sustainability

MDPI

Article

Do Green Bonds Play a Role in Achieving Sustainability?

Muhammad Alamgir * and Ming-Chang Cheng

Department of Business Administration, National Chung Cheng University, Chiayi 621301, Taiwan; bmamcc@ccu.edu.tw

* Correspondence: aalam@alum.ccu.edu.tw

Abstract: Green bonds play a pivotal role in promoting sustainability by channeling financial resources towards environmentally friendly projects, fostering a greener and more resilient future. This research investigates the role of "Green Bonds" in the attainment of Sustainable Development Goals (SDGs), focusing on two specific goals: climate action, represented by per capita carbon emissions (CO_2), and clean energy, represented by per capita renewable energy production. Using data from 2007, when the first green bond was issued, up to 2021, we employed a one-step generalized method of moments (GMM) model to explore how green bonds impact global emission reduction and the increase in renewable energy production. The findings demonstrate that green bonds have a significant influence on both emissions and renewable energy production. Specifically, green bonds and renewable energy production have a positive and significant association, while emissions exhibit a negative relationship with green bonds. Our results reported a reduction in carbon emissions up to 0.8 tons, while an increase in renewable energy up to 66 kWh. Upon analyzing the data before and after 2015, we observe that prior to 2015, there was no significant effect of green bonds on emissions and renewable energy production. However, after 2015, green bonds substantially impacted both indicators. Furthermore, our results indicate that countries with higher green bond issuance are more likely to achieve their sustainability goals, particularly in terms of renewable energy production and carbon emission reductions. Conversely, countries with lower green bond issuance are struggling to attain their sustainability objectives in these areas.

Keywords: green bonds; carbon emissions; renewable energy; sustainability

Citation: Alamgir, M.; Cheng, M.-C. Do Green Bonds Play a Role in Achieving Sustainability? *Sustainability* **2023**, *15*, 10177. https://doi.org/10.3390/su151310177

Academic Editor: Samuel Asumadu-Sarkodie

Received: 18 May 2023
Revised: 18 June 2023
Accepted: 20 June 2023
Published: 27 June 2023

1. Introduction

The rapid expansion of the global economy has led to significant environmental challenges that are increasingly visible across the globe. Consequently, the issues surrounding economic growth and sustainable development have attracted considerable attention from various countries [1]. Consequently, there has been a notable increase in research focused on sustainable development [2,3]. Sustainable development emphasizes the significance of sustainable finance and investment. As a result, the concepts of the green economy and green finance have emerged as a means to harmonize economic, social, and environmental progress, playing a crucial role in today's era of economic advancement. The shift towards low-carbon green development has also become a global objective in environmental governance since the 21st United Nations Climate Change Conference of the Parties. This objective aims to transition the economy from a carbon-intensive model to a more environmentally friendly one.

The initiative for sustainable development began with the "Kyoto Protocol" in 1997, which mandated that industrialized countries and partners take measures to mitigate and reduce greenhouse gas (GHG) emissions. As part of this collective agreement, countries set individual targets. Subsequently, the Rio Conference in 2012 concluded by establishing a framework aimed at fostering a green economy that would facilitate sustainable development and alleviate poverty.

The participants agreed on a process to set global Sustainable Development Goals (SDGs). The 2015 Paris Agreement become the milestone for sustainable development, where the conference culminated the process of adopting the 2030 Agenda for Sustainable Development, with 17 SDGs at its core. The five key points of the conference were to limit temperature rise to "well below" 2 °C, to create the first universal climate agreement, to help poorer nations, to publish greenhouse gas reduction targets, and to become carbon neutral by 2050.

Under the UN Sustainable Development Goals (SDGs) and the Paris Agreement, global initiatives aim to balance economic growth with environmental stewardship by regulating carbon emissions and promoting renewable energy. However, implementing these frameworks requires substantial investments. The UNDP focuses on eradicating poverty, promoting peace and justice, and fostering sustainable growth (United Nations UN, 2015). The Paris Agreement aims to limit global temperature increases and secure funding for low-carbon development. To achieve the SDGs by 2030, an estimated annual investment of USD 5–7 trillion is needed (United Nations Conference on Trade and Development [4], while USD 53 trillion in energy-related investments will be required by 2035 to uphold the 2 °C temperature threshold (United Nations Conference on Trade and Development UNCTAD, 2014). Mobilizing significant public and private capital is crucial for supporting these ambitious environmental agendas.

Climate actions refer to the measures taken by individuals, communities, governments, and organizations to address and mitigate the challenges of climate change. These actions encompass a wide range of strategies to reduce greenhouse gas emissions, promote renewable energy sources, conserve natural resources, and adapt to the changing climate. Climate actions may include implementing renewable energy projects, adopting energy-efficient technologies, promoting sustainable transportation, afforestation initiatives, and developing climate-resilient infrastructure. Additionally, climate actions involve raising awareness, advocating for policy changes, and fostering international cooperation to achieve global climate goals outlined in agreements such as the Paris Agreement.

Climate change and environmental degradation have become pressing global challenges that require urgent action to ensure a sustainable future for our planet. The international community has recognized the need for concerted efforts to mitigate climate change and promote sustainable development, leading to the formulation of the Sustainable Development Goals (SDGs) by the United Nations. SDG 13 [5] specifically focuses on climate action, aiming to combat climate change and its impacts through various measures, including reducing greenhouse gas emissions and enhancing adaptive capacities [6].

Green finance plays a vital role in the global financial system, as it focuses on investing in environmentally sustainable projects and promoting low-carbon technologies. It is seen as a significant change within the financial system, aiming to foster sustainable growth and address social and environmental challenges. Financial tools are expected to be crucial in achieving the United Nations' Sustainable Development Goals by 2030. Countries worldwide recognize the importance of integrating these goals into their national development programs. The concept of a green financial system aligns with sustainable development principles and emphasizes the interdependence between human survival and the environment. It consists of institutions that use various financial instruments, such as green credit, bonds, stock indices, development funds, insurance, carbon finance, and policy incentives. The goal is to facilitate the transition to a more sustainable economy [7].

Green finance refers to financial activities and investment strategies prioritizing environmental sustainability and promoting the transition to a low-carbon and climate-resilient economy. It encompasses various financial instruments, such as green bonds, green loans, and sustainable investment funds, which channel capital towards environmentally friendly projects and initiatives. Green finance aims to address environmental challenges while creating economic opportunities [8,9].

Green bonds play a crucial role in climate action due to their potential to mobilize capital toward environmentally sustainable projects. Green bonds have gained attention due

to their unique features, as compared to other bonds, such as financing renewable energy and climate projects, scaling up climate-friendly investments, promoting transparency and accountability (use of proceeds and output of projects), and aligning financial markets with climate goals [10].

In recent years, there has been a significant increase in the usage of green bonds as a financial tool. A notable development in corporate finance has been the emergence of corporate green bonds. These bonds allocate their proceeds towards financing environmentally friendly and climate-conscious projects, such as renewable energy initiatives, green buildings, resource conservation, and sustainable transportation. Although corporate green bonds have gained popularity in practice, there remains a limited understanding of this relatively new financial instrument. At first glance, it may appear complex for companies to opt for green bonds instead of conventional bonds, as the funds raised from green bonds are dedicated to specific green projects, thereby imposing restrictions on companies' investment policies. Moreover, becoming a certified green bond issuer is no easy task, as companies must undergo third-party verification to ensure that the proceeds are indeed funding projects that generate environmental benefits. This verification process adds to the administrative and compliance costs for companies. Although this verification process adds to the administrative and compliance costs for companies, the literature found that there is always a positive impact of green bonds on firm performance. For example, Refs. [11,12] found that firms with green bonds not only improve their financial performance (decrease financing cost, increase firm value) but also their CSR performance and environmental rating.

According to the "Climate Bonds Initiative" [13] and their Green Bond Database, the green bond market has experienced a remarkable expansion, with an average growth rate of 54% over the past five years. As of the end of 2021, the total size of the green bond market amounted to USD 522.7 billion, with a total of 2089 green bond instruments issued. Following a decline in 2020, the green debt market experienced a resurgence, witnessing a 75% increase in volumes in 2021 compared to the previous year [13]. Despite the rapid growth of the market, there has been a noticeable lack of standardization among green bonds. Insufficient disclosure and clarity at the asset and project level within green bond frameworks present ongoing challenges for investors.

In recent years, there has been a significant increase in the utilization of green bonds as a financial tool. A notable development in the field of corporate finance is the emergence of corporate green bonds. These bonds are specifically designed to finance environmentally friendly and climate-conscious projects, such as renewable energy initiatives, green building projects, resource conservation efforts, and eco-friendly transportation systems. While corporate green bonds have gained popularity, there is still a limited understanding of this innovative financial instrument.

Initially, it may seem complex for companies to opt for green bonds instead of conventional bonds. This is because the proceeds from green bonds are exclusively allocated to green projects, which imposes constraints on companies' investment policies. Moreover, becoming a certified green bond issuer involves a non-straightforward process. Companies must undergo third-party verification to demonstrate that the funds raised are genuinely used for projects that generate environmental benefits. This verification process adds to the administrative and compliance costs incurred by companies.

According to the "Climate Bonds Initiative" and its Green Bond Database, the green bond market has witnessed substantial growth, averaging a remarkable rate of 54% over the past five years. As of the end of 2021, the total size of the green bond market reached USD 522.7 billion, with 2089 instruments issued. After a decline in 2020, the green debt market experienced a resurgence, with volumes increasing by 75% in 2021 compared to the previous year. Despite the rapid expansion of the market, there remains a notable lack of standardization among green bonds. Investors frequently encounter issues regarding inadequate disclosure and clarity at the asset and project level within green bond frameworks.

Another important concept introduced recently to fight against the increasing carbon emission is the concept of "Net Zero Emission", which is aimed at reducing greenhouse gas emissions to the lowest possible level, which could be zero. The Paris Agreement, a significant agreement reached at the United Nations Climate Change Conference (COP21), introduced and popularized the concept of achieving net zero greenhouse gas (GHG) emissions. This landmark deal involved nearly 200 countries committing to limiting the impact of GHG emissions by striving to achieve a balance between the emissions produced by human activities and the removal of GHGs from the atmosphere through carbon removal methods. Net-zero emissions will be attained when all GHG emissions caused by human activities are offset by the removal of GHGs from the atmosphere, thereby achieving a state of equilibrium.

Carbon dioxide (CO_2) is the leading contributor to the emission of greenhouse gases (GHGs). Many environmentalists argue that previous environmental initiatives, such as the Kyoto Protocol and United Nations Framework Convention on Climate Change, are no longer adequate and call for new regulations to improve environmental quality. However, policymakers face the challenge of striking a balance between economic growth and reducing environmental harm. The key challenge lies in implementing policy changes that encourage the development of reliable and affordable energy sources while simultaneously reducing GHG emissions. Given that a significant portion of GHG emissions originates from energy production using fossil fuels, various practical policy changes have been suggested to design effective environmental regulations that can impact emissions. One such policy tool is the use of environmental taxes, which not only help mitigate GHG emissions but also incentivize the adoption of renewable energy sources [14].

The Paris Agreement highlights the global issuance of green bonds through both governmental and corporate sectors as a means to compel corporations to adopt emission reduction policies and contribute to achieving Sustainable Development Goals (SDGs). Given that industries are major contributors to greenhouse gas emissions (GHG), collaboration between governments and industries becomes crucial in attaining SDG goals and net zero emission targets. Following the Paris Agreement, there has been a significant increase in the number of green bonds in the market, prompting numerous studies to explore their benefits for corporations, investors, and society. The majority of these green bonds are issued in sectors such as renewable energy, green transportation, eco-friendly housing, clean water, and electric batteries, among others. Nevertheless, the primary objective remains the reduction in carbon emissions and the promotion of renewable energy production.

In light of the growing importance of green bonds as a tool for climate action and sustainability, it is crucial to further explore their potential, evaluate their effectiveness, and identify ways to enhance their impact. This research aims to contribute to the existing body of knowledge by providing insights into the role of green bonds in achieving SDGs related to climate action and clean energy. Unlike previous studies, we will try to uncover whether there is a direct relationship between green bonds and sustainability in terms of CO_2 emissions and renewable energy production. Previous studies only focused on an indirect relationship through qualitative studies or they only examined the policy implications in this regard. We will examine the achievement of sustainable development goals through green bond issuance worldwide. The study will focus on two SDGs: SDG 7, affordable and clean energy, and SDG 13, climate action. This study will try to examine how the issuance of green bonds is impacting carbon emissions and renewable energy production worldwide. The reason for using SDG 7 and 13 is their crucial importance for the achievement of sustainable development goals. As we know, the main aim of sustainability is to reduce emissions and increase renewable energy production. We also used environmental tax as the moderating variable and FDI (foreign direct investment) as the control variable to counter the impact of foreign investments and other sustainability policies.

Our findings yield compelling results, indicating a direct and significant relationship between green bonds and the achievement of sustainable development goals. Particularly noteworthy is the observation that the impact of green bonds became particularly pro-

nounced after the adoption of the Paris Agreement in 2015. The post-2015 period marked a turning point where the influence of green bonds on sustainable development became increasingly evident.

Moreover, our study reveals a robust correlation between green bonds and the attainment of sustainable development goals, particularly in countries with higher levels of green bond issuance. In contrast, countries with lower issuance of green bonds face more challenges in advancing their sustainability objectives.

2. Literature Review

The European Investment Bank (EIB) issued the first green bond in 2007 to support renewable energy and energy efficiency projects. Since then, green bonds have gained significant popularity. Thereafter, the following years did not witness any significant growth in green financing; however, since 2013, there has been a remarkable worldwide surge in the issuance of green bonds after China entered the green bonds market. While the total issuance in 2008 was under USD 1 billion, it surged to USD 143 billion in 2018, a trend often referred to as the "green bond boom." Experts predict that this trend will persist in the future [15]. Green bonds are widely recognized as a promising instrument to tackle climate change, as highlighted by commentators and organizations such as Bloomberg [16]. Green bonds carry the same position and nature in the market as conventional bonds but what makes them different from conventional bonds is the types of projects where funds from green bonds can be used.

At present, a universally accepted definition of green bonds within the global community is lacking, leading scholars to engage in comparative studies to establish consistent identification criteria for green bonds. The name green bond is a self-proclaimed name and regulators worldwide in each country develop their criteria for binding financing to green bonds [17,18]. Green bonds, similar to traditional bonds, are backed by the financial standing of the institution and are tied to specific assets. These bonds also possess credit ratings. Numerous researchers, including [19,20], have documented the favorable impact of green bonds on the environment, society, and the economy. As the awareness of the risks and uncertainties stemming from climate change and the long-term economic progress has grown among investors, the significance of sustainability, climate mitigation projects, and environmentally friendly investments, such as green bonds, has also increased [21]. Consequently, over the past decade, governments and corporations in both developed and developing countries have increasingly turned to green bonds as a valuable form of fixed-income debt instrument [22].

The literature on green bonds can be divided into three different categories. First is yields or pricing (labeling) [23–25], second is the nexus between green bonds and other asset classes (as well as the dynamic spillover) [26,27], and third is the impact of green bonds on corporations and societies, which includes the most recent studies [11,28]. The existing body of literature on green bonds primarily emphasizes qualitative studies rather than quantitative analyses due to the limited period and variety of the sample [11]. In a more recent study, Ref. [28] examined global green bond data spanning from 2013 to 2018 and observed that companies experience enhancements in their environmental performance after issuing green bonds. These improvements are evident through higher environmental ratings and reduced emissions.

In today's era, where sustainable development is considered a sign of success and those businesses who care about ESG (economic governance and social) measures are receiving positive responses from all stakeholders, including corporate and social sectors, such actions compel businesses to undertake projects which are counted as aiding sustainable development. A firm's sustainable initiatives positively impact businesses, and it helps to start long-term and environmentally friendly projects [29]. Several studies discuss the relationship between green bonds and CSR (corporate social responsibility). According to [30], green bond issuance offers key benefits such as the potential to broaden the investor pool and attract environmentally conscious investors who value the environmental aspects

of these bonds. Furthermore, Ref. [18] highlights a growing interest in green finance from both individual and institutional investors, driven by the increasing awareness of environmental conservation and the impact of climate change. Ref. [31] discovered a notable link between corporate social responsibility (CSR) levels and information asymmetry, indicating that companies can enhance investor perception by reducing information asymmetry.

Green bonds are issued by both governments and corporations. Therefore, there are different outcomes attached to the issuance of green bonds. There are a wide range of drivers that act as catalysts to the institutional pressure that can force organizations to undertake the issuance and development of green bonds [19,22,32]. Several drivers can directly influence the decision to invest more in green bonds or sustainable development, including investors, standard setters, or strategic business partners, and some can influence businesses indirectly, such as government agencies and international bodies [22,32–34] discovered that macroeconomic determinates, such as trade openness and stock market capitalization, also act as drivers for green bond development.

Green bonds have emerged as a significant tool to mobilize funds for environmentally friendly projects. They offer several advantages. Firstly, green bonds enable issuers to access a broader pool of investors, including those with a specific interest in sustainability [35]. Secondly, they can enhance the issuer's reputation and signal their commitment to addressing environmental concerns [36]. Thirdly, green bonds can contribute to the growth of the green finance market and promote the transition to a low-carbon economy [37].

However, green bonds also come with certain limitations. One concern is the potential for "greenwashing" or the misallocation of funds, where projects may not deliver the intended environmental benefits [38]. Ensuring transparency and robust reporting standards is crucial to mitigate this risk [39]. Additionally, the green bond market may face challenges related to scalability and liquidity, as it remains a niche market compared to the overall bond market [40].

2.1. Green Bonds and Carbon Emissions

Till now the literature has focused on green bonds and their impact on a firm's financial performance. The limitation of the literature is due to access to green bond data. Currently, only a few studies discussed green bonds and their direct impact on society or sustainability. However, these studies did not use green bond data directly; in fact, they used the green bond index. Ref. [41], for example, investigated the relationship between the global green bond index (GRBI) and the environmental and social responsibility index (ESRI) index. The results found that there is a positive relationship between GRBI and ESRI, but that the positive impact of green bonds later declined gradually. Additionally, Ref. [42], investigated the role of green bond financing in economic growth and energy efficiency, and they found that green financing is very useful in economic recovery and producing efficient energy. However, no studies used green bond data directly in any research model, which was due to access to data regarding green bonds.

According to recent data, green bonds are issued by both government and corporate sectors. The corporate sector thus includes green energy or renewable energy, emission, green transportation, carbon emission, sustainable housing, clean waters, etc. Ref. [43]. Renewable energy is attracting the most investment through green bonds as well as foreign direct investment [44]. The increasing investment in clean energy is the result of countries planning to reduce carbon emissions and transfer most of their energy resources from carbon-based to clean and green energy. According to a study conducted by Sharma et al., in 2021, it was discovered that economic growth exhibited positive correlations with ecological footprint, non-renewable energy consumption, and carbon emissions.

Few studies demonstrated that the main aim of investing in green energies is to reduce emissions. Some initial studies focused on green finance and government support policies to make it efficient in promoting sustainable development. For instance, Ref. [45] suggested that the green finance market should be mechanized and regulated to facilitate the flow of funds from institutions to achieve the effective management of environmental risk and

the optimal allocation of environmental resources. They also argued that the construction of environmental protection should consider the mechanism of an efficient green finance system that coordinates the relationship between ecology and finance. Ref. [46] studied the opportunities and challenges surrounding green finance (GF) and suggested effective and long-term policy interventions by the government to ensure the aim of reducing the risks perceived by financial institutions in funding biomass producers. In a study by [47], it was suggested that implementing supportive policies to encourage the advancement of the renewable energy sector could yield dual benefits in the long run. These benefits include not only an increase in GDP growth but also a reduction in greenhouse gas (GHG) emissions. Ref. [48] argued that increasing renewable energy (RE) by 1% led to a decline in GHG emissions in the interval (0.166103, 0.220551). Ref. [49] found that investing in renewable energy can also contribute to decreasing missions.

Apart from financial benefits, there are also environmental benefits attached to green bonds and sustainable eco-friendly activities. Ref. [28] found that green bond issuers improve their environmental performance post-issuance (i.e., higher environmental ratings and lower emissions) and experience an increase in ownership by long-term and green investors. Ref. [11] analyzed the impact of green bond issuing announcements on corporate social responsibility (CSR) activities of the Chinese listed firms, which was further reciprocated by the social and environmental activities carried out by the firms [27] stated that the positive environmental effect instigated by the green bonds trade eases the implementation and diffusion of renewable energy solutions across nations. Ref. [50] stated that environmental finance can help in creating green financial tools, which in turn can control environmental pollution and optimize the structure of an industry.

Based on the above empirical literature, our first hypothesis is as follows:

H1: *Green Bonds will negatively affect carbon dioxide emissions (CO_2).*

2.2. Green Bonds and Renewable Energy

When we talk about greenhouse gas (GHG) emissions or carbon emissions and sustainable development there is another important factor, namely renewable energy, that should be treated with the same importance. If renewable energy can be integrated into energy systems worldwide, it will decrease the level of GHG emissions. Increasing the deployment of renewable energy sources (RES) aligns with various countries' policies aimed at achieving a primary outcome of minimizing greenhouse gas (GHG) emissions. Few studies demonstrated that the main aim of investing in green energies is to reduce these emissions. In 2019, Ref. [47] put forth the proposition that strengthening supportive policies to foster the growth of the renewable energy sector can yield dual benefits in the long run, namely stimulating GDP growth and reducing greenhouse gas (GHG) emissions. They argued that by boosting renewable energy development, both economic and environmental advantages can be achieved simultaneously. Similarly, in 2019, Vasilyeva et al. contended that a mere 1% increase in renewable energy adoption corresponds to a reduction in GHG emissions within the range of 0.166103 to 0.220551. Their findings highlighted the significant potential of renewable energy sources in mitigating climate change and lowering emissions. Building on this research, Ref. [49] further corroborated the notion that renewable energy plays a crucial role in decreasing emissions. Their study also provided additional evidence supporting the positive environmental impact of renewable energy, reinforcing the idea that transitioning to cleaner energy sources can contribute to emission reduction efforts.

Initial studies focused on the impact of renewable portfolio standards (RPS), feed-in-tariffs (FiTs), and other factors related to country economics that affect energy policies. Ref. [51] found that investor-owned utilities invest more than publicly owned utilities in regard to RPS and that mandatory green power options (MGPO) lead to greater amounts of green electricity and installed renewable capacity. Ref. [52] employed a difference-in-differences approach to evaluate the effects of renewable portfolio standards (RPS) on renewable energy (RE) generation, electricity prices, emissions linked to electricity production, and electricity demand. Their findings indicated that the implementation of RPS

policies can increase electricity prices, which is in line with the previous studies by [53,54] However, Refs. [55,56] have the opposite stance on using RPS. Refs. [57,58] claim that FiTs are the most suitable policies of choice for spurring RE deployment. Ref. [59] found that monetary, fiscal, and economic incentives, such as FiTs and direct investments, are the most impactful measures for investors in the wind, solar, and biomass sectors. Then, we have foreign direct investments (FDI), which are prominent factors in a country's development, especially in the energy sector. Ref. [44] stated that FDI improves clean energy usage and saves energy consumption by investing in more technologically efficient devices and instruments used to produce and transmit and distribute energy. Ref. [60] examined data from Chinese renewable energy firms and uncovered the fact that green bonds strengthen investment in renewable energy, while oil price volatility negatively impacts investment in the renewable energy sector. Additionally, they argued that environmental taxes and regulations strengthen renewable or green energy investments in China.

Based on the empirical literature discussed, our second hypothesis is:

H2: *Green bonds will positively affect renewable energy production.*

2.3. Other Variables Affecting Sustainability

Several research studies have examined the role of environmental taxes and foreign direct investment (FDI) in the context of environmental sustainability. Environmental taxes and FDI are the two vital instruments currently helping to reduce carbon emissions. Environmental taxes force organizations to reduce emissions out of fear of tax costs, and FDIs have been considered a source of sustainable investment in recent years. Ref. [61] highlighted the interplay between trade liberalization, corruption, and environmental policy formation. Ref. [62] found evidence that FDI contributes to environmental improvements in Chinese cities. Ref. [63] explored the impact of government corruption on lobbying for environmental cooperation under the Kyoto Protocol. Ref. [64] investigated the relationship between environmental performance, regional innovation capacity, and economic growth in China. Ref. [65] analyzed the link between carbon emissions and FDI in China. These studies provide insights into various aspects of the complex relationship between environmental taxes, FDI, and environmental sustainability, shedding light on the importance of policy frameworks, corruption, innovation, and economic growth in shaping environmental outcomes. Many studies argue that foreign investors prefer to invest in technology-oriented businesses, sustainable projects, or organizations with good ESG scores; as a result, the level of carbon emissions in countries with high FDI will be reduced. Ref. [66] argued that environmental tax has a negative relationship with carbon emissions in the presence of FDI, while FDI itself also plays a role in decreasing carbon emissions. Ref. [67] investigated the role of green growth in stimulating a sustainable environment. They found that environmental tax, human capital, and renewable energy use are found to decrease emissions. He et al. [68] found that environmental taxes help to reduce pollutant emissions, both in OECD countries and China.

Extending the current literature, we will try to find a direct relationship between green bonds and sustainability. Earlier studies examined CO_2 emissions and renewable energy in relation to other factors, such as green bonds and stock market/indices, green finance investment, sustainability policies, FDI, and GDP growth. However, the direct relationship of green bonds with sustainability, CO_2 emissions, renewable energy, and other factors related to sustainability have not been examined previously. The recent development in the green bonds market has made it necessary to examine the impact of green bonds on sustainable development and policies related to it. The most important factors are CO_2 emission and renewable energy.

This study will use green bonds, carbon emissions per capita, and renewable energy per capita data directly to identify whether green bonds play a role in reducing carbon emissions and increasing the production of renewable energy around the world. This study will add to the literature in many ways, as it will be the first study to examine the impact of the green bond on carbon emissions and renewable energy production. The study will also

provide detailed information about the recent green bonds market and its categorization. The results will be very useful for evaluating the steps in creating sustainable societies, as green bonds are the most prominent source currently used as a sustainable development tool by both governments and corporations around the world.

3. Data and Methodology

The main variables of our data are "Green Bonds, Renewable Energy per Capita (renewable energy/electricity produced in kilowatt-hours (kWh) per capita refers to the average amount of electricity generated within a specific geographic area or country per person.)" and "carbon emissions per capita (carbon dioxide (CO_2) emissions produced by an individual in a specific geographic area, typically measured in metric tons (tonnes) of CO_2 per person.)". "Green Bonds Data" were retrieved from Bloomberg Terminal from 2007 to 2021. Renewable energy (kWh) and emissions per capita (in tons) were retrieved from the Global Carbon Project through "Our World in Data". Then, we used environmental tax as a moderate variable and "Foreign Direct Investment" as a control variable in our model. The data for environmental tax and FDI were retrieved from the IMF (International Monitory Fund) database. We used data from 67 countries around the world.

We included both supranational bonds and bonds from 67 countries in the category of green bonds. Therefore, the total number of green bond issuers in our dataset is 68. Because supranational bonds are not attached to any country, we placed them in the worldwide category. In the same way, we used worldwide data for other variables in the data to balance our panel. The most important criterium for a country selection is that it must have issued a green bond. Then, we searched for other economic data relevant to that country. The proxy used for "Green Bonds" is the number of "Green Bonds" issued each year and then the amount/worth of these bonds.

We used the one-step generalized method of moment (GMM-One-Step) and a simple "Dynamic panel data model" to estimate our variables with a one-step lag of the dependent variable. The generalized method of moments (GMM) was introduced by [69]. GMM makes use of the orthogonality conditions to allow for efficient estimation in the presence of unknown heteroscedasticity. The application of the dynamic panel data (DPD) approach is often attributed to [70] in their influential study published in the Review of Economic Studies in 1991. However, it should be noted that they played a crucial role in popularizing the earlier work of [71] in the field of econometrics, specifically in the context of panel data analysis.

The GMM model is used to tackle the problems of the endogeneity of lagging dependent variables, heteroscedasticity, and serial correlation in the residuals, correlation, and previous checking of random effects. GMM also controls for the bias derived from omitted variables, because in our data, the number of bonds issued is different every year, and in some years, there were no bonds issued. To solve the problem of endogeneity we used the emissions lag as an instrumental variable to solve the problem of endogeneity. Our data structure also allows us to apply the GMM model, as the number of cross-sections is greater than periods (N > T). The basic equation for the models is as follows:

$$g(\theta) = (1/n) \sum [m(Xi, \theta)Zi]$$

$g(\theta)$ represents the vector of moment conditions. These moment conditions capture the economic relationships. θ represents the vector of unknown parameters to be estimated (dependent variable). n represents the sample size. $m(Xi, \theta)$ represents the individual moment conditions, which are functions of the observed data (Xi) and the unknown parameters (θ) (independent). Zi represents the instrumental variables (IVs) associated with each moment condition. IVs are variables that are correlated with endogenous variables but not directly affected by the error term.

Our model is defined as follows:

$$CO_2\ Emissions = \alpha_i + \beta_1 GBonds(Numbers) + \beta_2 ETax + \beta_3 \log FDI + \varepsilon \quad (1)$$

$$CO_2\ Emissions = \alpha_i + \beta_1 GBonds(Value) + \beta_2 ETax + \beta_3 \log FDI + \varepsilon \quad (2)$$

$$Renewable\ Energy = \alpha_i + \beta_1 GBonds(Numbers) + \beta_2 ETax + \beta_3 \log FDI + \varepsilon \quad (3)$$

$$Renewable\ Energy = \alpha_i + \beta_1 GBonds(Value) + \beta_2 ETax + \beta_3 \log FDI + \varepsilon \quad (4)$$

The dependent variables in the model above are CO_2 emissions, which represent the total amount of carbon emissions per capita, and renewable energy, which refers to the renewable energy produced per capita. The independent variable of interest is the annual number of green bonds issued by a country (G-bond Number), while the alternative independent variable is the value of green bonds issued (G-bond Value). A moderating variable, E-Tax, measured as the percentage of environmental tax per GDP, is introduced to assess the impact of environmental tax policies on the relationship. Additionally, a control variable, log-FDI, representing the logarithmic value of foreign direct investment in millions (USD), is included. The study aims to analyze how green bonds, environmental taxes, and FDI influence CO_2 emissions and renewable energy production per capita.

4. Results

4.1. Descriptive Results

Tables 1 and 2 and Figures 1 and 2 show the descriptive statistics of our data as well as the number of green bonds issued worldwide by sector and each year. Our descriptive results exhibit the numbers for all the variables that are used in this study. Additionally, the correlation matrix shows that there is a negative correlation between green bonds and emissions, while green bonds show a positive correlation with the renewable energy produced.

Table 1. Descriptive Statistics.

Variable	Mean	Std. Dev.	Min	Max
Green Bonds (Number Issued)	5.522	21.577	0	336
Green Bonds (Amount Issued)	1.638×10^9	6.341×10^9	0	8.500×10^{10}
E-Tax as a Percentage of GDP	2.712	10.918	−1.53	104.781
FDI	43,578.492	191,628.16	−162,704	2,100,000
CO_2 Emissions (Per Capita)	1.686	0.903	−1.382	3.933
Renewable Energy (Per Capita)	2661.522	7241.148	0	56,769.699

Table 2. Pearson Correlation Matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Emissions	1.000					
(2) Renewable Energy	0.068 (0.029)	1.000				
(3) Green Bonds (Number Issued)	−0.002 ** (0.042)	0.037 ** (0.023)	1.000			
(4) Green Bonds (Amount Issued)	−0.017 (0.583)	0.079 ** (0.012)	0.435 * (0.000)	1.000		
(5) FDI (Log)	0.118 * (0.000)	−0.151 * (0.000)	0.273 * (0.000)	0.310 * (0.000)	1.000	
(6) E-Tax	−0.060 (0.056)	−0.020 (0.527)	0.190 * (0.000)	0.192 * (0.000)	0.369 * (0.000)	1.000

** $p < 0.05$, * $p < 0.1$.

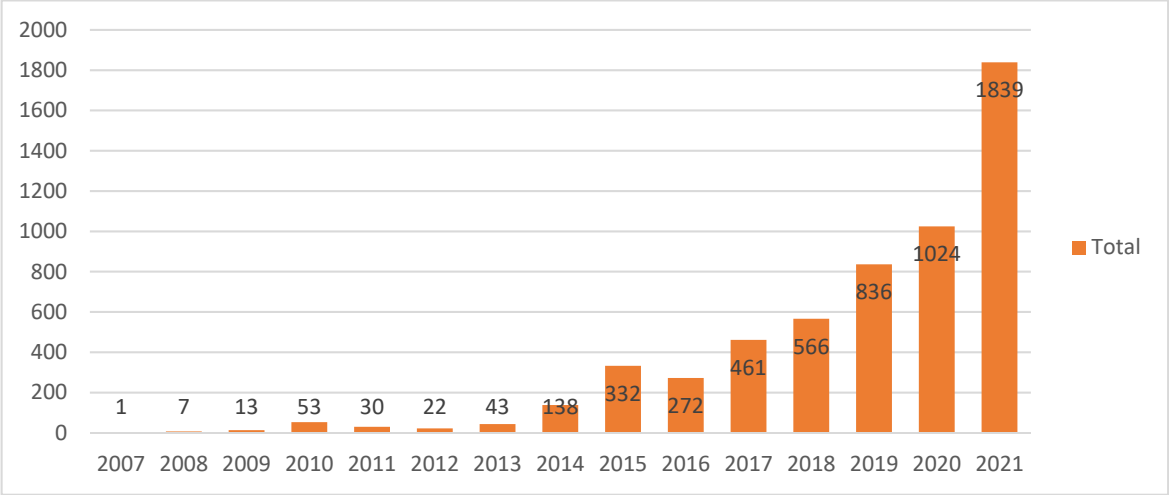

Figure 1. Number of green bonds issued by year.

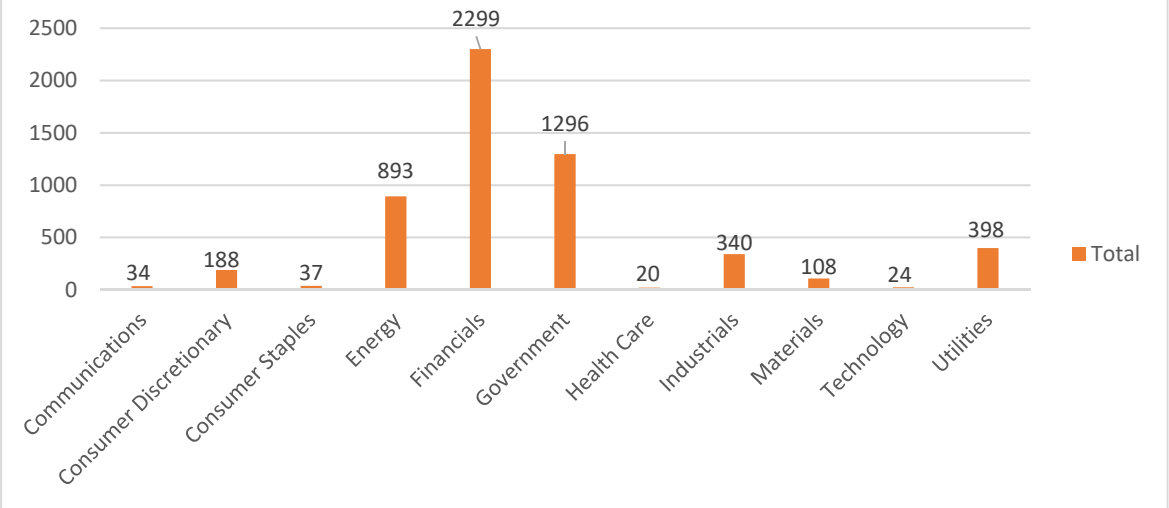

Figure 2. Number of green bonds issued by sector.

Table 1 "Green Bonds (Amount)" represents the value of green bonds issued in USD billions. "FDI" is the foreign direct investment for each country in USD millions, "CO_2 Emissions" are the carbon emissions per capita in each country measured in tons, and "Renewable Energy (Per Capita)" is the portion of renewable energy in total energy per capita in each country measured in kilowatt hour (kWh).

The data show that financial, government, and energy are the top three sectors where a high number of green bonds are issued. According to the data, the government includes supranational bonds as well, such as the bonds issued by the World Bank, Asian development banks, African banks, European Union banks, and other development banks around the world. Such bonds come under the umbrella of supranational because they are issued worldwide in multiple currencies. The rest of the government sector includes country governments and local bodies, as well as development banks at the country level. Yearly data show that the number of green bonds has increased year by year. The sudden increase in the number of green bonds can be seen in 2015, and 2021 is the year with the highest number of green bonds issued.

Figure 3 shows data by country. China is the highest issuer of green bonds, with 742 bonds issued up to the end of 2021, while Sweden holds second position, Germany is in third place, the US is in fourth place, and France is in fifth place in regard to the number of issuances. Overall, based on counts, supranational bonds are number two worldwide. The

countries that are not shown here have issued less than fifty green bonds in total. Due to space limits, we did not include them in the graph. Figure 4 displays data for the value of bonds issued per year in millions (US Dollars). We can see that investment in green bonds has been increasing consistently year by year since its launch in 2007, particularly after 2015. Figures 5 and 6 display data for carbon emissions and renewable energy produced per capita worldwide.

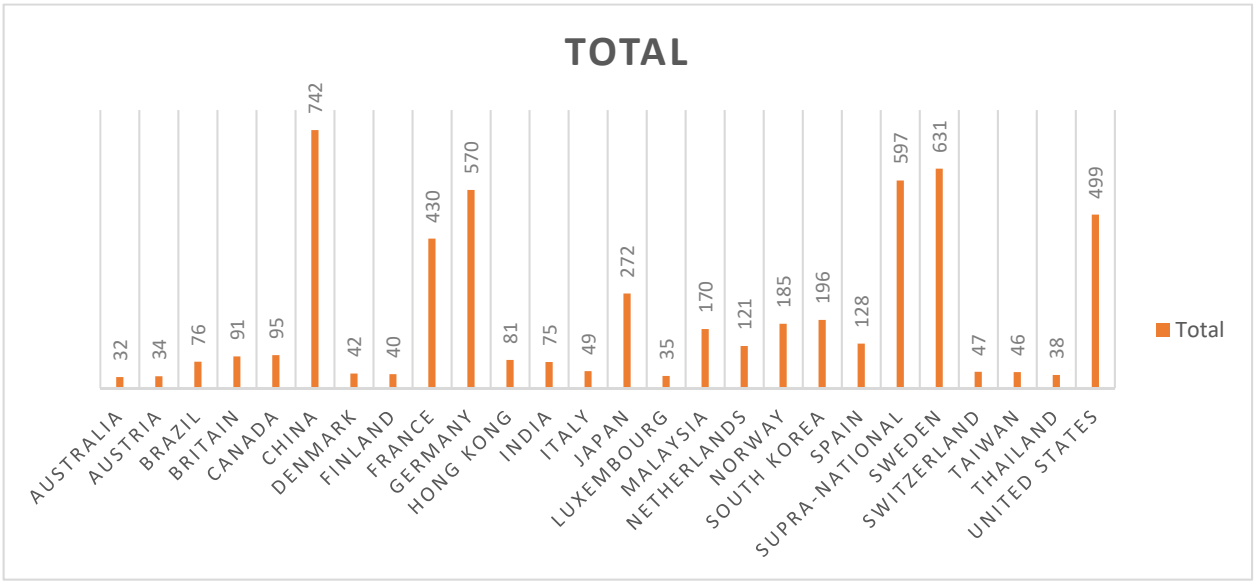

Figure 3. Number of green bonds issued by country.

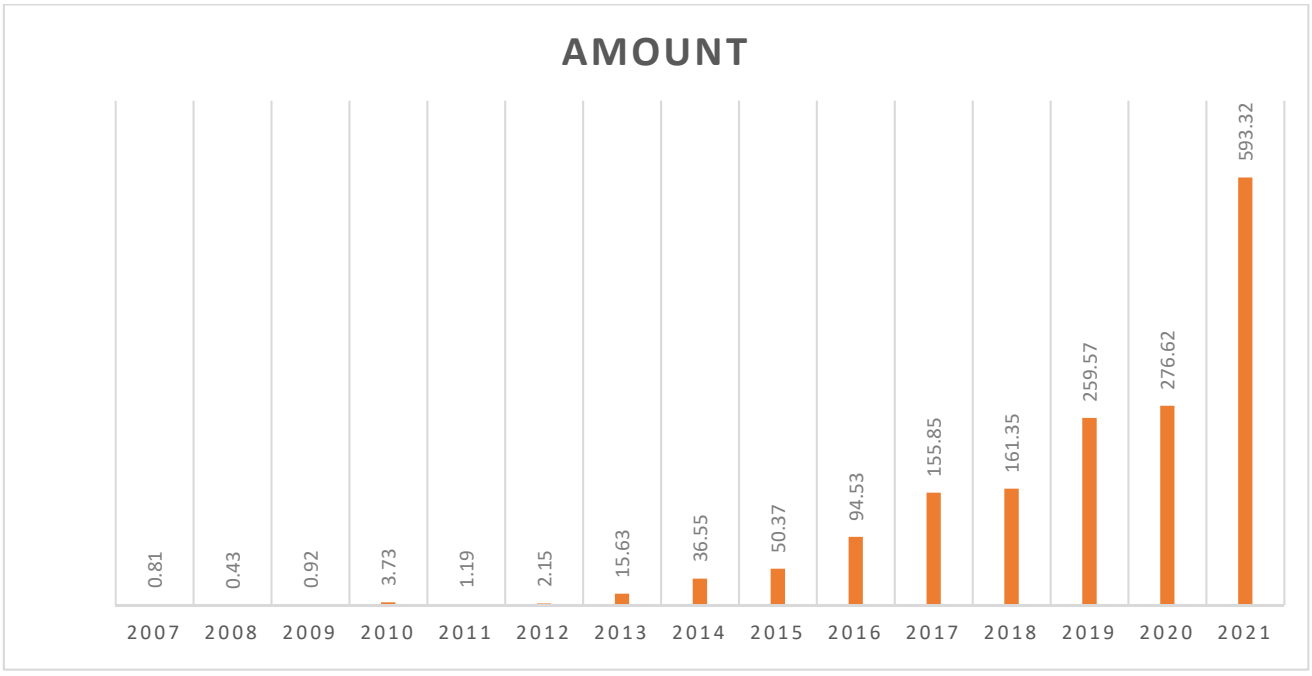

Figure 4. Value of green bonds issued by year. (Amount in Billion USD).

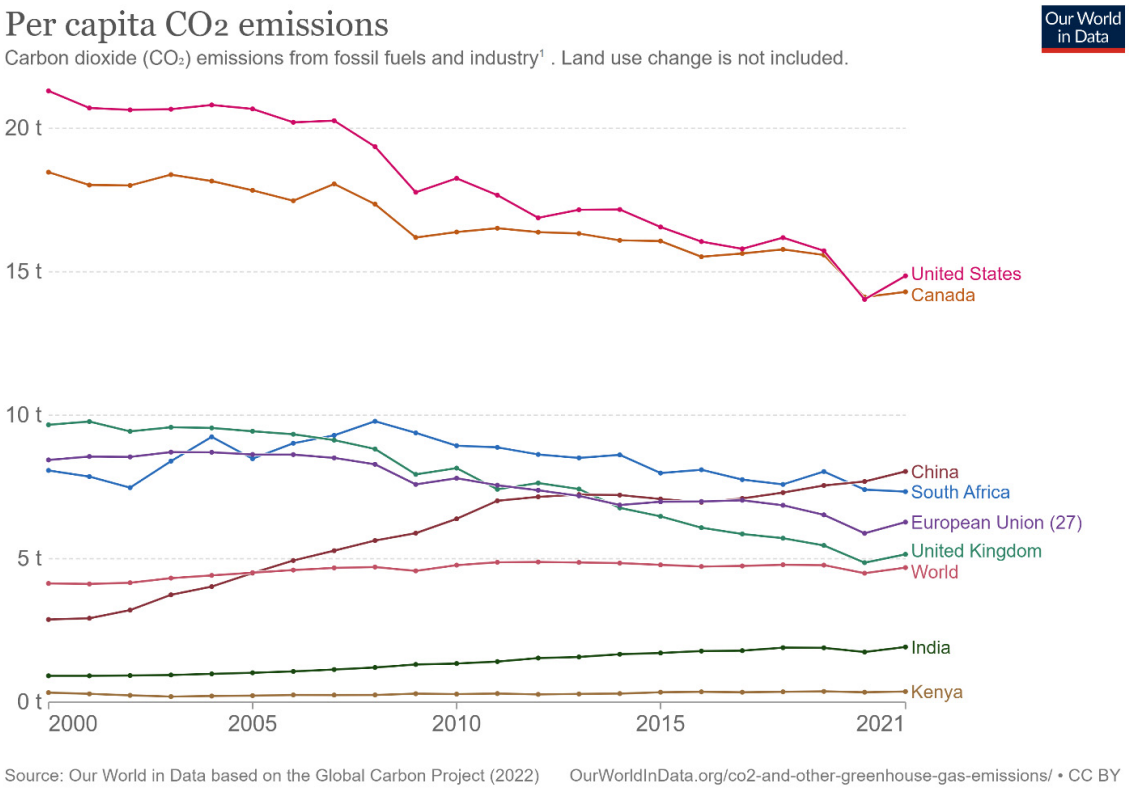

Figure 5. Carbon emission per capita worldwide from 2000 to 2021. (Retrieved from Our World in Data).

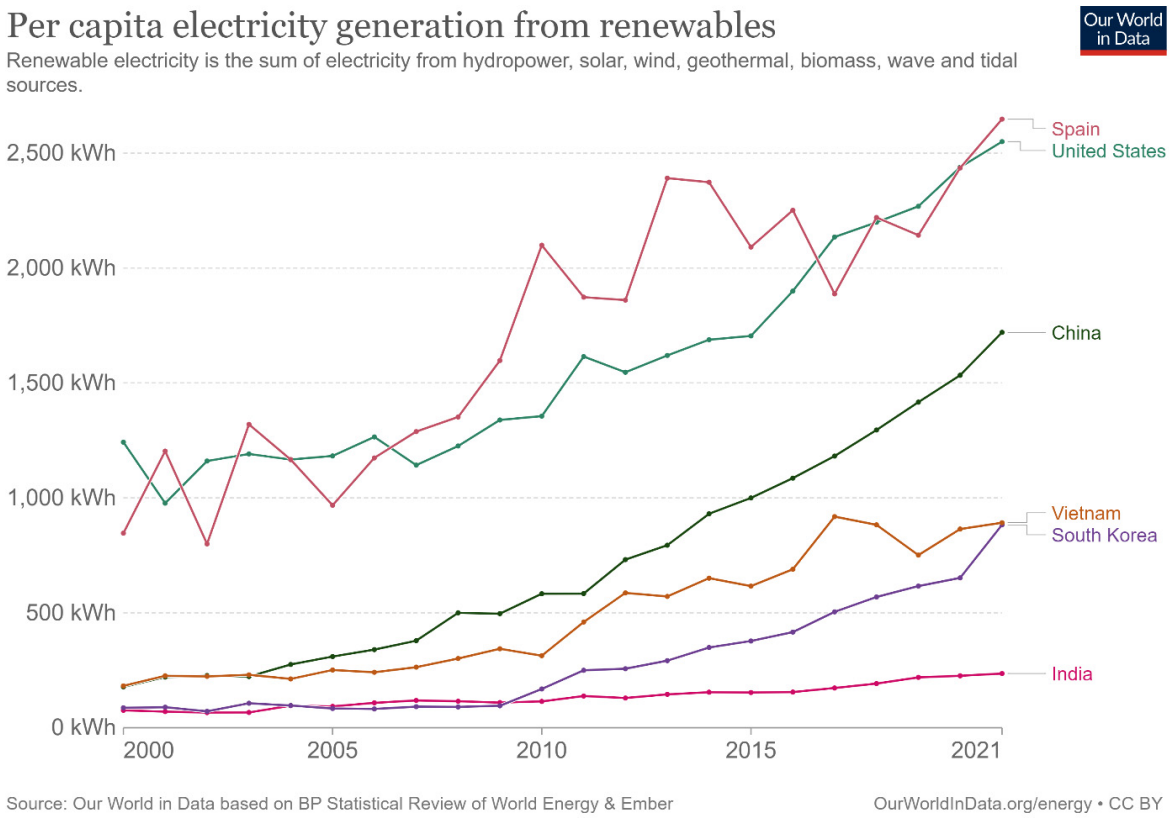

Figure 6. Renewable energy per capita worldwide from 2000 to 2021. (Retrieved from Our World in Data).

Figure 3 displays the number of green bonds issued by a country each year. The table displays the top issuers of green bonds worldwide.

Figure 4 displays the value of green bonds issued by year. The bar shows two values, the lower one shows the number of green bonds issued in the current year and the upper value shows the total value of bonds issued in billion USD. The total value shown is in billions.

4.2. GMM Analysis

4.2.1. Green Bonds and Carbon Emissions

Table 3 exhibits GMM results for our model. We applied our model in three steps. First, we included green bonds and emissions in the model, and this revealed that there is a negative relationship between green bonds and carbon emissions. Secondly, we added FDI into the GMM equation as a control variable in order to confirm the validity of green bond results. We used log-FDI as a control variable. Again, in the presence of FDI, we can see that green bonds display a negative relationship to emissions. However, FDI itself shows a positive relationship to emissions. The results testify that green bonds are helping to decrease carbon emissions. Thirdly, we included environmental tax in our model as a moderating variable. The results still show that there is a negative relationship between green bonds, environmental tax, FDI, and emissions.

Table 3. GMM results (dependent variable is CO_2 emissions per capita).

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**	**CO_2 Emissions**	**Coef.**
G-bonds (Number Issued)	−0.04 *** (−26.36)	G-bonds (Issued)	−0.035 *** (−18.69)	G-bonds (Number Issued)	−0.028 *** (−9.25)
Constant	7.772 *** (353.53)	Log-FDI	0.39 *** (8.74)	E-Tax	−0.967 *** (−26.90)
		Constant	3.439 *** (8.53)	Log-FDI	−0.203 *** (−2.72)
				Constant	11.959 *** (16.66)
AR1	0.000	AR1	0.000	AR1	0.000
AR2	0.363	AR2	0.373	AR2	0.330
Hansen Test	0.000	Hansen Test	0.940	Hansen Test	0.873
Chi-square	164,149.027	Chi-square	579.700	Chi-square	38,717.289
Number of Obs	1020	Number of obs	954	Number of Obs	796

*** $p < 0.01$.

Table 3 displays the GMM (one-step) results. The dependent variable is "Carbon Emissions" (CO_2) per capita measured in tons. The independent variable is "Green Bonds (Number)", which represents the number of green bonds issued in any country per year. "FDI" (foreign direct investment) is the control variable proxied by the FDI log. "E-tax" is the moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Before adding the E-tax into our model, we removed those countries where no environmental tax is implemented or E-Tax had only been implemented for less than three years. As a result, we can see that the number of observations decreased in the last column of Table 3. The results demonstrate that not only can green bonds mitigate environmental pollution but environmental tax can also moderate this relationship and plays a role in decreasing environmental pollution. Additionally, the FDI shows a positive relationship with emissions, but in the presence of E-tax, FDI is showing a negative relationship with emissions, which means E-tax is affecting the role of foreign investment in increased emissions and forcing businesses to adopt sustainable policies.

To confirm the robustness of our model, we replaced the green bond numbers (count) with the total amount issued under green bonds. So, the modified model will be described in the following paragraph.

Table 4 displays the result for the GMM model after we replaced the number of green bonds with the value/amount of bonds issued. The results show a negative relationship between green bond value and carbon emissions worldwide. As in the first model, we separately placed the control variables and moderating variables into the model, but the results were stable and there was no change in green bonds significance or coefficient value. We can see that the impact of the green bond became stronger after we added E-Tax to the model. This means that E-tax plays a significant role in decreasing carbon emissions in different countries around the world where green bonds are issued for sustainable projects. Additionally, the FDI has a negative coefficient value, which means that foreign direct investment helps to decrease emissions or that the FDI investment is directed toward environmentally friendly projects. Hence, our hypothesis H1 is valid, and we proved that there is a negative relationship between green bonds and emissions.

Table 4. GMM results (replacing number of bonds with value of bonds).

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**	**CO_2 Emissions**	**Coef.**
Green Bonds (Amount Issued)	−0.075 *** (−23.97)	Green Bonds (Amount Issued)	−0.0711 *** (−15.41)	Green Bonds (Amount Issued)	−0.084 *** (−16.29)
Constant	8.04 *** (283.43)	FDI	0.282 *** (6.43)	E-Tax	−0.905 *** (−33.05)
		Constant	19.389 *** (18.91)	FDI	−0.158 *** (−4.82)
				Constant	11.682 *** (40.09)
Number of Obs	1020	Number of Obs	954	Number of Obs	796
AR1	0.000	AR1	0.000	AR1	0.000
AR2	0.915	AR2	0.953	AR2	0.778
Hansen Test	0.000	Hansen Test	0.000	Hansen Test	0.120
Chi-square	147,017.782	Chi-square	31,165.563	Chi-square	

*** $p < 0.01$.

Table 4 displays GMM (one-step) results. The dependent variable is "Carbon Emissions (Per Capita)" measured in tons. The independent variable is "Green Bonds (Amount Issued)", representing the value of green bonds issued in any country annually. "FDI" (foreign direct investment) is the control variable proxied by the FDI log. "E-tax" is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

4.2.2. Green Bonds and Renewable Energy

Table 5 displays the GMM results of the relationship between green bonds and renewable energy per capita. As in the previous section, we applied our model in three steps. First, we applied green bonds with renewable energy per capita as the dependent variable and then added FDI and E-Tax into the model to further confirm the validity of the model. The result shows that there is a positive and significant relationship between green bonds and renewable energy. After adding FDI and E-Tax into model, the positive and significant nature of green bonds was still present. Although by including FDI, the coefficient value of green bonds became stronger, FDI itself displayed a negative relationship with emissions. While adding E-tax into the equation the impact of green bonds was still positive, E-tax itself did not provide any significant results. FDI also exhibited a negative relationship with emissions. Finally, we can say that green bonds

help to add renewable energy into systems, and investment in renewable energy projects using green bonds is proving to be useful.

Table 5. GMM results (dependent variable is renewable energy per capita).

Renewable	Coef.	Renewable	Coef.	Renewable	Coef.
Green Bonds (Number Issued)	39.828 *** (26.66)	Green Bonds (Number Issued)	66.2 *** (7.50)	Green Bonds (Number Issued)	17.35 *** (17.64)
Constant	2441.611 *** (126.82)	FDI	−4475.996 *** (−28.18)	E-Tax	0.673 (0.27)
		Constant	42,667.194 *** (29.69)	FDI	−481.495 *** (−13.86)
				Constant	6905.726 *** (22.52)
AR1	0.013	AR1	0.00	AR1	0.00
AR2	0.810	AR2	0.14	AR2	0.564
Hansen Test	0.00	SARGAN	1.00	Hansen Test	0.422
Chi-Square	24,117.35	Chi-Square		Chi-Square	
Number of Obs	1020	Number of Obs	954	Number of Obs	796

*** $p < 0.01$.

Table 5 displays GMM (one-step) results. The dependent variable is renewable energy produced per capita measured in kWh. The independent variables are "Green Bonds (Number Issued)", representing the number of green bonds issued in any country annually. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

To confirm the validity of the results, we replaced the number of green bonds issued with the total amount of green issued per year. Table 6 displays the results of the GMM model with green bond value as the independent variable instead of green bond numbers. The results are still valid, and there is a positive relationship between green bonds and renewable energy. The results remain positive and have significant values both in the presence and absence of moderating and control variables. On the other hand, E-tax shows a positive and significant relationship, which shows the moderating nature of the E-tax, and we can say that environmental tax positively affects the role of green bonds in improving renewable energy production. Finally, we can argue that our results for green bonds and renewable energy are valid and that there is a positive relationship between green bonds issued and renewable energy produced per capita. Hence, our second hypothesis H2 remains valid, and we can say that green bonds positively affect renewable energy production.

Table 6 displays GMM (one-step) results. The dependent variable is "Renewable Energy Produced Per Capita" measured in kWh. The independent variable is "Green Bonds (Amount Issued)", representing the value of green bonds issued in any country annually. "FDI" (foreign direct investment) is the control variable proxied by the log of FDI. "E-tax" is moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 6. GMM results (replacing number of bonds with value of bonds).

Renewable	Coef.	Renewable	Coef.	Renewable	Coef.
Green Bonds (Amount Issued)	61.247 *** (32.54)	Green Bonds (Amount Issued)	39.336 *** (17.94)	Green Bonds (Amount Issued)	32.251 *** (8.62)
Constant	2657.074 *** (117.79)	FDI	−434.767 *** (−24.87)	E-Tax	28.36 *** (10.08)
		Constant	6005.295 *** (38.83)	FDI	−847.069 *** (−25.87)
				Constant	10,027.021 *** (34.43)
Number of Obs	855	Number of Obs	945	Number of Obs	796
AR1	0.000	AR1	0.000	AR1	0.000
AR2	0.416	AR2	0.411	AR2	0.349
Hansen Test	0.000	Hansen Test	0.8	Hansen Test	1.000
Chi-square	28,332.473	Chi-square	19,763.971	Chi-square	12,278.946

*** $p < 0.01$.

5. Robustness

To check the robustness of our model and the validity of the data, we applied different tools. The first is econometrics, and the second is data splitting. As we know, the GMM model considers the autocorrelation of the variables. According to Roodman [72] if AR2 > 0 means there is no second-order serial correlation, then the current conditions are correctly specified. The Hansen test was first implemented by Hansen [69] and is concerned with over-identifying restrictions in a statistical model. All of our results tables mention the AR (1), AR (2), and Hansen test values, and the results for the Hansen test are significant, as for AR (2), since they are non-significant results which show that the model is fit and that our variables do not suffer from second-order serial correlation.

To check the robustness, we first conducted all our tests with and without control and moderating variables, i.e., FDI and E-Tax. The results are shown in Tables 3–6. Additionally, we used the "number of bonds" and the "value of bonds", which are both given in USD. Both variables provide significant results and do not change anywhere in our results.

Next, we split our data into two groups, namely 2007–2014 and 2015–2021, to further check the authority of our results. We ran the GMM model separately on both, using green bond numbers issued and amounts issued, as was carried out previously. We split the data before and after 2015, as the Paris Agreement was in 2015, and the boom in the number of green bonds issued occurred in 2015 and the year following. Before 2015, there was no such stress on green bonds from governments and institutions. Tables 7 and 8 display results for the data before 2015. The results in Table 7 show that green bonds have no significant relationship with emissions for both green bond number and the amount issued. However, in Table 8, we can see that green bonds (numbers) have a positive and significant relationship with renewable energy. Meanwhile, when we applied the amount issued for green bonds instead of green bond numbers, the result was not significant. This means that green bonds do not affect the renewable energy produced, and green bonds have no significant impact on emissions.

Table 7. GMM results (2007–2014) CO_2 emissions per capita as dependent variables.

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**
Green Bonds (Number Issued)	−0.236 (−0.64)	Green Bonds (Amount Issued)	−0.012 (−1.10)
E-Tax	−6.631 *** (−15.07)	E-Tax	−0.105 *** (−20.69)
FDI	−5.85 *** (−7.05)	FDI	1.089 *** (25.28)
Constant	78.09 *** (9.62)	Constant	−1.797 *** (−4.67)
AR1	0.05	AR1	0.000
AR2	0.001	AR2	0.893
Hansen Test	0.00	Hansen Test	0.000
Chi-square	1579.469	Chi-square	43,126.402
No of Obs	518	No of Obs	518

*** $p < 0.01$.

Table 8. GMM results (2007–2014) renewable energy per capita as dependent variable.

Renewable	**Coef.**	**Renewable**	**Coef.**
Green Bonds (Number Issued)	163.068 ** (2.15)	Green Bonds (Amount Issued)	11.204 (0.94)
E-Tax	246.694 *** (8.19)	E-Tax	32.245 *** (5.77)
FDI	−5475.101 *** (−20.24)	FDI	−955.179 *** (−19.36)
Constant	51,489.286 *** (21.26)	Constant	11,089.503 *** (25.18)
AR1	0.000	AR1	0.000
AR2	0.140	AR2	0.428
Hansen Test	1.000	Hansen Test	1.0
Chi-square	688.660	Chi-square	5817.966
No of Obs	518	No of Obs	518

*** $p < 0.01$, ** $p < 0.05$.

Table 7 displays results for the GMM (one-step) model for 2007–2014. The left-hand side displays the result for green bonds (numbers) as the independent variable and emissions as the dependent variable. The right-hand display green bonds (value) as the independent variable and emissions per capita as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 8 displays results for the GMM (one-step) model for 2007–2014. The left-hand side displays results for green bonds (numbers) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Next, we applied our model to the data after 2015. Tables 9 and 10 display the results for data after 2015. Table 9 results show that there is a negative and significant relationship between green bonds and emissions. The result is the same for both green bond

numbers and the amount issued. Table 10 displays results for green bonds and renewable energy. The results show that there is a positive and significant relationship between green bonds and renewable energy. The results are holding the same nature for both green bond numbers and the amount issued. In conclusion, we can say that green bonds have had more impact on sustainable development after 2015. These results also indicate that increasing the number of green bonds increases green finance and can help to achieve sustainable development goals. Additionally, we can say that the initiative taken by the international community to achieve SDG goals is on the right track.

Table 9. GMM results (2015–2021) CO_2 emissions per capita as dependent variable.

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**
Green Bonds (Number Issued)	−0.029 *** (−6.98)	Green Bonds (Amount Issued)	−0.427 *** (−7.23)
E-Tax	−0.148 *** (−6.01)	E-Tax	−2.813 *** (−12.23)
FDI	2.683 *** (11.03)	FDI	1.295 *** (3.33)
Constant	−16.857 *** (−7.78)	Constant	8.59 ** (2.44)
AR1	0.000	AR1	0.000
AR2	0.505	AR2	0.388
Hansen Test	1.000	Hansen Test	1.000
Chi-square	8156.109	Chi-square	1820.892
No of Obs	436	No of Obs	436

*** $p < 0.01$, ** $p < 0.05$.

Table 10. GMM results (2015–2021) renewable energy per capita as dependent variable.

Renewable	**Coef.**	**Renewable**	**Coef.**
Green Bonds (Number Issued)	62.854 *** (3.18)	Green Bonds (Amount Issued)	186.127 *** (3.76)
E-Tax	−765.805 *** (−6.64)	E_Tax	−1095.18 *** (−4.31)
FDI	−1994.297 *** (−16.65)	FDI	−2801.7 *** (−10.56)
Constant	21,728.461 *** (18.69)	Constant	28,550.378 *** (11.83)
AR1	0.000	AR1	0.000
AR2	0.650	AR2	0.940
Hansen Test	1.000	Hansen Test	1.000
Chi-square	1454.135	Chi-square	589.876
No of Obs	436	No of Obs	436

*** $p < 0.01$.

Table 9 displays results for the GMM (one-step) model for 2015–2021. The left-hand side displays the result for green bonds (numbers) as the independent variable and emissions as the dependent variable. The right-hand column displays green bonds (value) as the independent variable and emissions per capita as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 10 displays results for the GMM (one-step) model for 2015–2021. The left-hand side displays results for green bonds (numbers) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Country-Wide Tests

To verify our results, we identified the impact of green bonds in different countries by creating two groups. Table 11 displays the list of the highest and lowest green bond issuers. The first group consists of fifteen (15) countries with the highest number of green bonds issued, and the second group consists of fifteen countries with the lowest number of green bonds issued. Tables 12–15 display results generated from the group data. Tables 12 and 13 show results for countries with the highest number of green bonds issued. The results in Table 12 exhibit a negative and significant impact of green bonds on carbon emissions. The results are supported by both the number of green bonds and the value/amount of green bonds issued. Then, renewable energy is the dependent variable in Table 13, where we can see that there is a positive and significant relationship between green bonds and renewable energy.

Table 11. Highest and lowest green bond-issuing countries (2007–2021).

S. No	Country (High Issuers)	Green Bonds Issued	Country (Low Issuers)	Green Bonds Issued
1	China	742	ESTONIA	1
2	SWEDEN	631	KAZAKHSTAN	1
3	GERMANY	570	NAMIBIA	1
4	United States	499	PAKISTAN	1
5	FRANCE	430	Qatar	1
6	Japan	272	SLOVENIA	1
7	SOUTH KOREA	196	COLOMBIA	2
8	NORWAY	185	COSTA RICA	2
9	MALAYSIA	170	EGYPT	2
10	Spain	128	Guatemala	2
11	NETHERLANDS	121	ISRAEL	2
12	CANADA	95	KENYA	2
13	United Kingdom	91	PANAMA	2
14	Hong Kong	81	Saudi Arabia	2
15	BRAZIL	76	Serbia	2

Tables 14 and 15 show the results for the countries with the lowest number of green bonds issued. Table 14 shows that there is no significant relationship between green bonds and carbon emissions. In the same way, the results in Table 15 also show that there is no significant relationship between green bonds and renewable energy. Although green bonds show a significant relationship at the 10% level in terms of the amount issued, the observed effect size is relatively small, indicating a weak impact.

Table 12. Dynamic panel results, CO_2 emissions per capita as dependent variable (top 15 countries with highest green bonds issuing).

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**
Emissions (lag)	0.75 *** (16.89)	Emissions (lag)	0.708 *** (15.21)
Green Bonds (Number Issued)	−0.003 *** (−3.19)	Green Bonds (Amount Issued)	−0.014 *** (−4.17)
E-Tax	−0.066 (−1.25)	E-Tax	−0.021 (−0.44)
FDI	0 * (1.90)	FDI	0 ** (1.96)
Constant	2.086 *** (5.31)	Constant	2.504 *** (6.01)
Number of Obs 195	Chi-square 447.210	Number of Obs 195	Chi-square 472.713

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 13. Dynamic panel results, renewable energy per capita as dependent variable (top 15 countries with highest green bonds issuing).

Renewable	**Coef.**	**Renewable**	**Coef.**
Renewable (lag)	0.131 * (1.74)	Renewable (lag)	0.161 ** (2.09)
Green Bonds (Number Issued)	4.067 *** (3.71)	Green Bonds (Amount Issued)	8.562 ** (1.98)
E-Tax	−162.572 ** (−2.23)	E-Tax	−263.758 *** (−3.86)
FDI	−0.001 (−1.01)	FDI	−0.001 ** (−0.49)
Constant	3841.88 *** (11.14)	Constant	3793.83 *** (10.68)
Number of Obs 195	Chi-square 49.016	Number of Obs 195	Chi-square 37.033

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 14. Dynamic panel results, CO_2 emissions per capita as dependent variable (top 15 countries with lowest green bonds issuing).

CO_2 Emissions	**Coef.**	**CO_2 Emissions**	**Coef.**
Emissions (lag)	0.659 *** (13.27)	Emissions (lag)	0.656 *** (13.29)
Green Bonds (Number Issued)	−0.289 (−1.56)	Green Bonds (Amount Issued)	−0.03 * (−1.95)
E-Tax	−0.04 (−0.29)	E-Tax	-0.045 (−0.33)
FDI	0 (−0.63)	FDI	0 (−0.66)
Constant	2.858 *** (6.44)	Constant	2.896 *** (6.55)
Number of Obs 195	Chi-square 184.028	Number of Obs 195	Chi-square 187.777

*** $p < 0.01$, * $p < 0.1$.

Table 15. Dynamic panel results, renewable energy per capita as dependent variable (top 15 countries with lowest green bonds issuing).

Renewable		Coef.		Renewable		Coef.	
Renewable (Lag)		0.675 *** (10.42)		Renewable (Lag)		0.676 *** (10.49)	
Green Bonds(Number Issued)		21.602 (0.85)		Green Bonds (Number Issued)		1.947 (0.89)	
E-Tax		−20.943 (−1.10)		E-Tax		−20.599 (−1.08)	
FDI		−0.001 (−0.16)		FDI		−0.001 (−0.16)	
Constant		301.252 *** (4.91)		Constant		299.565 *** (4.88)	
Number of Obs	195	Chi-square	125.540	Number of Obs	195	Chi-square	125.757

*** $p < 0.01$.

Table 12 displays the results for the dynamic panel data model. The left-hand side displays the results for green bonds (numbers) as the independent variable and emissions per capita as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and emissions per capita as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the log of FDI. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 13 displays the results for the dynamic panel data model. The left-hand side displays the results for green bonds (numbers) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the log of FDI. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 14 displays the results for the dynamic panel data model. The left-hand side displays the results for green bonds (numbers) as the independent variable and emissions per capita as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and emissions per capita as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Table 15 displays the results for the dynamic panel data model. The left-hand side displays the results for green bonds (numbers) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. The right-hand side displays green bonds (value) as the independent variable and renewable energy produced per capita (kWh) as the dependent variable. FDI (foreign direct investment) is the control variable proxied by the FDI log. E-tax is a moderating variable proxied by the percentage value of the environmental tax to GDP ratio.

Concluding the discussion, it can be seen that countries with the highest green bond-issuing are moving towards sustainability—thus, we can say that a positive impact of green financing and green projects is present—while the countries with the lowest level of green bond-issuing are having trouble achieving sustainability goals. Additionally, they are still facing the problems of high carbon emissions and use only limited renewable resources to produce power.

6. Conclusions

The study examines the role of green bonds in affecting the initiatives of sustainable development. Especially in regard to achieving SDGs 7 and 13, which are related to renewable energy and climate action. We used green bond data from 2007 to 2021 and

examined the impact of green bonds on emissions and renewable energy globally. The data include all the countries worldwide where green bonds are issued. This study found that there is a negative relationship between green bonds and CO_2 emissions, while green bonds show a positive relationship with renewable energy. As we know, green bonds are still in their early stages and, according to different authors and historical data, the boom in green bonds occurred around 2015, when the Paris Agreement was signed by UN member states. To identify the effect of international cooperation and the impact of green bonds, we split the data into two groups, before and after 2015. We found that there was no significant effect of green bonds on emissions and renewable energy production before 2015, while after 2015, there are significant effects of green bonds on emission reductions and renewable energy production. This means that the expansion of the green bond market plays a significant role in achieving sustainable development goals. The study also found that environmental tax plays a positive role in moderating the impact of green bonds. This means E-tax can be productive, along with other initiatives adopted in pursuit of sustainable development.

We also investigated the impact of green bonds on high and low-green bond-issuing countries. Moreover, our study reveals a robust correlation between green bonds and the attainment of sustainable development goals, particularly in countries with higher levels of green bond issuance. In contrast, countries with lower issuance of green bonds are facing more challenges in advancing their sustainability objectives. This means green bonds are playing a significant role in achieving sustainability goals in countries with a high number of green bonds. These findings are helpful for the countries where the green bond market is still in its early phase. Countries with low green bond-issuing can follow in the footprints of other countries, which will not only develop the financial markets but also help achieve sustainability goals.

Hence, we can conclude that green bonds play a significant role in decreasing carbon emissions and increasing renewable energy production. These findings highlight the instrumental role of green bonds in promoting sustainable development and emphasize the importance of their implementation, especially in countries aspiring to achieve their sustainability targets. By effectively aligning financial resources with environmentally beneficial projects, green bonds have the potential to drive meaningful progress toward sustainable development goals.

7. Discussion

Green bonds are currently playing a crucial role in the financial industry and are pivotal for promoting sustainable development. However, the green bond market is not yet fully developed, with only a few affluent countries actively participating. Previous studies could not explore the impact of green bonds, as the market was still new and the data were not easily available. While many big projects are still underway, many have already been finished or have produced some output, and thus, their outcome data is not easy to obtain. We examined the latest green bond data and the related impact on sustainability goals worldwide. Our research reveals a strong correlation between countries that issue a significant number of green bonds and their notable achievements in sustainability. These findings can further encourage countries with low green bond issuance to utilize them to help achieve sustainable development goals. Moreover, our findings highlight the substantial impact of green bonds on sustainability, particularly following the 2015 Paris Agreement, where financial instruments were linked to sustainable goals. These results demonstrate the effectiveness of green bonds in facilitating environmental sustainability by reducing carbon emissions and increasing renewable energy generation. Furthermore, the findings emphasize the importance of international commitments made under the umbrella of the United Nations in formulating and advancing policies for sustainable development. In summary, the discussion underscores the effectiveness of green bonds as a powerful instrument for attaining sustainability objectives. This effectiveness is amplified

through the involvement of esteemed organizations and the dedication of the international community to fulfill their commitments.

8. Contribution and Implications

The study is the first one to directly examine green bonds with emissions and renewable energy. Previously, only green bond indices and sustainability indices were examined in order to confirm the relationship between green finance and its impact on society/environment. This study is not limited to a single or a few countries, it spans the whole world—wherever green bonds are issued. This provides a complete overview and the latest information regarding the green bond market. This study could be very useful not only as an addition to the literature but also for designing future sustainability strategies and plans. Future studies can focus on the regional level, where we can differentiate how green bonds are affecting sustainability in different regions of the world. This study is the first to report any relationship between green bonds and sustainable development goals. The outcome of this study could be very useful in designing and implementing policies regarding SDG achievement. The outcomes of this study could be useful in deciding the future of the green bond market and the usefulness of initiatives taken by countries and organizations, such as the UN, World Bank, and other institutions. The planet-wide results can further make way for institutions to encourage countries with low green bond-issuing in order to create a feasible environment for sustainable investments so that the world can cope with the threat of environmental degradation.

Research on green bonds and their relationships to sustainability has several future implications. There are several ways to apply research on green bonds, especially our research. First, green bonds can play a crucial role in financing environmentally sustainable projects, such as renewable energy infrastructure, energy efficiency improvements, and clean transportation. Research in this area can help identify the most effective use of green bond proceeds and guide investments toward projects that contribute to the transition to a low-carbon economy. Second, research on green bonds can contribute to the development of robust standards and frameworks for assessing the environmental impact and sustainability credentials of projects financed through these bonds. This can help enhance investor confidence in green bonds, ensuring that the proceeds are used for genuine green initiatives. Third, green bonds are still relatively new to the market, and research can drive their further growth and innovation. By exploring new structures, mechanisms, and instruments, research can expand the range of potential issuers, increase market liquidity, and reduce transaction costs. This can lead to a more diverse and dynamic green bond market, attracting a wider spectrum of issuers and investors and creating new opportunities for sustainable investments. Fourth, research on green bonds can also contribute to the evolution of sustainable finance beyond environmental considerations. It can explore the integration of social and governance factors into the evaluation and selection of green projects.

Author Contributions: Conceptualization, M.A. and M.-C.C.; methodology, M.A.; software, M.A.; validation, M.A.; formal analysis, M.A.; investigation, M.A.; resources, M.A. and M.-C.C.; data curation, M.A.; writing—original draft preparation, M.A.; writing—review and editing, M.A.; visualization, M.A.; supervision, M.-C.C.; project administration, M.-C.C.; funding acquisition, M.-C.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Restrictions apply to the availability of these data. Data was obtained from Bloomberg and Eikon Data Stream and is not available publicly.

Acknowledgments: We would like to express our heartfelt gratitude to President Securities Corporation, Taiwan for their invaluable support and resources throughout the course of this research. We extend our sincere appreciation to Wen CHUN Yu also known as Simon Yu, AVP Fixed Income Fund Manager for his guidance, mentorship, and unwavering support throughout this research journey.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

List of Abbreviations

No.	Abbreviation	Definition
1	CO_2 Emissions	Carbon dioxide emissions
2	GHG	Greenhouse gas emissions
3	kWh	Kilowatt hour
4	SDGs	Sustainable Development Goals
5	CSR	Corporate social responsibility
6	UN	United Nations
7	FDI	Foreign direct investment
8	GDP	Gross domestic product
9	E-Tax	Environmental tax
10	GMM	Generalized method of moments

References

1. Cuaresma, J.C.; Palokangas, T.; Tarasyev, A. *Green Growth and Sustainable Development*; Springer: Berlin/Heidelberg, Germany, 2013.
2. Serfati, C. Globalised finance-dominated accumulation regime and sustainable development. *Int. J. Sustain. Dev.* **2000**, *3*, 40–62. [CrossRef]
3. Scholtens, B.; Cerin, P.; Hassel, L. Sustainable development and socially responsible finance and investing. *Sustain. Dev.* **2010**, *16*, 137–140. [CrossRef]
4. United Nations Conference on Trade and Development 2014, World Investment Report 2014: Investing in the SDGs: An Action Plan (Report No. UNCTAD/WIR/2014). Available online: http://unctad.org/en/PublicationsLibrary/wir2014_en.pdf (accessed on 12 December 2022).
5. United Nations. Sustainable Development Goal 13: Climate Action. Available online: https://sdgs.un.org/goals/goal13 (accessed on 12 December 2022).
6. IPCC. Global Warming of 1.5 °C. 2018. Available online: https://www.ipcc.ch/sr15/ (accessed on 9 January 2023).
7. The People's Bank of China. Guidelines for Establishing the Green Financial System. 2016. Available online: http://sg.cufe.edu.cn/info/1231/5043.htm (accessed on 20 November 2022).
8. United Nations Environment Programme (UNEP). Sustainable Finance. Available online: https://www.unep.org/topics/sustainable-finance (accessed on 19 April 2023).
9. European Commission. Sustainable Finance. Available online: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en (accessed on 19 April 2023).
10. International Capital Market Association (ICMA). Green Bond Principles 2021. Available online: https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/ (accessed on 25 October 2022).
11. Zhou, X.; Cui, Y. Green bonds, corporate performance, and corporate social responsibility. *Sustainability* **2019**, *11*, 6881. [CrossRef]
12. Flammer, C. Green Bonds: Effectiveness and Implications for Public Policy. *Environ. Energy Policy Econ.* **2020**, *1*, 95–128. [CrossRef]
13. Climate Bonds Initiative. What Are Green Bonds? Available online: https://www.climatebonds.net/market/what-are-green-bonds (accessed on 25 October 2022).
14. Ciplet, D.; Roberts, J.T. Climate change and the transition to neoliberal environmental governance. *Glob. Environ. Chang.* **2017**, *46*, 148–156. [CrossRef]
15. Morgan Stanley. Behind the Green Bond Boom. 2017. Available online: https://www.morganstanley.com/ideas/green-bond-boom (accessed on 19 April 2023).
16. Bloomberg. Security That Triggered a Recession Reworked to Green the Earth. 2018. Available online: https://www.bloomberg.com/news/articles/2018-10-09/security-that-triggered-a-recession-reworked-to-green-the-earth (accessed on 19 April 2023).
17. Schumacher, K. The shape of green fixed income investing to come. *J. Environ. Investig.* **2020**, *10*, 5–29. [CrossRef]
18. Tang, D.Y.; Zhang, Y. Do shareholders benefit from green bonds? *J. Corp. Financ.* **2020**, *61*, 101427. [CrossRef]
19. Yamahaki, C.; Felsberg, A.V.; Köberle, A.C.; Gurgel, A.C.; Stewart-Richardson, J. Structural and specific barriers to the development of a green bond market in Brazil. *J. Sustain. Financ. Investig.* **2020**, *12*, 389–406. [CrossRef]
20. Zhang, H. Regulating green bond in China: Definition divergence and implications for policy making. *J. Sustain. Financ. Investig.* **2020**, *10*, 141–156. [CrossRef]
21. Reboredo, J.C.; Ugolini, A. Price connectedness between green bond and financial markets. *Econ. Model.* **2020**, *88*, 25–38. [CrossRef]
22. Pineiro-Chousa, J.; López-Cabarcos, M.Á.; Caby, J.; Šević, A. The influence of investor sentiment on the green bond market. *Technol. Forecast. Soc. Chang.* **2021**, *162*, 120351. [CrossRef]
23. Ehlers, T.; Packer, F. Green Bond Finance and Certification. BIS Quarterly Review. 2017. Available online: https://ssrn.com/abstract=3042378 (accessed on 19 April 2023).

24. Gianfrate, G.; Peri, M. The green advantage: Exploring the convenience of issuing green bonds. *J. Clean. Prod.* **2019**, *219*, 127–135. [CrossRef]
25. Zerbib, O.D. The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *J. Bank. Financ.* **2019**, *98*, 39–60. [CrossRef]
26. Broadstock, D.C.; Cheng, L.T.W. Time-varying relation between black and green bond price benchmarks: Macroeconomic determinants for the first decade. *Financ. Res. Lett.* **2019**, *29*, 17–22. [CrossRef]
27. Reboredo, J.C. Green bond and financial markets: Co-movement, diversification and price spillover effects. *Energy Econ.* **2018**, *74*, 38–50. [CrossRef]
28. Flammer, C. Corporate green bonds. *J. Financ. Econ.* **2021**, *142*, 499–516. [CrossRef]
29. Harford, J.; Kecskés, A.; Mansi, S. Do long-term investors improve corporate decision making? *J. Corp. Financ.* **2018**, *50*, 424–452. [CrossRef]
30. Baulkaran, V. Stock market reaction to green bond issuance. *J. Asset Manag.* **2019**, *20*, 331–340. [CrossRef]
31. Cho, S.Y.; Lee, C.; Pfeiffer, R.J. Corporate social responsibility performance and information asymmetry. *J. Account. Public Policy* **2013**, *32*, 71–83. [CrossRef]
32. Erdogan, S.; Acaravci, A. On the Nexus Between Institutions and Economic Development: An Empirical Analysis for Sub-Saharan African Countries. *Eur. J. Dev. Res.* **2022**, *34*, 1857–1892. [CrossRef]
33. Sangiorgi, I.; Schopohl, L. Explaining Green Bond Issuance using Survey Evidence: Beyond the Greenium. British Accounting Review. 2021. Available online: https://ssrn.com/abstract=3994375 (accessed on 7 February 2023).
34. Tolliver, C.; Keeley, A.; Managi, S. Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability. *J. Clean. Prod.* **2020**, *244*, 118643. [CrossRef]
35. Flammer, C. Does Corporate Social Responsibility Lead to Superior Financial Performance? A Regression Discontinuity Approach. *Manag. Sci.* **2018**, *64*, 3013–3035.
36. Semenova, N.; Hassel, L.; Nilsson, J. Green bonds and corporate social responsibility. *J. Bus. Ethics* **2020**, *167*, 473–495.
37. Levi, M.; Arjomandi, A.; Shams, S.; Stewart, J. Green bonds and environmental performance: Evidence from China. *J. Corp. Financ.* **2019**, *56*, 430–449.
38. Hawn, O.; Ioannou, I. Mind the gap: The interplay between external and internal actions in the case of corporate social responsibility. *Strateg. Manag. J.* **2018**, *39*, 3033–3061. [CrossRef]
39. Erb, C.; Nelling, E.; Zhang, Y. Green bonds: Evidence on social and environmental impacts. *J. Bus. Ethics* **2018**, *148*, 355–370.
40. Karpf, A.; Mandel, A.; Musulin, L. Scaling the Green Bond Market. *Rev. Financ. Stud.* **2020**, *33*, 105–149.
41. Sinha, A.; Mishra, S.; Sharif, A.; Yarovaya, L. Does green financing help to improve environmental & social responsibility? Designing SDG framework through advanced quantile modelling. *J. Environ. Manag.* **2021**, *292*, 112751. [CrossRef]
42. Zhao, L.; Chau, K.Y.; Tran, T.K.; Sadiq, M.; Xuyen, N.T.M.; Phan, T.T.H. Enhancing green economic recovery through green bonds financing and energy efficiency investments. *Econ. Anal. Policy* **2022**, *76*, 488–501. [CrossRef]
43. Tolliver, C.; Keeley, A.R.; Managi, S. Green bonds for the Paris agreement and sustainable development goals. *Environ. Res. Lett.* **2019**, *14*, 064009. [CrossRef]
44. Hamdi, H.; Sbia, R.; Shahbaz, M. The nexus between electricity consumption and economic growth in Bahrain. *Econ. Model.* **2014**, *38*, 227–237. [CrossRef]
45. Wang, Y.; Zhi, Q. The Role of Green Finance in Environmental Protection: Two Aspects of Market Mechanism and Policies. *Energy Procedia* **2016**, *104*, 311–316. [CrossRef]
46. Falcone, P.; Sica, E. Assessing the Opportunities and Challenges of Green Finance in Italy: An Analysis of the Biomass Production Sector. *Sustainability* **2019**, *11*, 517. [CrossRef]
47. Bilan, Y.; Streimikiene, D.; Vasylieva, T.; Lyulyov, O.; Pimonenko, T.; Pavlyk, A. Linking between renewable energy, emissions, and economic growth: Challenges for candidates and potential candidates for the EU membership. *Sustainability* **2019**, *11*, 1528. [CrossRef]
48. Vasilyeva, T.; Sysoyeva, L.; Vysochyna, A. Formalization of factors that are affecting stability of Ukraine banking system. *Risk Gov. Control. Financ. Mark. Inst.* **2016**, *6*, 7–11. [CrossRef]
49. Zafar, M.W.; Saleem, M.M.; Destek, M.A.; Caglar, A.E. The dynamic linkage between remittances, export diversification, education, renewable energy consumption, economic growth, and emissions in top remittance-receiving countries. *Sustain. Dev.* **2022**, *30*, 165–175. [CrossRef]
50. Anderson, J.; Rami-ah, V.; Gregoriou, G.N. *Handbook of Environmental and Sustainable Finance*; Academic Press: Cambridge, MA, USA, 2016.
51. Delmas, M.A.; Montes-Sancho, M.J. U.S. state policies for renewable energy: Context and effectiveness. *Energy Policy* **2011**, *39*, 2273–2288. [CrossRef]
52. Upton, G.B., Jr.; Snyder, B.F. Funding renewable energy: An analysis of renewable portfolio standards. *Energy Econ.* **2017**, *66*, 205–216. [CrossRef]
53. Kydes, A.S. Impacts of a renewable portfolio generation standard on US energy markets. *Energy Policy* **2007**, *35*, 809–814. [CrossRef]
54. Schmalensee, R. Evaluating policies to increase electricity generation from renewable energy. *Rev. Environ. Econ. Policy* **2012**, *6*, 45–64. [CrossRef]

55. Carley, S. State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy* **2009**, *37*, 3071–3081. [CrossRef]
56. Yin, H.; Powers, N. Do state renewable portfolio standards promote in-state renewable generation? *Energy Policy* **2010**, *38*, 1140–1149. [CrossRef]
57. Del Rio, P.; Bleda, M. Comparing the innovation effects of support schemes for renewable electricity technologies: A function of innovation approach. *Energy Policy* **2012**, *50*, 272–282. [CrossRef]
58. Jenner, S.; Groba, F.; Indvik, J. Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries. *Energy Policy* **2013**, *52*, 385–401. [CrossRef]
59. Polzin, F.; Migendt, M.; Taube, F.A.; von Flotow, P. Public policy influence on renewable energy investments—A panel data study across OECD countries. *Energy Policy* **2015**, *80*, 98–111. [CrossRef]
60. Li, Z.; Kuo, T.-H.; Siao-Yun, W.; Vinh, L.T. Role of green finance, volatility and risk in promoting the investments in Renewable Energy Resources in the post-COVID-19. *Resour. Policy* **2022**, *76*, 102563. [CrossRef]
61. Damania, R.; Fredriksson, P.G.; List, J.A. Trade liberalization, corruption, and environmental policy formation: Theory and evidence. *J. Environ. Econ. Manag.* **2003**, *46*, 490–512. [CrossRef]
62. Cole, M.A.; Elliott, R.J.; Zhang, J. Growth, foreign direct investment, and the environment: Evidence from Chinese cities. *J. Reg. Sci.* **2011**, *51*, 121–138. [CrossRef]
63. Fredriksson, P.G.; Neumayer, E.; Ujhelyi, G. Kyoto protocol cooperation: Does government corruption facilitate environmental lobbying? *Public Choice* **2007**, *131*, 217–241. [CrossRef]
64. Geng, Y.; Sarkis, J.; Ulgiati, S. Environmental performance, regional innovation capacity, and economic growth in China: A meta-frontier non-radial approach. *J. Clean. Prod.* **2016**, *112 Pt 1*, 741–752.
65. Zhang, Y.F.; Parker, D.; Kirkpatrick, C. Carbon emissions and foreign direct investment: Evidence from China. *Energy Econ.* **2011**, *33*, 1109–1118.
66. Bashir, M.F.; Ma, B.; Shahbaz, M.; Jiao, Z. The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. *PLoS ONE* **2020**, *15*, e0242412. [CrossRef]
67. Hao, L.N.; Umar, M.; Khan, Z.; Ali, W. Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy, and human capital is? *Sci. Total Environ.* **2021**, *752*, 141853. [CrossRef] [PubMed]
68. He, P.; Ning, J.; Yu, Z.; Xiong, H.; Shen, H.; Jin, H. Can environmental tax policy really help to reduce pollutant emissions? An empirical study of a panel ARDL model based on OECD countries and China. *Sustainability* **2019**, *11*, 4384. [CrossRef]
69. Hansen, L. Large sample properties of generalized method of moments estimators. *Econometrica* **1982**, *50*, 1029–1054. [CrossRef]
70. Arellano, M.; Bond, S. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Rev. Econ. Stud.* **1991**, *58*, 277–297. [CrossRef]
71. Holtz-Eakin, D.; Newey, W.; Rosen, H.S. Estimating Vector Autoregressions with Panel Data. *Econometrica* **1988**, *56*, 1371–1395. [CrossRef]
72. Roodman, D. How to Doxtabond2: An Introduction to Difference and System GMM in Stata. *Stata J.* **2009**, *9*, 86–136. [CrossRef]