# IMPACT OF GREEN BONDS ON CARBON EMISSIONS AND GDP GROWTH: A CASE STUDY OF THE INDIAN ECONOMY

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**Abstract**

**Purpose:** Green bonds have emerged as potent financial instruments for advancing environmental conservation objectives. By focusing on the Environmental and Economic impacts we tried to concentrate on the CO2 and GDP areas. By collecting year-wise data for CO2 and GDP, we can create a link between these two factors and green bond issuance.

**Design/methodology/approach:** Through rigorous econometric analysis, specifically **ordinary least squares regression**, we examined the intricate relationships between green bond investments, CO2 emissions, and GDP growth. Statistical tests were performed using an academic software.

**Findings:** The findings unequivocally underscore the significant and positive impact of green-bond investments on both GDP growth and CO2 emission reduction, thereby propelling holistic sustainable development. In the near future, it will be compulsory for the government to adopt sustainable practices for long-term growth.

**Implications:** Sustainability is a new age concept, and if a country gives enough attention to arrears such as green bonds, then clean environment creation can be much easier. Available sources focuse on different techniques for sustainability, and this study attempts to advance this area.

**Key words:** Green bonds, CO2 emissions, GDP.

## 1. Introduction

Green bonds, a distinctive category of financial instruments, have garnered attention as a viable channel for financing projects with environmental benefits. Green bonds serve to fund projects that promote eco-friendliness, with an emphasis on initiatives aimed at mitigating CO2 emissions. India's pledge to decrease emissions intensity by 30-35% by 2030, as articulated in its commitment to the United Nations Framework Convention on Climate Change, necessitates substantial capital infusion, estimated at approximately $2.5 trillion. Green bonds, therefore, present a compelling avenue for simultaneously accomplishing these ambitious objectives and stimulating economic growth.

This study meticulously evaluates the multifaceted impact of green bonds on India's carbon emissions and GDP, thereby illuminating their pivotal role in harmonizing economic and environmental imperatives.

### *1.1 BENEFITS OF INVESTING IN GREEN BONDS:*

- Green bonds offer a means of supporting environmental causes through investment.
- Purchasing green bonds may prove too expensive for individual investors; nevertheless, they facilitate investment in diversified portfolios of green bonds.
- Green bonds afford an opportunity to generate tax-exempt income.
- Invested funds are utilized in a non-detrimental manner.
- The environmentally-friendly aspect of green bonds appeals to an increasing number of individuals who are conscious of and committed to combating climate change.
- The rising demand for green bonds leads to a decrease in the cost of capital, resulting in reduced business expenses. These savings are either distributed to investors as dividends or utilized to decrease the cost of funds, thereby enhancing profitability.
- Certain issuers allocate funds towards the restoration of water ecosystems and habitats, as well as efforts to reduce carbon emissions. Such bonds typically carry equivalent credit ratings to other debts issued by the same entity.

**TABLE-I *TYPES OF GREEN BONDS*:**

- "Use of Proceeds" Bond
- "Use of Proceeds" Revenue Bond or Asset-Backed Securities (ABS)
- Project Bond
- Securitisation (ABS) Bond
- Covered Bond
- Loan
- Other debt instruments

Source: https://www.climatebonds.net/market/explaining-green-bonds

(*Green Bonds in India.Pdf*, n.d.)

## Table-V *Eligible Category of Projects under Green bonds:*

| Green Project Category | Environmental Objective | Eligibility Criteria |
|---|---|---|
| **Renewable Energy** | Climate Change Mitigation,<br>Net Zero Objectives | • Investments in projects related to solar, wind, biomass, hydropower, and energy storage technologies aimed at integrating energy generation and storage.<br><br>• Providing incentives to encourage the uptake of renewable energy sources. |
| **Energy Efficiency** | Climate Change Mitigation | The design and implementation of energy-efficient and energy-conserving systems and facilities in governmental edifices and premises.<br><br>• Facilitating enhancements in public lighting (e.g. substitution with Light Emitting Diodes).<br><br>• Facilitating the construction of novel low-carbon structures along with retrofits for enhancing energy efficiency in current structures.<br><br>• Initiatives aimed at diminishing losses in the electricity grid. |
| **Clean Transportation** | Climate Change Mitigation | • Providing financial incentives to encourage the adoption of environmentally friendly fuels such as electric vehicles, alongside the development of charging infrastructure.<br>• Advocating for the utilization of public transportation, particularly focusing on its electrification and enhancement of transport safety. |
| **Climate Change Adaptation** | Climate Change Adaptation | • Initiatives focused on enhancing the resilience of infrastructure to the effects of climate change, alongside allocations towards information support mechanisms, such as climate monitoring and advance notification systems.. |
| **Sustainable Water and Waste Management** | Climate Change Mitigation | • Promotion of water-efficient irrigation methodologies. Enhancement or replacement of wastewater infrastructure encompassing conveyance, purification, and elimination systems.<br><br>• Preservation of water reservoirs.<br><br>• Development of flood mitigation mechanisms. |
| **Pollution Prevention and Control** | Climate Change Mitigation,<br>Environment protection | • Efforts are focused on initiatives aimed at diminishing air pollutants, regulating greenhouse gases, addressing soil contamination, managing waste, preventing waste generation, recycling waste materials, decreasing waste volume, and increasing the efficiency of energy and emissions in waste-to-energy processes. |
| **Green Buildings** | Climate Change Mitigation | • Projects those are associated with structures that adhere to regional, national, or globally acknowledged criteria or certifications in terms of environmental efficiency. |
| **Sustainable Management of Living Natural Resources and Land Use** | Natural Resource Conservation | • Management of agriculture, animal husbandry, fishery, and aquaculture with a focus on environmental sustainability. The practice of sustainable forestry management, which encompasses afforestation and reforestation techniques.<br><br>• Assistance provided for certified organic farming initiatives.<br><br>• Conducting research related to living resources |

| | | |
|---|---|---|
| | | and the protection of biodiversity. |
| **Terrestrial and Aquatic Biodiversity Conservation** | Biodiversity Conservation | • Projects concerning coastal and marine environments.<br><br>• Projects associated with the preservation of biodiversity, encompassing the conservation of endangered species, habitats, and ecosystems. |

Source:(*Framework for Sovereign Green Bonds.Pdf*, n.d.)

**Excluded Projects:**

• Projects involving the initiation or continuation of activities related to the extraction, production, and distribution of fossil fuels, whether new or existing, including enhancements and advancements; or those reliant on fossil fuels as the primary source of energy.

• The generation of nuclear power

• The process of direct waste incineration

• Industries involved in the production of alcohol, weapons, tobacco, gambling, or palm oil

• Renewable energy initiatives that produce energy from biomass utilizing materials originating from protected regions

• Initiatives focused on landfill management

• Hydropower facilities with a capacity exceeding 25 MW

### *1.3 Role of IFC in green bonds market*

The International Finance Corporation (IFC), a constituent of the World Bank Group, stands as the primary global development institution focusing on the advancement of the private sector. Its principal objective is to support developing nations in attaining sustainable growth through the provision of financial resources for private sector ventures, mobilizing capital from global financial markets, and delivering advisory services to enterprises and governmental bodies. Furthermore, IFC assumes a catalytic function by showcasing the profitability of investments and taking a leading role in impact investment within emerging economies.

The Green Bond Program initiated by IFC has been instrumental in establishing new standards in benchmark issuance, currency diversification, and impact assessment during the last ten years. By the conclusion of Fiscal Year 2022 on June 30, 2022, IFC had successfully issued $10.5 billion through 178 bonds denominated in 20 different currencies.

### *1.4 IFC Green Bond Program Aligns To The Four Core Components Of The Green Bond Principles:*

1. *Use of proceeds*

The funds generated from the issuance of Green Bonds by the International Finance Corporation (IFC) are designated for a distinct sub-portfolio specifically tied to the provision of loans for projects addressing climate change ("Eligible Projects"). These projects are carefully chosen from IFC's portfolio of climate-focused loans, which includes initiatives that align with IFC's established criteria and measurements for Climate-Related Activities..

2. *Evaluation and selection*

In addition to satisfying the requirements for green bond eligibility, all initiatives funded by the International Finance Corporation (IFC) adhere to the IFC's Performance Standards concerning environmental and social matters, as well as the IFC's Corporate Governance Framework, following a meticulous due diligence procedure.

3. *Management of proceeds*

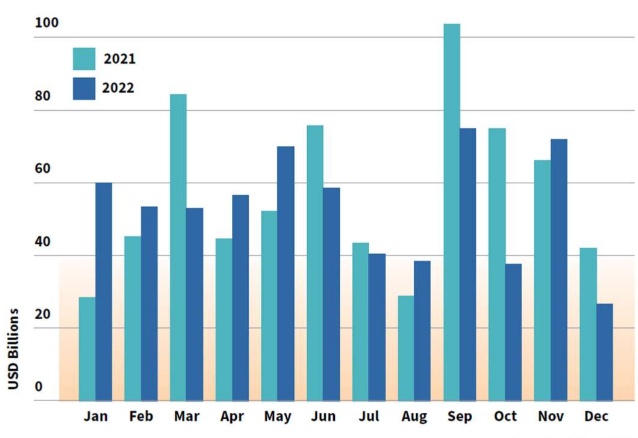
The revenues generated from IFC Green Bonds are allocated to a specific Green Cash Account, which follows IFC's cautious liquidity strategy until the funds are disbursed to qualified projects. The disbursement process for eligible projects is carried out in accordance with IFC's established guidelines and procedures, and may be spread out over a period of time based on project milestones, and so on.

4. *Reporting*

The IFC Green Bond Impact Report adheres to the GBP's reference framework for reporting, which aims to achieve greater transparency and maintain the integrity of the market. This framework, titled "Working towards a harmonized framework for Green Bond impact reporting," serves as a guide for reporting green bond impacts.

### *1.5 Green bond issuance by world economies in year 2021 and year 2022*

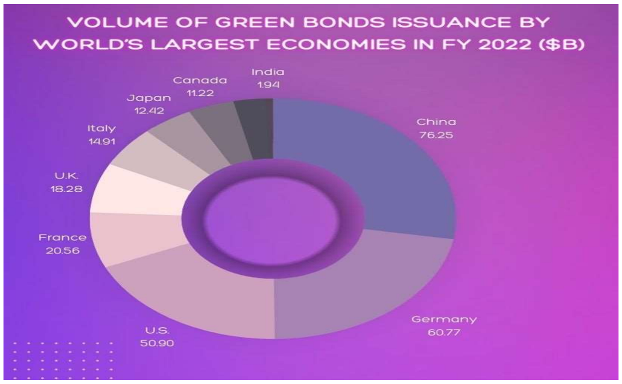
**Figure-1.**




(*Cbi_pricing_h2_2022_01c.Pdf*, n.d.)

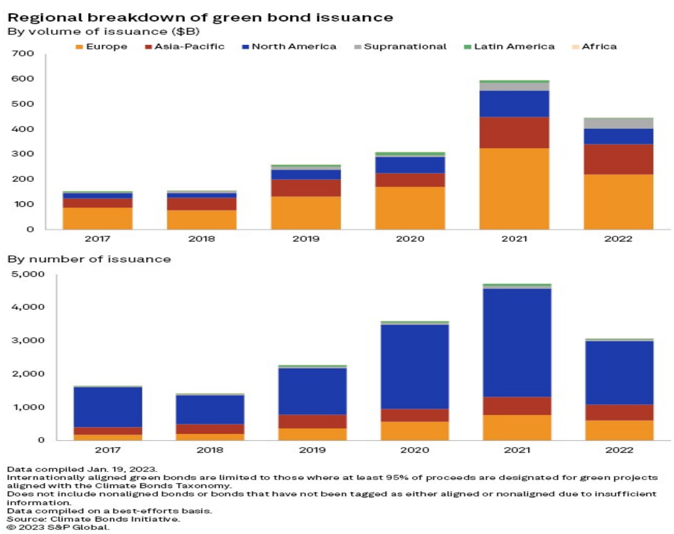
### *1.6 Volume Of Green Bonds Issuance By World's Largest Economy:*

**Figure-2.**




Reference: (*Global Green Bond Issuance Poised for Rebound in 2023 amid Policy Push _ S&P Global Market Intelligence.Pdf*, n.d.)

**Figure-3. Regional breakdown of green bond issuance**




Reference: (*Global Green Bond Issuance Poised for Rebound in 2023 amid Policy Push _ S&P Global Market Intelligence.Pdf*, n.d.)

### *1.7 AMBITION: 2030 TARGETS*

Nationally Determined Contribution: Mitigation

**TARGETS**

India's NDC is a target of reducing the emissions intensity of its GDP by 45% compared to 2005 by the year 2030, and also aims to achieve at least 50% non-fossil-fuel electric power capacity by 2030.

**ACTIONS**

* Encouraging the increased utilization of renewable energy sources while also increasing the capacity of installed renewable energy systems

* Improving energy efficiency

* Creating climate-resilient urban centers

* Converting waste into energy

* Implementing sustainable green transportation networks

* Planting trees as part of a planned afforestation program

Reference: (*CT2022-India-Web.Pdf*, n.d.)

## 2. Objectives of the study:

1. To gain deep knowledge of every aspect of green bonds.
2. To understand the concept of sustainability
3. To check the impact of green bonds on environmental protection.
4. To check how much effect green bonds can create over the CO2 emission and the GDP of the country

## 3. Review of literature:

Abhilash, Sandeep S. Shenoy1, Dasharathraj K. Shetty, Lumen Shawn Lobo, and Subrahmanya Kumar N. had published the paper on "Green Bond as an Innovative Financial Instrument in the Indian Financial Market: Insights From Systematic Literature Review Approach". The whole topic was divided in different parts like assembling, arranging and assesing and then studied thoroughly. (Abhilash et al., 2023)

Muhammad Usman Khurram, Wenwu Xie, Sultan Sikandar Mirza and Hao Tong studied the topic "Green bonds issuance, innovation performance, and corporate value: Empirical evidence from China". They showed potential of green bonds as a financial mechanism to support environmentally friendly projects. Their findings focused on the need for supportive policies to encourage more and more enterprises to issue green bonds, thereby fostering green capital and contributing to the country's economic and environmental goals.(Khurram et al., 2023)

Jianda Wang and Ying Ma (2022) had studied the topic, "How Does Green Finance Affect CO2 Emissions? Heterogeneous and Mediation Effects Analysis" and they applied econometric methods for the study and had reached some conclusion of a positive relation between reduction of co2 emissions and green finance investment further at conclusion stage they proposed some policy creation. (Wang & Ma, 2022)

Muhammad Saeed Meo and Mohd Zaini Abd Karim (2022) had worked on "The role of green finance in reducing CO2 emissions: An empirical analysis". They examine the co2 emissions and green finance investment by the top ten economies, i.e.Canada, Denmark, Hong Kong, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and the United States. As a statistical tool, they used quantile on quantile regression test and conclude that there is a negative impact of green finance on co2 emission.(Saeed Meo & Karim, 2022)

Nini Johana Marín-Rodríguez, Juan David González-Ruiz and Sergio Botero (2022) had prepared a paper on “Dynamic relationships among green bonds, CO2 emissions, and oil prices” They took total 2,206 observations corresponding to daily information from 1 January 2014 to 15 June 2022. After applying various statistical tools, the conclusions were that the Green Bond Index shows a negative dynamic correlation to the oil return and the CO2 futures’ returns, presenting a strong correlation in uncertainty periods.(Marín-Rodríguez et al., 2022)

Miklesh Prasad Yadav, Priyanka Tandon, Anurag Bhadur Singh, Adam Shore and Pali Gaur had done the analysis on “Exploring time and frequency linkages of green bond with renewable energy and cryptomarket”. They tried to establish a linkage between green bond and crypto currency. They took the data from from October 3, 2016 to February 23, 2021 for their study. (Yadav et al., 2022)

Giuseppe Cortellini and Ida Claudia Panetta (2021) worked on “Green Bond: A Systematic Literature Review for Future Research Agendas”. Their main aim was to review the previous publications to shape future predictions. (Cortellini & Panetta, 2021)

ABHISHEK KUMAR (2021) had researched An Evaluative Study of Green Bond Scenario in India. He includes various banks in his studies, i.e. Yes bank, IDBI bank, Axis bank and SBI bank. (Kumar, 2021)

Ursule Yvanna Otek Ntsama, Chen Yan, Alireza Nasiri and Abdel Hamid Mbouombouo Mboungam (2021) had published a paper on “Green bonds issuance: insights in low- and middle-income countries”. They used a systematic analysis approach. (Otek Ntsama et al., 2021)

Chiyoung Cheong and Jaewon Choi (2020) had done research on the “Green bonds: a survey”. They add mainly the review of different past papers and gave a new sight to look the green bonds as a socially responsible investing tool. (Cheong & Choi, 2020)

Ms. Ashima Verma and Dr. Rachna Agarwal (2020) did the research on “A Study of Green Bond Market in India: A Critical Review”. They analysed green bond principles , SWOC analysis for the research concern. (Verma & Agarwal, 2020).

Sourabh Bansal (2020) had analysed the “Green Bonds-Trend and Challenges in India”.They explained green bonds as an environmental sustainable tool and further to draw the trend of green bond and challenges so far in context to the Indian financial market. He mainly used the secondary data from different government reports and concludes that some challenges attached with green bonds can surely reduce by government strategies. (Bansal, 2020).

Prof. Renu Jatana and Dr. Mehjabeen Barodawala (2020) presented a paper on “An Analytical Study of IFC’s Green Masala Bonds”. They focused mainly on the green infrastructure projects by YES bank. They focused over the analysis over the CO2, SO2 and NOx emission reduction. Moreover, focus was also on the social impact of green masala bonds.(Jatana, 2020)

Dr. Varsha Agarwal, Khushi Thakkar, Riya S Jain, and D Keerthan (2020) joitly studied “Sustainable Financing: A study on effect and development of green bonds in Asia”. They focused on development and the growth of green bonds in Asia. For this purpose they used secondary data and worked on the limitations of the bond market.(Agarwal et al., 2020)

Vasundhara Saravade and OlafWeber (2020) presented a paper titled as “An Institutional Pressure and Adaptive Capacity Framework for Green Bonds: Insights from India’s Emerging Green Bond Market”. They introduced a framework and highlighted ‘invisible’ social norms such as awareness about climate finance, changing regulatory priorities and the institutional strength of social actors. They contribute to the literature on the topic.(Saravade & Weber, 2020)

Gianfranco Gianfrate and Mattia Peri (2019) had done the research on “The Green Advantage: Exploring the Convenience of Issuing Green Bonds” for the study purpose they studied 121 European green bonds issued during the years 2013 to 2017. As a resul, they found green bonds were financially convenient as compared to others. (Gianfrate & Peri, 2019).

Gianfranco Gianfrate (2019) did the study on “The Green Advantage: Exploring the Convenience of Issuing Green Bonds”. They studied 121 European green bonds issued between 2013 and 2017(*1-S2.0-S0378426618302358-Mmc1.Pdf*, n.d.).

Maria Jua Bachelet, Leonardo Becchetti and Stefano Manfredonia (2019) focused on “The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification”. They conclude Green bonds from institutional issuers have higher liquidity with respect to their brown bond correspondents and negative premia before correcting for their lower volatility.(Bachelet et al., 2019)

**Research Gap**

While above all the studies focused different dimensions of green bonds, the statistical model that can help reader to understand the net impact of green bond on environment is lacking.

By having that gap in mind here in our paper we tried to fill out this gap by different statistical methods. By the end of studying this paper a reader will be well equip with the through information regarding all three variables, i.e. green bonds, GDP and CO2 emission. This knowledge can be further helpful in concentrating the sustainable practices in future.

## 4. Green bonds data in Indian context

| *India Level Data: CO2 Emission* | |
|---|---|
| **Year** | **CO2 Emission** |
| 2016 | 2067.83 MT |
| 2017 | 2184.8 MT |
| 2018 | 2316.5 MT |
| 2019 | 2277.63 MT |
| 2020 | 2074.96 MT |
| 2021 | 2648.78 MT |
| 2022 | 3680 MT |
| Source: (*CO2 Emission_India*, n.d.) | |

| *India Level GDP Data: GDP ($B)* | |
|---|---|
| | GDP ($B) |
| 2016 | $2,294.80B |
| 2017 | $2,651.47B |
| 2018 | $2,702.93B |
| 2019 | $2,831.55B |
| 2020 | $2,667.69B |
| 2021 | $3,176.30B |
| 2022 | $3,737B (estimated) |
| Source: (*India GDP 1960-2023*, n.d.) | |

| *Indian Level Data: Green Bond Investment Data (US$B)* | |
|---|---|
| **Year** | **Investment (in US$B)** |
| 2016 | $0.806B |
| 2017 | $3.168B |
| 2018 | $0.6469B |
| 2019 | $3.0137B |
| -2020 | $0.45B |
| 2021 | $3.5254B |
| 2022 | $2B |
| Source: Authors' construction from different sources | |

## 5. Research methodology:

To robustly gauge the ramifications of green bonds on carbon emissions and GDP, we adopted a comprehensive econometric approach that is well suited for exploring relationships within real-world datasets. Specifically, we employ ordinary least squares (OLS) regression as our primary analytical method. However, while the conventional OLS model investigates the linear associations among green bond investments, CO2 emissions, and GDP, we recommend augmenting the methodology with a dynamic panel data model. To check the robustness of the model, we applied a non-frequentist regression model: Bayesian Regression model. (Kalia, 2024)

**HYPOTHESIS:**

H1: There is a linear relationship between the Co2 emission of Indian economy and the investment in green bonds.

H2: There is a linear relationship between the GDP of India and the investment in green bonds.

**Statistical Output:**

H1: There is a linear relationship between the Co2 emissions of Indian economy and the investment in green bonds.

**Table-IX Summary statistics**

| Summary statistics: | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Variable | Observations | Obs. with missing data | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
| CO2 Emission | 7 | 0 | 7 | 2067.830 | 3680.000 | 2464.357 | 570.898 |
| investment | 7 | 0 | 7 | 45.000 | 3525.400 | 1886.429 | 1396.836 |

**Table-X Correlation matrix**

| Correlation matrix: | | |
|---|---|---|
| | | |
| | investment | CO2 Emission |
| investment | **1** | 0.251 |
| CO2 Emission | 0.251 | **1** |

**Table-XI Regression of variable CO2 Emission**

| Regression of variable CO2 Emission: | |
|---|---|
| | |
| Goodness of fit statistics (CO2 Emission): | |
| | |
| Observations | 7 |
| Sum of weights | 7 |
| DF | 5 |
| $R^2$ | 0.063 |

In this particular case, 6 % of the variability of the CO2 is explained by the Green bond investment. The remainder of the variability is due to some effects (other explanatory variables) that have not been included in this analysis.

**Table-XII Analysis of variance (CO2 Emission)**

| Analysis of variance (CO2 Emission): | | | | | | |
|---|---|---|---|---|---|---|
| Source | DF | Sum of squares | Mean squares | F | Pr > F | p-values signification codes |
| Model | 1.000 | 123065.991 | 123065.991 | 0.336 | 0.587 | ° |
| Error | 5.000 | 1832478.222 | 366495.644 | | | |
| Corrected Total | 6.000 | 1955544.213 | | | | |
| *Computed against model Y=Mean(Y)* | | | | | | |
| *Signification codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1* | | | | | | |

Given that the probability connected to the F value is 0.587, we would be taking a 0.58% risk in assuming that the null hypothesis (no effect of the two explanatory variables) is incorrect. In other words, we can confidently conclude that the variables do bring a significant amount of information.

The table below provides information on the model. This table is useful when predictions are needed, or when comparing the coefficients of the model for a given population with those obtained for another population. As we can see, the 95% confidence range of the CO2 parameter is quite narrow, while the one for the intercept of the model is wider.

**Table-XIV Predictions and residuals (CO2 Emission)**

Predictions and residuals (CO2 Emission):

| Observation | Weight | investment | CO2 Emission | Pred(CO2 Emission) | Residual | Std. residual | Std. dev. on pred. (Mean) | Lower bound 95% (Mean) | Upper bound 95% (Mean) | Std. dev. on pred. (Observation) | Lower bound 95% (Observation) | Upper bound 95% (Observation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 1 | 806.000 | 2067.830 | 2353.582 | -285.752 | -0.472 | 298.162 | 1587.131 | 3120.032 | 674.831 | 618.874 | 4088.289 |
| 2017 | 1 | 3168.000 | 2184.800 | 2595.756 | -410.956 | -0.679 | 322.140 | 1767.669 | 3423.843 | 685.762 | 832.948 | 4358.564 |
| 2018 | 1 | 646.900 | 2316.500 | 2337.269 | -20.769 | -0.034 | 316.948 | 1522.529 | 3152.009 | 683.339 | 580.692 | 4093.847 |
| 2019 | 1 | 3013.700 | 2277.630 | 2579.935 | -302.305 | -0.499 | 303.543 | 1799.654 | 3360.217 | 677.225 | 839.073 | 4320.798 |
| 2020 | 1 | 45.000 | 2074.960 | 2275.557 | -200.597 | -0.331 | 398.134 | 1252.121 | 3298.992 | 724.573 | 412.982 | 4138.131 |
| 2021 | 1 | 3525.400 | 2648.780 | 2632.400 | 16.380 | 0.027 | 369.393 | 1682.844 | 3581.955 | 709.188 | 809.375 | 4455.424 |
| 2022 | 1 | 2000.000 | 3680.000 | 2476.002 | 1203.998 | 1.989 | 229.696 | 1885.549 | 3066.454 | 647.500 | 811.550 | 4140.453 |

**H2: There is a linear relationship among the GDP of India and the investment in the green bonds.**

**Table-XV Summary statistics**

| Summary statistics: | | | | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Observations | Obs. with missing data | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
| GDP | 7 | 0 | 7 | 2294.800 | 3737.000 | 2865.963 | 464.458 |
| Investment | 7 | 0 | 7 | 45.000 | 3525.400 | 1886.429 | 1396.836 |

**Table-XVI Correlation matrix**

| Correlation matrix: | | |
|---|---|---|
| | investment | GDP |
| investment | **1** | 0.380 |
| GDP | 0.380 | **1** |

**Table-XVII Regression of variable GDP**

| Regression of variable GDP: | |
|---|---|
| | |
| Goodness of fit statistics (GDP): | |
| | |
| Observations | 7 |
| Sum of weights | 7 |
| DF | 5 |
| $R^2$ | 0.144 |

In this particular case, 14 % of the variability of the GDP is explained by the Green bond investment. The remainder of the variability is due to some effects (other explanatory variables) that have not been included in this analysis.

**Table-XVIII Analysis of variance (GDP)**

| **Analysis of variance (GDP):** | | | | | | |
|---|---|---|---|---|---|---|
| Source | DF | Sum of squares | Mean squares | F | Pr > F | p-values signification codes |
| Model | 1.000 | 186640.270 | 186640.270 | 0.842 | 0.401 | ° |
| Error | 5.000 | 1107684.855 | 221536.971 | | | |
| Corrected Total | 6.000 | 1294325.125 | | | | |
| *Computed against model Y=Mean(Y)* | | | | | | |
| *Signification codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1* | | | | | | |

Given that the probability connected to the F value is 0.842, we would be taking a 0.84% risk in assuming that the null hypothesis (no effect of the two explanatory variables) is incorrect. In other words, we can confidently conclude that the variables do bring a significant amount of information.

The table below provides information on the model. This table is useful when predictions are needed, or when comparing the coefficients of the model for a given population with those obtained for another population. As we can see, the 95% confidence range of the GDP parameter is quite narrow, while the one for the intercept of the model is wider.

**Table-XX Predictions and residuals (GDP)**

Predictions and residuals (GDP):

| Observation | Weight | investment | GDP | Pred(GDP) | Residual | Std. residual | Std. dev. on pred. (Mean) | Lower bound 95% (Mean) | Upper bound 95% (Mean) | Std. dev. on pred. (Observation) | Lower bound 95% (Observation) | Upper bound 95% (Observation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 1 | 806.000 | 2294.800 | 2729.543 | -434.743 | -0.924 | 231.815 | 2133.644 | 3325.442 | 524.667 | 1380.844 | 4078.242 |
| 2017 | 1 | 3168.000 | 2651.470 | 3027.780 | -376.310 | -0.800 | 250.457 | 2383.960 | 3671.600 | 533.166 | 1657.234 | 4398.326 |
| 2018 | 1 | 646.900 | 2702.930 | 2709.454 | -6.524 | -0.014 | 246.420 | 2076.011 | 3342.898 | 531.281 | 1343.752 | 4075.157 |
| 2019 | 1 | 3013.700 | 2831.550 | 3008.297 | -176.747 | -0.376 | 235.998 | 2401.645 | 3614.950 | 526.528 | 1654.813 | 4361.781 |
| 2020 | 1 | 45.000 | 2667.690 | 2633.456 | 34.234 | 0.073 | 309.541 | 1837.756 | 3429.155 | 563.340 | 1185.343 | 4081.568 |
| 2021 | 1 | 3525.400 | 3176.300 | 3072.907 | 103.393 | 0.220 | 287.196 | 2334.647 | 3811.166 | 551.378 | 1655.543 | 4490.270 |
| 2022 | 1 | 2000.000 | 3737.000 | 2880.303 | 856.697 | 1.820 | 178.584 | 2421.238 | 3339.368 | 503.418 | 1586.227 | 4174.379 |

**Table-XXI Bayesian Linear Regression: Model Comparison - GDP of India (Amount in $B)**

**Model Comparison - GDP of India (Amount in $B)**

| Models | P(M) | P(M\|data) | $BF_M$ | $BF_{10}$ | $R^2$ |
|---|---|---|---|---|---|
| Null model | 0.500 | 0.593 | 1.457 | 1.000 | 0.000 |
| Green Bonds Invesment (Amount in $B) | 0.500 | 0.407 | 0.686 | 0.686 | 0.146 |

**Table-XXII Posterior Summary**

**Posterior Summaries of Coefficients**

| | | | | | | | | 95% Credible Interval | |
|---|---|---|---|---|---|---|---|---|---|
| Coefficient | P(incl) | P(excl) | P(incl\|data) | P(excl\|data) | $BF_{inclusion}$ | Mean | SD | Lower | Upper |
| Intercept | 1.000 | 0.000 | 1.000 | 0.000 | 1.000 | 2865.963 | 176.442 | 2435.120 | 3330.040 |
| Green Bonds Invesment (Amount in $B) | 0.500 | 0.500 | 0.407 | 0.593 | 0.686 | 29.251 | 76.640 | -141.456 | 259.677 |

**Table-XXIII Bayesian Linear Regression: Model Comparison - CO2 Emission (Amt in MT)**

**Model Comparison - CO2 Emission (Amt in MT)**

| Models | P(M) | P(M\|data) | $BF_M$ | $BF_{10}$ | $R^2$ |
|---|---|---|---|---|---|
| Null model | 0.500 | 0.630 | 1.700 | 1.000 | 0.000 |
| Green Bonds Invesment (Amount in $B) | 0.500 | 0.370 | 0.588 | 0.588 | 0.054 |

**Table-XXIV Posterior Summary**

**Posterior Summaries of Coefficients**

| | | | | | | | | 95% Credible Interval | |
|---|---|---|---|---|---|---|---|---|---|
| Coefficient | P(incl) | P(excl) | P(incl\|data) | P(excl\|data) | $BF_{inclusion}$ | Mean | SD | Lower | Upper |
| Intercept | 1.000 | 0.000 | 1.000 | 0.000 | 1.000 | 2464.357 | 221.130 | 1908.057 | 2981.857 |
| Green Bonds Invesment (Amount in $B) | 0.500 | 0.500 | 0.370 | 0.630 | 0.588 | 19.154 | 86.159 | -193.277 | 278.495 |

**Interpretation:**

Bayesian Linear Regression for Impact Analysis:

• This approach uses statistical methods and prior knowledge to assess the relationship between Green Bond Investment (independent variable) and CO2 Emission (dependent variable) as well as between Green Bond Investment (independent variable) and GDP (dependent variable). We applied this model to check the robustness of our study.

• Posterior Summaries:

o This section focuses on the posterior distribution of the coefficient for the Green Bonds Investment variable. The coefficient represents the estimated impact of Green Bond Investment on CO2 emission in the model.

o P(incl): This represents the posterior inclusion probability. It indicates the probability that Green Bond Investment is a relevant factor influencing CO2 emission, considering both the data and any prior knowledge incorporated in the model. Values closer to 1 suggest stronger evidence for a significant impact.

o P(excl): This represents the posterior exclusion probability. It's the opposite of the inclusion probability and indicates the probability that Green Bond Investment is not relevant for predicting CO2 emission.

o P(incl data): This shows the probability of inclusion based solely on the data (without considering prior knowledge).

o P(excl data): This shows the probability of exclusion based solely on the data.

o BFinclusion Mean SD, Lower, and Upper: These represent the posterior distribution's mean, standard deviation, and credible interval for the coefficient of Green Bond Investment. The credible interval captures a range of plausible values for the impact, considering the uncertainty in the estimate.

Interpretation of the Results (considering limitations):

• The posterior inclusion probability (P(incl)) for Green Bond Investment is 0.5, indicating moderate evidence that it might influence CO2 emission. The credible interval also includes negative values, but the mean has a slightly negative value. This suggests some uncertainty but also a possible negative association between green bond investments and CO2 emission in these models, which is desirable as it indicates potentially lower emissions with more green bond investments.

• Overall:

• This Bayesian linear regression analysis suggests that Green Bond Investment in India might have a negative impact on CO2 emission, which is aligned with the expected outcome of green bonds financing eco-friendly projects. However, more data or a stronger prior belief might be needed for a more conclusive determination.

• The posterior inclusion probability (P (incl)) for Green Bond Investment is 0.5, suggesting moderate evidence for its influence on GDP.

• The credible interval also includes zero, but the mean has a slightly positive value. This indicates some uncertainty but also a possible positive association between green bond investments and GDP in this model.

## 6. Conclusion:

An analytical examination confirms the transformative capacity of green bonds within the Indian economic terrain, revealing their advantageous impact on GDP growth and CO2 emission reduction. India's adoption of green bonds underscores its steadfast dedication to sustainable development, effectively furthering environmental and economic objectives. The nation's pioneering endeavor toward sovereign green bonds propels the trajectory towards a more ecologically balanced future, thereby solidifying India's role as a global advocate for environmental preservation. Although statistical models indicate modest effects of green bonds on GDP and CO2 emissions, real-world situations demonstrate considerable efficacy. Other countries can undoubtedly achieve better outcomes by focusing on additional sustainability tools, such as green banking, green finance, and green bonds.

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Model 1: OLS, using observations 1-7
Dependent variable: CO2

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| const | 2268.61 | 433.564 | 5.232 | 0.0034 | *** |
| investment | 100.676 | 189.049 | 0.5325 | 0.6172 | |

| | | | |
|---|---|---|---|
| Mean dependent var | 2464.357 | S.D. dependent var | 570.8976 |
| Sum squared resid | 1850580 | S.E. of regression | 608.3716 |
| R-squared | 0.053675 | Adjusted R-squared | -0.135590 |
| F(1, 5) | 0.283598 | P-value(F) | 0.617159 |
| Log-likelihood | −53.63042 | Akaike criterion | 111.2608 |
| Schwarz criterion | 111.1527 | Hannan-Quinn | 109.9238 |

Model 2: OLS, using observations 1-7
Dependent variable: GDP

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| const | 2603.52 | 335.124 | 7.769 | 0.0006 | *** |
| investment | 134.982 | 146.126 | 0.9237 | 0.3980 | |

| | | | |
|---|---|---|---|
| Mean dependent var | 2865.963 | S.D. dependent var | 464.4576 |
| Sum squared resid | 1105638 | S.E. of regression | 470.2421 |
| R-squared | 0.145780 | Adjusted R-squared | -0.025064 |
| F(1, 5) | 0.853295 | P-value(F) | 0.398010 |
| Log-likelihood | −51.82765 | Akaike criterion | 107.6553 |
| Schwarz criterion | 107.5471 | Hannan-Quinn | 106.3182 |