–2015 for assessing renewable energy policy effectiveness have been conducted. The results indicate that public policies positively impact renewable energy (RE) investment. However, tax incentives alone are insufficient for implementing RE technology. As per [23], increased renewable energy consumption has advantageous impact on economic output and minimizes $CO_2$ emissions among 85 developing countries during 1991-2012. This research highlights the significance of renewable energy and good governance to foster economic enhancement and reducing $CO_2$ emissions. As per [24], the effect of political instability on economic advancement, trade globalization, renewable energy use on $CO_2$ emissions from 1990-2018 using dynamic ARDL method have been analyzed. The findings show that economic growth, political instability, integration of renewable energy, and internatio nal trade are long-term predictors of CO2 emissions in Canada. Moreover, the results also confirm that political stability brings more FDI. As per [25], 1% rise in GDP per capita and energy prices could lead to an upsurge in renewable energy between 0.05% and 1.01%, and 0.07% and 0.99% respectively across 78 countries (24 developing and 48 developed) from 1980-2016. The study also revealed that oil prices, income, and $CO_2$ emissio ns significantly influence renewable energy deployment.

The impact of carbon based and clean energy and also economic and social factors (institutional quality, population growth, GDP, and capital formation) on $CO_2$ emissions in South Asian economies including (Bangladesh, India, Nepal, Pakistan, and Sri Lanka) using ARDL technique from 1996Q1-2019Q4 have been investigated. In the long run the outcomes showed that economic growth is unsustainable in Pakistan, Bangladesh, and Sri Lanka while Nepal is growing and reducing its $CO_2$ emissions. Moreover, the better institutional quality can help India Sri Lanka and Nepal in achieving their sustainable clean energy production. Also, population growth negatively affects $CO_2$ emissions in Pakistan and Bangladesh [26]. As per [27], the key variables influencing the deployment of renewable energy in nine MENA nations between 1984 and 2014 includes governance quality, innovation, political stability, and financial development. Additionally, the study also highlighted the potential of highly efficient performance to influence good governance for increasing renewable energy deployment. The key macroeconomic factors (income, exchange rate, and inflation) that influence the adoption of renewable energy in Nigeria have been examined by [28] using an ARDL approach from 1990 to 2020. The outcomes reveal that these factors significantly influence renewable energy adoption. The study also highlighted that education and health human capital helps in development of promoting renewable energy. As per [29], the income and fossil fuel prices don't significantly impact renewable energy enhancement across 24 EU countries from studied/examined from 1990-2016.However, conventional energy resources impede renewable energy deployment, and social awareness and $CO_2$ reduction are insufficient for promoting a renewable energy transition.

### 2.2 Nexus between institutions and renewable energy

Although, a significant quantity of research is available on the effects of macroeconomic variables. There are few studies examining the institutional determinants that determine the penetration of renewable energy. In general, initiatives that fall under this category investigate the ways in which key institutional issues such as lobbying, democracy, and political uncertainty influence renewable energy. Examining the effect of political factors on the adoption of renewable energy in EU countries, the findings suggest that the manufacturing industry lobbying hinders RE deployment. Moreover, left-leaning politica l groups encourage the adoption of renewable energy more than their right wing [12].

As per [30], the correlation between political powers and renewable energy have been investigated highlighting the need to oppose and destabilize established energy systems to achieve a smooth shift from fossil fuels to sustainable energy. This study suggests democratic renewable energy futures can be achieved by strengthening democratic practices, expanding energy system democratization, and challenging capitalist, market, growth, and industrialist influences. As per [31], the link between institutional quality, $CO_2$ emissions and energy usage has been examined from 1990-2016 in BRICS economies based on (EKC) theory. The findings indicate institutional effectiveness and environme nt-related technologies negatively impact environmental footprint. Moreover, increase in economic activities led to increased pollution. In Pakistan, higher income levels lead to reduced $CO_2$ emissions, aligning with the Environmental Kuznets Curve, manifesting a mutual causality between $CO_2$ emissions and institutional quality [32]. As per [33], Belt and Road Initiative (BRI) countries from 1992 to 2018 manifested that economic rise escalates environmental impact. However, renewable energy usage and better institut ions can minimize that effect. As per [34], the E7 economies have lower institutional quality and commitment to environmental sustainability compared to the G7. Also, poor institutional structures result in a deterioration of environmental conditions while economic globalization and renewables enhance it.

[35] conducted research on impact of democracy on $CO_2$ emissions from 1977-2010 in 19 emerging nations using panel quantile regression. This study showed that democracy decreases $CO_2$ emissions in countries attaining a particular level of income. A positive correlation exists between institutional quality, $CO_2$ emissions, and economic growth in three East Asian economies examined from 1990-2016. Additionally, institutio nal effectiveness, trade openness, and energy use enhance economic growth, with a unidirectional causality between institutional quality and economic growth [36]. The causal link between institutional quality, $CO_2$ emissions, exports, and economic growth during 1984- 2000 in Malaysia have been investigated using ARDL model. The results indicate a positive correlation between the GDP growth rate and $CO_2$ emissions, exports, and institutional quality. Also, the implementation of law and order significantly impacts the reduction of $CO_2$ emissions [37]. The dynamic model for renewable energy policy considering long-term horizons, political contention and technological path dependency has been studied highlighting that political dynamics crucially shape renewable energy growth and $CO_2$ emissions that subsequently affect a country's climate mitigation goals [38].

### 2.3 Simulation tools used for Econometric analysis

*2.3.1 R*

R is a software environment and open-source programming language designed for the purpose of statistical computation and graphics. This software offers a flexible framework that assists in data visualization, econometric modeling, and analysis.

2.3.1.1 Advantages:

- Rich statistical packages and libraries.
- It's freely available, making it accessible to a wide audience.

2.3.1.2 Disadvantages:

- The learning curve can be steep for beginners.
- Limited graphical user interface (GUI) compared to some commercial alternatives.

*2.3.2 Ox Metrics*

Ox Metrics is a collection of software products that offer a comprehensive solution for conducting econometric analysis. The software package consists of Ox, a programming language specifically designed for matrix operations, as well as multiple modules that enable time series analysis, financial econometrics, and other functionalities.

2.3.2.1 Advantages:

- Comprehensive suite covering various econometric methods.
- User-friendly interface and command-line options.
- Helps programming in Ox language.

2.3.2.2 Disadvantages:

- Costly
- Not as widely used as some other econometric tools.

*2.3.3 SAS*

SAS, short for Statistical Analysis System, is a comprehensive software suite utilized for complex analytics, corporate intelligence, and data management. It offers an extensive array of tools for data analysis, statistical modeling, machine learning, and other related tasks. SAS is extensively utilized throughout diverse sectors, including banking, healthcare, and research.

2.3.3.1 Advantages:

- Powerful set of built-in features.
- Extensively utilized in both industry and academia.

2.3.3.2 Disadvantages:

- Costly as compared to other tools.
- Difficult and rapid learning process.

### *2.3.4 SPSS*

The acronym for "Statistical Package for the Social Sciences" is SPSS. The social sciences, healthcare, and business are just a few of the many areas that make use of this statistica l analysis software package. Data cleaning, descriptive statistics, hypothesis testing, and data visualization are just a few of the many statistical techniques and tools available in SPSS, an environment for data analysis created by IBM.

2.3.4.1 Advantages:

- SPSS's well-known ease-of-use interface makes it suitable for analysts and researchers with varied degrees of statistical knowledge.
- SPSS offers descriptive statistics, regression analysis, factor analysis, and more. It can handle simple data exploration to large statistical modelling due to its adaptability.

2.3.4.2 Disadvantages:

- Its flexibility may limit analysis customization.
- SPSS syntax is difficult for graphical users to employ for advanced analysis.

- Storage of sensitive data in SPSS may pose security problems, especially for projects with tight data protection standards.

### *2.3.5 E-VIEWS*

E-Views is a statistical package used for a variety of statistical tasks, including model simulations, forecasting, and analysis 1. It is an Object-Oriented User Interface (GUI) that allows users to write basic applications in E-Views programming through menus. Automation and presentation tools are both made possible by this package's multi-wi ndow design.

#### 2.3.5.1 Advantages:

- EViews may generate missing data using interpolation and frequency filters. This makes EViews suitable for time series analysis.
- It can import SAS, SPSS, and STATA data in.sas,.sav, and.dta formats. Additionally, it can import text, binary, HTML, Gauss dataset, and more.

#### 2.3.5.2 Disadvantages:

- Due to its inadequate visualization capabilities, the suitability of its diagrams and graphs for presentations may be weakened. Data forecasting using EViews could take several minutes.

### *2.3.6 Stata*

Stata is a highly effective statistical software that is widely employed in the analysis of econometric panel data. By providing streamlined data management tools, an extensive range of estimation techniques, and reliable statistical methods, Stata streamlines the intricacies associated with handling longitudinal and cross-sectional datasets. User experience is enhanced by its programming support, graphical representation capabilit ies, and publication-quality output production.

#### 2.3.6.1 Advantages:

- Simple to use and all commands, models, and functions are accessible through a straightforward dashboard featuring a streamlined design.

- It can perform multiple data sampling operations. In all aspects, results are instantaneous and verifiable.
- Provides several panel data economic models. Fixed-effects, random-effects, dynamic panel data, and instrumental variable estimation are common.

2.3.6.2 Disadvantages:

- This is closed-source proprietary software, means that its source code is not accessible to users.

### 2.4 Preference for Stata over other estimation tools

- Stata is preferred in the current research due to their:
- User-friendly data management, statistical analysis, and graphing interface. Easy analysis reproducibility is possible with its intuitive command syntax.
- It provides robust data management functionalities, enabling effic ie nt manipulation, cleansing, and transformation of data.
- Enables users to generate an extensive variety of charts and graphs that are suitable for better understanding.
- Enables the estimation of models incorporating random and fixed effects, while also providing robust standard errors against heteroscedasticity, clustering, and other types of non-normality.
- Incorporates the Mata programming language, which provides direct support for matrix programming in addition to structures, pointers, and classes.
- Provides a wide variety of features that makes the estimation easier.

# CHAPTER 3: MODEL AND DATA SPECIFICATIONS

## 3.1 Model of Study

To investigate the impact of key institutional factors such as bureaucratic quality, democratic accountability, law and order, corruption, and government stability on renewable energy penetration, this study utilizes a panel dataset including 15 Asian countries from 1984 to 2020, resulting in a comprehensive set of 555 observations. The selection of states and timeframe is determined by the accessibility of data. Additiona l ly, annual GDP per capita growth (annual %) and $CO_2$ emissions per capita are included as independent variables to assess the influence of environmental as well as economic variables. The implicit model of this study is ass followed in Eq (1)

REG= $f$ (IQt, GDP$_{t,}$, CO2$_t$)

$$REG = \beta_o + \beta_1 IQ_{it} + \beta_1 GDP_{it} + \beta_3 CO2_{it} + \epsilon_{it} \qquad (3.1)$$

b1, b2 and b3 are partial slope coefficients. $\epsilon_{it}$ is intercept error term and $\beta_o$ is stochastic error term while cross sections (countries) are denoted by $i$, while time periods are represented by $t$. The dependent variable is renewable energy (RE) generation which is expressed in terawatt-hours (TW-h). It includes energy generated from wind, solar and hydro sources.

## 3.2 Variables considered for institutional quality indicators

Institutional quality data is collected from ICRG. Five different metrics have been selected to assess the institutional quality (IQ):

(i) **Law and Order**: This reflects the level to which citizens comply with laws and the effectiveness of the rule of law.

(ii) **Corruption**: It refers to the unethical practices in the political system in which administrative powers are enforced for personal benefits and in seizing control of the state.

(iii) **Bureaucratic Quality**: This assesses whether the education and recruitment of bureaucrats occur taking advantage of a particular framework which is independent of political power.

(iv) **Democratic Accountability**: This provides an evaluation of the degree to which the government pays attention to and responds to the problems of the people, as well as the way in which it addresses these issues.

(v) **Government Stability**: This evaluates the capability of the government to implement the authorized programs.

The indicators for bureaucratic quality and government stability are also scored within 0 to 4 and 0 to 12 respectively while law and order, corruption, and democratic accountability are scored from 0 to 6, while In accordance with [39] [40] the aggregate of these indicators represents institutional quality variable in this study. These indicators are then transformed and standardized from 0 to 10, with higher levels show better institutional quality. In this model GDP per capita growth (annual %) is obtained from World Bank and $CO_2$ emissio ns per capita from Our world data.

With no logarithmic modifications implemented, Table 3.1 presents data characteriza t ion for RE, IQ, GDP, and $CO_2$ across a dataset of 555 samples. The variable RE spans from the lowest value of 0.37 TWh to a maximum of 2184.93 TWh, with a mean value of 67.30905. The value of institutional quality ranges from a minimum of 5 to a maximum of 32, with a mean value of 20.05766. The variables GDP and $CO_2$ are incorporated as environmental and macroeconomic indicators, respectively. In this model having maximum values 55.88925 and 19.21304 tons per person respectively. Conversely, the minimum values for the variables are -64.42584 USD and 0.0970 tons per person, respectively. Furthermore, the average values for these variables are 3.115553 USD and 4.198468 tons per person, respectively. Evaluating the levels of quality of institutions and renewable energy generation for each nation may yield significant findings regarding trends, patterns, and possible correlations.

**Table 3.1:** Descriptive statistics

| Parameters | RE | CO2 | IQ | GDP |
|---|---|---|---|---|
| **Mean** | 67.30905 | 4.198468 | 20.05766 | 3.115553 |
| **Medium** | 16.870 | 2.443 | 20.000 | 3.199 |
| **Maximum** | 2184.93 | 19.21304 | 32.0000 | 55.88925 |
| **Minimum** | 0.37 | .0970464 | 5.000 | -64.42584 |
| **Std.Dev** | 214.7532 | 4.581873 | 5.497317 | 6.169736 |
| **Skewness** | 6.75 | 1.567 | 0.006 | -0.892 |
| **Kurtosis** | 53.88 | 5.02 | 2.790 | 47.400 |
| **Jarque - Bera** | 64107.5 | 322.20 | 1.016624 | 45662.99 |
| **Probability** | 0.0000 | 0.0000 | 0.6010 | 0.0000 |
| **Sum** | 37356.52 | 2330.150 | 11132.00 | 1729.132 |
| **Sum Sq. Dev** | 25549898 | 11630.43 | 16742.49 | 2108.37 |
| **Observations** | 555 | 555 | 555 | 555 |

Figure 3.1 illustrates the findings of institutional quality from 1984-2020 across each cross-section. The findings indicate New Zeeland, Australia and Japan have the maximum level of institutional excellence while the countries with lowest value of institutional quality include Pakistan, Bangladesh, and Iraq.

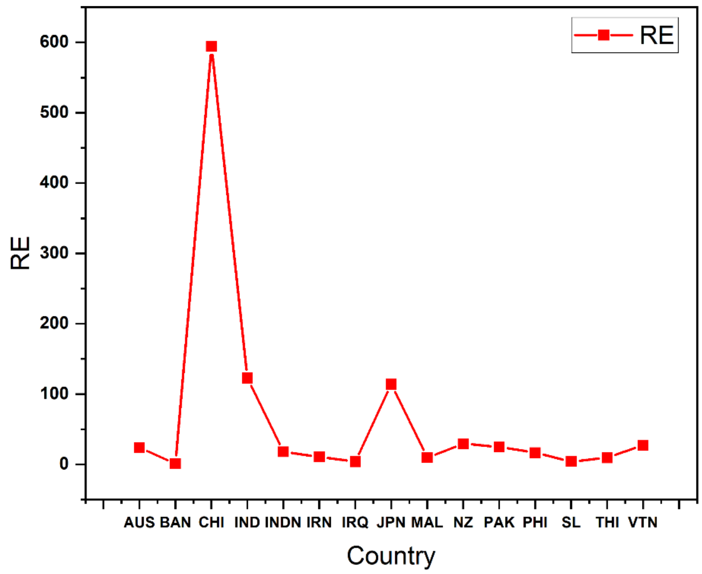


**Figure 3.1:** Institutional quality

Similarly, the results of renewable energy generation are represented in Figure 3.2.

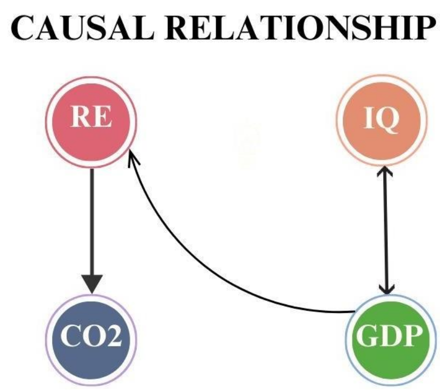


**Figure 3.2**: Renewable energy generation

The countries with highest contribution of renewables to total energy generation include China, India, and Japan in contrast with lowest level of renewable energy generation include Bangladesh, Iraq, and Malaysia. Lastly, results of PMG and causality are shown in Figure 3.3 and 3.4 respectively.

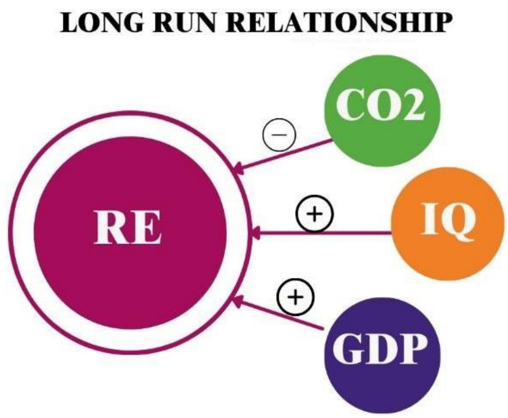


**Figure 3.3:** PMG Results

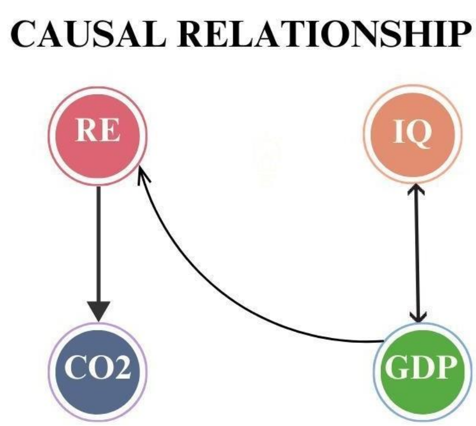


**Figure 3.4:** Causal Relationship

# CHAPTER 4: METHODOLOGY

## 4.1 Cross sectional dependence

Interdependence among cross sections is one of the frequent problems in panel dataset evaluation which means that the results of one country can influence other that need to estimate before econometric estimation. Therefore, neglecting the cross sectional dependence across different sections may have detrimental effects [41].Conventional stationarity tests assume cross sectional independence that leads towards incorrect outcomes, hence it is imperative to deal with CSD. To solve this problem, we employ four CSD tests mainly [42] developed by Pesaran and LM [43] test can be approximated using Eq 4.1.

$$\boldsymbol{LM} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \boldsymbol{T}_{ij} \hat{\boldsymbol{\rho}}_{ij}^{2} \rightarrow \boldsymbol{x}^{2} \frac{\boldsymbol{N}(\boldsymbol{N}-\boldsymbol{1})}{\boldsymbol{2}} \tag{4.1}$$

The relationship mentioned above in eqn. 4.1, cross-section is represented by N and time dimensions are denoted by T. In this study N=15 and T=37 where as $\hat{\rho}_{ij}^2$ is the correlation parameter which is distributed asymptotically under the null hypothesis as ($\chi 2$) with degrees of freedom equal to N(N-1)/2. This test is conducted by computing the mean of squared pairwise sample correlation coefficients of the errors. It is applicable when N remains constant, and Tij approaches infinity (that is, when N is quite minimal relative to T). Under the conditions of this test, the assumption that cross-sectional variables are independent can be formulated as follows:

$H_0\hat{p}_{ij} \coloneqq 0$ for $i \neq j$ in contrast with the counter-hypothesis Ha, which suggests cross-sectional dependence with $H_a : \hat{p}_{ij} \neq 0$ for $i \neq j$. However, there are specific limitat ions to this test as N approaches infinity, it becomes inefficient and subject to size distortion.

To address the issue of size bias in the [43], [42] proposed the CD test as an alternative method for examining cross-sectional dependency across longitudinal data which could be estimated as following:

$$\boldsymbol{CD} = \sqrt{\frac{\mathbf{2}}{\boldsymbol{N}(\boldsymbol{N}-\mathbf{1})}} \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{N}-\mathbf{1}} \sum_{\boldsymbol{j}=\boldsymbol{i}+\mathbf{1}}^{\boldsymbol{N}} \boldsymbol{T}_{\boldsymbol{ij}} \hat{\boldsymbol{\rho}}_{\boldsymbol{ij}} \rightarrow \boldsymbol{N}(\mathbf{0},\mathbf{1}) \tag{4.2}$$

Whereas '$\hat{\rho}_{ij}$' refers to the correlation indices derived from the residuals of the above formula. The CD statistic follows an asymptotic distribution of N (0, 1) under the null hypothesis, given that $T_{ij}$ approaches infinity, followed by$N \rightarrow \infty$. The zero hypothesis of the [42] CD test is the same as that of the [43] test.

## 4.2 Unit root

The conventional non-stationarity tests such as LLC [44] ,IPS b[45] are enhanced modifications of first generation non-stationarity tests which are frequently utilized in literature to evaluate the stationarity of variables incorporating cross-sectional dependence through various transformations. Cross-sectional dependence is not eliminated through these modifications. Therefore, the study also employs the second-generation CADF unit root test introduced by [46] that incorporates cross-sectional dependence in order eliminate any bias from first-generation tests. [46] expanded the Dickey-Fuller regressions employing the method of mean of lagged levels and initial differences to address cross-sectional dependence. This yields new asymptotic results for individual and average CADF statistics. The CADF test is applicable regardless of whether N is greater than T or T is greater than N making it more versatile. It provides reliable results when series have cross-sectional dependence [47].CADF can be estimated by the formula given below in equation 4.3.

$$\Delta y_{it} = a_i + Q_{iy_i,t-1} + c_i\bar{y}_{t-1} + \sum_{j=0}^{q} di_j\Delta\bar{y}_{t-j} + \sum_{j=1}^{q} i_j\Delta y_{i,t-j} + e_{it} \quad (4.3)$$

Where mean of all N cross-sections at time T is represented by $\bar{y}_t$.

### 4.3 Co-integration results

To figure out the long run connection within the variables under examination cointegrat ion tests are employed [48] [49] .The null assumption rejects the presence of cointegrat io n. Pedroni in which three group statistics and four panels are obtained. Pedroni [49] excludes cross-sectional correlation, presence of CSD leads towards inaccurate results .Hence, the second generation cointegration test based on error correction. Westlund method in [48] is applied which consists of four panel statistics out of these four two are panel data statistics (denoted by Pt and Pa) in contrast, the other two are group mean statistics (represented as Gt and Ga).

### 4.4 ARDL estimation

After determining the variables' cointegration, ARDL-PMG approach can be utilized for the estimation of long-term equations. It permits variations in intercepts, short-term coefficients, and co-integrating factors across cross-sections. The approach proposed by [50] is deemed to be more appropriate compared to other methods offering the dual benefit of aggregating and average. The PMG evaluation allows the variation in error variance within different countries and forecasts the rate of correction between long-term and short-term. This method also allows for variations in short-term parameters among groups, while ensuring uniform long-term coefficients within countries. Thus, it is anticipated that the long-term relationships will be uniform across countries, while the short-term coefficie nts are recognized as unique and country specific. Moreover, this model takes into consideration the lag times of explanatory and responding variables, which effective ly resolves correlation isue [51].

Lastly, it permits the computation of base regressors irrespective of which of the series is I (1) or I (0) in addition this is capable of simultaneously generating long-term and short-term estimations. Equation (4.4) represents the ARDL framework.

$$\Delta(\boldsymbol{RE})_t = \boldsymbol{\psi_0} + \boldsymbol{\psi_1 RE_{t-1}} + \boldsymbol{\psi_2 IQ_{t-1}} + \boldsymbol{\psi_3 CO2_{t-1}} + \boldsymbol{\psi_4 GDP_{t-1}} + \sum_{i=1}^{k} \boldsymbol{\psi_6 \Delta RE} + \sum_{i=1}^{k} \boldsymbol{\psi_7} \Delta(\boldsymbol{IQ})_{t-i} + \sum_{i=1}^{k} \boldsymbol{\psi_8 \Delta(CO2)_{t-i}} + \sum_{i=1}^{k} \boldsymbol{\psi_9 \Delta(GDP)_{t-i}} \quad (4.4)$$

The PMG model runs under the assumption that the long-term parameters remain fixed, while permitting short-term coefficients to vary among cross-sections. According to [50] illustrating the long-term variables connection, the ARDL (p, q) framework can be expressed in this manner:

$$\Delta \boldsymbol{Y_{I,it}} = a_{\boldsymbol{Ii}} + \boldsymbol{\lambda_{Ii} Y_{I,it-1}} + \sum_{I=2}^{k} \boldsymbol{\lambda_{Ii} X_{I,it-1}} + \sum_{j=1}^{p-1} \boldsymbol{\phi_{Iij}} \Delta \boldsymbol{Y_{I,it-j}} + \sum_{j=0}^{q-1} \boldsymbol{x} \sum_{I=2}^{k} \boldsymbol{\phi_{Iij}} \Delta \boldsymbol{X_{I,it-j}} + \mathrm{s}_{\boldsymbol{I,it}} \quad (4.5)$$

$$\Delta \boldsymbol{Y_{I,it}} = a_{\boldsymbol{Ii}} + \boldsymbol{\lambda_{Ii} Y_{I,it-1}} + \sum_{I=2}^{k} \boldsymbol{\lambda_{Ii} X_{I,it-1}} + \sum_{j=1}^{p-1} \boldsymbol{\phi_{Iij}} \Delta \boldsymbol{Y_{I,it-j}} + \sum_{j=0}^{q-1} \boldsymbol{x} \sum_{I=2}^{k} \boldsymbol{\phi_{Iij}} \Delta \boldsymbol{X_{I,it-j}} + \mathrm{s}_{\boldsymbol{I,it}} \quad (4.6)$$

$$\Delta \boldsymbol{Y}_{\boldsymbol{I},\boldsymbol{it}} = a_{\boldsymbol{Ii}} + \boldsymbol{\lambda}_{\boldsymbol{Ii}}\boldsymbol{Y}_{\boldsymbol{I},\boldsymbol{it-1}} + \sum_{\boldsymbol{I=2}}^{\boldsymbol{k}} \boldsymbol{\lambda}_{\boldsymbol{Ii}}\boldsymbol{X}_{\boldsymbol{I},\boldsymbol{it-1}} + \sum_{\boldsymbol{j=1}}^{\boldsymbol{p-1}} \boldsymbol{\phi}_{\boldsymbol{Iij}}\Delta \boldsymbol{Y}_{\boldsymbol{I},\boldsymbol{it-j}}$$

$$+ \sum_{\boldsymbol{j=0}}^{\boldsymbol{q-1}} \boldsymbol{x} \sum_{\boldsymbol{I=2}}^{\boldsymbol{k}} \boldsymbol{\phi}_{\boldsymbol{Iij}}\, \Delta \boldsymbol{X}_{\boldsymbol{I},\boldsymbol{it-j}} + \varepsilon_{\boldsymbol{I},\boldsymbol{it}} \qquad (4.7)$$

In Equation (4.5), $Y_I$ denotes the dependent variable, and $X_I$ represents the repressor term, where I values range from 1 to 4. Furthermore, the error term is denoted as $\varepsilon_I$, $\alpha_I$ is the constant term, the constant term is represented by Δ and I signifies observation index.

$$\boldsymbol{\Delta Y}_{\boldsymbol{I},\boldsymbol{it}} = a_{\boldsymbol{Ii}} + \sum_{\boldsymbol{j=1}}^{\boldsymbol{p}} \boldsymbol{\phi}_{\boldsymbol{Ii}}\boldsymbol{\Delta RE}_{\boldsymbol{it-j}} + \sum_{\boldsymbol{i=o}}^{\boldsymbol{q}} \boldsymbol{\phi}_{\boldsymbol{2i}}\Delta \boldsymbol{IQ}_{\boldsymbol{it-j}} + \sum_{\boldsymbol{i=0}}^{\boldsymbol{q}} \boldsymbol{\phi}_{\boldsymbol{3i}}\, \Delta \boldsymbol{GDP}_{\boldsymbol{it-j}} \qquad (4.8)$$

$$+ \sum_{\boldsymbol{i=o}}^{\boldsymbol{q}} \boldsymbol{\phi}_{\boldsymbol{4i}}\Delta \boldsymbol{CO2}_{\boldsymbol{it-j}} + \boldsymbol{\lambda}_{\boldsymbol{1i}}\boldsymbol{RE}_{\boldsymbol{it-1}} + \boldsymbol{\lambda}_{\boldsymbol{2i}}\boldsymbol{IQ}_{\boldsymbol{it-1}} + \boldsymbol{\lambda}_{\boldsymbol{3i}}\boldsymbol{GDP}_{\boldsymbol{it-1}} + \boldsymbol{\lambda}_{\boldsymbol{4i}}\boldsymbol{CO2}_{\boldsymbol{it-1}}$$

In Equation (4.8), the most desirable lag lengths are represented by p and q while $\phi_1, \phi_2, \phi_3$ and $\phi_4$ represent the error correction dynamics. Additionall y, $\lambda_1 i$, $\lambda_{2i}$, $\lambda_{3i}$ *and* $\lambda_{4i}$ stand for the long-term coefficients. Both short-term and long-term relationships can be analyzed if co-integration correlations are present among the variables. If a long run correlation is established, then the short run varying association among variables can be determined by estimating the error correction method. The ECM approach is described as follows:

$$\Delta \boldsymbol{Y}_{I,it} = a_{Ii} + \sum_{j=1}^{p-1} \mathrm{Q}_{Iij} \boldsymbol{Y}_{I,it-j} + \sum_{j=0}^{q-1} \sum_{I=2}^{k} \mathrm{Q}_{Iij} \Delta \boldsymbol{X}_{I,it-j} + \boldsymbol{\lambda}_{Ii} \boldsymbol{ECT}_{I,it-1} + \varepsilon_{I,it} \tag{4.9}$$

In Equation (4.9), $\varepsilon_{Iit}$ is error term where $i$ =1, 2, 3, 4 denotes an error term that is both independent and adheres a normal distribution. The mean of this error term is zero, and its variability remains constant. In addition, $ECT_{I,it\ -1}$ represents error correction term that is obtained from the long-term correlation. Lastly, $\gamma_{Ii}$ shows the rate of change towards the equilibrium value. The ECM model can be stated as shown in Equation (4.8) when Equation (4.7) is put into effect to the key variables under study.

$$\Delta \boldsymbol{Y}_{I,it} = a_{Ii} + \sum_{j=1}^{p-1} \mathrm{Q}_{1ij} \boldsymbol{\Delta RE}_{it-j} + \sum_{j=o}^{q-1} \mathrm{Q}_{2ij} \Delta \boldsymbol{IQ}_{it-j} + \sum_{j=0}^{q-1} \mathrm{Q}_{3ij} \Delta \boldsymbol{GDP}_{it-j} + \sum_{j=o}^{q-1} \mathrm{Q}_{4ij} \Delta \boldsymbol{CO2}_{it-j} + {}_{Ii} \boldsymbol{ECT}_{I,it-1} + \varepsilon_{I,it} \tag{4.10}$$

## 4.5 Panel causality test

This research implements the [47] causality test to look into the causal links within the variables RE, IQ, GDP, and $CO_2$ emissions. This approach extends the standard Granger causality framework which takes cross sectional dependence into account. The Wald criteria for Granger non-causality depends upon averaging the Wald statistics of each cross-sectional unit. This statistic sequentially approaches a normalized distribution while the partially asymptotic distribution of this mean statistics is specified with a fixed T-sample. The null assumptions of DH causality test show absence of causality among the variables. For applying DH causality test variables must be free from unit root. Here is the linear model of this test,

$$\boldsymbol{Y} = {}_{i} + \sum_{k=1}^{K} \boldsymbol{\lambda}^{k}_{i} \boldsymbol{Y}_{i,t-K} + \sum_{k=1}^{K} Q^{(k)}_{i} \boldsymbol{X}_{i,t-K} + s_{i,t} \tag{4.11}$$

whereas i varies from 1 to N while the time t ranges from (1…. T). Explanatory variables are represented by X and Y while $\lambda^k_i$ is AR parameter while $\beta^{(k)}_i$ regression coefficie nts slopes which vary among different units.

$$W^{Hnc}_{N,T} = \frac{1}{N} \sum_{i=1}^{N} W_{i,t} \tag{4.12}$$

$$Z^{Hnc}_{N,T} = \frac{\sqrt{N} \left( W^{Hnc}_{N,T} - N^{-1} \sum_{i=1}^{N} E(W_{i,t}) \right)}{\sqrt{N^{-1} \sum_{i=1}^{N} Var\,(W_{i,t})}} \tag{4.13}$$

Where E(Wi, T) denote the mean and Var (Wi, T) represents the variance of the statistic Wi, T as defined in Equation (4.12) and (4.13).Wald statistics of each countries are represented by Wi,t .$W^{Hnc}_{N,T}$ is employed to evaluate the reliability of null theory. It represents the mean of the Wald statistics computed for every individual unit. Conversely, $Z^{Hnc}_{N,T}$ is computed considering the predicted variance and mean of every Wald statistic. As a result of this specific test statistic, panels with unit heterogeneity can be tested using the DH causality test.

The complete process of estimation is shown graphically in figure 4.1.

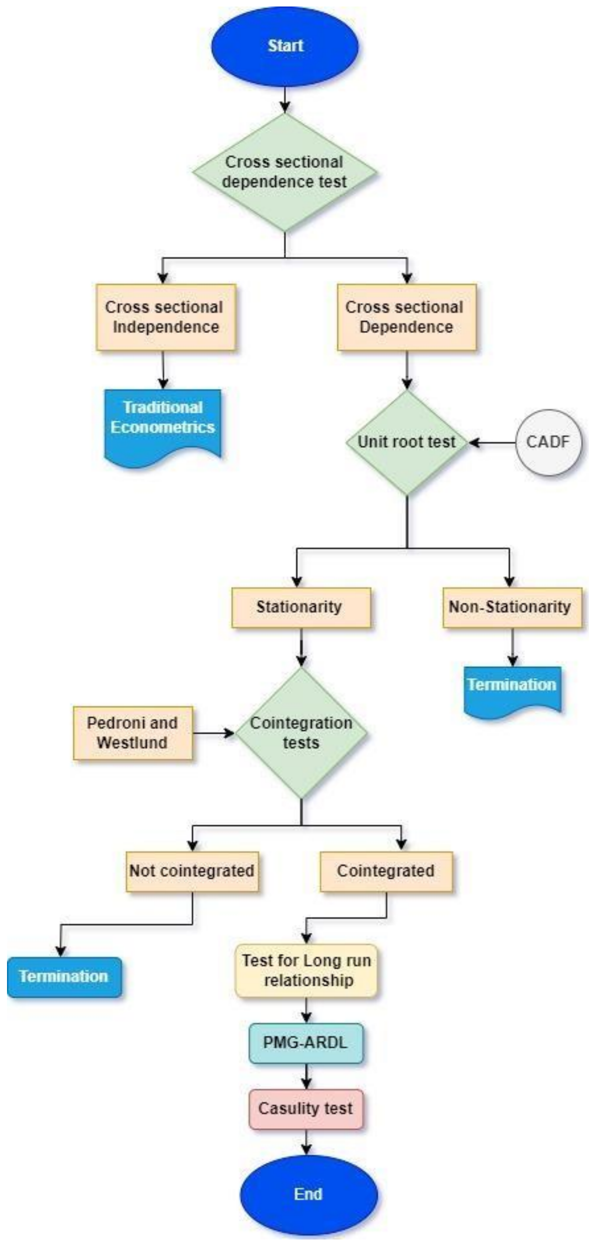


**Figure 4.1:** Graphical representation of methodological framework

# CHAPTER 5: RESULTS AND DISCUSSIONS

The section initiates with cross-sectional dependence analysis among the countries. Stationarity is then assessed using CADF tests, which incorporate cross-sectional dependence. This is followed by an exploration of long-term relationships via panel co-integration tests. Lastly, both short-term and long-term estimations are presented by implementing PMG-ARDL model and DH Granger Causality test [47].

## 5.1 Econometric Analysis

The study runs four distinct tests to check dependence between the variables. [43] and [42] CD tests in particular are frequently utilized in to examine CSD. The findings of these tests are illustrated in Table 5.1 below.

**Table 5.1**: Cross sectional dependence tests

| **Evaluation Tests** | **RE** | **IQ** | **GDP** | **CO2** |
|---|---|---|---|---|
| **Breusch-Pagan LM** | 2250.215*** (0.000) | 923.07***(0.000) | 373.37***(0.000) | 2110.258***(0.000) |
| **Pesaran scaledCD** | 148.0339*** (0.000) | 56.72***(0.000) | 18.519***(0.000) | 138.37***(0.000) |
| **Bias-corrected scaledLM** | 147.8256*** (0.000) | 56.52***(0.000) | 18.311***(0.000) | 138.16***(0.000) |
| **Pesaran CD** | 43.33697*** (0.000) | 21.577***(0.000) | 12.78***(0.000) | 41.50***(0.000) |

Evidently, the p-values for all tests are less than 0.01, indicating that we can reject the null hypothesis at a 1% significance level that there is no CSD. This shows the existence of CSD. After performing the analysis on cross-sectional dependency, it's necessary to evaluate the unit root value of the parameters under investigation. [44] and [45] first generation unit root tests, are commonly applied in literature these tests cannot entirely eliminate cross-sectional dependence. The null hypothesis in both these tests shows the occurrence of a non-stationarity in the variables, while the alternative hypothesis proposes stationarity of the variables. The results of both LLC and IPS tests are presented in Table 5.2.

**Table 5.2**: LLC and IPS unit root tests results

| Variables | Tests | Level | 1st difference |
|---|---|---|---|
| **RE** | LLC | 12.9753(1.0000) | -7.5674***(0.0000) |
| | IPS | 5.6952 (1.0000) | -13.2328***(0.0000) |
| **IQ** | LLC | -3.2581**(0.006) | - |
| | IPS | -2.7023**(0.0034) | - |
| **$CO_2$** | LLC | 1.8355(0.9668) | -6.2185***(0.0000) |
| | IPS | 3.9166(1.0000) | -9.5534***(0.0000) |
| **GDP** | LLC | -3.7046**(0.0001) | - |
| | IPS | -7.0237***(0.0000) | - |

As per findings, the IQ and GDP are stationary at their level for both tests. $CO_2$ and RE both are stationary at I (1) for both first generation tests. Therefore, the CADF second generation unit root test formulated by Pesaran [42] is applied which incorporates cross-sectional dependence in [52].

**Table 5.3**: CADF test results

| | **Constant** | | |
|---|---|---|---|
| | **t-bar** | **Z[t-bar]** | **p-value** |
| **RE** | -2.452 | -2.810 | 0.002 |
| **IQ** | -2.359 | -2.426 | 0 .008 |
| **GDP** | -2.311 | -2.228 | 0.013 |
| **CO2** | -1.419 | 1.447 | 0.926 |
| **ΔCO2** | -2.412 | -2.644 | 0.004*** |
| **Constant and trend** | | | |
| | t-bar | Z[t-bar] | p-value |
| **RE** | -3.097 | -3.331 | 0.000*** |
| **IQ** | -3.189 | -3.738 | 0.000 |
| **GDP** | -2.793 | -1.995 | 0.023 |
| **CO2** | -1.924 | 1.830 | 0.966 |
| **ΔCO2** | -3.189 | -3.737 | 0.000*** |

The symbols ***, **, and * represent the significance level at 1%, 5%, and 10%, accordingly. The CADF test outcomes are depicted in Table 5.3. The findings reveal that the level of stationarity is present for the variables RE, GDP, and IQ in both constant and trend scenarios. The null hypothesis posits the occurrence of a unit root, whereas the other hypothesis posits its absence. While $CO_2$ exhibit unit root at I (0) for trend constant and solutions which is transformed into stationarity at significance level of 1% for trend and constant scenarios. The second generation CADF unit root test indicates that none of the variables requires a second differencing.

The results of the CADF test shows suitability of employing ARDL-PMG methodology. After unit root estimation cointegration test mainly [53] and Pedroni [49] are applied. Both tests have a null assumption of no cointegration while alternative indicates presence of cointegration. Both tests reject the null assumption at 1% significance, indicating variable co-integration. [49] does not allow cross-sectional correlation. As a result, the long- term connection between the variables is also examined using Westerlund ECM. [48] which is second generation test for co-integration that considers cross-sectional dependence cross-sectional dependence. The Westerlund test has developed four separate statistica l measures, all of which are rooted in the ECM, with the objective of overcoming the constraints of prior examinations. Two of these metrics are categorized as group mean statistics, which assess the presence of cointegration across the entire panel. The remaining two, known as panel statistics, are designed to detect the existence of cointegration in a minimum of one unit within the panel.

Table 5.4 and Table 5.5 display the findings of the executed cointegration tests. Using bootstrap values computed from 100 samples, the null assumption which suggests variables are not cointegrated is negated at a 1% level of significance (Gt and Ga). Similarly, using bootstrap values derived from 200 samples, the null hypothesis suggesting no cointegrat ion is also dismissed at 1% Gt and Ga significance levels. This robustness test thus leads to the conclusion that cointegration exists across the entire panel. After cointegration among the variables is confirmed, Eqs. (4.6) and (4.8) are used for approximating the long-run and short-run relationships between RE, IQ, GDP, and $CO_2$.

**Table 5.4**: Pedroni Cointegration test

| **SevenGroup Statistics** | **Statistic** | **p-value** |
|---|---|---|
| **Panel v-statistic** | 1.106659 | 0.1342 |
| **Panel rho-Statistic** | -0.091658 | 0.4635 |
| **Panel PP-Statistic** | -3.359577 | 0.0004** |
| **Panel ADF - Statistic** | -4.306958 | 0.0000*** |
| **Group rho-Statistic** | 1.344513 | 0.9106 |
| **Group PP -Statistic** | -1.699889 | 0.0446** |
| **Group ADF - Statistic** | -2.395875 | 0.0083** |

**Table 5.5**: Westlund Cointegration test

| **Statistics** | **Value** | **z-value** | **Bootstrap (100) p-value** | **Bootstrap (200) p- value** |
|---|---|---|---|---|
| **Gt** | -3.829 | -5.002 | 0.000*** | 0.000*** |
| **Ga** | -24.300 | -4.229 | 0.000** | 0.000*** |
| **Pt** | -12.260 | -2.890 | 0.002** | 0.115 |
| **Pa** | -23.485 | -5.756 | 0.000*** | 0.045** |

## 5.2 Long run and short run estimation

The results from the PMG estimators ARDL framework are detailed in Table 5.6. The outcomes of long-term coefficients determined through the Pooled Mean Group analysis suggest that institutional quality has a beneficial impact on renewable energy penetration. In the long run, renewable energy adoption will rise by 0.2130% for every 1% rise in institutional quality at a 10% level of significance. These findings correlates with [54] [55] and [17].

**Table 5.6**: PMG estimation results

| **Variables** | **Coefficient** | **St. Error** | **t-statistic** | **p-value** |
|---|---|---|---|---|
| **Long run result PMG** | | | | |
| **IQ** | 0.213037 | 0.122622 | 1.737344 | 0.830 |
| **CO2** | -0.622667 | 0.148262 | -4.199781 | 0.000 |
| **GDP** | 0.019271 | 0.010395 | 1.853763 | 0.0644 |
| **Short run results** | | | | |
| **ECT (-1)** | -0.156182 | 0.054343 | -2.874006 | 0.0042 |
| ($\Delta$) **IQ** | -0.052288 | 0.091378 | -0.572213 | 0.5675 |
| ($\Delta$) **GDP** | -0.199149 | 0.155939 | -1.277090 | 0.2022 |
| ($\Delta$) **CO2** | 0.001631 | 0.002419 | 0.674076 | 0.5006 |
| **C** | 0.193994 | 0.094578 | 2.051145 | 0.0480 |

The positive connection between institutional quality and renewable energy penetration can be interpreted through various perspectives. Firstly, handling of corruption can help to safeguard the effectiveness of environmental regulations. Implementing measures to prevent corruption can create a less stressful environment for entrepreneurs, streamlining bureaucratic processes, discouraging unfair practices while ensuring that the renewable industry is not dependent on government funding. This has the potential to greatly increase the generation of renewable energy. An institutional and regulatory structure that is strong and transparent aligned with governmental dedication can ensure consistent assistance for the beneficiaries, project developers and investors in the clean energy industry. Secondly, strong law and order can enforce carbon dioxide emissions control measures and companies are expected to respond promptly and willingly. Conversely, if institutio nal quality is weekend, firms might easily bypass the carbon dioxide emission control measures, neglecting the environmental consequences and implications that are inherent in the process of growth. Furthermore, enhancing the stability of the political landscape and the bureaucratic structure can heighten the awareness towards environmental issues. This, in turn, can pave the way for the implementation of incentive programs to encourage the adoption of sources of clean energy. Conversely, a democratic shortfall can hinder the discourse on environmental issues. Democratic systems, being receptive to such dialogues, can apply pressure on governing bodies through the open expression of their environme ntal needs. The public's influence on countries that are democratic can compel their governments to reassess their energy practices, potentially leading to a rise in renewable energy generation. Thus, strong institutions can be pivotal in preserving environme ntal integrity by integrating renewable energy into their energy mix, broadening the scope of their portfolio, and particularly bringing clean energy investments.

In contrast to institutional quality, per capita $CO_2$ emissions negatively impact renewable energy penetration. If there is 1 unit change in $CO_2$ emissions there will be -0.62 % decrease in renewable energy penetration these findings are similar to [56] [8] [57] and [9].The findings suggest that sources that are renewable can serve as effective alternatives to fossil fuels contributing to the mitigation of $CO_2$ emissions. Furthermore, countries adhering to international treaties like the Kyoto Protocol, $CO_2$ emissions exert significant pressure on governments. Thus, penetration of renewable energy can alleviate this pressure under these global agreements.

Similarly, annual GDP growth percentage influences renewable energy penetration positively if there is 1% change in annual GDP growth there will be 0.010% increase in renewable penetration. These results align with [58] [59] [21].This favorable relations hip between renewable energy penetration and GDP illuminates the drivers of future economic performance to simulate the adaptation of clean energy sources fostering a greener and more resilient energy environment.

**Table 5.7**: Causality test results as benchmarking

| **Null Hypothesis** | **Zbar-Stat.** | **p-value** |
|---|---|---|
| **DLIQ --- DLRE** | 0.31579 | 0.7522 |
| **DLRE --- DLIQ** | 0.77697 | 0.4372 |
| **DLCO2 --- DLRE** | 0.82811 | 0.4076 |
| **DLRE --- DLCO2** | 8.83782 | 0.000 *** |
| **DLGDP --- DLRE** | 1.78483 | 0.0743* |
| **DLRE --- DLGDP** | 0.41076 | 0.6812 |
| **DLCO2 --- DLIQ** | 0.39354 | 0.6939 |
| **LIQ --- DLCO2** | -0.69664 | 0.4860 |
| **DLGDP --- DLIQ** | 5.00467 | 6.E-07*** |
| **LIQ --- DLGDP** | -1.77937 | 0.0752* |
| **DLGDP --- DLCO2** | 0.10139 | 0.9192 |
| **DLCO2 --- DLGDP** | 2.35775 | 0.0184 |

The findings of short run analysis show the institutional quality negatively impacts renewable energy in contrast to initial assumptions while there is no statistical significa nce found in this coefficient. Likewise, $CO_2$ emissions and GDP growth have an adverse impact on renewable energy in the short run, these coefficients are also not statistically significa nt. In this scenario, the Dumitrescu and Hurlin [47] causality test is utilized to identify the causal connections between the variables. The results of the DH causality test are presented in Table 5.7. As per the findings bidirectional causality is found between GDP and IQ. In contrast there exists unidirectional causality from RE to $CO_2$ emissions per capital and from GDP to RE.

The causal connection between the variables can be interpreted as follows. Rise in economic activity results in a heightened need for energy, encompassing renewable sources, because of manufacturing on a larger scale. The unidirectional causality between the RE and $CO_2$ emissions indicates that future $CO_2$ emissions can be efficiently reduced in tandem with the growing need for renewable energy. The latest research supports the previously revealed by [60].Moreover, better institutional efficiency promotes economic output by establishing a favorable environment for growth. Simultaneously, an increasing GDP facilitates in bringing investments, strengthening governance structures and regulatory frameworks.

# CHAPTER 6: CONCLUSIONS AND FUTURE WORK

## 6.1 Conclusion

The implementation of renewable energy sources is crucial in the advancement of environmental sustainability. However, the existing research primarily emphasizes the effect of environmental and macroeconomic aspects of green energy neglecting the significance of political and institutional factors. This research fills a gap in existing research by examining the relationship between renewable energy penetration and quality of institutions across 15 nations during 1984 to 2020 by employing ARDL- PMG methodology. Furthermore, the model incorporates explanatory variables such as GDP per capita and $CO_2$ emissions.

This study's conclusions show that political factors significantly influence the process of adapting to renewable energy sources. Contextually, IQ influences renewable energy penetration positively. The promotion of democratic governance, corruption control, political stability, efficient bureaucracy, and the stringent legislation systems all contribute to the recognition of public interest in environmental quality and the prevention of environmentally detrimental initiatives. These apprehensions enhance the generation of environmentally friendly energy by encouraging the widespread penetration of sustainab le energy strategies that promote ecological sustainability. However, this analysis also indicates that reduction of $CO_2$ emissions is a fundamental constituent for the adoption of clean energy sources. This highlights the necessity for maximizing the integration of clean energy sources as the only viable strategy to alleviate carbon emissions. These observations may offer policymakers practical implications, underscoring the criticality of shift ing towards more sustainable and environmentally friendly energy alternatives to alleviate environmental impact. Finally, rapid growth of economic activities stimulates renewable energy penetration. The rise in GDP may result in a rising demand for sustainable energy instead of expensive fossil fuel-based energy.

The study's results show that economic variables motivate towards deployment of renewable energy transition. This is because economic agents prefer economic costs above any other consideration and favor environmentally friendly alternative energy sources. In contrast, renewable energy penetration is strongly influenced by environmental and institutional variables.

### 6.2 Recommendations and Future work

Considering these observations, the results of the investigation can offer significa nt recommendations for government officials. Competitive market mechanisms are not always effective in resolving environmental crises. Economic decisions can be made with a focus on the short term, even though cost is a crucial consideration. In a nutshell, such decisions might not consider the consequences over the long run. Additionally, the focus on promoting economic expansion in developing countries poses serious challenges in curbing energy derived from fossil fuels and $CO_2$ emissions. Consequently, countries benefit in the long run from well-established institutions. Thus, both individuals and policymakers can benefit significantly from the establishment of robust institutio ns. Establishing resilient institutions can mitigate political and socioeconomic issues and enhance societal well-being. Additionally, it can increase confidence in the deployment of clean energy sources which serve as a significant means of averting environmental issues and reliability of energy. Increasing the penetration of sustainable energy is a strategic choice made within the realm of politics. Thus, strong institutions have the potential to play vital role in implementing renewable energy by formulating plans for strategic action that consider environmental considerations. In fact, environmental advancements are intrica te ly linked to the development of democratic systems and global dispersion of politica l authority. Investing in renewable energy requires the support of incentives including tax concessions and financing. The provision of tax concessions, such as deductions and credits, enhances the economic attraction of renewable energy initiatives, thereby stimulating increased investment. Concurrently, the availability of credit facilit ies, including loans, alleviates financial limitations, enabling investors to obtain crucial funding for the execution of projects, especially in the early, potentially more expensive phases. The provision of tax concessions, such as deductions and credits, enhances the economic appeal of renewable energy initiatives, thereby stimulating increased investment. Meanwhile, the availability of credit facilities, including loans, alleviates financial limits, enabling investors to obtain significant funding for the execution of projects, especially in the early, potentially more expensive phases. Based on this framework, allocating more funding for research and development initiatives will significantly accelerate the reduction of expenses associated with renewable energy. The effectiveness of each of these motives is contingent upon a robust institutional structure. Although the current investigation contributes significantly to the previous research, it has its limitations. Two control variables were employed in this research to represent indicators related to economic performance and environmental aspects. This research can be further expanded to other regions or countries with a comparable level of growth. Furthermore, the results of the research indicate that political and economic variables are more vital than environmental variables in terms of renewable energy penetration. Thus, the future research could be focused on examining the impact of diverse socioeconomic determinants, including but not limited to human development, income distribution, gender equality, education, health, opportunity inequality, and social security, on the penetration of renewable energy.

# SUMMARY OF RESEARCH WORK

Energy is essential for socioeconomic development, by providing two crucial pathways for energy generation: conventional and renewable sources. There is a significant worldwide transition towards renewable energy sources, which is projected to account for 35-64% of primary energy by the year 2050. This transition is exemplified by the decrease in coal-fired power from 45% in 2006 to 11% in 2022, which is the result of increased investments in solar PV and wind energy. Because global warming is predominantly caused by the burning of carbon-based fuels, immediate changes to the energy sector are necessary to ensure environmental sustainability. Due to the critical nature of renewable energy adoption, its determinants must be thoroughly examined. The current body of literature primarily examines environmental and macroeconomic aspects, neglecting the significant contributions of political and institutional dimensions such as democratic levels, corruption, and governmental stability. It is crucial to address these analytical deficiencies, given the significant influence that political will and effective governance have significant impact on the penetration of renewable energy. This research highlights the importance of political and institutional determinants, offering valuable policy insights and a nuanced understanding that can streamline the smooth integration of renewable energy sources.

Research has demonstrated that trade liberalization, technological progress, and economic growth have a substantial influence on the long-term adoption of renewable energy. Income levels and pollutant emissions are important factors, especially in developing countries. They are studied using various methods, such as econometric studies and cointegration tests. Moreover, empirical evidence has demonstrated that the implementation of public policies and effective governance has a favorable effect on the investment and utilization of renewable energy sources. This, in turn, contributes to economic progress and a decrease in carbon dioxide emissions. The synthesis highlights the necessity to further investigate the political and institutional factors that influence outcomes, such as law and order, corruption, bureaucratic quality, government stability, democratic accountability. In a nutshell this analysis offers a detailed comprehension of the complex factors that impact the adoption of renewable energy and emphasizes the need for further investigation into

the political and institutional aspects of this sector. The influence of important institutio nal aspects on renewable energy penetration in Asian economies between the years 1984 and 2020 has been analyzed. The implicit model examines the relationship between renewable energy generation and factors such as institutional quality, GDP per capita (annual %), and CO2 emissions per capita. Important institutional indicators encompass Law and Order, Corruption, Bureaucratic Quality, Democratic Accountability, and Government Stabilit y. Countries exhibit variations in renewable energy generation and institutional quality, as indicated by descriptive statistics. China, India, and Japan are notable for their higher levels of renewable energy generation, whereas New Zealand, Australia, and Japan are distinguished by their higher institutional quality.

The research initiates by conducting a thorough evaluation of cross-sectional dependence (CSD) among variables using four tests: Breusch-Pagan LM, Pesaran scaled CD, Bias-corrected scaled LM, and Pesaran CD. After confirming the presence of CSD, unit root tests such as first-generation LLC, IPS, and second-generation CADF are used to determine if the data is stationary. Pedroni and Westlund cointegration tests are employed to investigate long run relationship between variables. The study utilizes the ARDL-PMG approach to thoroughly examine the long-term and short-term connections between the variables, ensuring a comprehensive comprehension of their interaction in the context of renewable energy penetration. In addition, the DH causality test is used to detect casual connection between the variables under investigation. The statistical analysis comprised diverse tests and data analyses aimed at analyzing the long run and short run impact. Notably, the results revealed that institutional quality impacts renewable energy penetration at 10% level of significance. Moreover, the findings suggest that decrease in $CO_2$ emissions increases renewable energy penetration while GDP fosters renewable energy.

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# APPENDIX

## Impact of Political, Institutional and Economic aspects on Renewable Energy Penetration in Asian and Pacific Countries

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## Abstract

The escalating global environmental degradation has attracted significant attention in global discourse and imposed substantial imperatives on policymakers, regulators, and individuals. The utilization of fossil fuels in energy generation has led to the emission of greenhouse gases, prompting a shift towards green and more sustainable energy sources, such as renewable energy. Despite the considerable contribution of renewable energy for the mitigation of environmental crises, there exist certain constraints that hinder an in-depth understanding of the determinants influencing its adoption. To fill this gap, this research analyzes the relationship among quality of institutions, economic growth, carbon dioxide emissions and renewable energy in 15 states spanning from 1984 to 2020 using panel ARDL-PMG methodology. The results of this study conclude that better institutional quality has a long run positive impact on the penetration of renewable energy. Additionally, GDP growth is a significant and favorable factor that determines renewable energy penetration. However, $CO_2$ emissions negatively impact renewable energy penetration. Within this framework, the significance of institutional quality measured by the reliability and performance of political as well as regulatory frameworks becomes a critical and deliberate determinant impacting the implementation of renewable energy and mitigates environmental issue.

**Keywords:** Institutional Quality, Renewable energy, Political Framework, Greenhouse gas emissions, Autoregressive Distributed Lag, Economic growth.

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