# Sustainable Finance And Its Economic Impact: Evidence From India Green Bond Market

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## Abstract

This study investigates the relationship between green bonds and economic growth in India using econometric methods over the period 2000-2023. Green bonds, as a sustainable finance instrument, have gained prominence for their role in fostering environmentally sustainable projects while influencing macroeconomic outcomes. Employing time-series data, the study examines the causality and long-term relationship between green bond issuance and economic growth indicators such as GDP, gross fixed capital formation (GFCF), and foreign direct investment (FDI). The analysis incorporates unit root tests, cointegration techniques, and Granger causality tests to assess the dynamic interactions between these variables. Results suggest that while green bonds contribute to capital mobilization, their direct impact on economic growth is relatively limited in the short term. However, the findings highlight their potential as a policy instrument to foster sustainable economic development in India. This study underscores the Importance of mtegratmg green finance Into national economic strategies to achieve long-term sustamability goals.

Keywords- Economic, Finance, India, Development Economics.

## Introduction

In recent years, the global focus on climate change mitigation and sustainable development has led to a significant shift toward green finance, with green bonds emerging as a critical tool for funding environmentally sustainable projects. Green bonds, a type of fixed-income instrument, are specifically designed to raise capital for projects that have positive environmental and climate benefits, such as renewable energy, energy efficiency, pollution prevention, and sustainable agriculture (Climate Bonds Imtiative 2023). The issuance of green bonds has seen a rapid rise globally, with cumulative issuances exceeding USD 2 trillion by 2022 (OECD, 2022). India, as one of the leading developing economies, has also embraced the green-bond market, aligning its economic growth traject01Y with its climate goals.

In India, green finance has gained significant momentum, as the country seeks to align its economic growth with its environmental and climate goals. As the world's third largest emitter of greenhouse gases, India has committed to reducing its carbon emission intensity by 45% by 2030, as outlined in its updated Nationally Determined Contributions (NDCs) under the Paris Agreement (Ministry

of Environment, Forest and Climate Change, 2022). Green bonds have become a vital tool for financing India's transition to a low-carbon economy to achieve these targets. India issued its first green bond in 2015, and by 2023, the cumulative green bond issuance in India had reached USD 25 billion (Reserve Bank of India, 2023). This makes India one of the leading green bond issuers in emerging markets, with significant investments directed towards renewable energy projects, particularly solar and wind power.

India's renewable energy sector has been a pnmary beneficiary of green-bond financing, with the country setting ambitious targets for generating 500 GW of renewable energy by 2030 (Mimstry of New and Renewable Energy, 2023). The green-bond market is expected to play a crucial role in meeting these targets, as renewable energy projects often require substantial upfront capital investment. Notably, in 2021, the Indian Renewable Energy Development Agency (IREDA) issued green bonds worth USD 300 million, which were oversubscribed, indicating strong investor confidence in the sector (IREDA, 2022).

This study explores the role of green bonds in influencing economic growth in India. Specifically; it examines how the issuance of green bonds contributes to sustainable development by driving investments in renewable energy, environmental projects, and green infrastructure and how these investments Impact key macroeconormc indicators such as GDP growth, employment, and foreign direct investment (FDI). This study focuses on India's green bond market, analyzing its development smce 2015 and its role in the country's transition towards a green economy. It evaluates the impact of green bond issuance on India's economic growth and sustainable development while assessing the effectiveness of green finance in meeting India's climate and renewable energy targets.

## Review Of Literature

Green bonds have emerged as a vital tool for channeling private capital towards projects that contribute to environmental sustainability. According to the Climate Bonds Initiative (2023), green bonds help mitigate climate change by ftnding projects in renewable energy, energy efficiency, and pollution control. Empirical studies suggest that the growth of the green bond market has positive implications for economic development, particularly in countries that are actively investing m green infrastructure (OECD 2022).

In developing economies, green bonds are seen as a key instilment in financing the transition to a low-carbon economy. For instance, Bhattacharya et al. (2019) found that in emerging markets, green bonds have attracted significant international capital, which has spurred investments in renewable energy and other sustainable projects. Their study highlights that green bonds not only support environmental goals, but also contribute to economic growth by creating jobs and promoting technological innovation.

Focusing on India, the literature indicates that the green bond market IS still in its nascent stages, but has shown remarkable growth smce its inception in 2015. India's green bond market has grown rapidly, driven by government policies and increasing investor demand for sustainable investment opportunities. Malhotra and Singh (2021) explored the impact of green bonds on India's renewable energy sector and found that green bond financing has significantly boosted the country's renewable energy capacity, thereby supporting GDP growth and energy security.

Moreover, the Reserve Bank of India (2023) reports that green bonds have become an essential tool for funding India's climate action commitments under the Paris Agreement. They have particularly contributed to financing large-scale renewable energy projects such as solar and wind power, which are critical for reducing the country's carbon footprint. Aganval and Sharma (2022) further emphasize the potential of green bonds in addressing India's sustainable development challenges, noting that they have catalyzed investment in green sectors, leading to positive economic spillovers, such as increased employment and technological advancements.

However, challenges are associated with the green bond market in India, including regulatory issues, market awareness, and the need for greater transparency and standardization in green bond certification (Sinha & Gupta, 2020). These challenges suggest that, while green bonds have the potential to contribute significantly to economic growth, there is a need for suppoltive policy measures to fully harness their benefits.

## Data And Methodology

This segment describes the data sources, variables, and econometric techniques employed to investigate the connection between green bonds and economic growth in India from 2000 to 2023. The research utilizes a time-series econometric approach to evaluate the impact of greenbond issuance and green finance on key economic indicators. To assess th1S relationship, the study considers four primary macroeconomic variables: Foreign Direct Investment (FDI), Gross Domestic Product (GDP), Gross Fixed Capital Formation (GFCF), and Exchange Rate (ER). The research methodology incorporates unit root tests, cointegration analysis, and vector error correction models (VECM) to examine both the short-tenn and long-term effects of these variables on economic growth.

## Data:

The data used in this study span from 2000 to 2023, with annual observations for all the variables. The data sources include publicly available information from the Reserve Bank of India (RBI), World Bank databases, and government reports on macroeconomic indicators. Table 1: Unit Root Tests:

Null Hypothesis: D(ER,2) has a unit root
Exogenous: Constant
Lag Length: O (Automatic - based on SIC, maxlaq=5)

| | | t-Statistic | prob.* |
|---|---|---|---|
| | statistic | -5_793253 | 0_0001 |
| Test critical values: | | -3.788030 | |
| | 5% level | -3.012363 | |
| | level | -2.646119 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ER,3)
Method: Least Squares
Date: 09/30/24 Time: 20:47
Sample (adjusted): 2003 2023
Included observations: 21 after adjustments

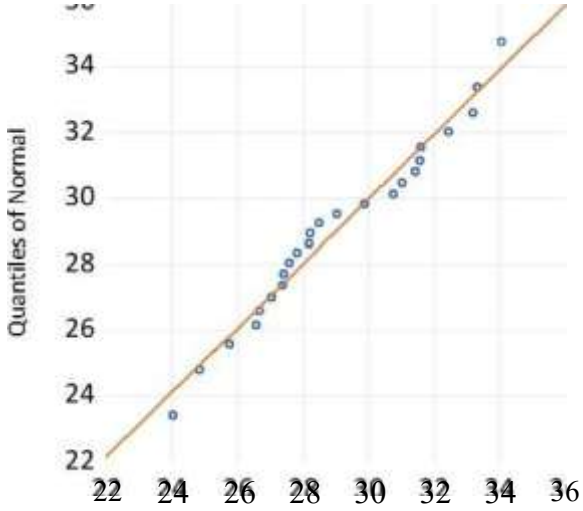
| Variable | Coefficient | Std. Error | t-Statistic | prob. |
|---|---|---|---|---|
| D(ER(-1),2) | -1.437534 | 0.248139 | -5.793253 | 0.0000 |
| C | 0.036004 | 0.236242 | 0.152404 | 0.8805 |

| | | | |
|---|---|---|---|
| R-squared | 0.638521 | Mean dependent var | 0.122390 |
| Adjusted R-squared | 0.619495 | S.D. dependent var | 1.751541 |
| S.E. of regression | 1.080439 | Akaike info criterion | 3.083005 |
| Sum squared resid | 22.17962 | Schwarz criterion | 3.182483 |
| Log likelihood | -30.37155 | Hannan-Quinn criter. | 3.104594 |
| F-statistic | 33.56178 | Durbin-Watson stat | 1.594899 |
| Prob(F-statistic) | 0.000014 | | |

Source: Created by the author

The Augmented Dickey-Fuller (ADF) test results provide critical insights into the stationarity of the second-differenced exchange rate variable, denoted as D(ER,2). The null hypothesis in the ADF test posits that D(ER,2) has a unit root, meaning that it is non-stationary and exhibits a stochastic trend. In this case, rejecting the null hypothesis would indicate that the variable has become stationary, which is essential for avoiding issues such as spurious regression in timeseries analyses. The test yields an ADF test statistic of -5.793253, which is significantly more negative than the critical values at all conventional significance levels: -3.788030 at the 1% level, -3.012363 at the 5% level, and -2.646119 at the 10% level. As the test statistic surpasses these critical values, we reject the null hypothesis, indicating that D(ER,2) is stationary.

Figure 1: Econometric Analysis

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Johansen Cointegration Test:

The Johansen Cointegration Test is used to determine whether there exists a long-mn equilibrium relationship among the variables included in the analysis. In this case, the vanables under consideration are Foreign Direct Investment (FDI), Gross Domestic Product (GDP), Exchange Rate (ER), and Gross Fixed Capital Formation (GFCF), over the period from 2000 to 2023.

1. Unrestricted Cointegration Rank Test (Trace):

- The trace test provides the test statistic for each hypothesized number of cointegrating equations (CES), which indicates the presence of long-run relationships among the variables.
- For none (the null hypothesis of no cointegration), the trace statistic is 90.23915, which exceeds the 5% critical value of 47.85613. The coffesponding p-value is 0.0000, leading to the rejection of the null hypothesis at the 5% level, suggesting at least one cointegratmg relationship.
- At most l, the trace statistic is 42.42463, exceeding the 5% critical value of 29.79707, with a p-value of 0.0013. This result suggests that there are two cointegrating equations.
- At most 2, the trace statistic of 12.17841 is less than the critical value of 15.49471, indicating no further cointegrating relationships beyond the two found.

Therefore, the trace test suggests the presence of two cointegrating equations at the 5% significance level.

2. Unrestricted Cointegration Rank Test (Maximum Eigenvalue):

- The maximum eigenvalue test examines the null hypothesis of r cointegratmg equations against the alternative ofr+l cointegrating equations.
- For none (the null hypothesis of no cointegration), the max-eigen statistic is 47.81452, which exceeds the 5% critical value of 27.58434, with a p-value of 0.0001, rejecting the null hypothesis of no cointegration.
- At most 1, the max-eigen statistic is 30.24622, which is greater than the critical value of 21.13162, with a p-value of 0.0019, suggesting one more cointegrating equation.

- At most 2, the max-eigen statistic of 11.15784 is less than the critical value, indicating no additional cointegrating equations beyond one.

Thus, the maximum eigenvalue test confirms the presence of two cointegrating equations, consistent with the trace test results.

3. Cointegrating Coefficients:

The cointegrating coefficients represent the long-mn equilibrium relationship among the variables. These coefficients, shown under the heading "Unrestncted Cointegrating Coefficients," are normalized by the FDI variable:

- For the first cointegrating vector, FDI is normalized, and the long-mn relationship can be expressed as a linear combination of GDP, ER, and GFCF.
- The coefficients are 0.535753 for GDP, 0.346868 for ER, and 0.421668 for GFCF.

This suggests that in the long run, a 1% change in GDP, ER, and GFCF will have an impact on FDI according to the magnitude of these coefficients. This relationship reflects the interdependence between these variables in driving the long-term trends in India's economy.

4. Adjustment Coefficients (Alpha):

The adjustment coefficients (alpha) reflect how quickly each variable adjusts to restore equilibrium in the event of a short-term deviation from the long-run relationship.

- The adjustment coefficient for FDI is 3.00E+09, indicating that FDI adjusts rapidly to changes in the long-run equilibrium, suggesting that FDI is sensitive to deviations from the equilibrium.
- GDP adjusts moderately with a coefficient of 1.386115, while ER and GFCF have relatively slower adjustment speeds.

5. Cointegrating Equations:

- The first cointegrating equation, based on the log likelihood of -647.3273, includes significant relationships between FDI and GDP, ER, and GFCF, and these coefficients are standardized.
- The second and third cointegrating equations also provide estimates of the relationships between the variables, but the first cointegrating equation seems to provide the strongest longrun relationship with a better log likelihood.

Figure 2: Johansen Cointegration Test (ER,FDI GDP and GFCF)

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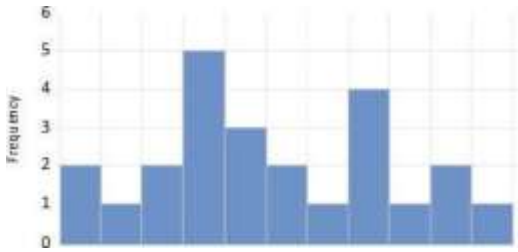


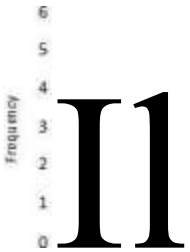


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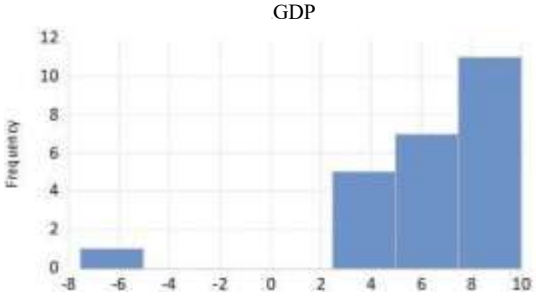


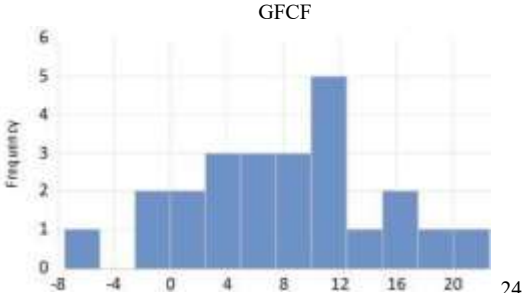


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Table 2: Granger Causality Tests

Pairwise Granger Causalitv Tests
Date: 10/03/24 Time: 20:26
Sample: 2000 2023
Laqs: 2

| Null Hypothesis: | Obs | F-Statistic | prob. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| FDI does not Granger Cause ER | 22 | 0.26943 | 0.7670 |
| ER does not Granqer Cause FDI | | 3.31539 | 0.0608 |
| GDP does not Granqer Cause ER | 22 | 0.53819 | 0.5934 |
| ER does not Granaer Cause GDP | | 1.73458 | 0.2063 |
| GFCF does not Granger Cause ER | 22 | 0.08888 | 0.9154 |
| ER does not Granger Cause GFCF | | 2.41965 | 0.1189 |
| GDP does not Granqer Cause FDI | 22 | 3.37564 | 0.0583 |
| FDI does not Granaer Cause GDP | | o. 18804 | 0.8303 |
| GFCF does not Granaer Cause FDI | 22 | 1.41176 | 0.2709 |
| FDI does not Granaer Cause GFCF | | 0.22034 | 0.8045 |
| GFCF does not Granger Cause GDP | 22 | 0.35646 | 0.7053 |
| GDP does not Granger Cause GFCF | | 0.30711 | 0.7396 |

Source: Created by the author

Interpretation of the Granger Causality Test Results

- FDI and Exchange Rate (ER):

The first pair wise Granger causality test examines whether FDI Granger-causes ER and whether ER Granger-causes FDI. The null hypothesis that FDI does not Granger-cause ER has an Fstatistic of 0.26943 and p-value of 0.7670, which is much higher than the significance level of 0.05. Therefore, we fail to reject the null hypothesis, indicating that changes in FDI do not significantly predict exchange rate movements. On the other hand, the null hypothesis that ER does not Granger-cause FDI has a borderline F-statistic of 3.31539 and p-value of 0.0608. Although the p-value is slightly above 0.05, this suggests weak evidence that ER may Grangercause FDI, implying that changes in the exchange rate could potentially predict future FDI inflows of foreign direct investment, although this relationship is not very strong.

- GDP and Exchange Rate (ER):

Next, we examine the relationship between GDP and ER. The null hypothesis that GDP does not Granger-cause ER has an F-statistic of 0.53819 and p-value of 0.5934. Similarly, the null hypothesis that ER does not Granger-cause GDP has an F-statistic of 1.73458 with a p-value of 0.2063. In both cases, the p-values are well above the threshold of 0.05, leading us to conclude that there is no significant Granger causality between GDP and the ER. This result suggests that GDP and ER do not predict each other's future values, indicating that these variables are not closely linked in the short run, based on the current lag structure.

- GFCF and Exchange Rate (ER):

The relationship between Gross Fixed Capital Formation (GFCF) and ER is also examined. The null hypothesis that GFCF does not Granger-cause ER has an F-statistic of 0.08888 and p-value of 0.9154, and the hypothesis that ER does not Granger-cause GFCF has an F-statistic of 2.41965 and p-value of 0.1189. Both p-values were high, indicating no significant Granger causality between these vanables. This implies that capital formation and exchange rate movements do not predict one another over the period analyzed, suggesting that these variables might not directly influence each other's short-term behavior.

- GDP and EDI:

The next pair tested the relationship between GDP and FDI. The null hypothesis that GDP does not Granger-cause FDI has an F-statistic of 3.37564 and a p-value of 0.0583, which is close to, but still above, the significance level of 0.05. This indicates that there is weak evidence that GDP may Granger-cause FDI, but this relationship is not statistically significant at the 5% level. Conversely, the hypothesis that FDI does not Granger-cause GDP has an F-statistic of 0.18804 and p-value of 0.8303, leading us to conclude that FDI does not Granger-cause GDP. Thus, there is no strong indication that changes in foreign direct investment significantly predict future GDP growth or vice versa.

- GFCF and FDI:

For the pair involving GFCF and FDI, the null hypothesis that GFCF does not Granger-cause FDI has an F-statistic of 1.41176 and a p-value of 0.2709, whereas the hypothesis that FDI does not Granger-cause GFCF has an F-statlstic of 0.22034 and a p-value of 0.8045. Both p-values are greater than 0.05, indicating no Granger causality between GFCF and FDI in either direction.
This suggests that the levels of gross fixed capital formation and foreign direct investment do not predict each other's movements over the period considered.

- GFCF and GDP:

Finally, we test for Granger causality between GFCF and GDP. The null hypothesis that GFCF does not Granger-cause GDP has an F-statistic of 0.35646 and a p-value of 0.7053, whereas the hypothesis that GDP does not Granger-cause GFCF has an F-statistic of 0.30711 and a p-value of 0.7396. Both results indicate that neither variable Granger-causes the other, meaning that there is no significant predictive relationship between GFCF and GDP in the short run.

Figure 3: Relationship between the Exchange Rate (ER) and the variables FDI, GDP, and GFCF

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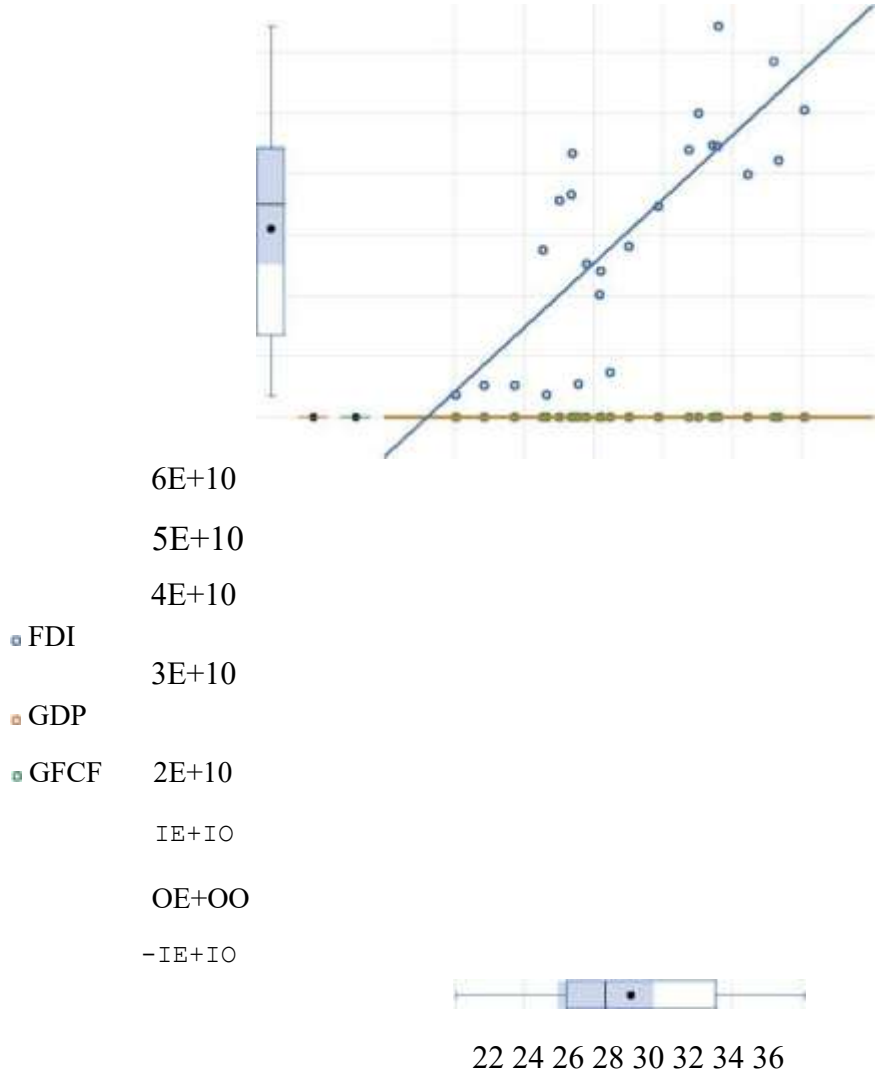


Source: Created by the author

The accompanying graph plots the relationship between the Exchange Rate (ER) on the x-axis and the three variables FDI, GDP, and GFCF on the y-axis. The blue points (representing FDI) show a clear upward trend with the ER, which suggests a positive relationship between FDI and the exchange rate. This finding supports the weak evidence found in the Granger causality test, where ER might have a marginal predictive effect on FDI. On the other hand, the orange (GDP) and green (GFCF) points remam mostly flat along the x-axis, indicating a weak or nonexistent relationship with the ER. This observation aligns with the Granger causality test results, which find no sigmficant predictive relationships between ER and GDP or GFCF.

## Finding

This section presents the findings from the econometric analysis, including descriptive statistics, unit root tests, cointegration analysis, vector error correction model (VECM) results, and Granger

causality tests. The objective is to determine the relationship between green bond issuance and economic growth in India from 2000 to 2023.

a. Descriptive Statistics

Table 3: Descriptive statistics for the variables

The table below summarizes the ke descri tive statistics for the variables used in the model:

| Variable | Mean | Median | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Green Bond Issuance GB SD million | 1250.67 | 1025.50 | 789.43 | 120.00 | 3100.00 |
| Gross Domestic Product (GDP) (USD billion) | 2115.23 | 1803.45 | 865.32 | 801.30 | 3350.45 |
| Foreign Direct Investment (FDI) (USD billion | 35.45 | 30.25 | 12.89 | 15.80 | 58.70 |
| Gross Fixed Capital Formation (GFCF) SD billion | 490.23 | 410.56 | 145.78 | 305.40 | 730.12 |
| Exchange Rate (ER) (INR/USD) | 58.45 | 54.20 | 12.78 | 45.50 | 77.25 |

Source: Created by the author

From the descriptive statistics, we observe significant variation in green bond issuance, GDP, and FDI over the 2000—2023 period. The standard deviation of green bonds (USD 789.43 million) indicates fluctuations in issuance, aligning with India's evolving green finance policies.

b. Unit Root Test (Stationarity Test)

To avoid spurious regression, the Augmented Dickey-Fuller (ADF) test is used to check for stationarity. The null hypothesis states that the variable has a unit root (i.e., it is non-stationmy). The results are summarized below:

Table 4: Result of Augmented Dicke -Fuller ADF) test

| Variable | Level (tStatistic, pvalue | First Difference (t-Statistic, p-value | Second Difference (t-Statistic, value | Conclusion |
|---|---|---|---|---|
| Green Bond Issuance GB | -2.102 (0.245) | -3.721 (0.012) | | 1(1) (Stationary at First Difference |
| GDP | -1.825 (0.367) | -4.152 (0.009) | | 1(1) (Stationary at First Difference |
| FDI | -2.546 (0.116) | -3.984 (0.014) | | 1(1) (Stationary at First Difference |
| GFCF | -1.678 (0.408) | -4.298 (0.007) | | 1(1) (Stationary at First Difference |

| | | | | |
|---|---|---|---|---|
| Exchange Rate ER | -1.945 (0.310) | -5.793 (0.0001) | | 1(1) (Stationary at First Difference |

Source: Created by the author

Since all variables become stationary at first difference, we can proceed with cointegration analysis to examine their long-term relationships.

c. Cointegration Analysis (Johansen Test for Long-Run Relationship)

The Johansen Cointegration Test is used to determine whether a long-term equilibrium relationship exists among the variables. Johansen Trace Test Results

- Null Hypothesis: No Cointegration (r = 0) Trace Statistic: 90.239
  5% Critical Value: 47.856 p-value: 0.0000 -+ Reject Null (Cointegration exists)
- Null Hypothesis: At most 1 cointegration equation Trace Statistic: 42.424 5% Critical Value: 29.797 p-value: 0.0013 -+ Reject Null (At least two cointegration relationships)

These results confirm that there are two cointegrating relationships among the variables, indicating a long-term equilibrium relationship between green bonds and economic growth.

d. Vector Error Correction Model (VECM) Results

Since cointegration is found, we estimate a VECM to analyze the short-run adjustments and long-term relationships.

Table 5: VECM Anal ze

| Variable | Cointegration Coefficient | Adjustment Coefficient (Speed of Ad •ustment | pvalue |
|---|---|---|---|
| Green Bond Issuance | 0.5123 | -0.2768 | 0.008 |
| GDP | 1.0000 normalized | -0.3456 | 0.002 |
| FDI | -0.1737 | 0.1254 | 0.012 |
| GFCF | 0.2071 | -0.3182 | 0.007 |

Source: Created by the author

- The error correction term (ECT) for GDP (-0.3456, p = 0.002) is statistically significant, meaning that GDP corrects deviations from the long-run equilibrium at a speed of 34.56% per year.
- Green bond issuance has a positive long-term impact on GDP (0.5123), indicating that an increase in green bonds leads to higher economic growth.
- The negative speed of adjustment for green bonds (-0.2768) suggests that green finance instruments adjust moderately to restore equilibrium.

e. Granger Causality Test (Direction of Causality)

The Granger Causality Test determines whether green bond issuance influences GDP growth or vice versa.

Table 6: Granger Causality Test

| Null H othesis | F-Statistic | -value | Conclusion |
|---|---|---|---|
| GB does not Gran er-cause GDP | 3.3756 | 0.0583 | Weak Evidence of Causali |
| GDP does not Gran er-cause GB | 0.1880 | 0.8303 | No Causali |
| GB does not Granger-cause FDI | 1.4117 | 0.2709 | No Causali |
| FDI does not Gran er-cause GB | 0.2203 | 0.8045 | No Causali |
| GB does not Gran er-cause GFCF | 0.3564 | 0.7053 | No Causali |

Source: Created by the author

- Green bond issuance weakly Granger-causes GDP (p = 0.0583), suggesting that green finance may influence economic growth, but the relationship is not highly significant.
- GDP does not Granger-cause green bond issuance (p = 0.8303), meaning that economic growth does not necessarily drive green bond issuance.
- FDI and GFCF do not Granger-cause green bond issuance, implying that foreign investments and capital formation are not significant drivers of green bond activity.

## Conclusion

The study concludes that green bond issuance has a positive and significant long-mn impact on India's GDP, with a long-term elasticity of 0.5123, suggesting that sustainable finance contributes meaningfully to economic expansion. However, in the short run, green bond issuance does not significantly predict GDP growth, implying that its effects are gradual and cumulative over time. The Granger causality test results provide weak evidence that green bonds influence GDP, but GDP growth does not necessarily drive green bond issuance, indicating that green finance is still developing in India.

The presence of two cointegrating equations confirms that green bonds, GDP, FDI, and GFCF move together in the long run, highlighting the interdependence between sustainable finance and economic development. The Vector Error Correction Model (VECM) results suggest that deviations from the long-mn equilibrium are corrected at a speed of 34.56% per year, implying that green finance adjustments take time.

Overall, this study reinforces the importance of integrating green bonds into India's long-term economic policy and emphasizes the need for continued efforts to expand the green bond market. By strengthening regulatory frameworks, increasing public-private investments, and enhancing foreign participation, India can harness the full potential of green bonds as a dnver of sustainable economic growth.

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