Impact of Green bond on renewable energy transition

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ABSTRACT

This study examines the influence of green bond issuance on renewable energy consumption across 192 countries from 2007 to 2021. The findings reveal a promoting effect of green bond issuance on renewable energy transition, suggesting that green bonds serve as an effective financial mechanism for mobilizing private capital investment in renewable energy projects. This research contributes novel insights into the efficacy of green bonds in driving renewable energy utilization, particularly in countries with higher CO_2 emissions. The results underscore the importance of expanding green bond issuance to support the transition towards renewable energy sources and suggest policy interventions to encourage their utilization, including the implementation of supportive frameworks and government incentives to attract private investment and accelerate sustainable development efforts.

1. Introduction

The world's energy demand is continuously rising due to industrialization and population growth (Filho et al., 2022; Liu & Bae, 2018). To meet this ever-growing need, most countries rely heavily on fossil fuels, including coal, oil, and natural gas, as primary energy sources for residential, commercial, and industrial activities. Fossil fuels are crucial, accounting for approximately 88% of the global commercial energy sources used (Judkins et al., 1993). However, the excessive dependence on fossil energy resources for economic growth and expansion has led to numerous environmental threats, affecting ecological systems, biodiversity, and human well-being (Shang et al., 2023). Overexploitation of these resources increases pollution and contributes to global warming and climate change (Casper, 2010; Jiang et al., 2022). Moreover, these energy sources are finite and cannot be rapidly replaced once depleted. Therefore, a necessary and effective strategy to address ongoing environmental issues and meet the expanding energy demands of the population is the transition to clean sources of energy, renewable energy.

The transition from fossil fuels toward renewable energy sources like solar, wind, biomass, and hydro (Imteyaz & Tahir, 2019; Ou et al., 2018), is essential for achieving a greener and cleaner future (Imteyaz et al., 2021; Pilz et al., 2018). Unlike fossil fuels, renewable energy is much more sustainable than non-renewable ones since it can be replenished naturally over time. These resources offer alternatives for nations looking for secure energy resources since they can be utilized to enhance environmental quality without causing environmental damage (Khan et al., 2021). Above all, it helps mitigate climate change and diminishes its associated environmental and people health impacts (Panwar et al., 2011). According to Dong et al. (2017), Goh and Ang (2018), the transition from fossil fuels to environmentally friendly power sources, like renewable energy, leads to a reduction in CO_2 emission, making it a viable alternative for

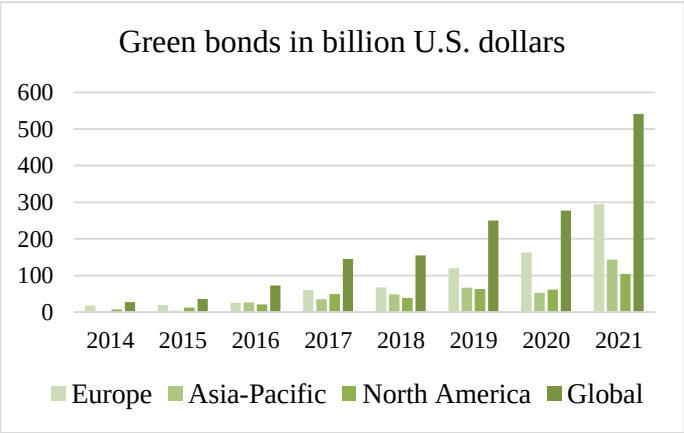
tackling global warming issues. Furthermore, the Clean Development Mechanism (Lewis, 2010; Shi et al., 2021) also encourages the uptake of renewable energy technologies, which is aimed at promoting clean energy development projects in developing countries, thus promoting economic growth (Bhattacharya et al., 2017). These above reasons make renewable energy an ideal candidate to help countries achieve sustainable development when focusing on promoting the energy transition. Importantly, it is essential to develop a mechanism for pooling financial markets effectively to fund eco-friendly initiatives aimed at boosting the adoption of green energy, thereby benefiting natural resources positively (Chuc et al., 2021; Li et al., 2021).

Sound financial systems have enormous potential to influence the energy transition (Hall et al., 2017; Mugume & Bulime, 2024; Saadaoui & Chtourou, 2023). Moving towards renewable energy transition is capital-intensive because the initial startup cost is much higher than fossil fuel energy sources (Liu et al., 2023; Mugume & Bulime, 2024). Despite the considerable reduction in overall costs associated with renewable energy production in recent years owing to technological advancements (IRENA, 2020), there hasn't been a proportional rise in investment. Furthermore, with the shifts in policies and the scale of capital involved, investors are becoming more cautious about assuming investment risks (Qadir et al., 2021), making the financing of the renewable energy transition one of the foremost challenges. In 2021, investments in renewable energy were USD 517 billion, representing only 22.26% of the USD 2.3 trillion in total energy sector investments, while investments in fossil fuels reached approximately 40% (International Energy Agency [IEA], 2021). The transition to renewable energy requires developing and deploying new technologies and innovations. Consequently, addressing the financial barriers to renewable energy development will emerge as a crucial issue shortly.

Since the World Bank was first issued in 2007, green bonds have gained significant attention as a way to fund environmentally friendly projects and connect investors with green initiatives. Green bonds have rapidly expanded in the international capital market, reaching a record issuance of USD 305 billion in 2020 - A 63% increase from the previous year. According to Statista Search Department (2024), global green bond issuance grew from USD 37 billion in 2014 to over USD 620 billion in 2023, a 16-fold increase. Figure 1 illustrates that Europe is the leading region for green bond issuance, with approximately USD 265 billion issued in 2021. This sharp rise underscores the crucial role of green bonds in fostering a sustainable economy, particularly in developing nations where government funding for green projects is limited (Bhutta et al., 2022).

Figure 1

Issued Green Bonds in Different Regions, 2014 - 2021, Billion US Dollars

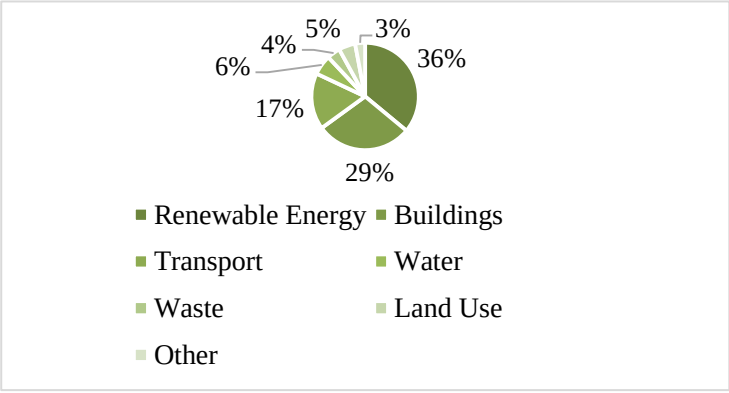


Source. The data are from "Value of green bonds issued worldwide from 2014 to 2023" by Statista Search Department, 2024 (https://www.statista.com/statistics/1289406/green-bonds-issued-worldwide/)

Promoting green bonds offers a sustainable solution for countries aiming for long-term energy efficiency (Bhutta et al., 2022; Ye et al., 2023). Studies have demonstrated that green bonds can unlock substantial capital and significantly support efforts to combat climate change and other environmental challenges (Gao et al., 2020). This financing tool not only mitigates risks associated with green investments but also enhances returns, thereby incentivizing private investors to participate in renewable energy projects (Lin et al., 2022; Ning et al., 2022). According to the Climate Bond Initiative (CBI, 2022), green bonds and loans are commonly used to fund renewable energy, waste, and pollution projects, clean transportation, and green building, with renewable energy projects comprising the largest share of global green bond issuance in 2021. Investing in renewable energy through green bonds is crucial for establishing long-term energy solutions, making it essential to evaluate the relationship between green bonds and energy efficiency to provide valuable insights for countries (Rasoulinezhad & Taghizadeh-Hesary, 2022).

Figure 2

Use of Proceeds from Green Bonds and Green Loans in 2021



Source. The data are from "Sustainable debt global state of the market" by Climate Bond Initiative, 2022 (https://www.climatebonds.net/files/reports/cbi_sotm_2022_03e.pdf)

The main objective of this paper is to investigate how green bond issuing promotes renewable energy transition and renewable energy efficiency in countries through cross-country analysis, utilizing the Environmental Kuznets Curve (EKC) theoretical framework. The Environmental Kuznets Curve (EKC) hypothesis suggests that economic growth initially leads to environmental degradation, which eventually decreases as economies mature and invest in cleaner technologies. Green bonds, by providing necessary funding for renewable energy projects, help economies move along the EKC curve towards improved environmental quality. Considering the impacts of different variables on renewable energy deployment and the role of countries in the development of the green bond market over 2008 - 2021. The research paper examines the model's test findings and suggestions regarding establishing green bonds for renewable energy projects in general.

This research provides three significant contributions, distinguishing it from prior literature. Firstly, it provides a comprehensive cross-country analysis utilizing the Environmental Kuznets Curve (EKC) theoretical framework to investigate how green bond issuance promotes renewable energy transition and efficiency. Previous studies have often focused on single-country analyses (Li et al., 2020; Sun et al., 2023; Yuan et al., 2018) or firm-level data rather than country-level data (Balcilar et al., 2023; O'Shaughnessy et al., 2021; Zhang & Kong, 2022). By focusing on country-level analysis, this research captures the broader economic and policy

contexts, providing more comprehensive insights into how national policies and market conditions influence the effectiveness of green bonds in promoting renewable energy transitions. Secondly, this study examines data spanning more than a decade (2008 - 2021) to analyze the effect of green bonds on renewable energy utilization, providing a long-term perspective that is often missing in earlier works. By incorporating a diverse set of variables affecting renewable energy deployment and assessing the role of countries in the development of the green bond market, this research offers robust evidence and insights into the mechanisms through which green bonds can influence the renewable energy sector. Thirdly, the study explores the moderating role of CO_2 emissions levels, finding that countries with higher CO_2 emissions experience a stronger positive impact of green bonds on renewable energy transition. This highlights the importance of green bonds in promoting sustainable development, especially in more polluted nations. These contributions advance our understanding of green finance's practical implications and guide policymakers and investors in making informed decisions to foster sustainable development.

The remainder of this article is organized as follows. Section 2 discusses the literature and presents hypotheses. Section 3 discusses the data collection, research framework**,** and research methodology. Section 4 presents the study results and discusses their implications. Finally, the paper is concluded in section 5 with a summary of the main findings and their significance

2. Literature review

2.1. Renewable energy transition

Renewable energy refers to the energy derived from natural resources, such as wind, rain, sunlight, and geothermal heat, which are renewable and do not deplete upon utilization (Armaroli & Balzani, 2016; Wang et al., 2023). In recent years, renewable energy technologies have evolved dramatically and are becoming a growing competitiveness with traditional power sources in terms of cost (Huang, 2023). According to the United States International Energy Agency (IEA, 2020), the global consumption of renewable energy increases at an average rate of 3% per year. Surprisingly, modern bioenergy was shown to be the most important renewable energy source worldwide, accounting for more than 50% of global energy demand in 2022 (International Energy Agency [IEA], 2022). The share of renewable energy utilization in the global environment is believed to grow by 13% to 18% between 2011 and 2050 (Kara et al., 2021).

Earlier studies, exemplified by Haldar and Sethi (2022); and Noailly and Smeets (2015), emphasized the importance of fostering the consumption of renewable energy as a policy to mitigate environmental pollution and achieve sustainable development goals (Haldar & Sethi, 2022; Noailly & Smeets, 2015). Empirical studies have demonstrated that renewable energy promotes sustainable development by reducing the surge in carbon emissions and enhancing industrial performance (Dong et al., 2023; Huang, 2023; Nan et al., 2022). Renewable energy contributes to lower pollutant concentrations, reduced greenhouse gas emissions, and lower risks to human health (Abanda, 2012). Furthermore, there exists a close connection between economic growth and energy consumption (Ahmad et al., 2021; Ozcan et al., 2020). Transitioning towards renewable energy can also address the challenge of enhancing the quality of life for rural populations (Sen & Ganguly, 2017). Heiligtag et al. (2019) confirmed that some forms of renewable energy may offer cost advantages over conventional fuel under some circumstances. Therefore, increasing the utilization of renewable energy sources is considered a feasible strategy that could mitigate environmental degradation and reduce reliance on energy sources that generate pollution. In this background, nations have the potential to enhance the proportion of

renewable energy in their energy mix as a step towards achieving an energy transition. The findings indicate that accelerating the pace of this transition can enhance environmental sustainability by reducing ecological footprint (Khan et al., 2022).

The renewable energy transition entails shifting from fossil-based energy sources to zero-carbon renewable systems to reduce energy-related CO_2 emissions and combat global climate change (Cavallaro et al., 2023; Li et al., 2020; Ozturk et al., 2022). In response to global climate change, environmental degradation, and the increasing scarcity and cost of fossil fuels, the global community is driven to adopt sustainable energy systems (Diesendorf & Taylor, 2023; Solomon & Krishna, 2011). This transition not only involves the adoption of renewable energy technologies such as solar, wind, geothermal, and bioenergy but also requires a fundamental transformation of the energy sector, impacting traditional utility regulation and necessitating supportive governmental policies (Outka, 2022). Furthermore, transitioning to renewable energy is essential for reducing greenhouse gas emissions and promoting sustainability and energy efficiency at the local level (Alagoz & Alghawi, 2023; Sun et al., 2023). As renewable energy adoption increases, there is a corresponding decrease in reliance on fossil fuels, aligning with global efforts to achieve carbon neutrality and sustainable development goals (Mirziyoyeva & Salahodjaev, 2023; Zissler, 2022).

The transition to the use of renewables began towards the end of the 20th century (Qadir et al., 2021). Nevertheless, it wasn't until the 2000s that renewable energy saw commercial success due to enhancements in its efficiency and performance (Kammen, 2006; Qadir et al., 2021). Chan et al. (2022) studied the critical factors influencing renewable energy development. The significant findings revealed that technology, policy, and finance are among the most critical influencing elements to promote renewable energy. Government policies encourage renewable energy development, and renewable energy policies in different markets have different effects on promoting its development (Hu et al., 2022). Geels et al. (2016) conducted a comparison of renewable energy policies of the United Kingdom and Germany. They found that various institutions and actors play an important role in achieving a policy shift towards renewable resources. Zhang et al. (2021) showed that policies for renewable energy resources vary across regions due to variations in resource availability. Moreover, Qadir et al. (2021) verified that advancements in technology reduce the costs associated with developing renewable energy, thereby boosting investment levels in this sector due to anticipated higher returns (Qadir et al., 2021). To overcome the financial challenges associated with the transition to renewable energy and to foster the development of renewable energy technologies, public financing in research and development for renewable energy is required (Bointner et al., 2016). It can be deduced from this that the effectiveness of renewable energy correlates directly with the impact of financial development (Dopierała et al., 2022).

2.2. Green bond

Green bonds were introduced by the World Bank in 2008 as a means to finance environmentally friendly or green activities (Kochetygova & Jauhari, 2014), offering investors a chance to contribute to sustainability efforts while also earning a financial return.

Green bonds, a financial instrument dedicated to environmental sustainability, are undergoing rapid growth. According to data from the Statista Search Department (2024), the market for green bonds has seen significant growth since 2014. As a result, the total volume increased from $11 billion in 2013 to $37 billion in 2014, and by 2016, the total volume of green bonds had reached $85 billion (Chen & Zhao, 2021). In 2020, this green financing tool had seen

remarkable growth, reached a record of 596 billion US $, and doubled to 1.1 trillion US $ in 2021 (Dong et al., 2023).

Introducing green financing policies represents a pragmatic approach to enhancing environmental performance and corporate social responsibility because it strengthens the regulation of firm-level environmental pollution (Deng & Lu., 2017). They find that green finance intervention strategies have a significant effect on improving environmental and social responsibility (Flammer, 2020, 2021; Zhou & Cui, 2019). Green bonds prove to be a viable tactic for climate financing, with corporate green bonds being shown to enhance firms' environmental ratings and decrease their CO_2 emissions in the medium to long run (Flammer, 2021). Zhou and Cui (2019) argue that green bonds offer significant economic and environmental benefits. They also claim that green bond issuing boosts corporate social responsibility activity.

According to Al Mheiri and Nobanee (2020), green bond issue financing green projects is crucial to accomplishing this sustainability target because when financial management is done correctly, it may improve environmentally friendly corporate operations. Overall, the results suggest that green bonds have the potential to improve environmental performance, but this is contingent upon external validation. Furthermore, the performance of the economy is unaffected by green bonds. The findings demonstrate that a green bond market that is nevertheless during its infancy and that is still dominated by inadequate governance may be the cause of the dependence of green bonds on external certification. Because of this, businesses frequently abuse the rising acceptance of green financing, contributing to the greenwashing issue.

Another area of impact is economic growth, where green bonds are seen to boost the economy. Green bonds can support job creation, improve productivity, and increase income generation, particularly in the renewable energy sector (Taghizadeh-Hesary et al., 2022). Additionally, green bonds have been found to positively impact the financial performance of firms issuing them (Liu et al., 2020). Green bonds can provide access to lower-cost capital, attract new investors, and increase a company's reputation and brand image.

2.3. Impact of green bond on renewable energy transition

Progressively heavier reliance on renewable energy has emerged as key for countries around the world to achieve sustainable development goals and reduce the effects of climate change. This trend has spurred nations to implement diverse strategies for transforming their energy sectors (Du et al., 2023). One prevalent approach is the enhancement of the green financing framework, which serves as a popular policy used to foster energy transition (Khan et al., 2021; Ren et al., 2020). The role of the intervening factor on green bonds and renewable energy consumption requires more investigation, so, this article will fill in this literature gap.

In recent years, the issues of green finance and energy efficiency have drawn the attention of a few scholars. Meo and Karim (2022) believed that market conditions and the mechanism of the green finance market are two crucial factors contributing to a positive relationship between green finance and green energy projects. Another study (Polzin & Sanders, 2020) highlighted the considerable role of green finance in assisting countries in achieving sustainable renewable energy development by attracting private investors and creating synergy among state and private sectors. Green bonds are one of the most efficient green financing tools for enhancing private investor involvement in these green projects (Sun et al., 2022). Researchers have emphasized the significance of issuing green bonds as a means to support green projects, which may lead to greater consumption of renewable energy and higher efficiency of natural resource utilization.

To explain and develop a hypothesis on the influence of green bonds on renewable energy transition using the Environmental Kuznets Curve (EKC) hypothesis, we can build on existing empirical studies that have investigated the impact of economic development and energy consumption on environmental quality. The EKC hypothesis, proposed by Grossman and Krueger (Grossman & Krueger, 1991, 1995), provides a crucial framework for examining the linkage between economic advancement and environmental indicators (Fakher, 2019; Khan et al., 2021). This hypothesis posits that environmental degradation initially increases with economic growth but eventually decreases as economies mature and invest in cleaner technologies.

Using the EKC theoretical framework, this study contributes to the existing research by focusing on the role of green bond issuance in promoting renewable energy consumption across countries. By addressing climate change problems created by unsustainable human behaviors, researchers have explored the relationship between economic activities and various environmental mitigation techniques (Abhilash et al., 2023). Several studies have highlighted the correlation between economic growth and environmental quality through the EKC hypothesis (Shahbaz et al., 2021), emphasizing the close relationship between a country's economic development and its renewable energy consumption (Fakher, 2019; Shahbaz et al., 2021).

Building on this theoretical background, we hypothesize that green bond issuance plays a pivotal role in accelerating the renewable energy transition. As countries issue green bonds, they attract investments in renewable energy projects, thereby facilitating the shift from fossil fuels to cleaner energy sources. This investment not only supports economic growth but also helps reduce environmental degradation, aligning with the EKC hypothesis. Therefore, we propose that green bonds enhance the renewable energy transition by providing the necessary financial resources for sustainable development, particularly in countries at various stages of economic growth.

Faster economic growth plays a key role in driving investment in renewable energy projects (Al Mamun et al., 2018). With renewable energy, it becomes important to study the link or correlation between renewable energy output and investment in environmentally friendly projects. Green bonds are related to the basis on which investments are made in financial instruments related to green finance, renewable energy, and other green sectors. Besides, extensive documentation suggests that the stock market's positive response to the green bond stems from its signaling quality on issuers' environmentally oriented activities (Roslen et al., 2017; Wang et al., 2020).

In general, most of the research concentrates on outlining specifics of the theoretical framework for taking into account the environmental effects of green bonds. Current reviews on green finance primarily focus on brief aspects of green bonds (Jones et al., 2020; Schiederig et al., 2012), or they are just a bibliography of studies related to green bonds (Zhang et al., 2019). Studies on the association between green bonds and renewable energy are available. The effect of green bonds on the shift to renewable energy, however, has not been thoroughly studied. Therefore, more investigation into this subject is required to close the knowledge gap left by earlier studies and provide certain theoretical and practical contributions. Using this substantial sample of 192 countries, this survey will examine and clarify the impact of green bonds on the transition to renewable energy, using data from a data sheet between the years 2008 and 2021 in terms of green bonds, renewable energy, GDP growth, population growth, labor force, urban population, openness, and regulation via regression model.

Based on the above discussion, the study proposes the first hypothesis.

H1: Green bond issuance could enhance renewable energy utilization

Contrary to the studies that have found positive impacts of green bond issuance, some studies have highlighted the adverse impact of green financing on renewable energy. For instance, Shahbaz et al. (2021) found that green bonds have a positive effect on the consumption of renewable energy, but this impact depends on economic development levels. There exists a negative association between economic growth and renewable energy utilization. Financial development reduces energy consumption, while economic growth and urbanization are key factors driving long-term increases in energy demand (Shahbaz et al., 2016). The research results of Shahbaz et al. (2021) show that the consumption of renewable energy decreases due to an increase in per capita income, and this income is directed toward fossil-based energy consumption. Likewise, Hafner et al. (2020) have shown that in developing or less developed economies, green bonds are ineffective because of the underdeveloped private sector and inadequate financial infrastructure. In addition, Chuc and Rasoulinezhad (2022) argued that the effectiveness of green bonds in enhancing energy efficiency could be compromised in the face of rising inflation and urbanization. The second hypothesis for this study is defined as follows:

H2: Green bond issuance could constraint renewable energy utilization

3. Methodology

3.1. Data and sample

To analyze the impact of green bond issuance on renewable energy utilization, my research is based on the EKC framework and has employed the Fixed Effect to estimate the model.

The sample consists of 1,789 observations from 192 countries from 2007 to 2021. Regarding renewable energy, this study employs diverse energy indicators, including renewable electricity, electricity production, and fossil fuel energy, as potential determinants of renewable energy consumption. Specifically, Renewable energy data is obtained from the World Development Indicators (WDI) from the World Bank. Regarding the green bond issue in each country, the author obtained information on green bond issuance from the International Monetary Fund (IMF) database. Finally, in terms of control variables, the literature incorporates a variety of economic indicators taken from the WDI database, for example, GDP growth, Population growth, Urban population, Foreign direct investment, Openness, and Labor.

3.2. Variable measurement

3.2.1. Renewable energy

RenewEnergy is the dependent variable, a proxy for renewable energy utilization. This study measures renewable energy consumption by taking the proportion of renewable energy in total final energy consumption. Country-level renewable energy data are sourced from the WDI database from the World Bank for this study.

3.3.2. Green bonds

Regarding the independent variable, this study uses the natural logarithm of green bond issuance in each country collected from the IMF database, to examine whether and to what extent green bond affects renewable energy consumption.

3.3.3. Control variables

To measure the impact of green bond issuance on renewable energy consumption, this research uses several control variables are introduced after referring to relevant literature

(Alharbi et al., 2023; Doytch & Narayan, 2016; Shahbaz et al., 2021), including GDP Growth (*GDPGrowth*), measured by the annual percentage growth rate of gross domestic product at market prices based on constant local currency. Population Growth (*PopulationGrowth*), measured by the annual population growth rate for year t is the exponential growth rate of the midyear population from year t-1 to t. Urban Population (*UrbanPopulation*), is measured by the people living in urban areas as defined by national statistical offices. Foreign Direct Investment (*FDI*), is the sum of reinvestment of earnings, equity capital, short-term capital, and other long-term capital. Openness (*Openness*), is measured by the total value of exports plus imports over a country's level of GDP. I also include the Labor (*Labor*), which is measured by the proportion of the population ages 15 - 24 that is economically active division to population. The detailed description and source of all variables in my baseline regression model are set out in Table 1.

Table 1

Description of the Variables

Variable	Description	Sources
Dependent variable		
Renewable energy	The share of renewable energy in total final energy consumption	WDI
Independent variable		
Green Bond	The natural logarithm of green bond issuance in each country	IMF
Control variables		
GDPGrowth	The growth rate of gross domestic product, expressed as a percentage change	WDI
PopulationGrowth	The growth rate of the population, expressed as a percentage change	WDI
UrbanPopulation	The share of the population living in urban areas as defined by national statistical offices	WDI
FDI	The sum of reinvestment of earnings, equity capital, short-term capital, and other long-term capital over the country's GDP	WDI
Openness	The natural logarithm of exports and imports of goods and services	WDI
Labor	The proportion of the population ages 15 - 24 that is economically active division to population	WDI

Source. Authors' own compilation

3.3. Model specification

To investigate the impact of green bond issuance on renewable energy consumption efficiency, this study specifies the following model:

$$RenewEnergy_{it} = \beta_0 + \beta_1 GreenBond_{i(t-1)} + \beta_2 GDPGrowth_{i(t-1)} + \beta_3 PopulationGrowth_{i(t-1)} + \beta_4 UrbanPopulation_{i(t-1)} + \beta_5 FDI_{i(t-1)} + + \beta_6 Openness_{i(t-1)} + \beta_7 Labor_{i(t-1)} + \varepsilon_{i(t-1)} \quad (1)$$

The subscripts i and t denote a country and year, respectively, whereas t-1 represents one year lagged. Further, β is the constant, and ε is the error term.

By incorporating the lagged variables into our model, we aim to establish causality by ensuring changes in the independent variables precede changes in the dependent variable, reducing the risk of reverse causality and endogeneity (Antonakis & House, 2014; Finkel, 1995). It also accounts for delayed effects and smooths out short-term fluctuations, providing more reliable insights into the long-term impact of green bond issuance and other economic factors on renewable energy consumption efficiency.

4. Empirical results

4.1. Descriptive statistics

The descriptive statistics calculated for the variables used in this paper are summarized in Table 2. The total number of samples to observe was 1,542 observations. The sample statistics show the annual mean and standard deviation of *RenewEnergy* are 32.529 and 30.222, respectively. The minimum value of *RenewEnergy* is 0, and the maximum value is 97.03, indicating that the energy efficiency level of selected countries varies substantially. Besides, the average annual mean of the green bond issue is 1,590e+10 in absolute terms and ranges between 2,305,316.1 and 6,882e+10. The mean values of *GDPGrowth*, *PopulationGrowth*, *UrbanPopulation*, *FDI*, absolute value of *Openness*, and *Labor* are 3.299, 1.461, 58.429, 4.203, 1.181e+12, and 0.379, respectively.

Table 2

Descriptive Statistics

	N	Mean	SD	Min	p25	Median	p75	Max
RenewEnergy	1,789	32.529	30.222	0	5.707	22.024	60.82	97.03
GreenBond	1,789	9,456e+09	1,590e+10	2,305,316.1	7,533e+08	1,500e+09	1,529e+10	6,882e+10
GDPGrowth	1,789	3.299	5.204	-50.339	1.394	3.391	5.602	86.827
PopulationGrowth	1,789	1.461	1.550	-6.852	.548	1.404	2.386	15.906
UrbanPopulation	1,789	58.429	23.250	10.118	38.694	57.117	78.37	100
FDI	1,789	4.203	8.343	-41.651	1.194	2.578	4.533	163.225
Openness	1,789	1,181e+12	3,898e+12	47,564,520	6,413e+09	2,565e+10	3,895e+11	3,272e+13
Labor	1,789	0.392	0.142	0	0.341	0.417	0.487	0.755

Source. Authors' own compilation

Table 3 presents the correlation coefficients among the *RenewEnergy* (dependent variable), *GreenBond* (independent variable), and other important control variables used in my baseline regression analysis.

This paper finds that the correlation between *RenewEnergy* and *GreenBond* is positive. The direction of the relationship between *GreenBond* and *RenewEnergy* is in the direction predicted, supporting my empirical prediction that green finance fosters renewable energies. In the table, the dependent variable *RenewEnergy* has a positive correlation with *GDPGrowth* and *PopulationGrowth*, and the correlation between *RenewEnergy* and *PopulationGrowth* is stronger than the correlation between *RenewEnergy* and *GDPGrowth*.

The table's diagonal shows the Variance Inflation Factor (VIF) for each variable, which measures how much the variance of the estimated regression coefficients is increased due to multicollinearity between the independent variables. The last column of Table 2 reports the value of VIF. The VIF index of less than 10 shows that the pairwise correlation between the independent variables is weak, so there is no multicollinearity in the model. Therefore, the variables included in the model are consistent with the research data. The mean value of VIF is 1.21, which is far lower than the standard threshold of 10 (O'brien, 2007), illustrating that the multicollinearity problem does not seriously threaten the empirical model.

Table 3

Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	VIF
(1) RenewEnergy	1.000								
(2) GreenBond	0.079	1.000							1.08
(3) GDPGrowth	0.095	0.040	1.000						1.11
(4) PopulationGrowth	0.312	0.139	0.127	1.000					1.08
(5) UrbanPopulation	-0.633	-0.094	-0.135	-0.156	1.000				1.18
(6) FDI	-0.070	-0.102	0.056	0.010	0.098	1.000			1.0
(7) Openness	-0.341	0.017	-0.297	-0.173	0.347	-0.030	1.000		1.65
(8) Labor	-0.104	-0.141	-0.090	-0.010	0.206	0.056	0.502	1.000	1.41

Source. Authors' own compilation

4.2. Baseline results

Table 4 presents the results of the baseline model. Column 1 shows the result of the model using year-fixed effects, and Column 2 shows the result of the model using country-year fixed effects.

Table 4

Baseline Regression Result

	(1)	(2)
VARIABLES	**Year FEs**	**Country FEs and Year FEs**
GreenBond	0.737***	0.864***
	(0.152)	(0.162)
GDPGrowth	-0.075	-0.079*
	(0.042)	(0.044)
PopulationGrowth	-0.050	-0.088
	(0.071)	(0.069)
UrbanPopulation	-0.744***	-0.497***
	(0.041)	(0.051)
FDI	-0.046***	-0.051***
	(0.010)	(0.011)

	(1)	(2)
VARIABLES	**Year FEs**	**Country FEs and Year FEs**
Openness	-0.225*	-0.207
	(0.124)	(0.121)
Labor	10.110**	13.004***
	(3.394)	(2.793)
Constant	63.231***	44.919***
	(3.920)	(5.079)
Observations	1,531	1,531
R-squared	0.992	0.992

Notes. This table presents baseline regression results for the impact of green bond issuance on renewable energy consumption, in the sample of 192 countries for the period 2007 to 2021. The dependent variable is *RenewEnergy*. The main independent variable is *GreenBond*, which represents the number of green bonds issued in any country per year. Column (1) is the regression of the model using year-fixed effects, Column (2) is the regression of the model using country-fixed effects and year-fixed effects. The table also contains the significance levels (p-values), where ***, **, and * measure the 1%, 5%, and 10% significance levels, respectively. The data are from Authors' own compilation

Table 4 reveals that *GreenBond* has a positive and statistically significant impact on *RenewEnergy* at both estimations, with a significance level of 1%. The result of the model supporting hypothesis 1 is that countries with higher levels of green bond issuance could boost renewable energy consumption. This is in line with earlier; for example, Chuc and Rasoulinezhad's (2022) research suggests that the tool of green bonds is a potential policy to increase energy consumption efficiency. These results are also supported by Hanif et al. (2019), which also states the positive and statistically significant impact of the issuance of green bonds on renewable energy efficiency in the short term and long term. By providing a lower cost of debt for green projects (Teti et al., 2022), green bonds become a reliable and efficient financing tool to increase the private sector's participation in environmentally friendly projects (Zhao et al., 2022). A country with a high-issued green bond, which means that it's attractive private capital and supports finance environment-friendly projects or green economy growth. Green bonds may also be a new political tool for countries to promote renewable energy projects (Dong et al., 2023). The growth of the green economy leads to improved renewable energy production and consumption patterns in individual countries (Hu, 2023). Therefore, these results suggest that an increase in green bond issuance may have a higher level of renewable energy consumption while promoting sustainable growth.

In general, both estimations give the same results that the estimated coefficient of *Labor* is positive and statistically significant with *RenewEnergy*, implying that an increase in labor force participation leads to an increase in renewable energy consumption. The result is consistent with prior literature on the relationship between labor and renewable energy (Apergis & Payne, 2012; Kahia et al., 2017). Kahia et al. (2017) found that the short-term labor force has a positive association and statistically significant effect on renewable energy use. The increased labor force participation in the modern world has had a positive effect on renewable energy consumption (Apergis & Payne, 2012).

Regarding the other control variables, the results of the fixed effects model suggest a negative and statistically significant linkage between *GDPGrowth*, *UrbanPopulation*, *FDI*, and *Openness* with *RenewEnergy*. As can be seen in Table 4, *UrbanPopulation* displays favorable and statistically significant effects on *RenewEnergy*. More specifically, a unit rise in *UrbanPopulation* causes a decline in the consumption of *RenewEnergy*. This outcome is contrary to that of Akintande et al. (2020), who found that the renewable potential of the urban population is the cause of increasing energy consumption from renewable sources. The study's findings suggest that the *Openness* variable has a negative and statistically significant coefficient with *RenewEnergy*, with a significance level of 1%. This suggests that countries with a higher trade openness are less likely to utilize renewable energy. However, the findings of the current study do not support previous research. For example, Dong et al. (2023); Zhang (2022) found a positive association between trade openness and renewable energy utilization. Similarly, *FDI* flows into countries are negatively correlated and statistically significant with *RenewEnergy* consumed at both estimations, indicating that if the levels of foreign direct investment into a country increase, the share of renewable energy consumption decreases. This result is in contrast to the result of some previous research (Akintande et al., 2020; Tan & Uprasen, 2022). The results are in line with those of Murshed et al. (2021), who analyzed the case of Bangladesh and five other South Asian economies, and found that FDI inflows were referred to reduce renewable energy use.

4.3. Robustness tests

In Table 5, this study presents several sensitivity analyses aimed at ensuring the robustness of the study's results. The robustness of our findings is tested by running the model after changing the model specification and sample period.

Table 5

Robustness Tests

	(1)	(2)
VARIABLES	**Region FEs and Year FEs**	**Exclude Financial crisis**
GreenBond	0.575*	0.853***
	(0.306)	(0.151)
GDPGrowth	2.239***	-0.162
	(0.725)	(0.116)
PopulationGrowth	1.994***	-0.070
	(0.447)	(0.104)
UrbanPopulation	-0.594***	-0.438***
	(0.032)	(0.100)
FDI	-0.113*	-0.042***
	(0.065)	(0.013)
Openness	-1.820***	-2.259***
	(0.419)	(0.391)

	(1)	(2)
VARIABLES	**Region FEs and Year FEs**	**Exclude Financial crisis**
Labor	37.384***	14.527*
	(5.488)	(8.036)
Constant	80.611***	91.784***
	(10.330)	(11.597)
Observations	1,245	1,404
R-squared	0.581	0.993

Notes. This table presents Robustness tests for the impact of green bond issuance on renewable energy consumption, in the sample of 192 countries for the period 2007 to 2021. The dependent variable is *RenewEnergy*. The main independent variable is *Green Bond*, which represents the number of green bonds issued in any country per year. Column (1) is the baseline regression using Region-Year Fixed effects. Column (2) is the baseline regression after excluding the Financial crisis period. The table also contains the significance levels (p-values), where ***, **, and * measure the 1%, 5%, and 10% significance levels, respectively. The data are from Authors' own compilation

Several additional sensitivity analyses were conducted to validate the reliability of the baseline results. In Column 1, we adopt an alternative model specification by incorporating region-year fixed effects. This approach allows us to consider unobserved variations across different regions and time-related factors. Furthermore, the global financial crisis happened in the period between mid-2007 and early 2009, so the benefits of the renewable energy policy may decline due to a contraction in credit availability (Barone et al., 2018), making it more challenging for renewable energy projects to secure funding. To address this potential issue, this study drops the observations in the period 2007 to 2009, re-estimates this study equation, and presents the results in Column (2) of the table.

The robustness test results are displayed in Table 5 and confirm the previous findings. Overall, our results suggest that both columns yield the same results as the Baseline regression result, and the signs in the *GreenBond* variables and control variables remain consistent across all models. Thus, it can be concluded that the model is robust. Furthermore, these results explain that the model presented in this paper strengthens the research results.

4.4. Additional analysis

To measure the impact of green bond issuance on renewable energy and determine whether the impact differs according to the level of CO_2 *emissions*, we use the CO_2 *emissions* level as a moderating variable in the baseline regression model.

Carbon dioxide is the leading contributor to the emission of greenhouse gases. The primary challenge facing nations in the world lies in enacting policy reforms that encourage the development of reliable energy sources while simultaneously reducing greenhouse gas emissions. Non-renewable sources, such as coal, oil, and gas, represent a significant share of the energy supply for countries (Judkins et al., 1993). The result is a significant increase in CO_2 emissions in the atmosphere, which are considered to be the main greenhouse gas emission factor that has led to environmental degradation (Shafiei & Salim, 2014). One such green tool is the use of green bonds, which not only aid in mitigating greenhouse gas emissions but also encourage the adoption of renewable energy sources.

Table 6

Moderating Role of CO_2 Emission on the Impact of Green Bond Issuance on Renewable Energy Utilization

	(1)
VARIABLES	**Moderating role of CO_2 Emissions**
GreenBond	-0.095
	(0.156)
CO_2	-2.753***
	(0.303)
GreenBond#CO_2	0.084***
	(0.018)
	(1)
VARIABLES	**Moderating role of CO_2 Emissions**
	(0.097)
PopulationGrowth	0.043
	(0.066)
UrbanPopulation	-0.588***
	(0.058)
FDI	-0.030***
	(0.006)
Openness	-2.111***
	(0.453)
Labor	7.273
	(4.799)
Constant	124.414***
	(9.085)
Observations	1,453
R-squared	0.993

Notes. This table presents the additional analysis on the moderating effect of CO_2 Emission for the impact of green bonds on renewable energy, in my sample of 192 countries for the period 2007 to 2021. The table also contains the significance levels (p-values), where ***, **, and * measure the 1%, 5%, and 10% significance levels, respectively. The data are from Authors' own compilation

We investigate the moderating effect of the country's CO_2 emissions level on the effect of green bonds on renewable energy transition. The result from Table 6 reveals a significant moderating effect. The results indicate that countries with higher levels of CO_2 emissions tend to experience a stronger positive impact of green bonds on facilitating the transition toward renewable energy sources. This suggests that in nations where the level of air pollution are more

pronounced, the allocation of financial resources through green bonds plays a significant role in driving the shift towards renewable energy infrastructure and technologies. Such results underscore the importance of targeted financial mechanisms in promoting sustainable development. Prior literature also shows that the primary objective of investing in green energies is to mitigate emissions and enhance environmental conditions (Kochetygova & Jauhari, 2014; Wang et al., 2023). According to Wang et al. (2023), performance post-issuance green bonds cause higher environmental ratings and lower emissions. Hence, green bond issuance and CO_2 emission play a crucial role in economic growth and renewable energy efficiency.

5. Conclusion

This study applied an interactive Fixed-Effects (FEs) panel threshold model to examine the influence of green bond issuance on renewable energy consumption across countries. The data was collected from the World Development Indicators and the United States International Energy Agency database in 192 countries from the period 2007 - 2021. The results indicate that countries with higher levels of green bond issuance tend to utilize more renewable energy. The results of this observational study suggest that using green bonds is an effective financial mechanism for mobilizing private capital investment in renewable energy while promoting sustainability strategies and reducing countries' financing costs. These findings have significant implications for investors and businesses seeking to lower green investment risk and increase the rate of return, two crucial motivation factors in their investment decisions.

The novelty of the study lies in its topical framework and research directions, talking about the way forward for renewable energy efficiency financing, which is a pressing issue of recent times. The research has offered innovative findings and contributions regarding the impact of green bond issuance on the efficiency of energy and natural resources consumption in selected countries. In addition, the results imply that countries with higher CO_2 emissions can leverage green bonds effectively to accelerate their transition towards renewable energy sources.

Overall, the results of this study provide valuable insights into the relationship between green bonds, green projects, and the economic context of renewable energy utilization, which can help stakeholders make more informed decisions about green project investments. Through analyzing and evaluating the current situation and causes of the problem, this research suggests that green bonds are an effective financial mechanism for mobilizing private capital. Expanding the issue of green bonds to fund green projects can be an effective strategy for promoting the effectiveness of renewable energy and natural resources while creating incentives for sustainable economic growth. Hence, to implement an effective development program for the green bond market, governments must take the lead in establishing a suitable financial platform and transparent regulations that will attract private investors to invest in these projects. Moreover, policymakers should consider implementing supportive frameworks and incentives to encourage the issuance and utilization of green bonds in the countries with high level of pollution, thereby fostering a more rapid and sustainable shift towards renewable energy infrastructure.

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