

**CAPITAL UNIVERSITY OF SCIENCE AND
TECHNOLOGY, ISLAMABAD**



**The Pathway to Environmental Sustainability:
Evaluating the Environmental Kuznets Curve
with the Moderating Role of Financial Inclusion
and Green Bonds**

by

Aiman Shahzad

A thesis submitted in partial fulfillment for the
degree of Master of Science

in the

**Faculty of Management & Social Sciences
Department of Management Sciences**

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This thesis is dedicated to both my parents for always supported and motivated me at every stage and my brother who is my inspiration and strength. All my success and achievements are because of their motivation and support.



CERTIFICATE OF APPROVAL

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(Aiman Shahzad)

Abstract

Environmental sustainability has become a worldwide priority as the countries are facing the challenges of resource scarcity and climate change, driving countries to pursue economic growth without risking the well-being of the planet. This study examines the impact of economic performance and renewable energy usage on environmental sustainability with the moderating roles of financial inclusion and green bonds, using a panel dataset from G-20 countries. The research also explores the validity of the Environmental Kuznets Curve (EKC) hypothesis, which suggests an inverted U-shaped relationship between economic performance and environmental sustainability. The result confirms the significance of economic performance as an indicator in EKC fitting. This study employs the GMM (Generalized Method of Moments) model, to address the endogeneity issues and offer robust estimates. The results reveal that both financial inclusion and green bonds when paired with economic performance and renewable energy usage significantly enhance the environmental quality by supporting cleaner investments and broader access to sustainable financial tools. The study has significant implications, suggesting that promoting financial inclusion and green bonds into economic planning can reinforce sustainable development goals and support a greener global economy.

Keywords: Economic Performance, Renewable Energy Usage, Financial Inclusion, Green Bonds, Environmental Sustainability, G-20 countries, EKC (Environmental Kuznets Curve)

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Abbreviations

CO₂	Carbon Dioxide
EKC	Environmental Kuznets Curve
EMT	Ecological Modernization Theory
EP	Economic Performance
ES	Environmental Sustainability
FI	Financial Inclusion
GB	Green Bonds
IR	Inflation Rate
RNE	Renewable Energy Usage
SDGs	Sustainable Development Goals
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1

Introduction

In the past few years environmental sustainability has raised the most important international concern, mainly due to the industrial expansion and economic growth ([Zou & Chau, 2023](#)). Keeping the sustainable environment while attaining the strong economic success is a challenging and commonly argued topic. There is an increasing pressure on the world's economies to embrace the sustainable practices while promoting economic growth because of the rising of industrialization development ([Zeeshan, Sha, Tomlinson, & Azeez, 2021](#)).

The relationship of economic performance and renewable energy usage with environmental sustainability has gained substantial importance, as policy makers are struggling to reveal the persistent challenges of climate change and sustainable development ([Alola, Alola, Akdag, & Yildirim, 2022](#)). This research highlights the moderating effect of financial inclusion and green bonds between the variables in G-20 countries.

Economic performance plays a dual role in G-20 countries because it enlists both developed and developing countries. Developing countries which is characterized by the robust economic development and substantial environmental challenges. It drives growth and scarcity reduction, but if it is not managed properly, it can cause environmental deprivation ([Raihan & Said, 2022](#)). On the other hand, the developed countries with their established financial system, keep on facing the challenge of supporting their economic growth while progressing to low-carbon economies ([Ashraf, 2022](#)).

Economic performance is a vital element in the line of environmental sustainability, mainly in the setting of G-20 countries. Many debates have been taking place regarding the relationship between economic growth and sustainable environment, with the different viewpoints contributing different perspective ([Adanma & Ogunbiyi, 2024](#)). Alternatively, many current researches are challenging this concept, disagreeing that the shift in sustainable development not only requires economic growth but it also demands the essential change in how these economic activities are being conducted, with the significant importance on decarbonization and green innovation ([Hysa, Kruja, Rehman, & Laurenti, 2020](#)).

Economic performance is typically measured using the proxy GDP per capita, and it is generally been linked with increased energy consumption and environmental degradation because of the dependence on fossil fuels ([Z. Ahmed, Ahmad, Rjoub, Kalugina, & Hussain, 2022](#)). Although this change towards renewable energy usage offers a gateway to differentiate economic performance from environmental damage. Research indicates that progressive economic growth can energize savings in renewable energy technologies which lessens the carbon emissions and boost environmental sustainability ([He, Li, Huang, & Wang, 2022](#)). Hence, the interlink between economic performance and sustainable environment is profoundly impacted by the energy mix of the country.

It is more important than ever to comprehend how economic performance either promotes or inhibits environmental sustainability in the current global context, which is characterized by environmental degradation, destruction of resources, and sustainability goals (such the UN's SDGs). While developing countries struggle to strike a balance between ecological protection and growth needs, developed countries frequently use their riches to adopt green inventions and environmental regulations. Key concerns are brought up by this dynamic, including whether economic expansion can be made environmentally friendly and what tools, including inclusive development, green financing, and renewable energy, can assist balance environmental and economic priorities.

The analysis of the EKC curve in relation to economic performance is another significant accomplishment. According to the EKC theory proposed by [Grossman and Krueger \(1995\)](#), economic performance and environmental degradation are

inversely correlated. Environment Kuznets Curve (EKC) theory is an economic theory which states that there is a U-shaped relationship between economic performance and environmental deterioration. The name of this theory was inspired by the economist Simon Kuznets who proposed a similar curve for income inequality. This theory declares that the quality of environment will first decline as countries develop and economies industrialize, but after some time when income level rises, environmental preservation becomes the number one priority. According to the theory, at the early stage of economic development when countries develop and become more industrialize, environmental degradation gets worse. And when companies establish, energy consumption increases, and natural habitats endure damage to satisfy the increasing demand for services and products, economic growth during this phase typically comes with increased level of pollution, environmental stress and resource exploitation.

According to the theory, societies emphasize environmental protection measures and grow progressively concerned about ecological problems as economies develop and income levels rise. Over time, advances in resource management and environmental quality result from governments and individuals investing in conservation initiatives, cleaner technologies, and environmental regulations made possible by higher earnings. According to the EKC theory, structural socioeconomic changes like the transition from manufacturing and agriculture to services have an impact on environmental results. Pollution intensity, resource utilization, and environmental effect per unit of output may decrease as economies shift from resource consuming industries to service-based industries ([Mahmood, Furqan, Hassan, & Rej, 2023](#)).

There is a high impact of renewable energy usage in encouraging the sustainable environment by limiting carbon emissions and reducing the ecological impact of economic activities. This change concerning renewables such as wind, solar and hydropower reduces reliance on fossil fuels and also rises sustainable economic performance ([Bekun, 2022](#)).

Due to the atmospheric condition and exposure of greenhouse gases, mainly carbon dioxide, that are mostly the activities resulting from human influence like deforestation and burning of fossil fuels, which alarms the 21st century by the

serious global climate change concerns (Zeeshan et al., 2021). It is anticipated that the ongoing rise in CO_2 emissions will have disastrous effects on every aspect of society and have major implications for the global climate system (Raihan & Said, 2022). Apart from the expansion stage, researchers and policy makers generally believe that lowering the global emissions should be given priority to preserve environmental sustainability.

In order to improve the global response to climate change challenges in the framework of sustainable development and efforts to eliminate poverty, the UNFCCC (United Nations Framework Convention on Climate Change) negotiated the Paris agreement, a multilateral environmental pact. As the first nation to sign the Paris Agreement in 2016, Brazil joined international efforts to restrict global warming to 1.5 °C, well below the target of 2 °C. This further demonstrates the nation's commitment to reducing national emissions and adapting to the consequences of climate change. Brazil plans to take part in worldwide collective action to lower future emissions as part of a broad and ambitious international agreement. Brazil finds a balance between implementing policies to achieve sustainable development and reducing the effects of climate change (UNFCCC).

Three beliefs are of a great significance when we talk about energy, environment and the economy: (i) the reinforcement of energy from renewable resources, (ii) the development of the finance sector (iii) the impact of clean energy and economic growth to maintain the environment sustainable. Encouraging and increase use of renewable energy sources, which are seen a clean, green and environmentally healthy in the first priority. This will help CO_2 and other pollutants to reduce with the help of energy sources (Kahia et al., 2017). About the second belief a number of observed studies have shown that by encouraging technological developments in the energy sector, the financial sector can play a positive role in reducing carbon emissions (Kirikkaleli & Adebayo, 2021). According to recent studies, environmental quality and the use of renewable energy and positively interconnected. The decrease in carbon footprints, conversion in air quality, and improved struggle to environmental risks have all been informed by nations that have made important investments in renewable infrastructure. Given that renewable energy is a practical means of achieving climate goals and sustainable development targets,

such those defined in SDG 7 and SDG 13, policymakers internationally are now giving green energy transitions top priority through grants, carbon pricing, and investment incentives.

Although worldwide development, different nations and regions have different levels of renewable energy adoption. Developing countries frequently have structural obstacles such inadequate funding, technological gaps, and inconsistent policies, whereas affluent nations are at the forefront of renewable energy capacity and policy frameworks. Designing focused, efficient, and inclusive energy and climate policy thus requires an understanding of the relationship between the use of renewable energy and sustainable development across various economic situations ([Z. Ahmed et al., 2022](#)).

In advanced nations, financial inclusion has drawn attention as a key factor in promoting environmental sustainability. Financial inclusion is the distribution of affordably priced financial services to low-income and unprivileged groups and individuals through banking, credit, insurance and savings ([Madein, 2020](#)).

The convenience of financial facilities grants people and businesses to invest in renewable energy sources, and adopt technologies that are energy-efficient and involve in sustainable practices. Nevertheless, there is a complex relation between financial inclusion and environmental sustainability ([Klapper, El-Zoghbi, & Hess, 2016](#)). Studies shows that although financial inclusion can boost economic growth in the developing countries, it can also worsen environmental conditions if it is not controlled with suitable regulatory frameworks and green financing options ([Li, Udemba, & Gündoğdu, 2024](#)). To make sure that ecological well-being is not sacrificed for economic development, it is imperative that financial inclusion programs be integrated with environmental policies.

Financial inclusion encourages businesses and people to engage more actively in economic activities by ensuring broader access to financial services, such as investments, insurance, credit and online payments. This ultimately encourages business ownership, increased productivity and facilitating it to invest in both developed and developing sectors. Nonetheless since financial inclusion is crucial for promoting economic activities it also fosters in promoting environmentally friendly development.

Innovations in the financial industry increase access to new goods that are energy efficient and cutting-edge technologies while also expanding the scope of cross-border investment. Through the optimal use of energy appliances and the reduction of national pollution, these technologies have an impact on the environment. There are several ways in which financial inclusion might negatively impact the environment. For instance, financial expansion forces customers to take out loans to buy luxuries like properties, air conditioning units, and refrigerators, which increases environmental emissions (Jaiswal et al., 2022). Additionally, financial expansion lowers the expense of financial resources for businesses, which they can use to construct new facilities, expand their operations, and buy more machinery and equipment, all of which raise emission levels. Thus, it is crucial to examine how financial inclusion affects carbon emissions in nations with technological advancement and relatively high emission levels (Zaidi, Hussain, & Zaman, 2021a).

Two ideas that have been frequently associated with sustainable development are financial inclusion and environmental sustainability (Yin, Li, Zhang, & Zhang, 2019). There are two ways that financial inclusion and environmental sustainability can contribute to the attainment of the Sustainable Development Goals (SDGs). In particular, the environmental sustainability agenda promotes sustainable development by lowering climate change through proactive ecologically friendly policies (Yuan & Zhang, 2020), while the financial inclusion agenda lowers global poverty levels by offering affordable financial services to the marginalized population (Park & Mercado Jr, 2018).

By providing capital for green initiatives and low-carbon technology, financial inclusion may encourage the use of renewable energy sources for sustainable environment. Access to financial resources increases the likelihood that people would accept cleaner energy solutions, invest in energy-efficient practices, and promote sustainable consumption, particularly in areas with low incomes (Dikshit & Pandey, 2021). Another advantage of financial inclusion is that it can help bridge the gap between environmental goals and practical implementation by effectively mobilizing resources through instruments like microfinance and green bonds.

By releasing funds for low-carbon technology and green investments, financial inclusion can serve as a catalyst for environmental sustainability and the use of

renewable energy. People are more likely to embrace cleaner energy solutions, make investments in energy-efficient practices, and encourage sustainable consumption when they have access to finance instruments, especially in marginalized communities (Zaidi et al., 2021a). Additionally, financial inclusion facilitates the efficient mobilization of resources through tools like microfinance and green bonds, which can close the gap between environmental objectives and real-world execution (Saqib, Ozturk, & Usman, 2023). Therefore, creating comprehensive and forward-looking sustainability policies requires an understanding of how financial inclusion modifies the relationship between economic growth, the uptake of renewable energy, and environmental effects.

One important technique in this regard is green bonds. The special purpose of these debt securities is to generate capital for green projects, such as energy efficiency initiatives, renewable energy projects, and sustainable farming methods (Alamgir & Cheng, 2023). Their simultaneous commitment to giving investors financial returns while guaranteeing that the funds are used for projects that have a good environmental impact is what makes green bonds special. The convergence of economic and environmental goals has made green bonds an essential instrument in the worldwide endeavor to advance environmental sustainability (Saha & Maji, 2023).

According to the “Climate Bonds Initiative” and its green bond database, with the average growth rate of 54%, green bond market has seen an impressive increase over the past five years. By the end of 2021 green bonds market was has a worth of USD 521billion, and total 2089 green bonds were issued. But after a recession in 2020, the green debt market rebounded, with volumes rising 75% in 2021 over 2020. After that the green debt market expanded quickly, but there hasn’t been much uniformity among green bonds (Climate Bonds Initiative, 2021).

Beyond just lending money, green bonds also act as a moderating factor that strengthens the link between the use of renewable energy sources and environmental sustainability. Green bonds promote the uptake and application of clean energy technology by providing a specific source of funding for renewable energy projects. Consequently, this promotes a more sustainable energy environment and speeds up the decrease of carbon emissions (R. Ahmed, Yusuf, & Ishaque, 2024).

According to empirical research, issuing green bonds is favorably connected with higher investments in renewable energy, which helps achieve more environmental objectives (Jaiswal et al., 2022).

By supplying the funding required for renewable energy projects, green bonds strengthen this relationship even more. Green bonds, which are specifically created to finance eco-friendly projects, guarantee that capital is allocated to projects that have a good environmental impact. Environmental sustainability and the use of renewable energy have advanced more significantly in nations with larger green bond issuances (Tang Zhang, 2023). Consequently, the use of renewable energy and environmental sustainability are strengthened by green bonds, which serve as an important moderating influence.

Moreover, green bonds have emerged as a transformative financial innovation that aligns capital markets with sustainability objectives. These instruments are specifically earmarked to fund projects with environmental benefits, such as clean energy infrastructure, pollution reduction, and climate adaptation initiatives (Ning et al., 2023). By providing a dedicated channel for green investments, green bonds help bridge the funding gap and mobilize private capital for public environmental goals.

The aim of this thesis is to investigate the multifaceted interaction between economic performance, renewable energy usage and environmental sustainability, with a main focus on the moderating roles of financial inclusion and green bonds. The analysis is conducted using the data of G-20 countries, this research seeks to reveal how these financial mechanisms can be leveraged to boost environmental outcomes within various economic contexts. Considering these dynamics is vital for financial institutions, policymakers and stakeholders that are committed to sustain future through informed financial and environmental strategies.

1.1 Theoretical Background

1.1.1 Stakeholder Theory

As society is one of the important stakeholders in any business and financial activity, therefore the link between environmental sustainability and green bonds is

well explained by Stakeholder theory. R. Edward Freeman proposed a stakeholder theory in 1984, which explains that the companies are obligated to consider the interest of all the stakeholders not just the shareholders, i.e. creditors, employees and society. The ignorance of society is the primary reason of environmental degradation.

The main goal of the company is to optimize the communication between all its stakeholders. By keeping the balance and interest of all stakeholders' company can attain good governance practices (Alola et al., 2022). According to stakeholder theory a company can enhance its image and reputation by demonstrating the clear picture of the company which shows the improved engagement to ecological practices, which helps the company to balance the challenging needs of many stakeholders (Nguyen, Elmagrhi, Ntim, & Wu, 2021). A firm's commitment can be seen from the issuance of green bonds, which aligns with the expectations of stakeholder and boosting company's image. A company issuing green bonds and use it to fund for energy-efficient activities will ensure to maintain the environment at any cost.

1.1.2 Ecological Modernization

The Ecological Modernization Theory proposed by Joseph Huber in 1980, who suggest that through economic restructuring and technological advancement, contemporary industrial societies may achieve sustainable environment. Ecological Modernization theory main focus is to integrate the environmental concerns into technological and economic progress for sustainable development. On the other hand, affluent, reconstructed communities inspire and drive individuals to maintain a clean environment. However, new developments, R&D, the use of green technologies, and sustainable development laws all help to track the deterioration of the environment (Yang & Khan 2021).

Ecological modernization theory suggests that via improved technology, more economical resource usage, and stricter environmental laws, industrial civilizations may separate economic expansion from environmental deterioration. According to the theory, environmental protection and economic expansion can coexist. EMT

asserts that by implementing eco-friendly technology, contemporary society can minimize environmental damage while experiencing economic growth. In line with the EMT, green technology, such as renewable energy sources, lowers CO_2 emissions and is essential to economic growth. By directing funds toward environmentally friendly initiatives that promote sustainable development, green money plays a critical role.

1.2 Problem Statement

Given the growing effects of climate change and environmental degradation, achieving sustainable environment is key necessity that has to be achieved worldwide. The rise in severe weather conditions, biodiversity loss, and expanding carbon emissions requires sudden sustainable development solutions across countries.

The G-20 countries, representing both developed and developing countries as whole that exhibit different economic performance patterns, energy change and sustainability efforts. Nevertheless, it is still unclear that how much renewable energy and economic performance subsidize to environmental sustainability, mainly financial inclusion and green bonds are taken into account as moderators.

Financial inclusion and green bonds are the two most discussed instruments in the field of finance. Financial inclusion improves access to green investments and finances, which hypothetically speed up sustainable initiatives, whereas green bonds are a vital instrument for funding environmentally friendly projects. Even though both these financial instruments vary importance, but their part in shaping relation between economic performance and renewable energy usage and environmental sustainability has not been extensively examined especially in the context of G-20 countries.

It is crucial to disclose this difference, especially keeping in mind the current conditions in which G-20 countries are endeavoring to achieve global sustainability, such as Paris Agreement. This study will attempt to investigate the impact of economic performance and renewable energy usage on environmental sustainability with the emphasis on the moderating function of financial inclusion and green bonds.

The goal of this research is to offer insights that can guide improved and effective context-specific policy arrangements that can promote sustainable development worldwide i.e G-20 countries.

To formulate the effective policies and to promote sustainable development while reducing environmental hazards in both developed and developing countries, in-depth understanding of these relationships is vital for financial institutions and policy makers and environmental strategists.

1.3 Gap Analysis

Economic development and renewable energy usage are playing vital roles in forming sustainable environment as making the environment sustainable is becoming the global concern. Many present studies have widely explored the relationship between economic performance, renewable energy usage and environmental sustainability, substantial questions remain unanswered in understanding the relative impact on developed and developing countries, specifically G-20 countries.

First of all, majority of researches are done on either developed or developing countries individually. The G-20, which includes both developed and developing nations, was chosen for this study.

Secondly, although economic performance is commonly studied factor of environmental sustainability, research frequently ignores the moderation effect of financial inclusion and green bonds. As financial inclusion can improve the capital accessibility for green investment, whereas green bonds generate finances for sustainable projects. Both have the influence on economic performance, renewable energy and their impact on environmental sustainability. Very restricted researches have accessed their interaction effects, but never in the context of G-20 countries.

Furthermore, preset literature mainly depends on conventional environmental metrics, such as carbon emissions without including the green finance mechanisms in modifying environmental degradation. More study is required to determine how well green bonds and growing financial availability in developed and developing countries can link the gap between sustainability and economic development.

Lastly, there exist a methodological gap among previous studies, as many authors rely on cross-sectional models, which limits the capability to attain long-term relationships.

So, this research used advanced econometric technique which is GMM (Generalized Method of Moments) estimation, which provides profound analysis of economic growth and renewable energy on environment sustainability, with the moderating effect of financial inclusion and green bonds.

1.4 Research Questions

Q1) Does economic performance improves the environmental sustainability, and does it contribute to the argumentation of the EKC hypothesis?

Q2) Does renewable energy usage help in environmental sustainability?

Q3) Does financial inclusion influence the relationship between renewable energy usage and environmental sustainability?

Q4) Does green bonds influence the relationship between economic performance, renewable energy usage and environmental sustainability?

1.5 Research Objectives

1. To examine the impact of economic performance on environmental sustainability, with a specific focus on its role in shaping the Environmental Kuznets Curve (EKC) relationship.

2. To examine the influence of renewable energy usage on achieving a sustainable environment.

3. To investigate the moderating effect of financial inclusion between renewable energy usage and environmental sustainability.

4. To investigate the moderating effect of green bonds between economic performance, renewable energy usage and environmental sustainability.

1.6 Significance

This study examines the relationship between economic performance, renewable energy usage on environmental sustainability of G-20 countries. Investors, policy-makers, and environmental activists should understand how financial inclusion and green bonds moderate these relationships especially when the world is dedicated to sustainable development and climate change mitigation. The way forward is to promote and adopt renewable energy usage and financial practice, this research will help government to strike a balance environmental responsibility and economic prosperity. Moreover, this study contributes to the literature on green finance by exploring how financial inclusion encourages the savings in renewable energy and mitigate the emissions. The G-20 countries provide how economic structures of both developed and developing countries impact sustainable outcomes. The significance of studying the impact of economic performance and renewable energy usage on environmental sustainability, with the moderating effect of financial inclusion and green bonds lies in its potential to notify the policy makers at a global level. As the world is facing a serious challenges of resource depletion, climate change and environmental degradation, having enough understanding of the dynamics between the variables is very crucial. This information will help financial institutions, government and international organizations to formulate strategies that will help them to strike a balance between economic expansion and environmental protection, which helps them to achieve global objective of sustainable environment. Few (SDGs) Sustainable Development Goals of the UN are substantially supported by this study. SDG 7 Affordable and Clean Energy, highlights the importance of increasing energy from renewable sources, whereas, SDG 8 Decent Work and Economic Growth, that encourages constant inclusive and sustainable economic performance. Lastly, SDG 13 Climate Action, which requires immediate measures to mitigate the consequences of climate change. By studying how economic performance and renewable energy usage affect environmental sustainability and how financial inclusion and green bonds can moderate this relationship, the important insights mention in this research will help countries link their economic strategies with SDGs. Lastly, the findings will help the countries to encourage economic growth without endangering the wellbeing of the environment.

Chapter 2

Literature Review

Environmental sustainability has become a central concern when discussing economic and energy strategies, particularly in the context of rising global emissions and climate change. As nations strive for sustainable development, the connection between economic growth, renewable energy usage, and sustainable environment has grown significant scholarly attention. The Environmental Kuznets Curve (EKC) hypothesis recommends that economic growth initially leads to environmental degradation but improves sustainability beyond a certain revenue threshold. Additionally, financial instruments such as green bonds and financial inclusion play a crucial role in facilitating green investments and promoting low-carbon transitions. This section reviews the existing literature on the linkages between economic performance, renewable energy usage, environmental sustainability, and the moderating roles of financial inclusion and green bonds.

2.1 Economic Performance and Environmental Sustainability in EKC Fitting

Maintaining a sustainable environment has occurred as a serious global priority, especially in the context of swift industrial development and economic growth, which often come at the cost of environmental degradation. In the context of G-20 countries, understanding how economic performance influences environmental sustainability is crucial, as the countries collectively account for a significant

portion of global emissions. Recent studies, such as those by [Kumari and Sharma \(2023\)](#), underline that while economic growth can drive sustainable environment, the implementation of renewable energy sources can counterbalance this effect by reducing carbon footprints and promoting sustainable practices.

Economic performance is a vital element in the pursuit of environmental sustainability, particularly within the context of G-20 countries as both developed and developing countries covered in this sector. The relationship between economic growth and sustainable environment has long been discussed, with different schools of thought offering varying perspectives ([Sadiq et al., 2023](#)). On the other hand, recent studies challenge this notion, arguing that the conversion to sustainable development requires more than just economic growth, it necessitates a fundamental shift in how economic activities are conducted, with an emphasis on decarbonization and green innovation ([Zahoor, Khan, & Hou, 2022](#)).

Present literature discovers the complex relationship between economic growth and environmental pollution, highlighting the Environmental Kuznets Curve (EKC) hypothesis, which suggests that pollution initially increases with economic growth but decreases once a certain income level is reached ([Grossman & Krueger, 1995](#)).

[Grossman and Krueger \(1995\)](#) proposed the Environmental Kuznets Curve which proposes the relationship between economic performance and environmental degradation. The theory states that when the economy develops it undergoes various stages with respect to environmental degradation. When the state of economy starts to flourish the environment, condition remains the same but eventually as the economy is at its peak it makes the environment miserable. EKC suggests three stages of economic development and environment degradation.

(i) So, at the initial level also known as low low-income level as countries are less industrialized hence the pollution level is low. Low production level and by-products keep the environmental degradation at the lower side. (ii) At the second stage production level takes its place and economic activity starts rising. With the increase in development and production comes the high level of environmental degradation which increases the pollution, resource consumption and energy consumption. (iii) At the final stage, environment degradation because the economy has reached to maturity level. The companies will invest in environmentally

friendly campaigns. This means that after reaching the specific maturity the environmental damages start declining. This is because of the shift towards the green investments, technological advancement which makes the decline in environmental degradation.

[Ji and Liu \(2024\)](#) have further explained the intricate relationship between economic performance and environmental sustainability. A study analyzing data from 276 Chinese cities found that implementing low-carbon governance strategies led to significant reductions in carbon emissions and air pollution, while simultaneously promoting economic growth.

Recent contributions to the literature also stress the importance of inclusive and sustainable economic growth. The United Nations Sustainable Development Goals (SDGs) advocate for economic progress that is not only equitable but also environmentally responsible. In this context, the concept of “green growth” has gained power, emphasizing that environmental sustainability should be embedded within economic strategies rather than treated as a trade-off (OECD, 2011). Empirical studies supporting this approach demonstrate that investment in renewable energy, innovation, and sustainable infrastructure can stimulate economic growth while reducing environmental harm ([Zoundi, 2017](#); [Nathaniel, 2021](#)).

A recent study by [Sarkodie and Owusu \(2022\)](#) revisited the EKC hypothesis using data from high- and low-income countries and found that the EKC holds primarily in nations with well-established regulatory systems and high investments in environmental research and development (R&D). In contrast, the curve fails to materialize in countries with weak governance or heavy reliance on extractive industries. This distinction emphasizes that the institutional context significantly shapes how economic performance translates into environmental outcomes.

Moreover, emerging literature is increasingly considering multidimensional indicators of economic performance, such as sustainable development indices, rather than traditional GDP alone. For example, [Murshed et al. \(2022\)](#) examined the effects of economic complexity and growth on environmental sustainability in South Asia. Their study concluded that complex, diversified economies are better equipped to reduce environmental degradation compared to economies focused on primary resource extraction. This aligns with findings by [Rahman and Alam \(2021\)](#), who

argue that the quality and inclusiveness of growth are more important than mere output expansion when assessing environmental impacts.

Post-pandemic research has also highlighted the environmental consequences of aggressive economic recovery strategies. According to [Yu, Li, Duan, and Song \(2023\)](#), stimulus-driven economic rebound in several emerging economies has led to temporary spikes in emissions due to increased industrial activity and relaxed environmental norms.

The study calls for incorporating green recovery principles in post-COVID-19 economic planning to avoid reinforcing the "grow now, clean up later" approach. Likewise, [Z. Ahmed et al. \(2022\)](#) advocate for the alignment of macroeconomic growth objectives with environmental thresholds, emphasizing that economic growth must operate within planetary boundaries to be truly sustainable.

Additionally, the literature is increasingly acknowledging the role of green finance mechanisms, such as carbon pricing, subsidies for clean technologies, and environmental taxes, in mediating the relationship between economic growth and sustainability. For instance, [Bhattacharyya and Khan \(2023\)](#) argue that without financial instruments explicitly aimed at decarbonization, economic growth is unlikely to meet climate mitigation targets set under international agreements like the Paris Accord.

Similarly, research focusing on 50 major economies demonstrated that enhancing economic intricacy alongside increased renewable energy usage, effectively mitigated ecological footprints, suggesting that advanced economic activities can co-exist with environmental preservation ([Abbas, Kousar, Sharyar, & Akhtar, 2023](#)).

Furthermore, an analysis of 124 countries over the period from 1955 to 2020 revealed that high environmental degradation correlates with increased GDP growth volatility, underscoring the necessity for sustainable practices to achieve economic resilience ([Laghari, Ahmed, & Ozturk, 2022](#)).

These findings collectively emphasize that while economic growth can pose challenges to environmental sustainability, strategic policy frameworks and investments in green technologies can harmonize economic and environmental objectives.

Hypothesis 1: *Economic performance significantly influences environmental sustainability and follows an inverted U-shaped pattern, consistent with the EKC hypothesis.*

2.2 Renewable Energy Usage and Environmental Sustainability

In our daily life energy is the necessity to promote economic growth and production and to improve the human development. While the best way to slow down the climate change is to switch towards renewable energy sources but it must be sustainable to meet future generation's energy needs. Renewable energy is documented as a vital factor in mitigating pollution by reducing the dependence on fossil fuels (Fatima, Li, Ahmad, Jabeen, & Li, 2021). Past researches have shown that the use of renewable energy resources contributes to lower carbon emissions which then helps to promote sustainable environment (Shahbaz, 2013).

Latest researches have highlighted the significance of the relationship. For example, (Tang, Liu, & Zhang, 2023) explore that by combining renewable energy into the economic structures of developing countries is crucial for meeting global climate targets. Moreover, recent literatures extend the investigation by considering county specific dynamics, technological advancements and policy framework that shape the usefulness of renewable energy in promoting sustainable environment.

Raihan and Said (2022) discovered that by reducing carbon emissions, how economic expansion, technical advancement and consumption of renewable energy sources might help Kazakhstan achieve environmental sustainability. According to the observed research, Kazakhstan's carbon emissions are increased by the economic expansion and the use of fossil fuels, but they are reduced when renewable energy sources and technical developments are used which contribute to the sustainable environment.

Another investigation explores at how energy investment and renewable energy usage interact to reduce carbon emissions in India. The study finds a long-term equilibrium link between these factors and shows that carbon emissions are greatly

decreased by higher energy investments and consumption of renewable energy. These results highlight how crucial it is to support strategic energy investments and renewable energy in order to attain sustainable environment (Bekun, 2022).

Reduction of fossil fuels, environmental degradation and the claim that the use of renewable energy can promote the living standards in developing countries have all backed to a recent surge in interest in consumption of renewable energy globally. Its connection to environmental sustainability and its combined effect on economic growth is studied by Qudrat-Ullah and Nevo (2021). Their findings confirm that renewable energy consumption have a positive association in maintaining a sustainable environment both in long and short run in Africa.

According to Hou et al. (2023), using renewable energy helps both industrialized and developing countries reduce their CO_2 emissions over the long run. This is in line with the sustainable development goals, which see renewable energy as a vital means of attaining long-term ecological balance in addition to being a tool for energy security. Adoption of clean energy is a key tactic for environmental sustainability since the transition from energy generated by fossil fuels to energy from renewable sources lessens the negative environmental effects of urbanization and industrialization.

Sadorsky (2019) suggest that the impact of renewable energy on environmental sustainability is amplified in regions with supportive regulatory environments, public awareness, and investments in green technologies. Additionally, empirical evidence shows that renewable energy development has a synergistic relationship with other sustainability indicators, such as reduced ecological footprints and improved air quality. However, some scholars argue that the transition process may present environmental trade-offs, particularly in the early stages of renewable energy infrastructure development. As a result, a holistic policy approach is needed to maximize the environmental benefits of renewables while minimizing associated risks, ensuring that energy transition aligns with broader sustainability goals (Dogan & Seker, 2016).

This study by Zeeshan et al. (2021) is the first in the region to look into how students in the western Himalayas, Jammu & Kashmir, India, perceive and interact with the environment in light of climate change policies that engage local

people for mitigation and adaptation. They were found to be quite proactive in their desire to participate in actions that lessen environmental damage. It's interesting to note that female students are more aggressive in getting involved in pro-environmental activities like solid waste management and tree planting because they are comparatively more conscious of climate change and the dangers it causes. Since environmental education is taught as an extra subject in higher education, students there are more conscious. While students in rural schools frequently take the initiative to participate directly in environmentally beneficial activities, students in urban schools are more aggressive in advocating for policies that lessen the effects of climate change. It's clear that the kids relate environmental concerns to the situations they encounter in their local communities.

Another study examines the relationship between Peru's economic progress, usage of renewable energy, expansion of agricultural area, and carbon emissions. According to the data, the value of the coefficient of renewable energy usage is negative and substantial, meaning that a 1% increase in renewable energy use leads to a 0.52% long-term decrease in CO_2 emissions. The empirical results show that using more renewable energy enhances Peruvian environmental quality by lowering CO_2 emissions (Raihan & Said, 2022).

A global climate crisis has been brought on by rising atmospheric carbon dioxide levels. The majority of research on the connection between tourism and climate change has been on how changes in the weather impact visitor attendance at tourist destinations. The relationship between foreign tourists, energy consumption, economic development, and carbon dioxide emissions in Malaysia is examined Raihan (2024).

The population, GDP, financial development, tourism, and energy consumption from fossil fuels all significantly and favorably affect CO_2 emissions. Nevertheless, his study found a negative correlation between the use of renewable energy and carbon emissions, suggesting that greater use of renewable energy could be essential to achieving Malaysia's carbon neutrality target and fostering sustainable travel by lowering emissions from the travel and tourism industry.

Hypothesis 2: *Renewable Energy Usage significantly reduces the CO_2 emissions to make the environment sustainable.*

2.3 Financial Inclusion as a Moderator between Renewable Energy Usage and Environmental Sustainability

Financial inclusion is the availability of financial services to individual to fund the range of payments, credits and make investments in sustainable way (D. Zhang, Hao, & Morse, 2020), discovered that the financial inclusion enables the access to renewable energy equipment, mainly in the underdeveloped areas. The authors highlighted that the availability of financial products helps in the implementation of solar and wind technologies, where energy access is limited. In this research financial inclusion act as a moderator enhancing the effectiveness of renewable energy policies and evolving it to make the environment sustainable.

Soyemi, Olowofela, and Yunusa (2020) talked about how financial inclusion, mainly through green financing options for less privileged people, may encourage the adaption of renewable energy. Their study reveal that that is a direct link between financial inclusion and green investments, since the businesses and families can invest in energy efficient choices when they are given the financial services. Both the consumption of renewable energy resources and ecological friendly results were seen to have a positive relation with higher financial inclusion rates.

Another study examined the association between access to clean energy and financial inclusion, claiming that the increase access of financial services can directly increase the investments in renewable energy activities. In Liu et al. (2022) study the moderating role of financial inclusion was examined to increase the benefits of energy access in enhancing the sustainable environment, as more financial systems leads to better implementation of solar and wind technologies.

Another main component of financial inclusion that gives low-income people access to renewable energy solutions like solar in microfinance (Qiu et al., 2023). The relation between energy consumption and maintaining a sustainable environment was found to be greatly influenced by financial inclusion, enabling energy transitions in areas which is ignored by banking systems. Dou and Li (2022) examined that how the role of financial inclusion in moderated the impact of investments

in renewable energy across 50 countries. Financial inclusion was found to have a promising impact to maintain a sustainable environment because it increases the capacity of both businesses and households to invest in renewable energy.

[Ghani and O'Connell \(2020\)](#) emphasize how green bonds can make renewable energy projects possible. It concludes that by making green bonds available to a wider range of people, financial inclusion increases the impact of these financial instruments. The moderating influence of financial access in environmental sustainability initiatives was demonstrated by the fact that nations with greater financial inclusion were better equipped to use green bonds to finance renewable energy projects.

[Magazzino, Mele, and Schneider \(2021\)](#) highlights that for speed-up transition to renewable energy, financial inclusion is very important in developing countries. It was found that the financial inclusion enables the access of small-scale renewable energy projects and help to make the environment sustainable. Financial inclusion enables customers to adopt clean energy solutions, thereby enhancing both energy security and environmental results in low-income regions. [Hernandez, Jordaan, Kaldunski, and Kumar \(2020\)](#) examined financial inclusion and its role in driving renewable energy investments. It found that financial inclusion in developing markets facilitates access to capital for renewable energy solutions and increases investments in sustainable energy projects.

The financial inclusion eases the transition to green growth by supporting investments in renewable energy and environmentally sustainable projects. Nations with better financial inclusion were found to have more useful policies supporting green technologies, which contributed to better sustainability outcomes ([Jacob, 2020](#)).

The implication of financial services accessibility in endorsing the use of renewable energy in South Asia was investigated by [Magazzino et al. \(2021\)](#). By facilitating access to funding for solar energy projects, financial inclusion was found to dramatically weaken the relationship between the use of renewable energy and environmental sustainability. The study made clear that extending the use of renewable energy, especially in countryside regions, requires reasonable finance structures. [Tsimisaraka et al. \(2023\)](#), analyzed the role of financial inclusion in boosting renewable energy consumption in Latin America. It found that countries

with higher financial inclusion were more successful in utilizing renewable energy as a tool for environmental sustainability. The study showed that financial inclusion helps mitigate energy access barriers, which in turn enhances the broader adoption of renewable energy technologies and promotes sustainable development.

[Asongu, Bouanza, and Nnanna \(2025\)](#), explored the relationship of renewable energy and environmental sustainability with the moderating role of financial inclusion of sub-Saharan African countries. Firstly, the result shows that the consumption of renewable energy have a negative effect on CO_2 emissions which helps in sustainable environment. Secondly, the moderating role of financial inclusion between renewable energy consumption and environmental sustainability have a negative effect which helps in reducing the carbon emissions.

Another study concentrated on Pakistan's environment from 2004 to 2021 considering the effects of financial inclusion, digital finance and renewable energy. The results revealed that the shift towards digital financial systems in Pakistan has severely supported to make the environment sustainable. The growing use of digital payment methods has decline carbon footprint and deforestation. Financial inclusion, which has been encouraged by its extensive usage has enhanced Pakistan's sustainability ([Ansari et al., 2024](#)).

Financial inclusion, in addition to ICT, has influenced the country's environmental performance in one way or another and helped the economy flourish. It is commonly acknowledged that enhancing a country's environmental performance requires the use of renewable energy. Therefore, ICT and financial inclusion can both contribute to a rise in the use of carbon-free energy. [Feng, Sun, and Sohail \(2022\)](#), have looked into how China's environmental quality and renewable energy usage are affected by ICT and financial inclusion. According to the calculations, more ATMs and overall insurance contribute to better environmental quality by reducing CO_2 emissions. Understanding the complex links between natural resource, financial inclusion, and technological innovation in the context of energy and environmental sustainability served as the impetus for ([Qamruzzaman, 2025](#)) study. The study found a concerning connection between environmental deterioration and financial inclusion. Unregulated financial inclusion has been shown to worsen environmental problems, despite the fact that it can spur economic growth.

The research emphasizes how crucial it is to match sustainability goals with financial practices in order to strike a balance between environmental stewardship and economic prosperity.

Several studies look at financial inclusion from a variety of development angles. For example, [Bayar, Ozkaya, Herta, and Gavriletea \(2021\)](#) examine the relationship between the development of the financial sector and financial access and the amount of primary energy used. They discover a negative correlation between main energy consumption and financial accessibility.

The contribution of financial inclusion to inclusive growth in Indonesia is examined by [Rumbogo, McCann, Hermes, and Venhorst \(2021\)](#). They discover that the degree of provincial GDP growth in Indonesia is substantially and favorably correlated with financial access. [Zaidi, Hussain, and Zaman \(2021b\)](#) use data from 23 Organization for Economic Co-operation and Development (OECD) nations from 2004 to 2017 to examine the relationships among financial inclusion, energy consumption, and carbon emissions. The findings show a favorable relationship between energy use, carbon emissions, and financial inclusion.

Hypothesis 3: *Financial Inclusion moderates the relationship between Renewable Energy Usage and Environmental Sustainability.*

2.4 Green Bonds as a Moderator between Economic Performance and Environmental Sustainability

[Caliari \(2024\)](#) study examine how green bonds are used as financial instruments for sustainable investments and their potential to enhance environmental outcomes.

The results indicate that green bonds offer a viable alternative to traditional financing methods, especially in mitigating the environmental impacts of economic growth. They found that countries with strong financial markets have been more successful in using green bonds to support sustainable growth. The relationship between green bonds, economic growth, and environmental sustainability in emerging

economies studied by [D. Zhang et al. \(2020\)](#) suggest that green bonds, when combined with strong economic performance, can significantly improve environmental outcomes by financing renewable energy projects and low-carbon technologies. Another study investigates the role of green bond issuance in China's economic and environmental performance. The findings highlight a positive correlation between strong economic performance and increased green bond issuance, which in turn led to enhanced investments in clean energy, reducing carbon emissions ([Li, Ma, & Tomizuka, 2019](#)).

[Odugbesan, Ike, Olowu, and Adeleye \(2022\)](#) research highlight the moderating effect of financial inclusion on the relationship between green bonds and sustainability. The results suggest that while green bonds can foster environmental sustainability, their impact is more pronounced when financial inclusion is robust, allowing wider access to green financing tools.

The research of [Pushp et al. \(2023\)](#) evaluates the use of green bonds in developed economies and their moderating effect on the relationship between economic performance and environmental sustainability. The results show that green bonds facilitate sustainable investments, leading to reduced emissions and supporting green infrastructure, especially in developed nations.

[Kedia and Joshipura \(2023\)](#) investigates the relationship between economic performance, green bonds, and sustainability in the BRICS nations. The results suggest that green bonds can enhance sustainability by financing projects that promote environmental protection and resource efficiency, especially in rapidly developing economies. The results of financial performance of green bonds issued in global markets indicate that green bonds outperform traditional bonds in markets with strong economic growth, and they significantly contribute to reducing carbon emissions by financing green technologies ([Ning et al., 2023](#)).

[Alsmadi et al. \(2023\)](#) explore how green bonds can act as a financial tool to drive environmental sustainability. The results suggest that green bonds have the potential to create significant environmental improvements, particularly in countries with growing economies that can absorb green investment efficiently. The results of relationship between green bonds and environmental sustainability in Asian economies shows that green bonds significantly contribute to environmental

sustainability, especially in countries with high economic growth and progressive environmental policies (Pandey, Kiran, & Sharma, 2022).

The role of green bonds in moderating the relationship between economic growth and environmental performance studied (Anh Tu & Rasoulinezhad, 2022) suggested that green bonds can help to decouple economic growth from environmental degradation by financing projects aimed at environmental conservation. Similarly, Kumari and Sharma (2023) examines the role of green bonds in financing projects that mitigate climate change. The results show that green bonds have been particularly effective in high-income economies, where they help to fund low-carbon technologies and contribute to both economic growth and environmental sustainability.

The findings of comparative analysis of green bonds in developed and developing economies suggest that while green bonds contribute to environmental sustainability in both contexts, their effectiveness is greater in developed economies where financial markets are more mature (Shang, Zhu, Qian, & Xie, 2023).

Y. Zhang and Umair (2023) explore the role of green bonds in Latin America. The results show that while green bonds are still in their infancy in this region, they are becoming increasingly important for financing renewable energy projects, thereby enhancing environmental sustainability and economic resilience.

Rasoulinezhad and Taghizadeh-Hesary (2022) reviews existing literature on the role of green bonds in promoting economic growth and environmental sustainability. The authors conclude that green bonds have a significant moderating effect on the relationship between economic growth and environmental sustainability, particularly in economies that are transitioning to low-carbon energy systems. Sustainable economic and social growth is seriously threatened by climate change, which is made worse by global warming. Mitigating climate change requires a shift to low-carbon energy. In order to lower CO_2 in (Ji & Liu, 2024) look into how GBs can help with the shift in demand structures and energy supply. First, CO_2 is negatively impacted by the development of GBs. Whereas the growth of GBs in southern Jiangsu has no discernible impact on CO_2 , it has an inhibiting effect in northern Jiangsu. The creation of GBs encourages the use of clean energy and directly contributes to the acceleration of the changes in the structures of energy

supply and consumption. Lastly, by promoting the structural change in the supply and consumption of energy, GBs help to lower CO_2 .

[Pang, Wu, and Zhang \(2024\)](#), examines sample data on carbon emissions and green bonds from 26 Chinese provinces. Firstly, the findings indicate that regional carbon emissions and green bond issuance have a negative correlation, indicating that a higher number of green bonds issued is linked to lower carbon emissions. Secondly, by changing energy consumption patterns or prompting the effectiveness of green technology innovation, green bonds can contribute to the reduction of carbon emissions. Additional research indicates that because developed regions have more sophisticated and abundant technology, they can have a greater impact on lowering carbon emissions than economic development alone. This implies that green bonds are a more efficient way to cut carbon emissions, which also lessens their negative effects on carbon emissions locally.

Attention is being paid to how well green finance is promoting renewable energy and sustainable development in the modern day. In order to illustrate the impact of green bonds on renewable energy investment, CEI (clean energy investment) efficiency, and sustainable environment in 29 green bond issuing nations, [Shah, Murodova, and Khan \(2024\)](#) offers an empirical framework. According to this report, renewable energy investment is driven by the issuing of green bonds. The environmental quality of the chosen nations is adequately improved by green bonds. By lowering dependency on fossil fuels, these findings support the encouragement of green bonds in boosting the movement of capital to clean energy initiatives.

Hypothesis 4: *Green Bonds moderates the relationship between Economic Performance and Environmental Sustainability.*

2.5 Green Bonds as a Moderator between Renewable Energy Usage and Environmental Sustainability

[Flammer \(2021\)](#), study found that green bonds can help firms raise capital for environmentally sustainable projects. Green bonds reduce the cost of capital and

increase investor confidence in green projects, thereby promoting renewable energy usage and environmental sustainability.

[Caliari \(2024\)](#), concluded that green bonds are an effective financing tool for renewable energy projects. By linking financial performance with sustainability outcomes, they attract a broader range of investors, thus improving the financial viability of renewable energy initiatives. Green bonds positively impact the financing of renewable energy projects, enhancing their economic viability. The study found that green bonds support the transition to sustainability by raising capital for clean energy investments, helping mitigate climate change ([D. Zhang et al., 2020](#)).

Study of [Tang et al. \(2023\)](#), reveals that green bonds improve financing access for clean energy projects, increasing the rate of adoption of renewable energy technologies. It concludes that green bonds help in accelerating environmental sustainability by bridging financing gaps for renewable energy. Also study of [Carney \(2019\)](#), highlights how green bonds serve as a crucial source of capital for renewable energy infrastructure projects, which help reduce carbon emissions and promote environmental sustainability. Green bonds facilitate investment in green technologies.

Green bonds contribute to funding green projects, including renewable energy, and play an important role in achieving environmental sustainability. They are seen as a potential solution to the financing gap for large-scale clean energy initiatives ([Hunjra, Hassan, Zaied, & Managi, 2023](#)). Green bonds were identified as a viable means to finance renewable energy projects. Their role as a moderator is significant, enabling large-scale investment in clean energy, which helps in reducing greenhouse gas emissions and achieving sustainability targets ([Udeagha & Muchapondwa, 2023](#)).

Green bonds positively influence renewable energy adoption in emerging markets by providing access to capital for green energy projects. This has a substantial effect on long-term environmental sustainability by reducing reliance on fossil fuels ([Liu et al., 2022](#)).

The study of [Yeow and Ng \(2021\)](#) found that green bonds significantly promote renewable energy investments in emerging markets. The results suggest that the

issuance of green bonds accelerates the transition to sustainable energy, improving environmental outcomes. Green bonds are effective in channeling investment into renewable energy projects. This study shows that they have a direct positive relationship with environmental sustainability by helping reduce carbon emissions and facilitating clean energy adoption (Maltais & Nykvist, 2020).

Wang, Liu, and Wang (2022), research demonstrates that green bonds play an essential role in financing renewable energy projects, which significantly contribute to achieving a low-carbon economy. The study concludes that green bonds are a key financial instrument for sustainability. He et al. (2022), paper finds that green bonds are a critical enabler of renewable energy investment in BRICS countries. They moderate the relationship between renewable energy usage and environmental sustainability by providing the necessary funding for clean energy projects.

Another study reveals a significant positive relationship between green bonds and renewable energy projects, with green bonds acting as an effective financial mechanism for supporting environmental sustainability efforts (Zou & Chau, 2023; D. Zhang et al., 2020), concludes that green bonds are essential in financing renewable energy projects in China, significantly improving the nation's environmental sustainability. Green bonds act as a catalyst for large-scale renewable energy transitions. Chen, et al., (2019) identifies green bonds as a key tool in financing the renewable energy sector, highlighting their positive impact on environmental sustainability by enabling large investments in clean energy projects.

The United States of America has encountered challenges in achieving the Sustainable Development Goals. The policy gap that exists in terms of funding clean energy generation projects is one of the main causes of this. The policy documents offer methods to deal with this problem, but they mostly overlook the covert moderations that result from the political and socioeconomic contexts. Furthermore, due to the harsh market conditions, the dependency pattern of renewable energy generation and green finance may follow a tail dependence. Sinha, Ghosh, Husain, Nguyen, and Das (2023), examines the necessity of a policy reorientation that takes these two considerations into account. The study's findings show inter-quantile dependence and that the effect of green finance on the production of renewable energy is subject to external moderating.

One important instrument for raising money for ecologically beneficial initiatives is the emergence of green bonds. They have a number of benefits. First of all, issuers can reach a wider range of investors with green bonds, including individuals who have a particular interest in sustainability. Second, they can demonstrate the issuer's dedication to resolving environmental issues and improve their reputation. Lastly, green bonds can support the shift to a cleaner economy and help the green finance industry expand (Fan, Xiong, Li, & Gao, 2023).

Renewable energy is another significant issue that should be given equal weight when discussing greenhouse gas emissions, often known as carbon emissions, and sustainable development. GHG emissions will drop if energy from renewable sources can be included into global energy networks. Growing the usage of renewable energy sources (RES) is consistent with policies in many nations that have as their main goal reducing greenhouse gas (GHG) emissions. Few studies have shown that lowering these emissions is the primary goal of encouraging green energy. According to Bilan et al. (2019), reinforcing policies that encourage the expansion of the sector of clean energy can have two long-term benefits: it can boost GDP growth and lower the amount of greenhouse gas emissions. They maintained that simultaneously advancing the development of renewable energy might have positive effects on the economy and the environment. In a similar vein, (Vasylieva, Sysoieva, & Vysochyna, 2016) argued that a 1% increase in the use of renewable energy is equivalent to a 0.166103–0.220551 decrease in GHG emissions. Their results demonstrated the enormous opportunity of sources of clean energy to reduce emissions and mitigate climate change.

Hypothesis 5: *Green Bonds moderates the relationship between Renewable Energy Usage and Environmental Sustainability.*

2.6 Research Hypothesis

Following is the summary of the hypothesis of the study.

Hypothesis 1: Economic performance significantly influences environmental sustainability and follows an inverted U-shaped pattern, consistent with the EKC hypothesis.

Hypothesis 2: Renewable Energy Usage significantly reduces the CO_2 emissions to make the environment sustainable.

Hypothesis 3: Financial Inclusion moderates the relationship between Renewable Energy Usage and Environmental Sustainability.

Hypothesis 4: Green Bonds moderates the relationship between Economic Performance and Environmental Sustainability.

Hypothesis 5: Green Bonds moderates the relationship between Renewable Energy Usage and Environmental Sustainability.

Chapter 3

Methodology

3.1 Data and Data Source

This research utilizes the panel dataset of G-20 countries for the time period of 10 years from 2014 to 2023. This research utilizes the GMM (Generalized Method of Moments) model to estimate the econometric models, addressing the issues of endogeneity and ensuring the robust results. The study investigates the direct impact of economic performance and renewable energy usage on environmental sustainability with the moderating effect of financial inclusion and green bonds. The goal of this research is to provide in-depth knowledge of differential effects observed in G-20 countries, contributing to a substantial understanding of sustainability aspects in varying economic contexts.

3.2 Variable Measurements

3.2.1 Independent Variables

3.2.1.1 Economic Performance

Economic performance is measured using the proxy GDP per capita (current US\$). It calculates the economic performance of the country by dividing the entire GDP by the population, which reflects the living standards and average income level of

the people living in a country. The data is collected from the World Development Index (WDI) website for individual country. This proxy offers a detailed sight of each country's economic growth and wellbeing.

3.2.1.2 Renewable Energy Usage

Renewable energy usage is measured using the proxy percentage of total final energy consumption that arises from renewable sources. This proxy shows a percentage of overall energy that is initiated from the renewable sources like solar, hydro, wind and biomass with respect to country's complete energy use. A greater percentage denotes a greater dependence on sustainable energy lowering the reliance on fossil fuels and carbon emissions, which is essential for sustainable energy. World Development Index (WDI) website is used to collect the data for renewable energy usage.

3.2.2 Dependent Variable

3.2.2.1 Environmental Sustainability

Environmental sustainability is measured using the proxy CO_2 emissions, which calculate the average amount of carbon dioxide released by per person in a country, which is a crucial measure for sustainable environment. The data is gathered from the WDI (World Development Index) database. This metric shows how much carbon dioxide a country omits per person.

3.2.3 Moderating Variables

3.2.3.1 Financial Inclusion

The data for financial inclusion is gathered from World Development Index and the proxy used is (commercial bank branches (per 100,000 adults)) which measures that how easily accessible banking services are to the community. Better financial access to people is indicated by the higher number of bank branches available for 100,000 adults which enables people to engage in investments, credits, and saving

activities that promote sustainability and economic growth. Financial inclusion plays as a moderator in this research.

3.2.3.2 Green Bonds

Green bond is measured by using (green bonds issuance (billions of US dollars)) which measures the total value of bonds issued by a country to fund environmentally friendly projects.

Few examples are; renewable energy usage, climate adaptive efforts and clean transportation. A country's strong commitment to sustainable finance can be seen by number of green bonds issued by a country to invests in green projects.

The data is gathered from the (International Monetary Fund) IMF website.

3.2.4 Control Variable

3.2.4.1 Inflation Rate

Inflation rate is measured by using the proxy "consumer prices annual percentage". It shows that over a year how much services and goods become expensive for consumers.

When the inflation rate is high, each unit of currency buys less amount of goods and services. In this research, the proxy captures the yearly percentage change in the average consumer prices.

The date is collected from the WDI (World Development Index) website.

3.3 Modeling

Equation 1: Impact of Economic Performance and Renewable Energy Usage on Environmental Sustainability, indicating the presence of EKC curve

$$ES_{i,t} = \beta_1 ES_{i,t-1} + \beta_2 EP_{i,t} + \beta_3 RNE_{i,t} + \beta_4 IR_{i,t} + \varepsilon_{i,t}$$

Where:

$\beta_1 ES$ is the is the lagged term for Environmental Sustainability.

$\beta_2 EP$ is the coefficient for Economic Performance.

$\beta_3 EP^2$ is the coefficient for economic performance for EKC curve.

$\beta_4 RNE$ is the coefficient for Renewable Energy Usage.

$\beta_5 IR$ is the coefficient of Inflation Rate.

Equation 2: Moderating effect of Financial Inclusion between Renewable Energy Usage and Environmental Sustainability

$$ES_{i,t} = \alpha + \beta_1 ES_{i,t-1} + \beta_2 RNE_{i,t} + \beta_3 FI_{i,t} + \beta_4 (RNE_{i,t} \times FI_{i,t}) + \beta_5 IR_{i,t} + \varepsilon_{i,t}$$

Where:

α is the constant term.

$\beta_1 ES$ is the coefficient for Environmental Sustainability.

$\beta_2 RNE$ is the coefficient for Renewable Energy Usage.

$\beta_3 FI$ is the coefficient for Financial Inclusion.

$\beta_4 (RNE$ is the coefficient for the interaction term between Renewable energy usage and Financial Inclusion.

$\beta_5 IR$ is the coefficient for Inflation Rate.

$\varepsilon_{i,t}$ is the error term.

Equation 3: Moderating effect of Green Bond between Economic Performance and Environmental Sustainability

$$ES_{i,t} = \alpha + \beta_1 ES_{i,t-1} + \beta_2 EP_{i,t} + \beta_3 GB_{i,t} + \beta_4 (EP_{i,t} \times GB_{i,t}) + \beta_5 IR_{i,t} + \varepsilon_{i,t}$$

Where:

α is the constant term.

$\beta_1 ES$ is the coefficient for Environmental Sustainability.

$\beta_2 EP$ is the coefficient for Economic Performance.

$\beta_3 GB$ is the coefficient for Green Bond.

$\beta_4(EP \times GB)$ is the coefficient for the interaction term between Economic Performance and Green Bond. β_5IR is the coefficient for Inflation Rate. $\varepsilon_{i,t}$ is the error term.

Equation 4: Moderating effect of Green Bond between Renewable Energy Usage and Environmental Sustainability

$$ES_{i,t} = \alpha + \beta_1 ES_{i,t-1} + \beta_2 RNE_{i,t} + \beta_3 GB_{i,t} + \beta_4 (RNE_{i,t} \times GB_{i,t}) + \beta_5 IR_{i,t} + \varepsilon_{i,t}$$

Where:

α is the constant term. $\beta_1 ES$ is the coefficient for Environmental Sustainability. $\beta_2 RNE$ is the coefficient for Renewable Energy Usage. $\beta_3 GB$ is the coefficient for Green Bond. $\beta_4 RNE \times GB$ is the coefficient for the interaction term between Renewable Energy Usage and Green Bond. $\beta_5 IR$ is the coefficient for Inflation Rate. $\varepsilon_{i,t}$ is the error term.

3.4 Variable Table

TABLE 3.1: Variable

Variables		Indicator	Source	Reference
Economic Per-	formance	GDP per capital	WDI	Khan et al. (2022)
Renewable Energy Usage		% of final energy use	WDI	Jahanger et al., (2022)
Financial Inclu-	sion	Commercial bank branches (per 100,000 adults)	WDI	Chien, F.S. (2023)
Green Bonds		Green Bonds Issuances by Countries	IMF	Mertzanis, C. (2024)
Environmental Sustainability		CO2 emission / Carbon emission per capital	WDI	Fu, X. (2023)
Inflation Rate		Consumer price (annual %)	WDI	Abu Bakar, Adeel, (2019)

Chapter 4

Result and Analysis

4.1 Descriptive Statistics

To list and explain the fundamental characteristics of the data in a study, descriptive statistics are employed. The table shown below 4.1 provides the summary of descriptive statistics for the variables Economic Performance (EP), Renewable Energy Usage (RNE), Environmental Sustainability (ES), Financial Inclusion (FI), Green Bonds (GB) and Inflation Rate (IR). The table provide a summary about the sample and the measures, through some sort of measures (i.e: mean, median, mode, standard deviation, range value maximum and minimum).

The following result shows in the given descriptive statistics table that the economic performance has a mean value of 4.221582, with the standard deviation of 0.525648. The given stated value indicates that the average value of economic performance may differ up to 0.5% from year to year and country to country. Thus, the minimum value of economic performance is 3.115008 and the maximum value is 4.912196. The skewness -0.77 confirms a left-skewed distribution, while the kurtosis 2.36 indicates a relatively flat distribution compared to a normal curve.

The renewable energy usage has a mean value of 1.175303, with the standard deviation of 0.314017. The given stated value indicates that the average value of renewable energy usage may differ up to 0.31% from year to year and country to country. Thus, the minimum value of renewable energy usage is 0.505150 and the maximum value is 1.698970.

TABLE 4.1: Descriptive Analysis

	EP	RNE	ES	FI	GB	IR
Mean	4.2215	1.1753	7.0276	1.2822	12.0008	3.8419
Median	4.5283	1.1818	7.1300	1.3183	2.1143	2.9000
Maximum	4.9121	1.6989	16.000	1.7060	99.4288	30.7700
Minimum	3.1150	0.5051	0.7000	0.8208	0.0040	0.1000
Std. Dev.	0.5256	0.3140	4.3509	0.2338	20.5518	3.9702
Skewness	-0.7693	-0.1828	0.4092	-0.2110	2.5179	3.1914
Kurtosis	2.3616	2.5517	2.2877	1.7323	9.3365	19.62071
Jarque-Bera	15.032	1.8125	6.3765	9.6694	354.8572	1717.023
Probability	0.0005	0.04401	0.0412	0.0079	0.0000	0.000000
Sum	548.80	152.7983	913.5900	166.6954	1560.116	499.4500
Sum Sq. Dev.	35.643	12.7202	2442.119	7.0542	54486.69	2033.440
Observations	130	130	130	130	130	130

The environmental sustainability has a mean value of 0.727615, with the standard deviation of 4.350994. The given stated value indicates that the average value of environmental sustainability may differ up to 4.3% from country to country and year to year. Thus, the minimum value of environmental sustainability is 0.70000 and the maximum value is 16.00000. Similarly, the mean values of financial inclusion and green bond is 1.282272 and 12.00089 respectively and the standard deviation 0.233846 and 20.55182. The given stated value indicates that the average value of financial inclusion and green bonds may differ up to 0.23% and 20% from year to year and country to country. Lastly, the 130 observations for each variable signifies the size of the dataset used for analysis. This sample size ensures that the descriptive statistics accurately represent the population being studied, providing confidence in the reliability and generalizability of the findings.

4.2 Correlation Matrix

Correlation matrix is the method of estimation which is used to determine the strength of the relationship between variables. The table presents the correlation coefficients between the key variables Economic Performance (EP), Renewable Energy Usage (RNE), Environmental Sustainability (ES), Financial Inclusion (FI),

Green Bonds (GB), and Inflation Rate (IR). The value of correlation between 0.1-0.3 shows the weak correlation. If the value of correlation is in the range of 0.3-0.5 then it is moderately correlated, whereas the range of correlation exceeds form 0.5 then the values are highly correlated.

TABLE 4.2: Correlation Matrix

	EP	RNE	ES	FI	GB	IR
EP	1.0000					
RNE	-0.4080	1.0000				
ES	0.7417	-0.7221	1.0000			
FI	0.5837	-0.3281	0.3054	1.0000		
GB	0.4809	0.1968	0.1530	0.0377	1.0000	
IR	-0.5037	0.1872	-0.3573	-0.3623	-0.3137	1.0000

In the table 4.2, the Economic performance is negatively correlated with renewable energy usage ($r = -0.4080, p < 0.01$) and highly correlated with environmental sustainability ($r = 0.7417, p < 0.01$). It is also positively correlated with financial inclusion and green ($r = 0.5837, p < 0.01$) and ($r = 0.4809, p < 0.05$) respectively. EP is weakly correlated with inflation rate ($r = -0.5037, p < 0.05$). Renewable energy usage is negatively but highly correlated with environmental sustainability ($r = -0.7221, p < 0.05$) and negatively and moderately correlated with financial inclusion ($r = -0.3281, p < 0.05$). It is weakly correlated with green bonds and inflation rate ($r = 0.1968, p < 0.05$), ($r = 0.1872, p < 0.05$) respectively. Environmental sustainability is highly correlated with economic performance and negatively correlated with renewable energy usage and moderately correlated with financial inclusion ($r = 0.3054, p < 0.05$). ES is weakly correlated with green bonds ($r = 0.1530, r < 0.05$) and negatively correlated with inflation rate ($r = -0.357357, p < 0.05$). Financial inclusion is weakly correlated with green bonds and negatively correlated with inflation rate ($r = 0.0377, p < 0.05$) and (-0.3623) respectively. Green bond is weakly correlated with inflation rate ($r = -0.3137, p < 0.05$).

4.3 Panel Unit Root Test

Panel unit root tests are conducted to examine if the variables are stationary or not. A variable is considered to be stationary if its statistical properties, such as its variance and mean, don't change with time. Given the numerous numbers of observations in a dataset, the panel data is likely to have unit root.

This study uses Levin, Lin & Chu (2002) and Im, Pesaran and Shin (2003), the unit root measurements to verify the unit root in a dataset. The p value and t statistics are the two factors that the approach uses to make judgement.

TABLE 4.3: Pannel Unit Root Test at Level

Variables	Levin, Lin & Chu t*		Im, Pesaran and Shin W-stat	
	Statistic	Prob.	Statistic	Prob.
EP	0.309	0.621	0.832	0.797
RNE	-3.805	0.000	0.264	0.604
ES	-4.578	0.000	-0.011	0.495
FI	-1.411	0.079	0.434	0.668
GB	-4.496	0.000	-0.174	0.430
IR	-2.211	0.013	-0.141	0.443

The above table 4.3 provides the results of two-unit tests, Levin, Lin & Chu (LLC) and Im, Pesaran and Shin (IPS), For the variables Economic performance (EP), Renewable Energy Usage (RNE), Environmental Sustainability (ES), Financial Inclusion (FI), Green Bonds (GB) and Inflation Rate (IR). Both the test aims to determine whether these time series data sets are stationary or not.

Table 4.3.1 shows the outcomes of unit root. The results indicate that the EP is stationary as per Levin, Lin & Chu but not stationary as per Im, Pesaran and Shin at level. Whereas RNE is stationary as per Levin, Lin & Chu and not stationary as per Im, Pesaran and Shin. The insignificant p-value of the Levin, Lin & Chu and Im, Pesaran and Shin indicates that there is no stationarity among the variables. Likewise, ES is stationary as per Levin, Lin & Chu but not stationary as per Im, Pesaran and Shin at level. FI is not stationary either as per Levin, Lin & chu or Im, Pesaran and Shin. GB is stationary as per Levin, Lin & Chu and not

stationary as per Im, Pesaran and Shin. Lastly, IR is stationary as per Levin, Lin & Chu and not stationary as per Im, Pesaran and Shin.

TABLE 4.4: Pannel Unit Root Test at 1st Difference

Variables	Levin, Lin & Chu t^*		Im, Pesaran and Shin W-stat	
	Statistic	Prob.	Statistic	Prob.
EP	-8.193	0.00	-4.120	0.000
RNE	-2.594	0.00	-2.786	0.002
ES	-4.140	0.00	-2.311	0.010
FI	-8.679	0.00	-3.197	0.000
GB	-7.631	0.00	-4.033	0.000
IR	-5.294	0.00	-2.203	0.013

To make all the variables stationary existing study run unit root test at 1st difference and the results of the panel unit root test are presented in Table 4.4. The results from both the Levin, Lin & Chu (LLC) and Im, Pesaran, and Shin (IPS) tests indicate that all variable Economic Performance (EP), Renewable Energy Usage (RNE), Environmental Sustainability (ES), Financial Inclusion (FI), Green Bonds (GB), and Inflation Rates (IR) are stationary at 1st difference. All the variables for LLC test have a highly significant p-values (0.0000), which leads to the rejection of the null hypothesis of a unit root test. Whereas, IPS test confirms the stationary for all the variables, with p-values below 0.05 which is the condition for significance level.

The findings suggests that the variables do not require differencing to achieve stationarity, making them suitable for econometric modeling without transformations.

4.4 Results of GMM Estimation

An effective statistical and econometric method for estimating parameters and testing hypotheses in complex models is the Generalized Method of Moments (GMM). In the domains of statistics, finance, and economics, GMM is now a vital tool.

Heteroscedasticity, endogeneity, and other problems that come up in empirical research are especially well-suited for GMM. . Endogeneity, which occurs when lagged dependent variables correlate with error terms, is a major problem in the dynamic panel model.

The outcomes of estimations may be skewed by this association. The Generalized Method of Moments (GMM), which use instruments to get reliable results, can be used to address this problem. The variables that exhibit a correlation with the endogenous regressor but not with the error term are known as these instruments. By choosing values that correspond to observed moments and their theoretical equivalents, GMM is used to estimate a model's parameters. GMM estimator was implemented using orthogonal deviations in EViews.

The Arellano–Bond AR(1) and AR(2) serial correlation tests were not applied in this study because they are specifically derived under the first-difference transformation, and therefore their direct application is not valid when orthogonal deviations are used. The findings obtained are shown in table 4.4 below

4.4.1 Effect of Economic Performance and Renewable Energy Usage on Environmental Sustainability, Indicating the Presence of EKC Curve

$$ES_{i,t} = \beta_1 ES_{i,t-1} + \beta_2 EP_{i,t} + \beta_3 EP_{i,t}^2 + \beta_4 RNE_{i,t} + \beta_5 IR_{i,t} \quad (4.1)$$

The first consist of the effect of economic performance and renewable energy usage on environmental sustainability. The lagged value of ES is positive and highly significant, indicating strong persistence in environmental sustainability over time.

Approximately 47.63% of the previous period's sustainability level impacts the current period, suggesting a dynamic relationship where past sustainability directly influences present outcomes.

Economic performance has a significant yet positive effect on environmental sustainability. A 1-percentt increase in EP increases CO_2 emissions by 0.363962 percent. This suggests that economic growth can contribute to poor environmental outcomes, possibly due to more resources for environmental initiatives ([Ali et](#)

TABLE 4.5: Impact of EP and RNE on ES

Variable	Coefficient	Std. error	t-Statistics	Prob.
ES(-1)	0.4763	0.0477	9.9677	0.0000
EP	0.3639	0.1352	2.6903	0.0197
EP ²	-0.0466	0.0179	-2.6045	0.0230
RNE	-0.2733	0.0488	-5.5917	0.0001
IR	0.0051	0.0021	2.3734	0.0352
Mean dependent var	0.0187	S.D. dependent var		0.0248
S.E. of regression	0.0152	Sum squared resid		0.0231
J-statistic	30.9992	Instrument rank		38
Prob(J-statistic)	0.5670			

al., 2023). The squared economic performance EP^2 term is negative and significant. This suggests a non-linear, inverted U-shaped relationship between EP and ES, consistent with the Environmental Kuznets Curve (EKC). This study examines the impact of economic performance in the EKC fitting which also checks the validity of EKC curve for the full sample. The result shows that the EKC testing indicate the validity of U-shaped curve in the panel dataset. It means that initially when economic performance increases CO_2 emissions also increase, which implies the downfall of sustainable environment during the early stages of economic growth. However, the negative coefficient of EP2 indicates that after a certain point of economic development, further increase leads to a decrease in CO_2 emissions, which improves sustainable environment.

Renewable energy usage RNE has a negative and highly significant effect on environmental sustainability. A 1-percent increase in RNE reduces CO_2 by 0.273 percent. Many researchers who have studied the similar relation in developing countries got the similar association between renewable energy usage and environmental sustainability (Said & Acheampong, 2024). Hence the effect varies from country to country. This indicate that use of renewable energy helps in maintain the sustainable environment. These results are aligned with (Usman, Alola, & Saint Akadiri, 2022).

4.4.2 The Moderating Effect of Financial Inclusion between Renewable Energy Usage and Environmental Sustainability

$$ES_{i,t} = \beta_1 ES_{i,t-1} + \beta_2 RNE_{i,t} + \beta_3 FI_{i,t} + \beta_4 (RNE_{i,t} \times FI_{i,t}) + \beta_5 IR_{i,t} \quad (4.2)$$

The results from the GMM estimation examine the impact of RNE (Renewable Energy Usage), FI (Financial Inclusion) and IR (Inflation Rate) on ES (Environmental Sustainability) while considering the moderation effect of FI (Financial Inclusion).

TABLE 4.6: Moderating Effect of FI between RNE and ES

Variable	Coefficient	Std. error	t-Statistics	Prob.
ES(-1)	0.4316	0.0279	15.4491	0.0000
RNE	0.3166	0.1808	1.7508	0.0435
FI	0.6009	0.1976	3.0404	0.0031
RNE*FI	-0.4693	0.1616	-2.9033	0.0047
IR	0.0067	0.0024	2.7978	0.0063
Mean dependent var	-0.0062	S.D. dependent var		0.0176
S.E. of regression	0.0159	Sum squared resid		0.021930
J-statistic	7.3711	Instrument rank		14
Prob(J-statistic)	0.5985			

The results of the second model are shown in table 4.6. The moderation effect of financial inclusion between renewable energy usage and environmental sustainability has a negative coefficient yet significant affect which indicates that when the moderation effect of financial inclusion lined with the use of renewable energy

reduces the CO_2 emissions. A 1% increase in the interaction term causes the CO_2 emissions to decrease by 0.469335 percent. This finding implies that financial inclusion amplifies the beneficial environmental effects paired with renewable energy usage. As more individuals and businesses gain access to financial services, they may invest in cleaner technologies, energy-efficient solutions, and make use of Wind, solar, hydro and biomass for cleaner activities and sustainable practices thereby reducing CO_2 emissions (Musah, 2024).

4.4.3 The Moderating Effect of Green Bonds between Economic Performance and Environmental Sustainability

$$ES_{i,t} = \beta_1 ES_{i,t-1} + \beta_2 EP_{i,t} + \beta_3 GB_{i,t} + \beta_4 (EP_{i,t} \times GB_{i,t}) + \beta_5 IR_{i,t} \quad (4.3)$$

Equation 4.3 examines the impact of EP (Economic Performance) on ES (Environmental Sustainability) with the moderation effect of, GB (Green Bonds).

The result shows that significance result for the moderation effect which indicates that higher green bond issuance promotes the sustainable environment. The negative coefficient indicates that the green bonds issuance in the market decreases the CO_2 emissions. This finding is aligned with the findings of Alamgir and Cheng (2023).

The relationship between economic performance and environmental sustainability with the moderating role green bonds indicates that when a country's economic performance gets better, country will purchase more financial instrument which are specifically used to fund environmentally friendly projects which then makes the environment sustainable by declining the CO_2 emissions from the environment. This means that as economic performance improves, the presence of green bonds enhances its positive impact on environmental sustainability. The results align with Ordonez-Borrillo, Ortiz-de-Mandojana, and Delgado-Ceballos (2024).

The GMM results confirm that economic performance, when combined with green bonds, has a stronger impact on environmental sustainability. Their interaction with economic growth enhances their effectiveness in promoting sustainability.

TABLE 4.7: Moderating effect of GB between EP and ES

Variable	Coefficient	Std. error	t-Statistics	Prob.
ES(-1)	0.5462	0.0778	7.0144	0.0000
EP	0.0243	0.0095	2.5617	0.0122
GB	0.1291	0.0326	3.9511	0.0002
EP*GB	-0.0347	0.0079	-4.3731	0.0000
IR	0.0086	0.0028	3.0185	0.0033
Mean dependent var	0.0173	S.D. dependent var		0.0234
S.E. of regression	0.0156	Sum squared resid		0.0209
J-statistic	32.7676	Instrument rank		38
Prob(J-statistic)	0.4786			

Policymakers should focus on ensuring that green bonds are efficiently utilized in environmental projects and that economic growth is aligned with sustainable practices.

4.4.4 The Moderating Effect of Green Bonds between Renewable Energy Usage and Environmental Sustainability

$$ES_{i,t} = \beta_1 ES_{i,t-1} + \beta_2 RNE_{i,t} + \beta_3 GB_{i,t} + \beta_4 (RNE_{i,t} \times GB_{i,t}) + \beta_5 IR_{i,t} \quad (4.4)$$

The Generalized Method of Moments estimation examines the impact of RNE (Renewable Energy Usage) on ES (Environmental Sustainability) with the moderating effect of GB (Green Bonds).

Table 4.7 shows the results of impact of renewable energy usage on environmental sustainability with the moderating effect of green bond. The results indicate that the moderating role of green bonds between renewable energy usage and environmental sustainability helps in sustainable environment. The negative and significant coefficient of the interaction term confirms the moderating role of green

TABLE 4.8: Moderating Effect of GB between RNE and ES

Variable	Coefficient	Std. error	t-Statistics	Prob.
ES(-1)	0.4938	0.0634	7.7801	0.0000
RNE	-0.2980	0.0444	-6.6983	0.0000
GB	0.0099	0.0052	1.9116	0.0588
RNE*GB	-0.0107	0.0053	-1.9960	0.0487
IR	0.0001	0.0005	0.3428	0.7325
Mean dependent var	0.0187	S.D. dependent var		0.0248
S.E. of regression	0.0149	Sum squared resid		0.0221
J-statistic	37.098	Instrument rank		39
Prob(J-statistic)	0.3280			

bonds in enhancing the environmental benefits of renewable energy. This means that when countries issue green bonds to support renewable energy, the reduction in CO_2 emissions is even greater, improving environmental sustainability more effectively than renewable energy usage alone. This result is consistent with prior studies such as [Tang et al. \(2023\)](#), which emphasize the role of green bonds in promoting environmental performance by funding cleaner energy projects and increasing the impact of sustainable investments.

Chapter 5

Discussion and Conclusion

5.1 Discussion

In this chapter, the results of the findings are discussed. The discussion about the research hypothesis is also discussed in this chapter, whether the hypotheses are accepted or rejected. It also includes the practical implication of the study in this section. Directions for future studies are also mentioned in the chapter. Like every other study, this study also has some limitations that can be overcome in further studies. And lastly, the summary of this research in the conclusion section is also present.

The key reason of this research was to access the Environmental Kuznets Curve (EKC) hypothesis through the impact of economic performance, and the impact of renewable energy on environmental sustainability with the moderating role of financial inclusion and green bonds. Economic performance and renewable energy are the dependent variables of this study whereas environmental sustainability is the independent variable. Financial inclusion and green bond are the moderator between dependent and independent variables. For this study, the data of G-20 countries is collected. The data was collected from World Development Index (WDI) and International Monetary Fund (IMF) websites.

Given below are the hypothesis wise discussion which will state whether the hypothesis is accepted or rejected.

Hypothesis 1: Economic performance significantly influences environmental sustainability and follows an inverted U-shaped pattern, consistent with the EKC hypothesis.

Hypothesis 1 states that the economic performance have a significant impact on environmental sustainability. Environmental conditions have a substantial impact by economic performance. Higher economic activity can, result in increased numbers of individuals using resources and causing environmental damage. Increased industrialization, energy use, and resource exploitation during the early phases of economic expansion can result in environmental deterioration, including increased CO_2 emissions, pollution, and deforestation. Richer economies frequently start making investments in greener technologies, enforcing environmental laws, and moving toward service-oriented industries, all of which improve sustainability results.

The results validate the EKC hypothesis by confirming the existence of an inverted U-shape curve through the positive coefficient of economic performance (EP) and the negative coefficient of its squared component (EP^2). This suggests that economic performance weakens environmental sustainability until a certain point, at which point additional growth improves sustainability, mostly as a result of structural change, technical advancement, and the implementation of green policies.

This twofold effect has been confirmed by empirical research. For instance, [Shahbaz \(2013\)](#) discovered that while economic expansion initially raises CO_2 emissions, after a particular income threshold is reached, it eventually aids in the reduction of CO_2 emissions.

The hypothesis is based on the Environmental Kuznets Curve (EKC) theory, which suggests that there is an inverted U-shaped, non-linear relationship between economic performance and environmental sustainability (indicated by CO_2 emissions). Industrialization, urbanization, and rising energy use tend to raise emissions and worsen the environment in the early phases of economic growth. But when a nation develops, its priorities progressively change to cleaner technologies, environmental laws, and public awareness, which reduces environmental destruction even as incomes keep rising.

The results validate the EKC hypothesis by confirming the existence of an inverted U-shape through the positive coefficient of economic performance (EP) and the negative coefficient of its squared component (EP)². This suggests that economic performance weakens environmental sustainability until a certain point, at which point additional growth improves sustainability, mostly as a result of structural change, technical advancement, and the implementation of green policies.

The EKC theory was initially supported by [Grossman and Krueger \(1995\)](#), who discovered that when CO_2 emissions rise with income to a certain degree, then it starts declining when income rises further. After doing a thorough analysis of the EKC literature, [Dinda \(2013\)](#) came to the conclusion that the association is valid for a number of environmental indicators, particularly in high-income nations. [Shahbaz \(2013\)](#) demonstrated the impact of economic structure and energy intensity on environmental consequences by presenting EKC findings in relation to energy consumption and CO_2 emissions. In a panel of 46 Sub-Saharan African nations, [Acheampong \(2019\)](#) validated the EKC pattern, indicating that environmental advantages can arise with wealth growth so long as robust governance and renewable energy regulations are in place.

Hence null hypothesis is accepted for the validation of EKC curve in economic performance.

Hypothesis 2: Renewable energy usage has a significant impact on environmental sustainability.

Hypothesis 2 stated that the renewable energy usage has a significant yet negative impact on environmental sustainability. This hypothesis is accepted, as the result shows that the more usage of renewable energy will decrease the CO_2 emissions from the environment making the environment sustainable. Many literatures are in line with this hypothesis of [Bekun \(2022\)](#) and [He et al. \(2022\)](#). The hypothesis suggests that the extent to which a country utilizes renewable energy resources that is solar, wind and hydro plays a crucial role in defining the level of sustainable environment, which is measured by the proxy CO_2 emissions. The empirical results mean that increasing the share of renewable energy in a country's total energy consumption level leads to better environmental outcomes. The impact is significant because reducing pollution and promoting sustainability. [Raihan and Said \(2022\)](#) argued

that the use of renewable energy and use of technology innovation are the key factors for sustainable environment in Bangladesh. Owusul and Sarkodie studied the use of renewable energy in Turkey and argued that turkey has always been an energy importer, but over the time the country has realized and consuming fuelwood which is a type of renewable energy to sustain their environment. The authors suggested that the exploration of coal, oil and natural resources should continue to have a sustained developed in energy sector. [Kaygusuz \(2021\)](#) argued that there are number of environmental problems faced in Turkey for the past few years but the technology of hydropower, biomass energy and natural resources like wind and hydro have helped in achieving the sustainable environment.

The summary of all the arguments stated that the high use of renewable energy helps largely in maintaining the environment sustainable. Thus, it could be concluded that the hypothesis 3 is supported by the discussion provided. So, the hypothesis 2 which is renewable energy usage has a significant impact on environmental sustainability is supported by given literatures.

Hypothesis 3: Financial inclusion moderates the relationship between renewable energy usage and environmental sustainability.

The hypothesis 3 suggests that the effect of financial inclusion as a moderator influence how effectively renewable energy usage impacts environmental sustainability. It means the existence of strong financial inclusion where people and businesses have easy access to affordable and adequate financial services, can weaken or strengthen the effect that usage of renewable energy has on environment.

Financial inclusion enables the community and enterprises to invest in renewable energy like solar panels, energy efficient technology which will have a positive impact on environment. Several studies have emphasized the role of financial systems in promoting environmental objectives. For instance, ([Sarkodie & Owusu, 2022](#)) highlighted the importance of green financing in bridging the gap between renewable energy potential and actual implementation. Similarly, [Baloch, Ozturk, Bekun, and Khan \(2021\)](#) found that financial inclusion can indirectly support environmental quality by facilitating access to environmentally friendly technologies. With better access to finance, small and medium enterprises (SMEs) in developing countries can adopt cleaner technologies, while low-income households can

shift away from biomass and fossil fuels toward cleaner alternatives (Yoshino & Taghizadeh-Hesary, n.d.).

On the other hand, if financial access is not directed towards sustainable purposes, it may lead to increased consumption or investments in carbon intensive sectors, dampening the environmental benefits of renewable energy. For example, if loans and financial services are used to purchase fossil-fuel vehicles or expand polluting industries, the moderating effect could turn negative. With the help of above arguments, it can be said that the hypothesis is validated by the results.

Hypothesis 4: Green bonds moderate the relationship between economic performance and environmental sustainability. The moderating effect of green bonds on the relationship between environmental sustainability (ES) and economic performance (EP) is investigated in this hypothesis. It implies that how well green bonds are used within a country's financial system that affects how economic performance affects environmental results. Green bonds are financial products created especially to finance initiatives that have a good impact on the environment or on the climate, like the development of renewable energy, sustainable infrastructure, and pollution prevention (Flammer, 2021). Different countries may see different effects on the environment as a result of economic expansion. Ecological systems can be protected, carbon emissions can be decreased, and cleaner energy use may be encouraged if economic growth is accompanied by a rise in the issue of green bonds (Tolliver, Keeley, & Managi, 2020).

In this research, green bonds serve as a channel for reducing the environmental consequences of economic activity. They improve sustainability by making sure that the money made during economic growth is distributed in an ecologically conscious way. Green bonds have the potential to either strengthen the environmental consequences of economic performance or mitigate the negative environmental effects, including pollution or resource depletion, as a moderating variable.

Many literatures are in line with this result. According to Flammer (2021), companies who issue green bonds see an improvement in their environmental performance. Similarly, Tolliver et al. (2020) highlighted the use of green bonds in funding low-carbon development and climate mitigation plans. Furthermore, Wang et al. (2022) claim that by lessening the environmental impact of economic

activity, green bond markets aid in the shift to a sustainable economy. Hence the hypothesis 4 holds true based on the analysis.

Hypothesis 5: Green bonds moderate the relationship between renewable energy usage and environmental sustainability.

This hypothesis examines the impact of moderation effect of green bonds between renewable energy usage and environment sustainability. Actually, it suggests that the efficiency of renewable energy for enhancing the environmental consequences that includes reduction in pollution and carbon emissions may be improved or reduced based on the funding of green bonds available.

Renewable energy plays a critical role in reducing greenhouse gas emissions, improving air quality, and promoting a cleaner energy mix. However, the large-scale adoption and deployment of renewable technologies such as solar, wind, hydro, and biomass which often face substantial financial barriers, especially in developing economies. These projects typically require significant upfront capital investments, long payback periods, and supportive infrastructure, all of which can limit their expansion without adequate financial support [Versal and Sholoiko \(2022\)](#). The green bonds are financial instruments that are formed particularly to fund environmentally friendly activities, like clean transportation, efficient use of energy and mitigation of climate change. When the businesses and countries issue green bonds to finance environmentally friendly projects it mobilizes large scale investments in renewable energy infrastructures, which can have more significant impact to maintain a sustainable environment ([Flammer, 2021](#)). Countries that issue high number of green bonds, renewable energy projects tend to be well implemented, which gives a positive effect and leads to greater reduction in carbon emissions and environmental degradation ([Thag & Zhang, 2022](#)). Furthermore, by ensuring effective resource allocation, green bonds enhance accountability and transparency in environmental projects ([Maltais & Nykvist, 2020](#)). When the development banks, government and businesses issues green bonds, they offer the specific financing that specially help in scaling up the renewable energy projects which in turn strengthens the scope of renewable energy activities. Therefore, when green bonds are actively regulated, it tends to strengthen the relationship between renewable energy usage and environmental sustainability.

Hence, this hypothesis suggests that the relationship between two different relations finance and environment, that is how green bonds can bring shift to the environment and cause in low carbon economy. Therefore, the results support the hypothesis.

5.2 Practical Implication

The study's findings have a number of practical implications for financial regulators, policymakers, and financial strategists. Firstly, the results highlight the how essential is to combine investments in renewable energy and economic growth strategies in order to achieve the sustainable development goals.

Energy efficient technologies and green infrastructure that contribute to the long-term environmental assistance without compromising economic growth should be prioritize by policymakers in G-20 countries.

Secondly, this research emphasizes on how crucial is the role of financial inclusion in advancing environmental sustainability. Government should encourage population to increase their participation in energy savings projects, green financing schemes and environmentally friendly consumption designs by increasing the access to financial services.

This will help the economy to become more ecologically aware as a result of financial inclusion, which also helps in guiding investment opportunities in sustainable options. Additionally, the significant impact of green bonds implies that the financial markets can transform the environment.

Central banks and policymakers are advised to facilitate the growth of well-regulated green bond markets to draw attention of both foreign and domestic investors.

Lastly, this research emphasizes on how important it is to have coordinated policy framework that match the environmental objectives with financial innovation.

This involves creating a cross-sectoral partnerships between financial institutions, government and environmental organizations to make strategies that are both environmentally as well as economically beneficial.

5.3 Limitation of Research

Every research has limitation, a researcher can try hard to fulfill the criteria and fill in the gaps but that is not possible.

This research nevertheless also faced some limitations however, due to limited time and lack of resources I was unable to fill in all the gaps. But I disclose all the areas that has to be considered for the future researches.

For the analysis of this research, I used secondary data collected from World Development Indicators (WDI) and International Monetary Fund (IMF), which have gaps in data. The findings validity may be limited because of the inconsistent and lack of missing data across countries.

The data for green bonds was unavailable and scarce for some countries, especially for the developing countries due to the less developed financial markets, which leads to the biases while examining the impact of green bonds.

This research includes G-20 countries which comprises of both developed and developing countries that are quite diverse in terms of political, economic and institutional traits. These groups may differ greatly in how well green bonds and financial inclusion works, as a result the findings could not fully reflect the opportunities and challenges faced by individual country. Pakistan being not part of the G-20 group might have faced adequate challenges.

The research estimates the model using Generalized Methods of Moments (GMM) which assumes that the variables in the model are properly stated. However, bias maybe introduced into the results if endogeneity problems or omitted variables are not been taken into consideration.

For example, the model cannot account for external factors that can affect renewable energy usage and environmental sustainability like technological advancement, political stability etc.

Another limitation of this study is the time period that is chosen for the data. If the time frame does not adequately capture long-term effects, the assumptions can be skewed towards short-term dynamics, mainly in the case of developing countries.

5.4 Future Directions

This study analyzed the impact of economic performance and renewable energy usage on environmental sustainability with the moderating role of financial inclusion and green bonds. The current research is conducted using the G-20 countries which includes both developed and developing countries. Based on the findings and limitation of this research, there are several future directions that can be further explored to deeply understand the relationships between economic performance, renewable energy usage, green bonds, financial inclusion and environmental sustainability. This research used green bonds and financial inclusion as moderators, other factors like green finance and technological innovation can also help in shaping sustainable environment. Future researches can extend the time frame of the study to examine the long-term impact of economic growth and usage of renewable energy on environmental sustainability. The study mainly focused on G-20 countries, which may or may not have significant economic power because of the combined countries. Future studies could be done on the countries having same economic power like BRICS or G-7 or the research could enlarge the geographical scope of same regions. Because these regions have same opportunities and developmental challenges which helps in better understanding of how financial inclusion and renewable energy usage impact environmental sustainability which will provide the broader vision for policymakers.

Future studies can access the type of renewable energy specifically like solar, wind and hydropower, and study how each type contributes to environmental sustainability. The influence of different energy sources vary differ, and to understand that which type is more effective in different settings could assist in tailoring the energy policies for best environmental outcomes.

5.5 Conclusion

This research examined the EKC hypothesis through the relationship of economic performance, renewable energy usage and environmental sustainability with moderating role of financial inclusion and green bonds within the context of G-20

countries. The empirical outcome shows the significant understanding into the dynamics between these variables and their impact to achieve sustainable environment.

This study examines the impact of economic performance in the EKC fitting which also checks the validity of EKC curve for the full sample. The result shows that the EKC testing indicate the validity of U-shaped curve in the panel dataset which means that at lower levels of income, economic growth harms the environment, but at a higher level, it helps in reduction of CO_2 emissions, which forms an inverted U-shaped curve (EKC).

On the other hand, renewable energy usage has a significant relation with the environmental sustainability meaning that the more use of renewable energy resources helps in the reduction of CO_2 emissions which makes the sustainable environment. The interaction of financial inclusion between renewable energy usage shows a significant impact on environmental sustainability, suggesting that the immediate improvement of these variables enhances the sustainability outcomes.

The higher levels of financial inclusion enhance the effectiveness of renewable energy in reducing CO_2 emissions, thereby strengthening environmental outcomes. These findings highlight the importance of accessible financial systems in supporting the clean energy transition and achieving long-term sustainability goals.

Another moderating role is studied in this research which is green bonds. The results of green bonds as a moderator between economic performance, renewable energy and environmental sustainability amplifying the positive impact on environment. Green bonds can drive investments in sustainable projects, contributing to both economic and environmental progress.

However, the interaction between renewable energy and green bonds also showed positive results, suggesting that more use of renewable resources to invest in clean technologies enhances the environment and by utilizing the renewable energy it will help to make the environment sustainable.

This thesis provides compelling evidence of the compound relationships between economic performance, renewable energy, financial inclusion, green bonds, and environmental sustainability. The results pave the way for additional research on

financial inclusion and green bonds, a recent variable with little literature. Policymakers must consider these dynamics when designing strategies for achieving long-term environmental sustainability in the context of both developing and developed economies.

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