# Green Growth Realities: Examining the Role of Green Innovation and Financial Development in G5 Economies

***Rozina Sadiq*[*], *Mahnaz Muhammad Ali*[†], *Haleema Ghafoor*[‡]**


## Abstract

*Green growth represents a sustainable economic development approach which integrates environmental sustainability with economic prosperity. This concept emphasizes promotion of renewable energy, resource efficiency, and sustainable practices to address environmental challenges, such as climate change. The present study examines the impact of economic policy uncertainty, gross capital formation, urbanization, financial development, employment, green innovation, and renewable energy consumption on green growth (GRG) in G5 countries from 1996 to 2020. The empirical relationship among these variables is analyzed by using a Panel Quantile Regression (PQR) approach. The results indicate that green innovation, urbanization, and financial development contribute significantly to green growth. Additionally, gross capital formation has a marked positive effect on green growth, underscoring the crucial role of capital investments in maintaining economic activity. Likewise, renewable energy consumption positively influences the reduction of greenhouse gases (GHG). These findings align with several Sustainable Development Goals (SDGs), including SDG 07 (affordable and clean energy), SDG 09 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities), and SDG 13 (climate action). The insights provided by this research offer valuable guidance to policymakers, entrepreneurs, and researchers, emphasizing the significance of these variables in fostering green growth. Furthermore, the study highlights the necessity for cohesive policy frameworks that support financial mechanisms, technological innovation, and strategic urban development to promote sustainable economic growth.*


**Keywords:** Sustainable Growth, Green Innovation, Renewable Energy, G5

**JEL Codes:** O44, O31, Q42, R11

## Introduction

*“Unless we act now, the 2030 Agenda will become an epitaph for a world that might have been”* (António Guterres, *Secretary-General, United Nations, 2023).*

The focus of current research has switched from economic growth (EG) to green growth (GRG) to achieve both environmental stability and economic progress. GRG has become a critical viewpoint for sustainable development as efforts to reconcile environmental protection with economic advancement have come to light. As environmental and financial restrictions increase, governments everywhere have elevated sustainable development to a high priority. The notion of "green growth," which interweaves environmental sustainability with economic advancement, is fundamental to these initiatives.

This study employs a comprehensive model that includes important elements such as green innovation (GIN), urbanization (URB), renewable energy consumption (REC), gross capital formation (CAP), economic policy uncertainty (EPU), employment (EMP), and financial development (FD) to provide in-depth evaluation of GRG dynamics in G5 countries (Brazil, China, India, Mexico, and South Africa).

Globalization of finance industry and environmental research have both been demonstrated to enhance long-term GRG greatly. Concerns about the environment are pushing the transition from traditional economic growth to "green growth," and understanding "green growth" is critical to mitigate its detrimental impacts on the environment. Human resources, for all their significance, have a negligible and uncertain effect on economic progress. According to recent studies, combining green growth approaches is

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essential for a sustainable future. Green economic infrastructure significantly contributes to environmental sustainability through lowering $CO_2$ emissions, preventing resource exploitation, boosting energy from renewable sources, and fostering a healthy environment.

A key method for accomplishing sustainable development is green growth. Studies have demonstrated that sustainable development is substantially aided by ecological sustainability (Ploeg & Withagen, 2013; Mensah et al., 2019).

Growth of green economy can be obstructed by EPU and can lead to instability in the planning and investment. Stable and predictable policies, such those pertaining to carbon dioxide emissions and renewable energy subsidies, can promote sustainable growth (Bloom, 2009; Gu et al., 2021).

Financial stability is an essential component of economic development since it promotes capital allocation, investment growth, and capital expansion. This also helps to control energy use and reduces carbon footprints. Research and development can benefit from financial development since it can draw in foreign direct investment (FDI) and boost economic activity, both of which can enhance environmental quality (Anwar et al., 2023).

Energy from renewable sources uses less carbon and emits fewer greenhouse gases (GHGs) than conventional energy, it is acknowledged to raise the standard of the surrounding air that promoting the usage of clean energy could contribute to green and clean environment (Charfeddine & Kahia, 2019).

Because green innovation (GIN) uses cutting-edge methods and strategies to reduce the impact of environmental damage while achieving financial goals like reduced expenses as well as improved product quality, GIN is crucial for advancing green growth (GRG). GIN is essential to GRG, especially when it comes to reducing carbon footprint and providing clean energy at the lowest possible external cost (Alam & Murad, 2020).

Regulations about the environment have a big impact on employment trends. Strict environmental regulations have been shown to generate labor market movements, which can lead to job losses in some industries and opportunities in others.

The resource flow and expansion of industries are the main drivers of urbanization in China, according to Wu et al. (2024). As a result, as time has passed, the population of land areas and cities has grown rapidly. Considerable consumption of energy and pollution resulted from this fast urbanization, but it also encouraged technical advancement and economic development aimed at reorganizing the energy sector and lowering emissions of greenhouse gases.

This research attempts to provide insight into the complex processes of green growth (GRG) and adds to the current corpus of literature in certain respects. To begin, this is the most thorough examination of the implications of EPU, GIN, EMP, FD, REC, URB, and REC on GRG in G5 economies from 1996 to 2020. The G5 seeks to find common solutions to global challenges. Second, this analysis employs panel quantile regression (PQR), Being able to control the dependent variable's whole range makes this technique more effective than earlier ones. Additionally, the PQR tolerates outliers and lowers variability in the panel dataset. This study's relevance lies in its ability to assist policymakers in G5 economies in developing strategies to achieve high GRG rates and meet SDG objectives such as renewable energy, innovation, sustainable cities and communities, and climate change. This study will help future researchers to explore new areas of inquiry in this field.

The findings of this study, align with several Sustainable Development Goals (SDGs), including SDG 07 (affordable and clean energy), SDG 09 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and communities), and SDG 13 (climate action). The insights provided by this research offer valuable guidance to policymakers, entrepreneurs, and researchers, emphasizing the significance of these variables in fostering green growth. Furthermore, the study highlights the necessity for cohesive policy frameworks that support financial mechanisms, technological innovation, and strategic urban development to promote sustainable economic growth

The rest of the study is divided into four parts, where second part focuses on the literature review, while third part discusses theoretical and methodological approaches along with data, the results are in part four, and the fifth and final part is the conclusion.

## Literature Review

Modern research has turned its attention to green growth (GRG), which aims to combine environmental sustainability and economic prosperity. Green growth plans are based on the complex interplay of employment (EMP), gross capital formation (CAP), renewable energy consumption (REC), financial development (FD), green innovation (GIN), economic policy uncertainty (EPU), and urbanization (URB). Researchers have also investigated how green innovation breakthroughs and environment friendly technology have boosted their efficiency, as well as how volatility in economic decisions effects investments in green practices and technologies. Financial growth the formation of gross capital show how much of environment friendly investments are made in the economy. Because sustainable growth usually results in the development of fresh employment opportunities for emerging sectors, the dynamics of employment are particularly important. Urbanization trends are also being researched for their effects on the environment. Purpose of this review of literature is to synthesize research findings and clarify how many factors interact to promote sustainable development and ecological growth.

Wu et al. (2024) found that the resources flow and industrialization were the main forces behind China's urbanization that leads to increase the country's urban population. Environmental damage and massive energy usage were the results of the fast urbanization. To cut emissions and conserve energy, it also promoted structural improvement and technological advancement, the study looked at how urbanization affected ECER between 2011 and 2018. The findings revealed that the allocation of resources, economic expansion, internet development, and job structure were all enhanced by urbanization, which also boosted ECER somewhat. Dependent on the mediators, the relationship between urbanization and ECER was nonlinear. Unpredictability regarding economic policy, coupled with numerous policy adjustments, can make matters worse and hinder corporate green innovation.

Hussain et al. (2024) used the resource-based view to analyze the impact of environmental innovation on mergers and acquisitions (M&A) announcement returns. It is found that acquirers with higher environmental innovation, or innovative acquirers, earn higher deal announcement abnormal returns. This effect is consistent across product, process, and organizational innovation forms and is partly due to the transfer of environmental innovation from the acquirer to the target. The study also highlighted the transfer effect, suggesting that environmental innovation is a transferable resource in the takeover market.

Cui X et al. (2023) found that green innovation was adversely impacted by EPU. The issue was made worse by budgetary restrictions, especially in privately held businesses with little protection for intellectual property or little competition.

A study of five fragile countries was conducted by Anwar et al. (2023), the findings showed that financial development, green innovation, economic policy uncertainty, employment, and capital all positively affect GRG over the whole distribution. A thorough policy framework has been proposed by the study in light of the results to accomplish SDGs, 08 (Economic Growth), 09 (Innovation), and 13 (Climate Action).

Esmaeili et al. (2023) investigated the impact of clean energy use, and FDI on reduced carbon footprint, results emphasized the importance of economic heterogeneity in the early stages of modernization and confirmed the EKC. The study also found that switching to clean energy sources reduced emissions of carbon dioxide ($CO_2$), underscoring the importance of policy recommendations for sustainable development and preservation of ecology.

Chen et al. (2023) inspected the "green growth" concept and its relationship to economic globalization and innovative green technologies in the BRICS countries. The study found that environmental innovation and patents had a favorable effect on long-term green growth in these economies applying the CS-ARDL model. The study also suggested that more integration into global financial networks results in improved environmental advancement and highlighted the positive impact of financial globalization on GRG. A transition from traditional to green growth is being pushed by the growing concern of the international community about environmental deterioration.

Jiang et al. (2023) discovered that renewable energy consumption (RENE) and institutional quality (IQ), had a favorable influence on green growth (GRG) whereas economic policy uncertainty (EPU) had a negative impact. The data set of seven developing economies was used from 1996-2019 which have been switched from conventional to sustainable growth.

The idea of "green growth" has come to be seen as essential to limiting how economic activity affects the environment. Fu & Ullah (2023) found that green growth is crucial for mitigating the environmental impacts of economic activities. They studied China's green finance investment, technology capital, and renewable energy from 1996 to 2020, findings were that these factors positively influenced long-term green growth. Sustainable development was advocated through renewable energy investments and regulatory measures. The study called for comparative analysis to understand China's green growth trajectory and identify optimal global sustainable development methods.

Green innovation or sustainable innovation/environmental innovation is a procedure that improves both eco-friendliness and innovative efficacy. It is based on traditional innovation theory and emphasizes sustainable economic development and environmental concepts; a study demonstrated a positive correlation between the growth of EPU and an increase in green patent applications. Additionally, the impact of EPU on green innovation (GIN) varied geographically, with provinces that had higher levels of commercialization being more influenced by EPU and experiencing a greater boost in green innovation. This suggested that provinces with higher levels of trade openness had a stronger impact from EPU. (Peng et al., 2023).

A study by Ahmed et al. (2023) investigated the impact of environmental technology and the banking industry on green growth (GRG) in high-polluting countries. The findings were that the development of the banking sector and environmental technology encouraged GRG significantly.

Human capital is crucial for economic growth, fostering innovation, productivity, adaptability, entrepreneurship, good governance, health, and social cohesion, thereby laying the groundwork for sustained prosperity. A study of the impact of human capital on economic growth discovered a weak and ambiguous effect. The study, which used data from 104 nations from 1990 to 2014, discovered that both initial and changes in human capital stocks had a favorable impact on growth when taken combined. However, the study discovered that enlarged specifications could not give a consistent explanation for human capital's influence on growth. The initial human capital stock was positive, indicating countries' ability to absorb superior technologies. The study concluded that the omitted variable bias problem in previous literature was unsubstantiated and did not clarify the empirical inconsistencies regarding human capital's effect on growth (Eftimoski, 2022)

Green economic infrastructure supports environmental sustainability by reducing carbon emissions, preserving natural resources, promoting renewable energy, and encouraging ecological balance. Long-term sustainability and health are therefore guaranteed. The GMM outcomes showed that while green logistics reduced CO2 emissions in Europe, it raised them in Central Asia, OBRI, and MENA. It was observed that green technology stimulated ecological sustainability in OBRI economies and underlined the necessity for a review and modification of policies about the environment (Chen et al., 2022).

Cao et al. (2022) revealed an intricate connection among sustainable growth and local-financial organizations, and local firms aiding nearby provinces but negatively impacting their local development. The magnitude of the nearby stock market had an optimistic effect on green growth at both local and regional levels. Innovative technology originating from the region additionally helped spur growth locally, though it had fewer effects on neighboring provinces. However, green economic growth is adversely affected by the combination of economic and technological advances.

Liu et al. (2022) looked at the influence of financial inclusion on the environment and economic performance. The findings indicated a strong link between financial inclusion and the GDP-$CO_2$ nexus. Bank branches and credit have a long-term beneficial influence on GDP and $CO_2$ emissions whereas insurance premiums have an inverse effect on carbon emissions. It was seen that energy usage was greatly influenced by economic growth and emissions.

Cai et al. (2022) examined the obstacles, South Asian economies have, in accomplishing SDGs, especially fighting against global warming. Between 1990 and 2018, the study looked at how farming, increasing urbanization, economic growth, and the use of nonrenewable as well as renewable energy sources affected carbon dioxide emissions in some South Asian nations, the study found that while farming and the use of energy from renewable sources decreased carbon emissions, urbanization and the use of nonrenewable energy accelerated environmental degradation.

Ahmed et al. (2022) examined the function of clean energy production, green trade, and green innovation, utilizing data between 2000-2018, the study found that green innovation, green commerce, and energy from renewable resources all positively impacted the expansion of the green economy in South Asian nations. The research stressed the significance of renewable energy sources in mitigating dependence on limited resources, advancing ecological sustainability, and confirming the enduring feasibility of renewable-oriented economic output.

Information and communication technology (ICT) increase productivity, encourage innovation, and open up new business prospects, all of which lead to economic growth. The study discovered that while financial growth and economic expansion raised emissions of carbon dioxide, ICT lowered these emissions using Moments - Quantile Regression Methods. The study also discovered that different degrees of ICT and economic growth have varying effects on CO2 emissions, with higher levels being more noticeable. (Chien et al., 2021)

Abbasi and Adedoyin (2021) applied a dynamic ARDL model to examine the China's energy use, GDP, CO2 emissions, and economic policy uncertainty between 1970 and 2018. The results showed that the uncertainty in economic policy (EPU) had no impact on $CO_2$ emissions whereas energy usage significantly reduces CO2 emissions.

Academics are increasingly focusing on green innovation to address global environmental challenges. Traditional economic development models face challenges such as pollution and limited resources. Though it is now dealing with growing ecological issues, green technology innovation is essential to long-term and ecologically sustainable economic prosperity. Prior studies have disregarded uncertainties in economic strategies.

Li et al. (2021) examined the relationship between environmental regulation, economic policy uncertainty (EPU), and green technological innovation. According to the findings, environmental regulation promoted green innovation positively, whereas EPU harmed it.

Hao et al. (2021) looked at the impact of environmentally adjusted multifactor productivity growth, or "green growth," on $CO_2$ emissions. This study used the CS-ARDL model, a second-generation panel data methodology. Both linear and nonlinear components for green growth decreased $CO_2$ emissions, according to theoretical and empirical research. Furthermore, it has been demonstrated that human capital, ecological taxes, and the usage of clean electricity all reduce greenhouse gas emissions. A negative impact on the environment has been seen with the GDP expansion both short and long-term. However, the findings supported the theoretical concept that green growth protects environmental quality. The panel causality test produced consistent results as well. The outcomes might convince authorities of developed countries to support green growth

Green innovation (GI) literature has grown significantly in recent decades due to its numerous applications, environmental awareness, and the provision of green products and services. Takalo and Tooranloo (2021) presented GI methodologies and assessed 178 papers published between 2007 and 2019. The study found that papers on themes like the Benefits of GI implementation had the largest share, with manufacturing industries accounting for the majority. In short, Universities, organizations, and anyone interested in business may all benefit from these excellent reviews and studies

It is increasingly acknowledged that environment-friendly development is an essential strategy for achieving sustainable development. Ulucak (2020) focused on the BRICS nations and examined the relationship between environmentally safe technologies and green growth. The study used sophisticated panel data estimate approaches to overcome problems like heteroscedasticity, endogeneity, and cross-sectional dependency to get accurate results. The findings showed that eco-friendly technologies have a significant positive impact on GRG.

Particularly in the energy section, economic uncertainty has resulted from the UK's choice to exit the European Union. EPU, or economic policy uncertainty, has been found to have an initial negative impact on emissions but a subsequent positive one when examining the connection between economic circumstances, emissions of carbon dioxide, and energy usage from 1985 to 2017. The study suggested that prolonged reliance on EPU could worsen environmental problems while temporarily slowing down climate change. To fully comprehend the effects of Brexit uncertainty on the connections between energy and the environment, more research might be necessary (Adedoyin & Zakari, 2020).

It has been examined the financial growth, use of renewable energy, and carbon dioxide ($CO_2$) emissions and found that while renewable energy may have helped the environment, $CO_2$ emissions were negatively impacted by it. Financial improvement, however, only slightly boosted GDP. The paper suggested that the MENA area might accomplish economic and environmental benefits by supporting the banking sector and considering institutional, socio-demographic, and other environmental aspects (Charfeddine & Kahia, 2019).

Maji (2019) investigated the relationship between energy use and economic growth. Findings demonstrated that there was a negative correlation between economic growth and the utilization of green power, particularly from wood biomass. The study used pooled OLS and panel FMOLS to validate its findings. The policy recommendations included cleaner wood biomass technology, greater use of thermal, wind power, and energy from the sun, and the promotion of sustainable clean energy practices.

Wang et al. (2018) studied the connection between emissions of carbon dioxide, consumption of electricity, economic expansion, and urbanization between 1980 and 2011. The findings of Granger causality testing via VECM revealed long-term positive connections and varying levels of causation among income-based subpanels. Variance decomposition and impulse response research anticipated future impacts on CO2 emissions from urbanization, economic expansion, and energy usage, underlining the relevance of a country's affluence and development stage in $CO_2$ reduction efforts.

Ge and Zhi (2016) examined how employment and green economies relate to one another, focusing on renewable energy regulations across national boundaries. It proved that although employment outcomes from green economies are generally positive, they might vary based on the evaluation standards. The association between employment and a nation's degree of environmental evolution was also called into doubt by the study. The concept of "green jobs" and its impact on employment were examined in the study, with a focus on environmental regulations and weather change policy. Particularly in the developing nations, electricity efficiency and renewable energy have been mentioned as potential sources of green jobs. Nonetheless, the study recommended for a more comprehensive approach and pointed out flaws in the ways that research is currently conducted.

Environmental sustainability occupations exist in a wide range of areas, including energy, waste management, conservation, and agriculture. These vocations encourage environmental stewardship while offering employment. Bowen's (2012) study investigated the notion of "green jobs" and its influence on employment, concentrating on environmental legislation and climate change policy. The study suggested energy efficiency and renewable energy as potential sources of green jobs, especially in developing nations. The research highlighted the significance of combining immediate economic advantages with long-term environmental and social goals, particularly in emerging countries.

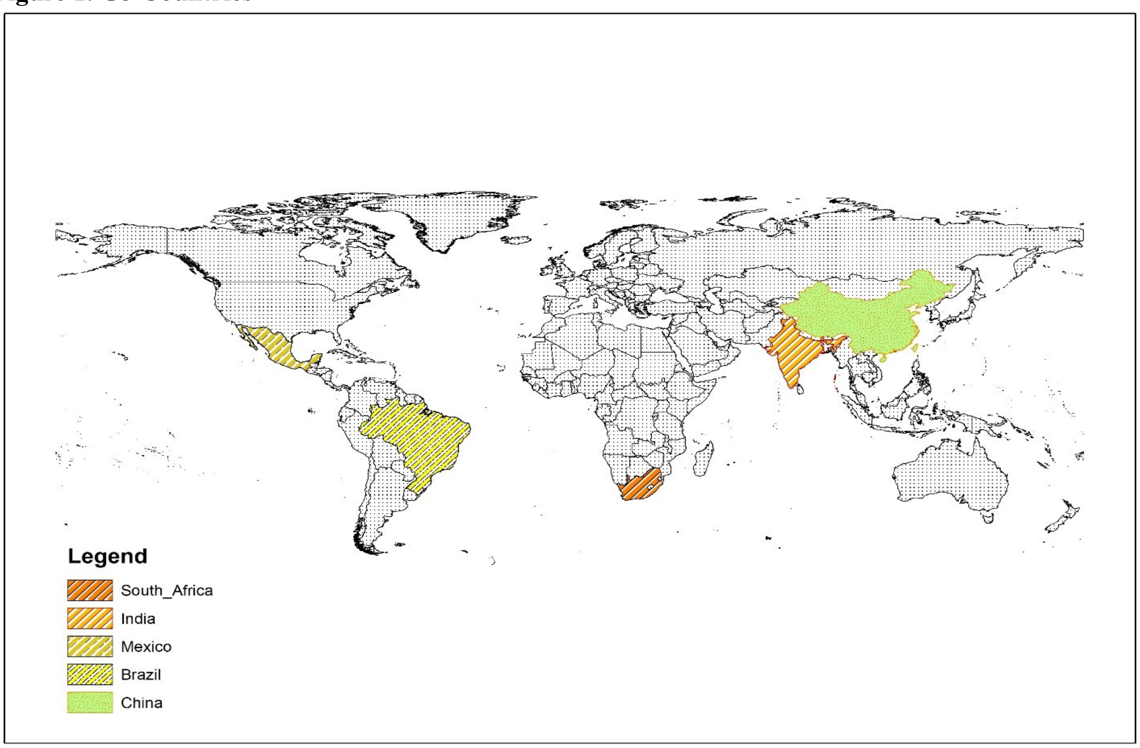
Shanghai's urbanization and its impact on meteorological and ecological elements were studied by Cui and Shi (2012). It was discovered that as a result of changing land uses, urban development, and population growth, temperatures, humidity, wind speeds, and vegetation are all rising. Green areas have reduced the urban heat island effect, but environmental problems persist.

According to Chadchan and Sankar (2009) urbanization is a significant transformation process globally that has led to unequal growth between areas, within regions and within countries. Globalization has increased India's overall economic growth rate, as urban economies and spatial patterns reflected the changing composition of global and regional markets. Globalization is a multi-faceted phenomenon that has far-reaching implications for various urban sectors, including real estate and land markets. India's future appeared contradictory as it will be in dire need to support urban population growth while maximizing scarce natural resources to compete globally and achieve sustainable economic growth. As per this study, a global strategy is needed to study and understand urban development and to build an adequate sustainable growth model.

Jago-on et al. (2009) used the DPSIR technique to evaluate key subsurface environmental concerns in seven Asian cities, such as excessive groundwater pumping, land subsidence, and groundwater pollution. The DPSIR paradigm helped to improve our knowledge of the impacts of increased urbanization and industrialization underground. This study concentrated on the topic of groundwater table decrease and land subsidence, evaluating the timing and impact of groundwater problems throughout critical phases of urban expansion. Responses to groundwater development were successful because alternate surface water supplies were plentiful. As cities grew, preventative and corrective measures were implemented, but groundwater quality remained an issue in regions with insufficient sewage, wastewater treatment, and dirty waste disposal systems.

Chen (2008) presented a fresh idea known as green core competence, which has been demonstrated to improve green innovation and corporate image. According to the study, green core talents have had a substantial influence on an organization's green innovation performance and image. It was also shown that green core competencies influence the association between green innovation performance and a company's green image. According to the study, SMEs in Taiwan's information and electronics sector should emphasize building green core competencies to improve their innovative performance and image.

**Figure 1. G5 Countries**




**Source: ArcG**

## Methodology

### Model Specification

The scope of this research is to examine the impact of the following variables on green growth (GRG); Economic Policy Uncertainty (EPU), Renewable Energy Consumption (REC), Gross Capital Formation (CAP), Employment (EMP), Urbanization (URB), Green Innovation (GIN), and Financial Development (FD).

The data set of G5 countries (Brazil, China, India, Mexico, South Africa) from 1996-2020 has been used for this study.

The following is the econometric equation form:

$$lnY_{it} = \alpha_0 + X_{it}\beta + \varepsilon_{it} \qquad Eq(1)$$

*Where,* $lnY_{it}$ (log of GRG) is the dependent variable, $X_i$ is a vector comprising independent variables, such as FD, CAP, EMP, GIN, URB, REC, and EPU, $i$ = countries, $t$= year, $\beta$ = vector of the independent variables' unobserved parameters, and $\varepsilon_{it}$ is the standard error term.

This can also be written as,

$$GRG_{it} = B_0 + B_1(EPU_{it}) + B_2(GIN_{it}) + B_3(CAP_{it}) + B_4(REC_{it}) + B_5(URB_{it}) + B_6(EMP_{it}) + B_7(FD_{it}) + \varepsilon_{it} \qquad Eq(2)$$

## Theoretical Framework

The study's theoretical foundation is presented in figure 2. The structure demonstrates green growth (GRG) is a function of economic policy uncertainty (EPU), green innovation (GIN), renewable energy consumption (REC), urbanization (URB), employment (EMP), gross capital formation (CAP) and financial development (FD). As a result, a variety of economic activities, including investment and the productivity of the industrial and agricultural sectors can influence green growth. Large amounts of natural resources, such as those used in agriculture, are needed for economic activity and have a direct impact on green development. More specifically, three effects, the size effect, composition effect, and method impact are revealed by the Kuznets Curve theory in the environment.

Considering that green growth necessitates greater resources, including natural resources (energy and raw materials), the scale effect implies that GDP growth at first inhibits green growth. According to the influence of composition, the nation's shift from a production-oriented to a service-oriented economy will lessen the detrimental consequences of economic expansion on the environment. Finally, research by Ahmad et al. (2020) & Fang et al. (2020) illustrated the effect of technique, which illustrates how economies adopt new technologies in tandem with income growth, leading to increases in productivity concerning environmental issues.

**Figure 2. Theoretical Framework**

## Data

This study will examine the "G5" economies from 1996 to 2020 to evaluate the impact of financial development (FD), gross capital formation (CAP), urbanization (URB), employment (EMP), green innovation (GIN), economic policy uncertainty (EPU), and renewable energy use (REC) on green growth (GRG). The dependent variable for this study is production-based CO2 emissions (index 2000 = 100), which represent green growth. To ensure a thorough understanding of the research framework, complete information about data sources and measurement units is provided in Table 1 for each factor.

**Table 1. Description of Variables**

| Sign | Variables | Definition | Data Source(s) |
|---|---|---|---|
| GRG | Green Growth | Production-based CO2 emissions Combined unit of measure: Index, 2000 | OECD (2024) |
| FD | Financial Development | Domestic credit to private sector (percentage of GDP) | WDI (2024) |
| CAP | Gross Capital Formation | percentage of GDP | WDI (2024) |
| EMP | Employment | Employment to population ratio, 15+, total (percentage) (modeled ILO estimate) | WDI (2024) |
| GIN | Green Innovation | Patents on environment technologies (indicator). | OECD (2024) |
| URB | Urban Population | Urban population (percentage of total population) | WDI (2024) |
| REC | Renewable Energy Consumption | Renewable energy consumption (percentage of total final energy consumption) | WDI (2024) |
| EPU | Economic Policy Uncertainty | Economic policy uncertainty: World Uncertainty index | EPU (2024) |

The operational definitions of variables are presented as follows;

(i) **Green Growth (GRG)** the production-based $CO_2$ emissions index 2000 base period measured green growth. It comes from the OECD (2024) and shows the level of $CO_2$ emissions compared to the base year.

(ii) **Green Innovation (GIN)** means the part of environmental technologies in comparison to the total number of technologies. This measure comes from the OECD (2024).

**(iii)** **Renewable Energy Consumption (REC) s**ourced from WDI (2024); this variable measures the percentage of total ultimate energy usage that comes from regenerating sources.

**(iv)** **Urbanization (URB)** calculates the share of the people that reside in urban regions; data derived from WDI (2024)

**(v)** **Employment (EMP) is** the percentage of the workforce in the labor force, sourced from WDI (2024).

**(vi)** **Financial Development (FD)** measures credit in the domestic private sector as a percentage of GDP, sourced from WDI (2024).

**(vii)** **Gross Capital Formation (CAP)** represents the capital value proportionate to GDP, which comes from WDI (2024).

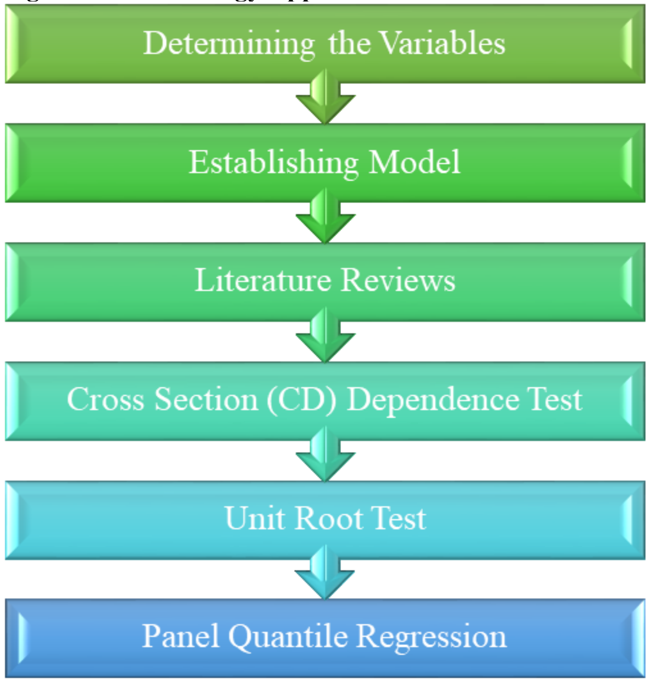
**(viii)** **Urbanization (URB)** represents the proportion of the overall cities' population as per WDI (2024).

## Methodological Approach

The study's methodology, as demonstrated in Figure 3, clarifies in a structured categorization. To begin with, the selection of data and methodology takes priority, followed by an examination of cross-sectional variation and a thorough review of the literature.

Subsequently, unit root tests are conducted on the dataset. Finally, Panel Quantile Regression (PQR) analysis is employed to draw insightful conclusions from the data.

**Figure 3. Methodology Approach**




## Cross-Section Dependence(CD) and Unit Root Test

Examining potential CD in panel modeling is crucial because it captures the mutual dependence and connection prevalent in actual global economies. Cross-country spillover refers to how an economic shock in one country affects economic statistics in other countries. Globalization is a common factor; cross-country reliance is growing, and CD checks are necessary. (Hsiao, 2022). This study employed diagnostic tools, including a CD, CADF test and CIPS (Pesaran, 2004, Pesaran, 2003, Pesaran, 2007), to confirm the prevalent international spillover effect and the stationary behavior of the variables. Similarly, panel stationarity ensures that the panel outcome estimators are consistent, thereby strengthening the validity and dependability of the panel modeling process (Baltagi & Kao, 2001). Thus, neglecting these problems could lead to erroneous statistical findings, skewed estimates, diminished statistical efficiency, and misleading recommendations for policymaking (Baltagi, 2008).

$$\boldsymbol{CD_{lm}} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{N(N-1)}}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (\mathbf{T}\hat{\rho}_{ij}^{2} - \mathbf{1}) \qquad \boldsymbol{Eq}(\mathbf{3})$$

Equation (1) utilizes ρ ̂ for binary connection valuation. The lack of any cross-sectional correlation is prime assumption of this investigation. When the time dimension $(T)$ is greater than the cross-section dimension $(N)$, the Pesaran (2004) test, with a chi-square asymptotic distribution at $\frac{N(N-1)}{2}$ degrees of freedom, may be used if $T \to \infty$, and N stays constant. Since $\hat{\rho}_{ij}^{2}$, $i = 1,2,..,N-1$, $j = i+1, 2, ..., N$, is asymptotically independent, the following form of $CD_{lm}$ test can be considered to evaluate the hypothesis of CD that allowed large $T$ and $N$.

## Panel Quantile Regression (PQR)

This study applies Koenker's (2004) PQR to examine the distinctive diversity within the panel statistics. This study investigates the PQR's fixed effect with a unique disturbance term. This approach is employed as it deals with every important variation between forecast and observed variables avoiding incorrect coefficients for regression. As opposed to earlier regression techniques, which may provide inaccurate regression coefficients, this approach assesses the average impact of covariates on observable variables. When a normal distribution is not present, conventional mean approaches yield unreliable results, while PQR makes no assumptions about distribution. Koenker and Bassett (1978) introduced the more flexible PQR analysis approach, solving the issue that emerges when the dependent variable has an imbalanced distribution by applying mean regression. While OLS provides estimates using the mean value, PQR provides an in-depth examination of the factors that have been selected because it measures the explanatory variables at the precise locations of the variable that responds. While conditional mean approaches follow certain distributional assumptions, the PQR process does not. In contrast to OLS, the normality assumption is not necessary for median regression to work. The Panel Quantile Regression (PQR) model is actually a layout method, and equations (3) and (4) represent the fundamental location model.

$$Y_i = X_i\beta_\tau + \varepsilon_i^\tau \qquad Eq(4)$$

$$Q_\tau(y_i X_i) = X_i^\tau \beta_\tau \qquad Eq(5)$$

$\beta_\tau$ = estimated coefficient for the regression at $\tau^{th}$ quantile $(0 < \tau < 1)$

$$Y_{i,t} = \alpha_i + \beta_{\tau,1}X_{i,t}^1 + \beta_{\tau,2}X_{i,t}^2 + \cdots + \beta_{\tau,m}X_{i,t}^m + \varepsilon_i^\tau. \qquad Eq(6)$$

Panel quantile regression with fixed effects eliminates outliers and produces consistent results. Furthermore, PQR assesses individual variables at various quantiles and investigates unobserved variability in each cross-section. Determining the importance of the factor to an extent of the distribution is also important from a policy standpoint for future policy opportunities. Apart from its econometric benefits, the fixed effect PQR provides a thorough analysis of variables like environmental metrics, policy uncertainty in the economy, and other elements at different phases of green growth.

The Canonical Cointegrating Regression (CCR) approach (Park, 1992) and the Fully Modified Ordinary Least Squares (FMOLS) techniques (Stock & Watson 1993) models were used in the investigation for a sensitivity evaluation and a long-term connection examination. Cointegration vector estimates are reliable and effective when endogeneity and serial correlation are taken care of by the CCR model. By accounting for these biases, FMOLS produces estimates that are reliable and asymptotically efficient. These models provide a full grasp of long-term data trends while also validating the initial panel quantile regression results.

## Results and Discussion

## Descriptive Statistics

Table 2 provides valuable insights into a variety of economic indicators. Green growth (GRG) is stable; the mean value is 4.93 and the narrow standard deviation is 0.35, albeit slightly skewed to the right (skewness of 0.872). Financial development (FD) and gross capital formation (CAP) have right-skewed distributions, with mean values (71.43 and 26.36, respectively) significantly higher than medians (52.38 and 22.56), indicating considerable variability across observations. The employment (EMP), with a mean of 56.28 and a standard deviation of 8.32, has a symmetric distribution, indicating stable labor market conditions. Green innovation (GIN) remains balanced; mean and median values are nearly identical at 9.74 and 9.6, respectively, whereas urban population (URB) and renewable energy consumption (REC) show significant variability, with the former slightly left-skewed (skewness = -0.295) and the latter right-skewed (skewness = 0.323). Notably, economic policy uncertainty (EPU) is strongly right-skewed, with a mean (0.96) exceeding the median (0.65), indicating significant variability and the presence of extreme outliers. To sum up, these statistical findings are essential for comprehending economic dynamics and providing guidance for making informed choices.

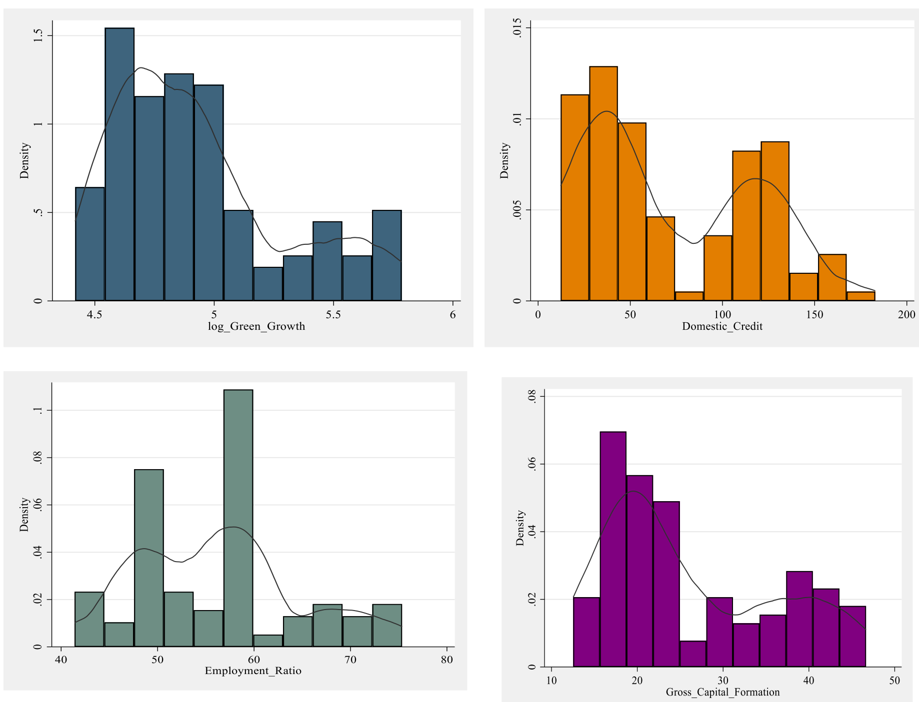
**Table 2. Descriptive Statistics**

| Variables | Obs | Mean | Median | Std | Min | Max | Skew | Kurt | JB test (prob) |
|---|---|---|---|---|---|---|---|---|---|
| Green Growth (GRG) | 125 | 4.93 | 4.84 | 0.35 | 4.42 | 5.79 | 0.872 | 2.838 | 0.000 |
| Financial Development (FD) | 125 | 71.43 | 52.38 | 45.32 | 12.24 | 182.9 | 0.433 | 1.801 | 0.003 |
| Gross Capital Formation (CAP) | 125 | 26.36 | 22.56 | 9.86 | 12.54 | 46.66 | 0.661 | 2.040 | 0.000 |
| Employment (EMP) | 125 | 56.28 | 57.27 | 8.32 | 41.39 | 75.36 | 0.465 | 2.593 | 0.068 |
| Green Innovation (GIN) | 125 | 9.74 | 9.6 | 2.91 | 3 | 16.9 | -0.000 | 2.511 | 0.537 |
| Urban Population (URB) | 125 | 59.74 | 61.43 | 20.19 | 26.82 | 87.07 | -0.295 | 1.642 | 0.003 |
| Renewable Energy Consumption (REC) | 125 | 25.08 | 17.28 | 15.45 | 7.72 | 50.05 | 0.323 | 1.374 | 0.000 |
| Economic Policy Uncertainty (EPU) | 125 | 0.96 | 0.65 | 0.95 | 0 | 4.72 | 1.97 | 7.08 | 0.000 |

The regularity of variables was also assessed by applying the Jarque-Bera test, the majority of the variables were found to deviate significantly from the normal distribution. Several variables, such as economic policy uncertainty (EPU), urban population (URB), gross capital formation (CAP), financial development (FD), usage of renewable energy (REC), and green growth (GRG), firmly contradict the null hypothesis of normalcy with p-values less than 0.05. These results suggest that these variables' distribution is not normally distributed. However, the p-values for the green innovation (GIN) and employment ratio (EMP) factors are 0.582 and 0.068, respectively, which are greater than 0.05, indicating that the null hypothesis of normality for these variables is not statistically rejected. The non-normal distribution of the variables is also evident in figure 4. These findings imply that parametric approaches based on the assumption of normalcy might not be appropriate. Non-parametric modeling techniques, on the other hand, ought to be viewed as substitute modeling techniques for better analysis. Quantiles of variables against quantiles of normal distribution are presented in figure 5 to the spread of data around normal distribution.

Finally, these figures provide a thorough overview of the consistency and fluctuations of significant ecological and economic indicators. They also serve as a strong basis for additional regression analysis, enabling a deeper investigation of economic associations and predictors.

**Figure 4. Distributions of Variables**



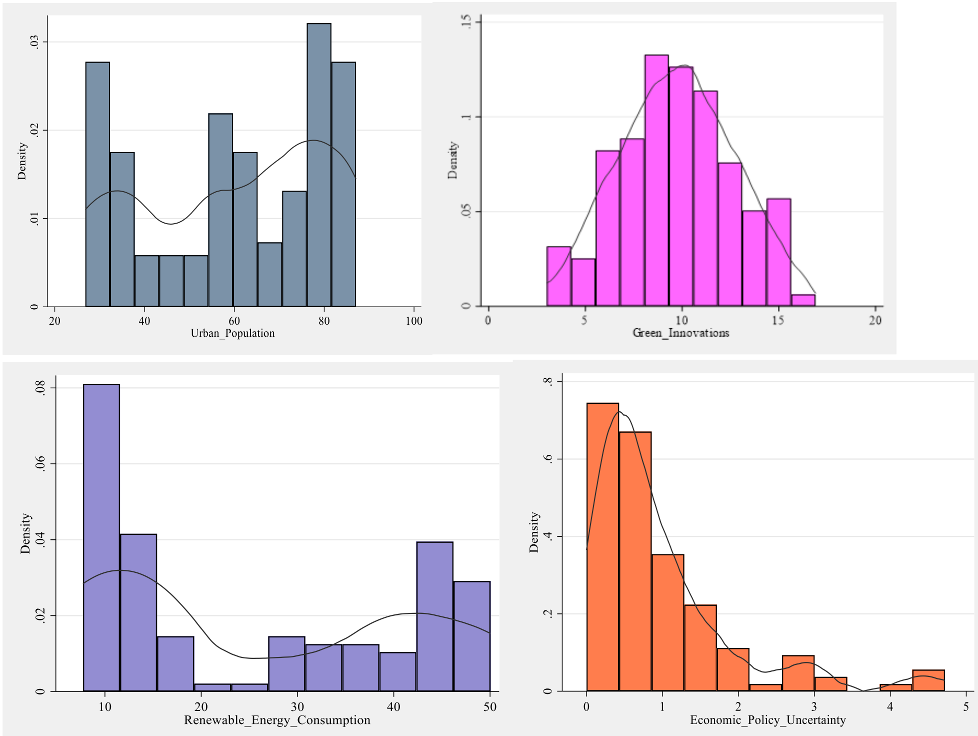
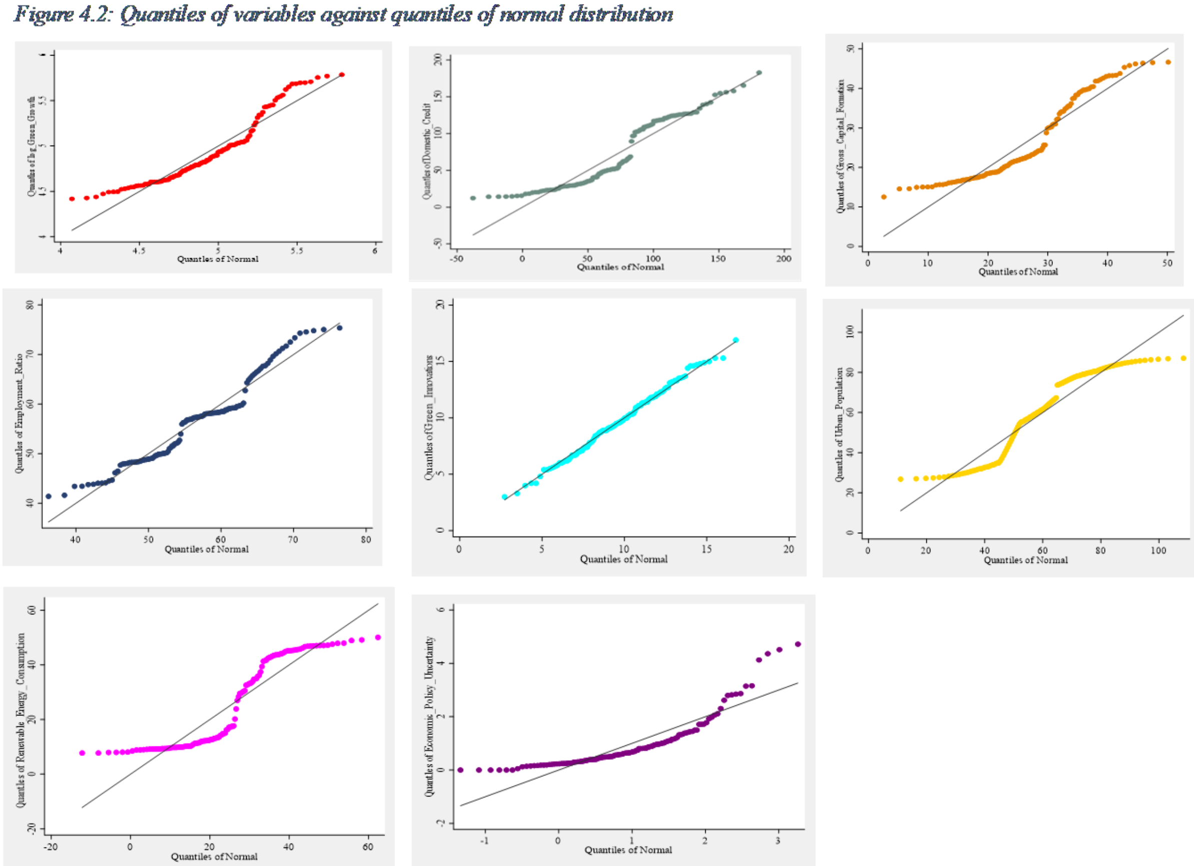



**Figure 5. Quantiles of variables against quantiles of normal distribution**

*Figure 4.2: Quantiles of variables against quantiles of normal distribution*



## Cross Section Dependency Test (CD) and Unit Root Test Outcomes

This section employed the CD test to ensure that the unit root analysis is appropriate. The outcomes of this test are shown in table 3. The study outcomes indicate that CD is prevalent in the G5 economies sample. It implies that the null hypothesis that there is no CD among these countries is rejected. The findings demonstrate noteworthy evidence of cross-sectional dependency in green growth, financial development, gross capital formation, employment, green innovation, urbanization, renewable energy use, and uncertainty in economic policy. Overall, the outcomes confirm the presence of the CD in this data set.

**Table 3. CD Test Statistics**

| Variables | CD-Test |
|---|---|
| Green Growth (GRG) | 14.02*** |
| Financial Development (FD) | 9.47*** |
| Gross Capital Formation (CAP) | 8.33*** |
| Employment (EMP) | 6.89*** |
| Green Innovation (GIN) | 6.22*** |
| Urban Population (URB) | 15.68*** |
| Renewable Energy Consumption (REC) | 6.18*** |
| Economic Policy Uncertainty (EPU) | 5.55*** |

Significance level: *P<0.1, **p<0.05, ***p<0.01

Once CD was confirmed, we assessed the CADF and CIPS unit root tests from Pesaran (2007). Serial correlation and CD are controlled by the unit root test CADF and CIPS. Besides determining the unit root, both of these methods help manage the series' heterogeneity.

**Table 4. Unit Root Estimates**

| Variables | CIPS Test | | CADF Test | |
|---|---|---|---|---|
| | I(0) | I(1) | I(0) | I(1) |
| GRG | -2.319* | | -2.072 | -3.287*** |
| FD | -1.839 | -3.435*** | -1.839 | -3.435*** |
| CAP | -2.248* | | -2.248 | -4.628*** |
| EMP | -1.548 | -3.593*** | -1.385 | -3.593*** |
| GIN | -3.82*** | | -3.821*** | |
| URB | -3.81*** | | -3.920*** | |
| REC | -1.892 | -2.947*** | -2.349* | |
| EPU | -2.97*** | | -2.965*** | |

Significance level: *P<0.1, **p<0.05, ***p<0.01

Table 4 shows the stationary of the variables at levels and the first difference using the CADF and CIPS tests. Estimates from the CADF Test show that employment, financial development, green growth, and gross capital are not stationary and become stationary after differencing. In contrast, the variables of urbanization, green technology, the usage of green power, and EPU remain constant. In the CIPS test results, all variables are stationary at their level, except Financial Development, employment ratio, and energy consumption. Therefore, based on these findings panel quantile regression (PQR) with fixed-effects can now be used.

## PQR Outcomes

To understand the varied effects of economic and environmental factors, this part explains the fixed effect PQR findings. The nine quantiles were employed in this paper to employ a thorough investigation of the link between environmental and economic factors and green growth. Moreover, because PQR can model the whole conditional distribution, it allows for various impacts of exogenous factors on the endogenous factor due to factor quantiles. Additionally, PQR assesses various slope parameters across multiple quantiles and regulates undetected heterogeneity for every cross-section (Dogan et al., 2020). Examining the magnitude of the estimators at the extremity of the distribution is also interesting for policy forecasting.

**Table 5. Estimates of PQR**

| | Quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **0.10** | **0.20** | **0.30** | **0.40** | **0.50** | **0.60** | **0.70** | **0.80** | **0.90** |
| FD | 0.003* (0.002) | 0.003*** (0.001) | 0.004*** (0.001) | 0.004*** (0.001) | 0.004*** (0.001) | 0.004*** (0.001) | 0.005*** (0.001) | 0.005*** (0.001) | 0.005*** (0.002) |
| CAP | 0.001 (0.005) | -0.001 (0.004) | -0.003 (0.004) | -0.005 (0.003) | -0.006* (0.003) | -0.007** (0.003) | 0.009* (0.004) | -0.010** (0.005) | -0.012** (0.006) |
| EMP | 0.017 (0.013) | 0.015 (0.010) | 0.014* (0.008) | 0.012* (0.007) | 0.011 (0.007) | 0.010 (0.008) | 0.008 (0.009) | 0.007 (0.011) | 0.004 (0.015) |
| GIN | 0.019*** (0.005) | 0.028*** (0.004) | 0.018*** (0.003) | 0.017*** (0.003) | 0.017*** (0.003) | 0.017*** (0.003) | 0.016*** (0.004) | 0.016*** (0.005) | 0.015** (0.006) |
| URB | 0.021*** (0.008) | 0.020*** (0.006) | 0.019*** (0.005) | 0.018*** (0.004) | 0.018*** (0.004) | 0.017*** (0.004) | 0.016*** (0.005) | 0.016*** (0.006) | 0.015* (0.008) |
| REC | -0.040*** (0.006) | -0.041*** (0.004) | -0.041*** (0.004) | -0.041*** (0.003) | -0.042*** (0.003) | -0.042*** (0.003) | -0.043*** (0.004) | -0.043*** (0.004) | -0.043*** (0.006) |
| EPU | -0.010 (0.018) | -0.011 (0.014) | -0.012 (0.011) | -0.014 (0.010) | -0.015 (0.010) | -0.015 (0.011) | -0.016 (0.013) | -0.017 (0.015) | -0.018 (0.020) |
| Observations | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |

“Parentheses report standard errors." Significance level: *P<0.1, **p<0.05, ***p<0.01

Green innovations have a positive effect on green economic growth over all quantiles. The expansion of green innovation infrastructure is positively correlated with green economic growth. On all green growth quantiles, the positive effect is highly significant and more pronounced at the 20th quantile. This outcome demonstrates the value of green innovations as a means of enhancing environmental sustainability. Green growth is generally encouraged by green innovations that lower emission levels and production waste. The rationale behind this is that green technological advances may encourage sustainable growth by aiding in the reusing and disposing of industrial waste. This is consistent with previous studies that businesses can diminish renewable energy use and encourage pollution while promoting green growth through the development of environmentally friendly green technologies (Ghisetti & Quatraro 2017; Danish 2020; Hussain et al., 2022; Chen et al., 2023).

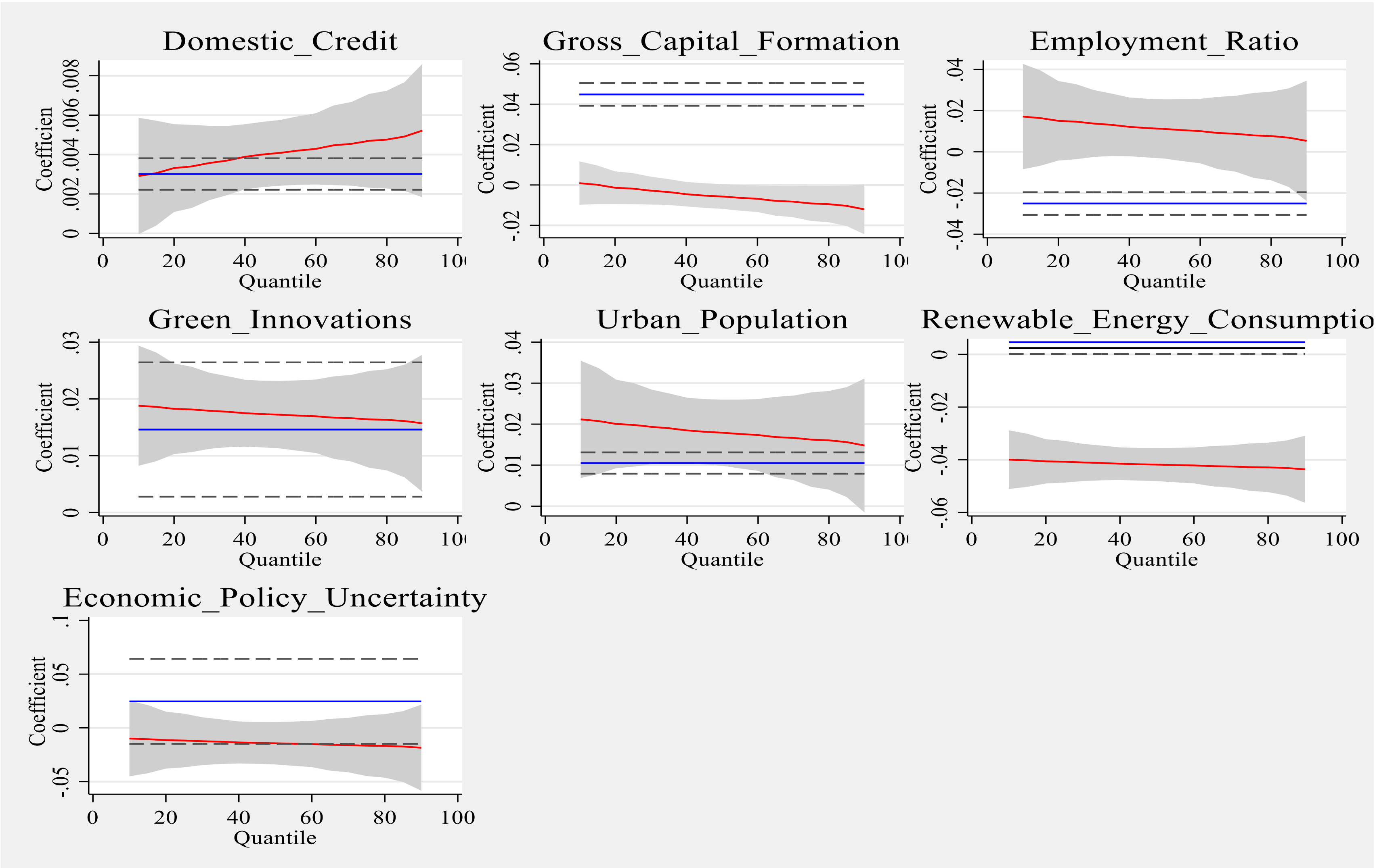
Similarly, the PQR estimates of urbanization on GRG are asymmetric and heterogeneous through the quantiles. The link is positive and significant on all quantiles. The rationale behind this advance in crucial fields like AI and ICTs, as well as their integration into innovative city structures to enhance transportation, environmental protection, and services provided by the government, are crucial steps toward boosting technological innovation and strengthening the importance of smart cities in fostering green economic growth. Additionally, the establishment of innovative centers for sustainable development and the creation of new city businesses will be supported by the use of smart cities to develop new technologies and infrastructure (Kirwan & Fu 2020; Jiang et al. 2021).

Similarly, financial development has a positive and notable impact on all quantiles of GRG. The findings show that the environmentally friendly growth of the G5 economies is significantly influenced by financial development (FD). In terms of GRG, the effect is larger at the upper quantiles and smaller at the lower quantiles. Anwar (2023) found that in fragile nations, FD has a significant and positive impact on green growth. This is justified by the fact that these nations' financial sectors are making a lot of effort to use green financing to promote environmentally sustainable growth. Another study conducted by Zafar et al. (2019) suggests that the financial industry can encourage growth that is environmentally friendly and improve the state of the environment.

On the contrary, green growth (GRG) in the G5 countries is positively and heterogeneously affected by the utilization of renewable energy (REC) at all quantiles. Consuming energy from renewable sources has a notably positive impact on each of the points. At the top and lower quantile points, the influence is increasing and decreasing, respectively. The justification for this is that not all environmental issues will be resolved by employing renewable energy sources. Although conventional air pollution and the emission of greenhouse gases from renewable energy sources are generally low, certain emissions and pollutants will still be produced during production and transportation. Certain manufacturing processes for photovoltaic (PV) cells, for instance, produce dangerous chemicals that have the potential to contaminate water sources. Renewable energy installations may also affect ecosystems and agricultural practices, and some of the technologies are water-intensive (ERR, 2011). Similarly, Akram et al. (2020) looked at the connection between the BRICS economies' economic growth and their use of renewable energy. As per their findings, growth is generally reduced by renewable energy use, and the unfavorable effects become more noticeable at higher economic growth levels. This emphasizes how crucial it is to take into account the various effects of renewable energy consumption at various phases of economic expansion.

In the same vein, the diverse impacts of gross capital formation (CAP) on green growth (GRG) are explained by the PQR results across all quantiles. At the upper quantiles (50th–90th), the effect is statistically significant and negative. In line with Aschauer (1998) results indicated no linear relationship between gross investment and green economic growth and high gross investment does not reflect green growth positively. Similarly, EPU has an inverse impact on green growth (GRG), but the effect is insignificant across all quantiles for G5 economies. This is consistent with Abbasi and Adedoyin (2021) that there is not a significant link between the two factors in their research study. In contrast, employment (EMP) positively correlated with green growth but it is insignificant for G5 economies.

**Figure 6. Panel Quantile Regression (PQR) with Pooled Ordinary Least Squares (POLS) Coefficients**




Note: The solid red line depicts the PQR coefficients at various quantiles, whereas the blue line depicts the POLS estimates that are consistent across all quantiles. Dotted lines show the 95% confidence interval for POLS estimates. The gray-highlighted area demonstrates the 95% confidence interval for PQR estimates.

## Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) Estimates

The long-term correlation coefficient with probability values between the CCR and FMOLS is represented in table 6. The PQR outcomes show how variable impacts vary at different distributional points, whereas the CCR and FMOLS models concentrate on delivering reliable long-run estimates.

**Table 6. FMOLS and CCR Estimates**

| | FMOLS | | | CCR | | |
|---|---|---|---|---|---|---|
| **Variables** | **Coeff** | **Std** | **Prob** | **Coeff** | **Std** | **Prob** |
| FD | 0.003 | 0.001 | 0.077 | 0.003 | 0.001 | 0.001 |
| CAP | 0.033 | 0.007 | 0.000 | 0.041 | 0.006 | 0.000 |
| EMP | -0.037 | 0.010 | 0.000 | -0.007 | 0.007 | 0.274 |
| GIN | 0.056 | 0.015 | 0.000 | 0.090 | 0.016 | 0.000 |
| URB | 0.001 | 0.005 | 0.808 | 0.007 | 0.003 | 0.012 |
| REC | -0.016 | 0.009 | 0.072 | 0.006 | 0.003 | 0.022 |
| EPU | 0.043 | 0.043 | 0.320 | 0.091 | 0.045 | 0.040 |

Significance level: *p<0.1, **p<0.05, ***p<0.01

Some factors have a favorable long-term link with green growth (GRG) in the FMOLS, CCR, and quantile regression models. The FMOLS and CCR regression models show the financial development (FD) has a significant and positive effect on green growth (GRG), with coefficients of 0.003 (p = 0.077 for FMOLS and p = 0.001 for CCR). This indicates that more financial development promotes green growth by encouraging investments in green technologies and infrastructure. Gross capital formation (CAP) also has a positive link with green growth; coefficients of 0.041 in CCR (p = 0.000) and 0.033 in FMOLS (p = 0.000) indicate that capital goods investments are necessary to sustain green economic activity. Green innovation (GIN) continuously demonstrates a strong positive effect in all models: 0.056 in FMOLS (p = 0.000), 0.090 in CCR (p = 0.000), and positive effects in PQR across all quantiles, underscoring the pivotal role that innovation plays in fostering sustainable growth. Ultimately, the benefits of urbanization (URB), such as improved infrastructure and increased capacity for innovation, are reflected in the favorable impact of urban population on green growth in CCR (coefficient 0.007, p = 0.012); however, this relation is not significant in FMOLS. There is no significant effect of economic policy uncertainty (EPU) in FMOLS (coefficient 0.043, p = 0.320), but a positive and significant link in CCR (coefficient 0.091, p = 0.040). This variation suggests that, although policy uncertainty might not always be negative for green growth, it might, in some cases, be very good because it can encourage creativity and flexible strategies. The reason behind this is that the adverse short-term consequence is caused by businesses avoiding investments in environmentally friendly projects due to volatile economic policies. In the long term, though, this uncertainty fosters creativity and adaptability to emerging policy trends, which eventually propels the advancement of sustainable innovation and techniques. These results are in line with Adedoyin and Zakari (2020) estimates that the relationship between economic policies volatility and green growth is converse in the short run, however, it is affirmative in the long run. Likewise, urbanization has a positive effect that is noteworthy in FMOLS but not in CCR, illustrating how different models can capture different dynamics and impacts.

Conversely, different models show differing long-term effects of use of REC on green growth (GRG). The results of FMOLS demonstrate a marginally significant negative coefficient of -0.016 (p = 0.072), suggesting that increased use of REC could have a minor detrimental effect on green growth. This is in line with the findings of the PQR, which also indicate a negative impact on all quantiles. Nonetheless, CCR shows a strong positive relation with a coefficient of 0.006 (p = 0.022), which may be due to the intricate interaction between the growth dynamics and the use of renewable energy. Furthermore, the employment (EMP) (coefficient of -0.037, p = 0.000) indicates a significant negative impact on growth in FMOLS, indicating a trade-off between reaching green growth objectives and expanding employment, whereas the CCR (coefficient of -0.007, p = 0.274) finds no significant impact. Both Ahmad et al. (2022) and Kousar et al. (2022) believe that skilled labor will be required to encourage the growth of a green economy. According to Bowen (2012), green job creation is becoming more feasible as a result of green economic growth; however, the literature rarely discusses the potential negative effects of these policies on labor employment and productivity costs. In general, CCR better captures long-term relationships and is more in line with the variable effects witnessed in the PQR findings.

## Conclusion

This research investigates the complex interactions among financial development (FD), green innovation (GIN), urbanization (URB), renewable energy utilization (REC), gross capital formation (CAP), employment (EMP) economic policy uncertainty (EPU), and green growth (GRG) employing the G5 countries data from 1996 to 2020. The study captures the distributional and long-term effects across various quantiles of green growth. This study encourages the advances of several Sustainable Development Goals (SDGs), consisting of SDGs 07, 09, 11, and 13.

According to the econometric findings, green innovation considerably increases green growth at all quantiles; at lower quantiles, this effect is more noticeable. The advancement of smart city infrastructure and financial mechanisms is crucial in supporting environmentally sustainable initiatives, as evidenced by the positive effects of urbanization and financial development on green growth. Furthermore, this study shows complex relationships between renewable energy use and green economic growth. Utilizing renewable energy has a positive effect on green growth, especially at higher quantiles, though there might be environmental trade-offs. Economic policy uncertainty boosts long-term green growth, implying that uncertainty can occasionally foster ingenuity and adaptability. Gross capital formation has been shown to have a considerable positive impact on green growth, emphasizing the importance of capital investments in maintaining economic activity. However, the employment ratio shows that the objectives of job creation and green growth must be traded off, with a clear detrimental effect on the former.

These results highlight the critical roles that financial development, urbanization, and green innovation play, in promoting sustainable growth, and they can offer useful information to researchers, businesses, and policymakers. The study emphasizes that to achieve the SDGs and encourage long-term green growth, integrated policy frameworks that support financial mechanisms, technological advancements, and strategic urban development are necessary.

Although this study captures the role of green innovation and financial development in promoting green growth within G5 economies it has some limitations also, for instance, some green innovation indicators (such as patent filings in clean technology) or financial measures may not be consistently reported or up to date, resulting in analytical gaps or biases. Secondly, Green growth plans and the importance of financial development may differ in smaller or less developed nations, limiting the results' application beyond the G5. Furthermore, the data on green innovation is not available in a few countries of past years so cross-country comparison was not possible.

These limitations point to areas for further study, such as extending studies to a more varied group of nations, utilizing longer periods, and including wider measures of green financing and innovation. By filling these gaps, future research can expand on our results and give more insight into the mechanics of green development.

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