Natural Assets and Public Debt: Evidence using Sovereign Green Bonds*

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Abstract

This study investigates whether public debt prices risk to natural assets. Analysis of sovereign green bonds (2016–2024) reveals that investors price natural capital depletion but not biodiversity loss—a 1% increase in depletion is associated with 32-basis-point higher yield. A novel dataset on green bond-funded projects, developed using an Artificial Intelligence (AI) model, shows that "green intentions" alone do not influence asset prices without "green efforts." While carbon emissions per capita remain unchanged after issuance, 40% of bonds funding sustainable forestry projects result in a 0.2% increase in forest area (as a percentage of habitable land) compared to pre-issuance trends.

KEYWORDS: Biodiversity Loss; Natural Resources Depletion; Sovereign Green Bonds; Sustainable Forestry; Carbon Intensity.

JEL Codes: G30, M14.

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1. Introduction

Over half of the global economy is highly or moderately dependent on nature and the goods and services it generates (known as "ecosystem services").[1] According to one estimate, the recent losses of ecosystem services have been estimated to cause damages of USD 4 trillion to USD 20 trillion per year (Kapnick, 2022). Yet even this estimate does not cover all nature-related benefits. A significant responsibility for natural assets (or green public goods) such as biodiversity conservation and the preservation of natural resources rests with public institutions, such as governments and municipalities because private institutions like corporates invest mostly in those forms of natural capital that are direct inputs for provisioning services (such as farms, plantations, houses, and similar others) whose products are excludable (Flammer, Giroux, and Heal, 2022; Karolyi and Puente, 2023; Dasgupta 2021). Therefore, it is essential to understand the role of public organizations and the potential risks to their external funding associated with biodiversity loss and the depletion of natural capital. This paper fills that gap. [2]

Giglio, Kuchler, Stroebel, and Zeng (2023) conducted a comprehensive survey to gauge the perceptions of biodiversity risks among finance academics, professionals, public sector regulators, and policy economists globally. One of the key findings from this survey revealed that approximately half of the respondents believe these risks are not adequately reflected in the pricing of stock, commodity, sovereign debt, and real estate markets. Only 14% to 19% of respondents feel that these risks are accurately priced. Recent cases of public finance investors engaging with Brazil and Bolivia on deforestation and biodiversity loss suggest

[1] *Source: World Economic Forum, Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy, 2020.*

[2] We focused on biodiversity loss and the natural capital depletion risks because recent evidence shows that environmental risks extend well beyond the climate change system to include these risks as well and the economic cost of these risks would exceed the GDP loss caused in 2020 by the Covid-19 pandemic in around half the countries (Pinzon et al. 2020; Dobson et al. 2020; Tollefson 2020). In addition, the global risks survey reports from 2021 to 2025 by World Economic Forum have ranked biodiversity loss and natural capital risk as 2nd and 4th among all 33 global risks.

that they are showing interest in mitigating these risks.[3] To understand whether investors price these risks to ecosystem services such as biodiversity loss and natural capital risk, we investigate the association of these risks with sovereign green bond pricing. Furthermore, we also analyze the environmental performance of the sovereigns who used green bond proceeds to invest in these services.

We focused on sovereign green bonds as these are financial instruments especially designed to address negative externalities, such as biodiversity loss and risks to natural capital. Since the proceeds from green bonds are intended for mitigating these negative externalities, we should not expect conventional bonds to incorporate these risks if investors are not pricing them into green bonds. Furthermore, we also investigate how "Green Intentions" and "Green Efforts" by sovereigns may influence this pricing dynamic. A sovereign's "Green Intentions" are reflected during the issuance of green bonds when the sovereign discloses the categories of green projects funded by the bond proceeds. On the contrary, "Green Efforts" are evident when the sovereign actually invests in those specified green categories.

To evaluate whether biodiversity and natural capital risks are incorporated into the pricing of sovereign green bonds, we analyze data from the Bloomberg Global Fixed Income Database. Our sample consists of 216 sovereign green bonds issued between 2016 and 2024. We exclude 65 zero-coupon bonds, as these are essentially stripped securities that do not directly finance green projects. Most of the bonds in our sample are senior unsecured and have been issued by countries from the Asia-Pacific region, Europe, and Latin America. Using Artificial Intelligence (AI) models such as large language models (LLMs), we have developed a novel database focused on green projects that are financed through the proceeds of the green bonds. This database provides details about the capital allocation on these projects and their impact. To create this database, we extract information from comprehen-

[3] https://www.unpri.org/Uploads/h/w/p/investorstatementondeforestationandforestfiresintheamazon_1oct2019_825656.pdf

sive reports related to each bond. These reports include ESG frameworks, impact reports, capital allocation reports, external review reports, term sheets, and prospectuses. Collecting these reports is essential because the ESG framework—which outlines the categories of green projects—is provided only once. In contrast, other reports, such as impact reports, capital allocation reports, and external review reports, may be issued multiple times throughout the life of the bond. Tracking these later reports alongside the issuance date is crucial for accurately monitoring the progress of the green projects. This detailed approach enables us to evaluate whether the sovereign's "Green Intentions", as outlined in the framework, and their "Green Efforts", as reflected in the outcomes from subsequent reports, correlate with bond pricing and to what extent these efforts help mitigate environmental externalities.

Our estimates of biodiversity and natural capital risk are derived from two primary sources. For biodiversity risk, we use country-level measures provided by Giglio, Kuchler, Stroebel, and Zeng (2023). This dataset includes three metrics: the percentage of endangered species, the biodiversity regulation index, and the biodiversity degradation index. The latter two indices are calculated based on the frequency of mentions of biodiversity regulation and degradation in news articles. For natural capital risk, we rely on country-level ESG data from the World Bank, which includes estimates on forest cover loss, the depletion rate of forests (% of GNI), the depletion rate of natural resources (% of GNI), and the water withdrawal rate (% of internal resources). In addition to our primary risk variables, we control for bond characteristics such as maturity, amount issued, option embeddedness, and coupon type (fixed or floating). Sovereign bond pricing could be influenced by macro variables such as the debt-to-GDP ratio, GDP growth, and terms of trade, as highlighted in previous research (Hilscher and Nosbusch, 2004; Duffie, Pedersen, and Singleton, 2003). We control for these variables as well. These macroeconomic variables are sourced from the World Bank database.

Our findings indicate that investors place greater importance on the preservation of natural resources compared to biodiversity conservation. Specifically, an increase in natural

resource depletion and natural forest depletion is associated with a rise in bond yields. In economic terms, we found that an increase in natural capital depletion, measured as natural forest depletion and natural resources depletion, by 1% increases the offer yield to maturity by 32 basis points. The positive association of bond yield with the natural resource and forest depletion rates indicates that investors are concerned about the country's economic growth. as the depletion of these resources could lead to reduced economic growth in the future (Stiglitz, 1974; Dasgupta and Heal, 1974). The relationship between biodiversity conservation and asset pricing is more complex and indirect. Additionally, the effects of biodiversity conservation often take a considerable amount of time to become apparent. While many sovereign green bonds have long maturities and are still outstanding, it remains uncertain whether biodiversity risk will be reflected in the pricing at the tail end of the maturity distribution.

As biodiversity loss and risk to natural capital can be restrained by initiating and implementing the green projects using the bond proceeds, we examine whether the intention to initiate green projects and efforts to implement them change the relation between the risks and bond prices. We measure green intentions using the ESG framework reports, which the issuer provides to the investors at the bond issuance. The framework highlights the green project categories in which proceeds would be used, management of proceeds, and green reporting in the future. We found that mere intentions do not significantly influence investor behavior towards these risks. Using the impact and capital allocation reports, we measure "Green Efforts" as the actual number of green projects implemented per dollar amount of proceeds. We find that green efforts by the sovereigns are recognized by the investors if the efforts are aligned with the direction of risks.

To mitigate these risks further, the 196 countries gathered for the Kunming - Montreal Convention, on 19th December 2022, to adopt the new global biodiversity framework (GBF). The Kunming - Montreal Convention on biodiversity which held on 19th December 2022 and

participated by the 196 countries, adopted the new global biodiversity framework (GBF). This framework, which is considered as "Paris Agreement for Nature", is designed to halt and reverse global biodiversity loss and serves as the successor to the Aichi Biodiversity Targets. Garel et al. (2024) find that post Kunming-Montreal convention, the investors are demanding the premium of 2.2% for corporate biodiversity risk. In contrast, we find a 54 basis point reduction in yield after the convention compared to before it for endangered species (in %), and similar findings for the biodiversity regulation index and the biodiversity degradation index. We hypothesized that bond yields would decline because investors are less worried about this risk, given the measures taken during the convention. We observe mixed results for natural capital risk; these are expected because the conventions and updates in GBF primarily focused on biodiversity risk, rather than risk to natural capital or natural resources management. This test serves as a placebo for natural capital risk; therefore, we anticipate mixed results or no change in the relationship between yield and natural capital risk.

Lastly, we also assess the environmental performance of the issuers. Since biodiversity loss affects carbon emissions (Weiskopf et al., 2024), we analyze the country-level carbon emissions per capita (carbon intensity). We find that green bond-issuing sovereigns with interim and net-zero targets do not have lower carbon intensity compared to others, even after a three-year span. Since carbon intensity may not be a concern for all issuers and might not be a negative externality for every sovereign, we focus on their environmental performance based on the projects funded by their green bonds. As 40% of sovereign green bonds are used for sustainable forestry projects, we examine the percentage of forest area in habitable land and the loss of forest cover (in hectares) in these sovereigns and compare them with other green bond issuers. We discovered a 0.2% increase in forest area as percentage of habitable land and a reduction of 68.4 million hectares in forest cover loss following the issuance of green bonds and investment in sustainable forestry.

Overall, our work shows that investors care about the preservation of natural capital and less about the conservation of biodiversity. This finding aligns with classic theoretical papers on exhaustible resources[4], which suggest that natural resources are crucial for a country's economic growth. Although green projects can be implemented to mitigate these risks, we discovered that merely expressing intentions to initiate such projects is insufficient to persuade investors. The efforts to implement these green projects must align with the perceived risks in order to influence investors' risk preferences effectively. Despite commitments to net-zero emissions, the improvement in environmental performance among these sovereigns issuing green bonds is not significant. As carbon intensity may not be a concern for all sovereigns, we focus on their environmental performance based on the sustainable forestry projects funded by their green bonds. We find the increase in forest area and reduction in loss of forest cover following these investments. These findings are robust across various tests.

The paper is structured as follows: Section 2 reviews the relevant literature and outlines our contributions. Section 3 covers data collection and the variables used for analysis. Section 4 presents our empirical specifications. Section 5 discusses the results, and Section 6 concludes the paper.

[4]Refer Stiglitz, (1974), Dasgupta and Heal (1974), and similar others.

2. Related Literature and Contribution

Our research contributes to the rapidly expanding literature on the intersection of financial markets, asset prices, and environmental health. Recent studies have extensively explored the impact of risks related to climate change on financial assets (e.g., Giglio et al., 2023; Bolton and Kacperczyk, 2023; Aswani, Raghunandan, and Rajgopal, 2024a, 2024b; Aswani and Rajgopal, 2024). Comprehensive review of this body of work is provided by Giglio et al. (2021), Stroebel and Wurgler (2021), and Hong et al. (2020). Despite of these works, research into the impact of biodiversity risks on asset values and economic activity is relatively sparse. Notable contributions in this area include Dasgupta (2021), who offers an overview of global biodiversity and the economic drivers behind its decline, and Flammer et al. (2023), who focus on financing for biodiversity conservation projects. Recent studies on impact of biodiversity loss mainly focuses on corporate outcomes. For instance, Gigilio et al. (2023) provide quantitative measures of aggregate biodiversity risk and investigate its pricing within equity markets. Similarly, Garel, Romec, Sautner, and Wagner (2024) investigates whether corporate biodiversity footprint (CBF) (developed by Iceberg Data Lab) is associated with stock returns. Authors find no association between CBF and stock returns using the data from 2018-2021 overall but find premium of 2.2 % annual return following major biodiversity-related policy changes such as Kumming Declaration and the launch of Nature-related Financial Disclosure (TNFD) in 2021.

Differentiating from previous studies, our research examines how biodiversity loss and natural capital degradation affect sovereign credit risk. We focus on sovereigns for two key reasons. First, although sovereign risk is traditionally associated with emerging economies in Latin America and Asia, the U.S. credit rating downgrade in August 2011 and the subsequent Eurozone debt crisis shifted global attention toward sovereign risk in advanced economies as well. Consequently, understanding the determinants of sovereign credit spreads and the

cross-country differences in spread levels has become an important area of inquiry (Doshi et al., 2017). Second, the responsibility for providing public goods—such as biodiversity conservation and natural capital preservation - rests primarily with governments rather than corporations. Assessing how these environmental risks influence sovereign bond yields is therefore essential to determine whether international investors price such risks into sovereign debt. Moreover, because sovereign green bonds are specifically designed to finance projects that mitigate environmental externalities, analyzing their pricing dynamics and environmental implications can reveal whether investors genuinely account for these risk factors and whether countries effectively address them.

A vast body of research has examined the determinants of sovereign credit risk, identifying both country-specific and global factors. For example, Hilscher and Nosbusch (2004) find that debt-to-GDP ratios and terms of trade account for a significant share of the variation in sovereign yield spreads. Similarly, Cantor and Packer (1996) and Kamin and von Kleist (1999) highlight the role of sovereign credit ratings as key determinants of yield spreads. Pan and Singleton (2008) document a strong relationship between sovereign credit risk and global market volatility, as captured by the VIX index. Investigating the commonality in sovereign credit spreads, Longstaff et al. (2011) use the principal components of changes in CDS spreads across 26 developed and emerging economies and show that common global factors explain a substantial portion of sovereign credit risk—more so than they do stock returns. Building on this literature, our study introduces an environmental dimension by demonstrating that risks associated with biodiversity loss and natural capital degradation represent additional, country-specific determinants of sovereign credit risk.

We also contribute to the growing literature on the pricing and environmental implications of green securities. Green bonds are financial instruments specifically designed to mitigate environmental externalities by channelling proceeds exclusively toward environmentally beneficial projects. Flammer (2021) finds that corporate green bonds are issued at a

premium relative to traditional corporate bonds and that issuers' environmental performance improves following issuance. However, Flammer (2021) does not account for the fact that most corporate green bonds are issued by financial institutions, which typically have limited direct environmental externalities. Addressing this limitation, Aswani and Rajgopal (2025) show that the observed "greenium" exists primarily for financial firms, whose environmental footprint is relatively small, and that this premium does not transmit to the green loan market. Moreover, they find that neither green bond issuers nor green loan borrowers exhibit significant improvements in environmental performance within a short horizon of three to five years. Extending this line of research, Aswani and Rigobon (2025) demonstrate that the adoption of sustainable governance mechanisms—such as appointing a Chief Sustainability Officer (CSO) or establishing an ESG committee—enhances issuers' ability to improve environmental performance following green bond issuance. In contrast, Larcker and Watts (2019), studying municipal green bonds, find no difference in the risk-adjusted pricing between green and conventional securities. Building on this literature, our study examines how risks associated with natural assets—specifically biodiversity loss and natural capital depletion—affect sovereign credit risk through the lens of green bond pricing. If investors recognize these environmental risks as material to sovereign creditworthiness, such concerns should be reflected in the pricing of sovereign green bonds earlier and more prominently than in traditional sovereign bonds.

Lastly, we contribute to the literature on artificial intelligence applications in finance. Using large language models (LLMs), we extracted and developed a structured dataset on project categories, capital allocation, and impact outcomes of green projects initiated using the proceeds of green bonds. We used this data to estimate intentions (Green Intentions) and efforts (Green Efforts), and check whether these estimates influence the sovereign green bond pricing.

To our knowledge, this is the first paper to examine how biodiversity and natural capital

risks are priced in sovereign green bonds and whether sovereigns' green intentions and efforts to mitigate these risks are factored in the debt valuation. Furthermore, we also explore how green projects (such as sustainable forestry) contribute to mitigating biodiversity and natural capital risks.

3. Data

3.1. Sovereign Green Bonds

Our data on sovereign green bonds comes from the Bloomberg Global Fixed Income database. We keep only the sovereign bonds that Bloomberg classifies as green. This leads to the sample of 214 sovereign green bonds issued from 2016-2024.[5] We drop 57 zero-coupon bonds from the sample, as these are strips from the existing bonds and have no association with the green projects. The majority of these bonds are senior unsecured and issued by countries from Asia-Pacific, Canada, Europe, and Latin America. Summary Statistics of these bonds are provided in Table 1 Panel D.

3.2. Biodiversity Loss

For the sovereign biodiversity loss, we use the measures on endangered species (in %), biodiversity degradation index, and biodiversity regulation index from Giglio et al. (2023). The list of endangered species for each country comes from the IUCN Red List of Threatened Species.[6] The percentage of endangered species in a country for the particular year is measured as the number of endangered species divided by the total number of species in that country. The biodiversity degradation index and the biodiversity regulation index are measured using textual analysis of IMF Article IV reports. Giglio et al. (2023) collected

[5]There are no sovereign green bonds issued prior to 2016.
[6]https://www.iucnredlist.org/resources/spatial-data-download

1,492 reports from 2010 to 2022 from the IMF website, covering 194 countries and regions, and identified biodiversity-related sentences in IMF reports using regular expression searches for the same biodiversity dictionary. From 2010 to 2022, they found 670 sentences related to biodiversity and manually classified the sentences into degradation or regulation. If a report contains at least one biodiversity degradation/regulation sentence, it is assigned a score of '1' to the country for that year; otherwise, 0. The summary statistics of these measures is provided in Table 1 Panel C.

3.3. Natural Capital Risk

The data on nature capital indicators comes from the World Bank Sovereign ESG database. The World Bank (Gratcheva, Emery, and Wang, 2021) has compiled data on the wealth of 141 nations, divided into three major categories: human capital (discounted lifetime earnings), produced capital (e.g., machinery, buildings, urban land), and natural capital (e.g., forests, cropland, protected areas, subsoil assets). Natural capital, or natural wealth, is further divided into renewable and non-renewable resources. The term "renewables" refers to natural capital that can produce benefits in perpetuity under sustainable management. The ESG database provides time-series information on 71 environmental and social indicators in 17 groups; however, we focus only on the indicators associated with natural capital endowment and management. The database provides five indicators for natural capital risk: natural forest depletion rate (% of GNI), natural resources depletion rate (% of GNI), freshwater withdrawal (in %), Forest cover loss, Forest area (% of total land), and Terrestrial and marine protected area. We didn't include forest cover loss and forest area (% of total land) in the analysis, as these variables are similar proxies to the natural forest depletion rate (% of GNI).

3.4. Control Variables

For regression analysis, we control for the bond characteristics such as maturity, coupon, option embeddedness, and whether the bond is fixed income or floating. Maturity is the number of years between the issue year and the year of maturity. Options is an indicator variable that takes the value 1 if the bond has options embedded, otherwise 0. Fixed is an indicator variable that takes the value 1 if the bond is straight (fixed-income), otherwise 0. Amount Issued is a logarithm of the amount issued by the sovereign issuing the green bond. In addition to controlling for bond characteristics, we also control for other determinants of sovereign credit risk, such as the Debt to GDP ratio, the natural logarithm of GDP, and terms of trade.

3.5. Green Intentions and Green Efforts of Sovereigns

Before issuing a green bond, the issuer establishes a general framework to identify which areas are eligible for sustainable finance and which projects qualify for funding. For instance, in 2020, Chile published a framework that included support for victims of human rights violations, as well as access to education and healthcare. In the same year, Mexico issued a bond to finance projects aligned with the UN Sustainable Development Goals (SDGs), covering areas such as education, agricultural development, healthcare, and sustainable infrastructure. Once a project receives approval from an external evaluator, funds are disbursed, and the project is monitored with periodic reporting.

We manually collected 118 impact reports, 115 capital allocation reports, 103 external review reports by auditors, 85 ESG framework reports, 39 prospectuses, and 19 term sheets for these bonds and linked them to each bond level. As there can be multiple impact reports, allocation reports, and external review reports, it is crucial to link these reports at the bond level to understand the time series of development of green projects. For instance, Belgium

issued a green bond in 2019, which has one framework report, one capital allocation report, three impact reports, and one external review report. Here we have briefly discussed the types of reports and their contents.

ESG Framework Report: A green bond framework is a document created by the issuer that clearly articulates the company's proposed use of proceeds for the bond. The framework should include information on the eligible categories (as per the Green Bond Principles) under which the projects being financed or refinanced fit. This disclosure enables investors to better assess the green eligibility of the projects and make more informed investment decisions.[7] For instance, Belgium's framework report of 2019 green bond suggests that the sovereign has decided to invest in five green project categories - *Energy Efficiency, Clean Transportation, Renewable Energy, Circular Economy,* and *Living Resources and Land Use.* These projects would be managed by the Belgian Debt Agency, ensuring that the allocation of proceeds will not allow for the listing of the same budget allocation twice. The report also mentions that the sovereign would provide allocation and impact reports for this bond, and the green project categories would be verified by a third party.

Second Opinion Report (SPO): Issuers obtain a SPO on their green bond framework from an external reviewer, such as Climate Bond Initiative (CBI) or its approved agencies, to confirm its alignment with the components of the Green Bond Principles. This step adds credibility to the issuer's proposal to issue a green bond. For instance, Belgium uses the services of Sustainalytics for the green bond issued in 2019 for the second opinion on green project categories.

Capital Allocation Report: This report provides information on the allocation of bond proceeds, in dollar terms, on green projects and their distribution across the countries. For instance, Belgium allocates the green bond proceeds on tax exemption green investment, tax deduction and exemption on clean transportation, and reduced package charge for individual

[7]https://www.sustainalytics.com/esg-research/resource/corporate-esg-blog/about-green-bond-principles

reusable drink packages.

Impact Report: This report provides information on impact parameters and their values for green projects. Belgium measured the impact of the green projects using parameters such as avoided carbon emissions and reduced use of materials – soda, lime, and sand for drink packages.

We utilized the methodology for large language models (LLMs) as outlined by Aswani (2025) to extract information from various reports. This allowed us to gather data on green project categories, the number of green projects, capital allocation to these projects, and the overall impact of the reports. We measure "*Green Intentions*" as the green projects' categories within the ESG framework report. These categories reflect the government's intentions regarding green initiatives in specific areas. Additionally, we quantify "*Green Efforts*" is the number of green projects initiated per dollar amount of proceeds as detailed in the impact and capital allocation reports.

4. Empirical Specification

To investigate whether sovereign green risk (proxied as green bond yield) is associated with biodiversity loss and natural capital depletion, we begin by using a simple specification,

$$Yield_i = \alpha + \beta\, BiodiversityLoss_i\,(or\, NaturalCapitalDepletion_i) + \gamma\, X_i + \delta\, Z_i + \epsilon_i \quad (1)$$

Yield is the sovereign green bond's offer yield to maturity. *Biodiversity Loss* is a vector of endangered species (in %), biodiversity regulation index, and biodiversity degradation index. *Natural Capital Depletion* is a vector of natural resources depletion (in %), natural forests depletion (in %), and freshwater withdrawal (in %). X is a vector of bond characteristics such as maturity, option embeddedness, fixed/floating coupon, and amount issued. Z is a vector of macroeconomic variables such as the Debt to GDP ratio, terms of trade, and the

natural logarithm of GDP. We test this specification using primary market yield as well as the monthly yield in the secondary market. ϵ is the error term with a normal distribution.

We further examine whether the sovereign's green intentions to mitigate these risks affect bond pricing. To test that, we use the following specification,

$$Yield_i = \omega_1 + \omega_2 GreenIntentions_i (or Green_Efforts_i) + \omega_3 X_i + \omega_4 Z_i + \nu_i \quad (2)$$

Green Intentions is a vector of two indicator variables – Biodiversity and Natural Resources. Biodiversity indicator variable takes the value 1 if the bond's ESG framework report mentions starting a green project to conserve biodiversity; otherwise, 0. Similarly, the Natural Resources indicator variable takes the value 1 if the ESG framework report mentions starting a green project to preserve natural resources; otherwise, it takes the value 0. ν is the error term with a normal distribution. "*Green Efforts*" is the number of green projects initiated per dollar amount of proceeds as detailed in the impact and capital allocation reports.

We also test whether a sovereign's green intentions impact the yield, especially when the sovereign has these risks.

$$\begin{aligned} Yield_i = \phi_1 + \phi_2 GreenIntentions_i (or Green_Efforts_i) * BiodiversityLoss_i \\ (or\, NaturalCapitalDepletion_i) + \phi_3 X_i + \phi_4 Z_i + \lambda_i \end{aligned} \quad (3)$$

The coefficient of interest in all the regressions is ϕ_2. The interaction term assesses whether green intentions (green efforts) improve external financing for sovereigns, particularly those facing these risks.

Finally, we assess the environmental performance of sovereign green bond issuers by examining whether their interim targets or net-zero commitments contribute to a reduction in carbon intensity (carbon emissions per capita) over a three-year period compared to other

issuers. We use the following specification to conduct this analysis,

$$\Delta CarbonIntensity_i = \eta_1 + \eta_2 Net - Zero_Commitment_i + \eta_3 X_i + \eta_4 Z_i + \mu_i \quad (4)$$

Here, carbon intensity is carbon emissions per capita.[8] Δ is difference between third year from issuance and the year of issuance. Commitment is a vector of indicator variables – Interim Target and Net Zero Target. Interim Target takes value 1 if the sovereign has the interim target (year) of reducing the emissions; otherwise, 0. Net Zero Target takes value 1 if the sovereign has the net-zero target (year); otherwise, 0.

5. Kunming - Montreal Convention and Sovereign Green Bonds

On 19th December 2022, the 196 countries attended the Kunming - Montreal Convention on Biodiversity and adopted the new global biodiversity framework (GBF). This framework is designed to halt and reverse global biodiversity loss and serves as the successor to the Aichi Biodiversity Targets. The framework provides four goals to achieve by 2050 - reduce the extinction of human-induced threatened species, valuing the ecosystem services for present & future generations, fairly sharing the monetary and non-monetary gains from genetic resources and associated traditional knowledge, and cooperation to bridging the 700 billion USD annual biodiversity finance gap. The framework also details the interim targets to be achivied by 2030 such as protect and conserve at least 30% of land, inland water, and marine areas; minimize pollution risk from all sources; reduce the pesticide risk by at least 50%; ensure managed areas under fishery, agriculture, aquaculture, and forestry are sustainable

[8]We use carbon intensity and not level emissions because Aswani, Raghunandan, and Rajgopal (2024a, 2024b) justified that scaled carbon emissions are preferred by the investors over the level of emissions. Although choosing the carbon intensity three years from issuance is random, our results are robust to this choice.

and increase biodiversity-friendly services; reduce rate of invasive alien species by at least 50%; and mobilize and align financial flows with biodiversity goals. This framework is considered as "Paris Agreement for Nature", providing a global roadmap for conservation, restoration, and sustainable use of biodiversity. [9]

Garel et al. (2024) find that post Kunming-Montreal Convention, the investors are demanding the premium of 2.2% for corporate biodiversity risk. If the global biodiversity framework (GBF) is crucial for highlighting the biodiversity loss and provides the roadmap for using it sustainability, there is a possiblity that it also influence the relation between bond yield and biodiversity & natural capital risk factors. We empirically test this hypothesis using the following specification.

$$Yield_i = \alpha + \beta_1 BiodiversityLoss_i + \beta_2 Kunming + \beta_3 KunmingX BiodiversityLoss_i \\ (or\, NaturalCapitalDepletion_i) + \gamma X_i + \delta Z_i + \epsilon_i \tag{5}$$

Here, *Kunming* is an indicator variable which takes value 1 if the bond is issued post 19th December 2022; otherwise 0. Furthermore, we also explore the possibility of GBF's impact on the association between bond pricing and green intentions. We test it by interacting the green intention variables in eq(3) by *Kunming* indicator variable.

$$Yield_i = \phi_1 + \phi_2 GreenIntentions_i + \phi_3 Kunming + \phi_4 Kunming X GreenIntentions_i \\ + \phi_5 X_i + \phi_6 Z_i + \lambda_i \tag{6}$$

The results for these tests are in Table 8.

[9] https://www.cbd.int/gbf/targets

6. Sustainable Forestry Projects and Deforestation

The deforestration is the result of market failure as the prices of forest-related products are undervalued ignoring its economic cost. Addressing the deforestation is equally crucial as the climate change considering the fact that world has lost 30 % of forest area on habitable land in last 10,000 years and 50% of it in last 100 years. According to UN Food and Agriculture Organization's (FAO) assessment, the 10 million hectares of land is cut down every year. [10] The deforestration directly impacts the timber, paper, construction, furniture, tourism, and related industries but its indirect consequences impacts every business as it releases carbon emissions in the atmosphere contributing towards climate change, increase extreme weather events, sea-level rise, and reduced agricultural productivity. The sustainable forestry is a solution to the loss in forest coverage and can provide economic benefits while protecting forests. The Sustainable forestry practices include selective logging, reforestation, and forest conservation. These practices help to maintain forest health, protect biodiversity, and provide a sustainable supply of forest products. [11]

From the 151 sovereign green bonds issued, excluding zero coupon bonds, 59 (40 %) green bonds proceeds are used for sustainable forestry projects. These projects are initiated by Canada, Brazil, China, Hungary, India, Indonesia, Nigeria, and Chile (see, Figure 4 for details). It is not surprising that the sustainable forestry projects are initiated at Europe, South America, Asia, Africa, and in Canada as these continents (or countries) have the greatest share of forest area, and therefore, the forest depletion or deforestation affects these areas more than others. To examine whether initiating the sustainable forestry projects help these sovereigns, we investigate the changes in forest area percentage of habitable land and the loss of forest cover (in hectares) in the sovereigns which used green bond proceeds for

[10] https://ourworldindata.org/deforestation

[11] https://climate.sustainability-directory.com/question/what-are-the-economic-impacts-of-deforestation/

these projects compare to sovereigns which used the bond proceeds for other projects.

$$ForestArea\,(ForestCoverLoss)_{i,t} = \alpha_i + \beta_{i,t}\, SustainableForestryCountry_i \\ (Post - GreenBondIssunace_{i,t}) + \gamma_c + \gamma_y + \epsilon_{i,t} \tag{7}$$

Here, *Sustainable Forestry Country* is an indicator variable which takes value 1 if the country has issued at least one green bond to support the projects related to sustainable forestry and 0 for countries which issued green bonds for other projects. *Post-Green Bond Issuance* is the indicator variable which takes the value 1 for years post green bond issuance supporting sustainable forestry projects; otherwise 0. Results for these tests are in Table 10.

5. Results and Discussion

Figure 1 illustrates the yearly and country-level distribution of sovereign green bond issuances. There is a sharp increase in issuances starting in 2018 especially of fixed and floating types. Reaching a peak in 2022-2023, with over 50 sovereign green bonds issued. Most of these bonds have been issued by countries in Europe, the Asia-Pacific, Canada, and Central America. Notably, Hong Kong (China), Canada, India, Chile, Hungary, and Indonesia have issued a considerable number of these bonds.

Figure 2 shows the credit rating of these bonds. In the sample, 63 % are rated; among these, 40 are rated AA, 12 are rated BBB, 8 are rated BBB-, and 3 are rated differently. Figure 3 shows the variation in biodiversity loss and natural capital risk with economic growth (proxied as the logarithm of gross domestic product (GDP)). Two hypotheses exist on the relationship between GDP and biodiversity/natural capital risk. The first hypothesis suggests that GDP is high for high biodiversity /natural capital risk, because countries grow using these resources. This leads to an increase in biodiversity / natural capital risk with

GDP. The second hypothesis proposes that GDP is high for countries with low biodiversity loss and natural capital risk because these countries have access to capital to conserve (or preserve) biodiversity (natural resources). Graphs in Figure 3 supports the first hypothesis as percentage of endangered species (Figure 3 (a)) and forest cover less (Figure 3 (b)) has linearly increased with logarithm of GDP.

Table 1 reports the characteristics and summary statistics of these bonds. Table 1 Panel A reports the distribution based on coupon type. Of the 216 sovereign green bonds, 151 are fixed (or floating) bonds, and 65 are stripped (or zero-coupon bonds). Panel B reports the green certification distribution of these bonds. Roughly 98% are green certified either by the Climate Bond Initiative (CBI) or its approved agencies. Panel C provides the distribution on maturity of these bonds. About 96% of these bonds expire on maturity, and only 3-4% are option embedded and can be called before maturity. Panel D shows the summary statistics of the bond characteristics. The average yield and amount issued of these bonds are 4.3% and 3.1 billion USD. The average coupon for these bonds is 3.4%. Other bond characteristics include indicator variables for option embeddedness, green certification, and for a straight (or fixed income) bond.

Table 2 presents the summary statistics for biodiversity loss and natural capital risk measures. The average percentage of endangered species among these sovereign nations is 13%, with a maximum of 25%. The average values for the biodiversity regulation index and the biodiversity degradation index are 0.284 and 0.068, respectively. On average, the depletion rate of natural resources in these countries is 1.2%, with some countries experiencing a maximum depletion rate of 14% due to extensive resource extraction. For the countries issuing green bonds, the average forest area represents 31% of total land area, while the maximum recorded is 68%. The average depletion of natural forests accounts for 4.2% of Gross National Income (GNI). Another key measure of natural capital risk is total annual water withdrawal as a percentage of internal resources. The average water withdrawal is

1.77%, with some countries reaching a maximum of 77.5%. These variables provide diverse estimates of biodiversity and natural capital risk.

Table 3 presents information about green reporting and disclosures by the sovereign green bond issuers. During the bond issuance process, the issuer provides a framework outlining the green project categories, which are based on the Green Bond Principles developed by the International Capital Market Association (ICMA). While we have access to information on green project categories for all the bonds from database, we managed to collect framework reports for 85 of these bonds. The allocation of proceeds to green projects is detailed in capital allocation reports. In some cases, the capital allocation report and the impact report are issued together. We have obtained 113 capital allocation reports related to these bonds. Some sovereign issuers have released multiple capital allocation reports from the date of issuance to maturity to update stakeholders on the management of proceeds. To share the progress of the green projects with the investors, the sovereign provides impact outcomes in impact reports. These outcomes include metrics such as carbon emissions avoided, kilowatt-hours (KWH) of energy generated using renewable resources, green infrastructure developments, and the number of buses or trains operating on renewables as part of smart transportation projects. We have collected 118 impact reports for these 85 bonds. Additionally, we gathered 39 prospectuses and 19 term sheets, which, while not directly useful for our analysis, assist in verifying information such as bond characteristics from term sheets against Bloomberg data or matching mentions of green projects in the framework with those in the prospectuses.

Panel B shows the green project categories in the ESG framework reports. It also reflects the sovereign's intentions to begin green projects in these categories to mitigate risks in these areas. Although renewable energy, energy efficiency, and smart transportation projects are common among the green bond issuers, the ESG frameworks of sovereign issuers suggest that 77% and 54% of these projects would be related to biodiversity conservation and preservation

of natural resources. The investment in green projects in these categories is much higher for sovereigns than for corporates, which supports the notion that public goods such as biodiversity conservation and natural resources preservation rely on the support from public organizations such as sovereigns and municipalities (local government).

Table 4 Panel A presents the regression results of offer yield to maturity on the biodiversity risk measures for the primary bond market. Columns (1) to (3) show results without any controls, while Columns (4) to (6) show results incorporating bond-level controls. Columns (7) to (9) results include bond-level controls along with error clustering at the country level. Our findings indicate that the yield increases by 1.5% with the percentage of endangered species, although this result is statistically insignificant. Similarly, both the biodiversity regulation index and the biodiversity degradation index are found to be insignificant. We confirm these results across all three specifications.

Panel B of the table reports the results of the primary market yield concerning natural capital measures. For this analysis, we focused on three specific measures of natural capital risk: natural forest depletion (as a percentage of total area), natural resources depletion (as a percentage of GNI), and freshwater withdrawal (as a percentage of internal resources). We found that the yield is positively associated with all three natural capital risk measures, and these results are consistent across all three specifications. Economically, our findings suggest that a 1% increase in natural resource depletion results in an increase of 98 basis points in the offer yield to maturity, while a 1% increase in the natural forest depletion rate raises the offer yield by 32 basis points. The negative response from debt holders to both natural resource and forest depletion rates indicates that investors are concerned about the country's economic growth, which is closely tied to its natural capital. The depletion of natural capital could ultimately lead to reduced economic growth in the future.

Table 5 Panel A reports the regression results of secondary market yield on biodiversity loss and natural capital risk measures. We have 3,681 monthly yield values for 127 bonds from

2016-2024. Like regression for primary market yield, our specification for this test includes the bond level controls and error clustering at the country level. We found that natural resource depletion is positively associated with yield. The 1 % increase in natural resources depletion increases the yield by 1.3%, 1 % increase in natural forest depletion increases the yield by 40 basis points, and 1 % increase in freshwater withdrawal (% of internal resources) increases the yield by 7 basis points. These results are in line with primary market results and support the theoretical predictions of Stiglitz (1974), Dasgupta and Heal (1974), Dasgupta and Heal (1974) and others on exhaustible natural resources. Stiglitz (1974) concluded that stocks of natural resources are complementary to capital markets and instability in the natural resources market would impact capital markets. In Panel A, the bond yield is unadjusted to the liquidity risk. However, as past literature has showed that illiquidity explains 30-40% of bond yield, it is crucial to adjust yield to liquidity risk. We compute illiquidity risk as,

$$Illiquidity = |BidYield - AskYield| \tag{8}$$

We adjust the yield to illiquidity risk controlling for other bond characteristics and country-level error clustering. To understand the impact of biodiversity and natural capital risk on the liquidity risk-adjusted yield (LAF), we rerun the eq (1) using the LAF. The results are in Table 5 Panel A and Panel B. Similar to Panel A results, we find that the natural capital risk factors influence the LAF. The natural resources depletion and natural forest depletion affect the LAF by 52 basis point and 83 basis point. In contrast to Panel A results for biodiversity risk, we find that biodiversity risk factors affects the LAF by 1-15 basis point. Nevertheless, the latter results are not robust and consistent with Panel A and Table 4 Panel A results. Overall, the Table 4 and Table 5 results suggest that natural capital risk, such as natural forests depletion and exhaustion of natural resources, has an

impact on the sovereign green bond yield in the primary as well as in the secondary market. Surprisingly, we don't find the same for biodiversity conservation measures.

Table 6 reports the regression results of yield on sovereign's green intentions to initiate biodiversity or natural resources management project. Sovereigns share this information with the investors at the issuance of the green bonds using the ESG framework. As discussed in Section 3, the ESG framework includes details on green project categories in which sovereigns have decided to use the proceeds. We use this information from the framework report to generate two indicator variables. Biodiversity is an indicator variable that takes value 1 if the framework reports the biodiversity as a green project category; otherwise, it takes the value 0. Similarly, Natural Resources is the indicator variable, which takes the value 1 if the framework report has natural resources management as the green project category; otherwise, it takes the value 0. Table 6 indicates that sovereign intentions to initiate green projects, including those focused on biodiversity, have no significant impact on bond yields. Testing for the effect of intentions to address natural capital risks also shows no impact on green bond yields, even in countries with these risks. This suggests that investors care less about the intentions of green bond issuers reported in framework reports. Consequently, it is essential to assess whether the impact outcomes of these projects are reflected in bond pricing in the secondary market, as information about capital allocation, project development, and impact achievements becomes available post-issuance.

Table 7 presents the results concerning the impact of bond issuers' green initiatives on secondary market yields. The green initiatives are quantified by the number of green projects funded for each dollar raised. This approach benefits investors, as diversifying green projects reduces risk compared to investing all proceeds into a single project. The regression analysis indicates that green initiatives are negatively correlated with bond yields; however, this relationship is statistically significant only when these efforts align with mitigating risks to natural capital.

As the Kunming-Montreal convention, which led to updates in GBF, is a major event to reduce biodiversity loss, we examine whether it altered the relationship between sovereign green bonds yield and biodiversity & natural capital risks. Results are reported in Table 8, Panel A. We find a 54 basis point reduction in yield after the convention compared to before it for endangered species (in %), and similar findings for the biodiversity regulation index and the biodiversity degradation index. These results contrast with those of Garel et al. (2024), which showed that investors demand a 2.2% premium for corporate biodiversity risk after the convention. We hypothesized that bond yields would decline because investors are less worried about this risk, given the measures taken during the convention. We observe mixed results for natural capital risk; these are expected because the conventions and updates in GBF primarily focused on biodiversity risk, rather than risk to natural capital. This test serves as a placebo for natural capital risk; therefore, we anticipate no change in the relationship between yield and natural capital risk.

So far, we have investigated the impact of biodiversity & natural capital risks on sovereign green bond pricing and compared it with conventional bonds. Nevertheless, it is also essential to check whether the issuance of green debt improves the environmental performance of these sovereigns. Table 9 illustrates the impact of green bond issuances on carbon intensity, measured as carbon emissions per capita, for issuers with net zero commitments versus those without. Table 9 Panel A outlines the types of commitments made by green bond issuers regarding carbon emission reduction. Notably, 44% of these bonds are issued by entities with net-zero targets, primarily aimed at 2050, although some have targeted 2040 or 2070. These issuers also establish interim targets for emission reductions, focusing on years such as 2025 or 2030. Panel B presents the regression results concerning the relationship between carbon intensity and the commitments made by green bond issuers. Our findings suggest that setting both interim and net-zero targets does not significantly reduce the carbon intensity of these issuers compared to their counterparts.

Since carbon intensity may not be a concern for all sovereigns, we focus on their environmental performance based on the projects funded by their green bonds. Approximately 40% of 151 green bonds, or 59 bonds, are used for sustainable forestry projects. Therefore, we examine the percentage of forest area in habitable land and the loss of forest cover (in hectares) in these sovereigns and compare them with other green bond issuers. Table 10 shows the results for these measures. We find that green bond issuers who invested in sustainable forestry projects have 2.5% more forest area and a high forest cover loss of 159 million hectares compared to those who invested in other projects. To gain deeper insights, we analyze these parameters both before and after green bond issuances for the sovereigns that invested in sustainable forestry. After issuing green bonds and investing in sustainable forestry, these sovereigns experienced a 0.2% increase in forest area and a reduction of 68.4 million hectares in forest cover loss.

Lastly, we conducted an external validity test of sovereigns' green intentions using the Sustainable Development Goals (SDGs) they have adopted. Since green bond issuers have also adopted SDGs, and two of these are related to biodiversity and natural capital risks, this provides a setting to verify the results in Table 6. SDG 14, "Life below Water," supports biodiversity by promoting the conservation and sustainable use of oceans, seas, and marine resources for sustainable development, protecting and restoring marine ecosystems, ending harmful fisheries subsidies, reducing marine pollution, and conserving coastal areas, among other goals. Similarly, SDG 15, "Life on Land," promotes natural capital by advocating for the end of desertification, the conservation and restoration of forests, wetlands, mountains, and drylands, reducing habitat loss, and restoring degraded land, among other objectives. There are 67 green bonds related to SDG 14 and 119 related to SDG 15. We examine whether adopting these SDGs influences bond pricing in the primary and secondary markets. The results are presented in Table 11. We find no effect of these SDGs on sovereign green bond yields, neither in the primary nor in the secondary market. These findings also confirm our

results in Table 6, which suggest that green intentions are insufficient to influence the pricing of sovereign green bonds.

6. Conclusion

Our paper explores whether public debt pricing is influenced by risk to natural assets such as biodiversity and natural capital, a crucial issue highlighted by Giglio et al. (2023). We specifically focus on sovereign green bonds because the responsibility for providing public goods—such as biodiversity conservation and natural capital preservation - rests primarily with governments rather than corporations. Assessing how these environmental risks influence sovereign bond yields is therefore essential to determine whether international investors price such risks into sovereign debt. Moreover, because the sovereign green bonds are specifically designed to finance projects that mitigate environmental externalities, analyzing their pricing dynamics and environmental implications can reveal whether investors genuinely account for these risk factors and whether countries effectively address them. Analysis of the sovereign green bonds issued between 2016 to 2024 reveals that the bond yields are affected by natural capital risk—proxied as natural resource and forest depletion rates—rather than by biodiversity loss. A 1% increase in natural capital depletion results in a 32-basis point rise in bond yield.

Compared to corporate green bonds, 70% of these bonds are associated with projects related to biodiversity conservation and natural resource management. Our investigation assesses whether biodiversity loss and natural capital risk affect bond pricing and whether sovereign's green intentions' and 'green efforts' impact this relationship. Using the large language models (LLMs), the 'Green Intentions' are estimated from ESG framework reports, which detail the types of green projects the sovereign intends to develop. 'Green Efforts' are measured through capital allocation and impact reports and proxied as number of green

projects implemented per dollar amount of the bond proceeds. By manually linking each report to the bond level, we track the timing of capital allocation and impact reports from issuance to maturity. We also account for cases with multiple reports for the same bond. We found that mere intentions do not significantly influence investor behavior towards these risks and that the green efforts by the sovereigns are recognized by the investors if the efforts are aligned with the direction of natural capital risk.

Regarding the environmental performance of issuers, we find that green bond-issuing sovereigns with interim and net-zero targets do not have lower carbon emissions per capita compared to others, even after a three-year span. Since carbon intensity may not be a concern for all issuers and might not be a negative externality for every sovereign, we focus on their environmental performance based on the projects funded by their green bonds. As 40% of sovereign green bonds are used for sustainable forestry projects, we examine the percentage of forest area in habitable land and the loss of forest cover (in hectares) in these sovereigns and compare them with other green bond issuers. We find that green bond issuers who invested in sustainable forestry projects have a 2.5% higher percentage of forest area in habitable land, but also a 159 million hectares higher loss of forest cover compared to those who invested in other projects. To gain deeper insights, we analyze these parameters both before and after green bond issuances for the sovereigns that invested in sustainable forestry. We discovered a 0.2% increase in forest area and a reduction of 68.4 million hectares in forest cover loss following the issuance of green bonds and investment in sustainable forestry.

Overall, our work shows that investors care about the preservation of natural capital and less about the conservation of biodiversity. This finding aligns with classic theoretical papers on exhaustible resources[12], which suggest that natural resources are crucial for a country's economic growth. Although green projects can be implemented to mitigate these risks, we discovered that merely expressing intentions to initiate such projects is insufficient to per-

[12]Refer Stiglitz, (1974), Dasgupta and Heal (1974), and similar others.

suade investors. The efforts to implement these green projects must align with the perceived risks in order to influence investors' risk preferences effectively. Despite commitments to net-zero emissions, the improvement in environmental performance among these sovereigns issuing green bonds is not significant. As carbon intensity may not be a concern for all sovereigns, we focus on their environmental performance based on the sustainable forestry projects funded by their green bonds. We find the increase in forest area and reduction in loss of forest cover following these investments. These findings are robust to battery of checks.

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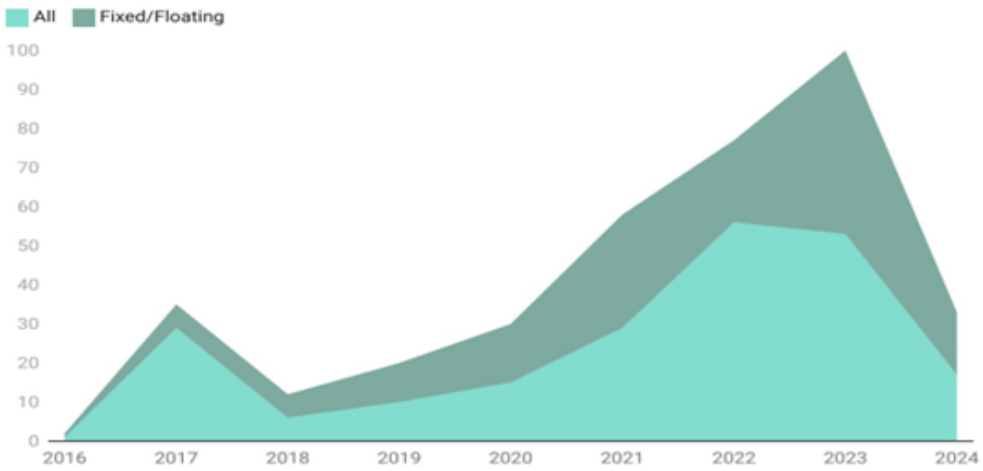
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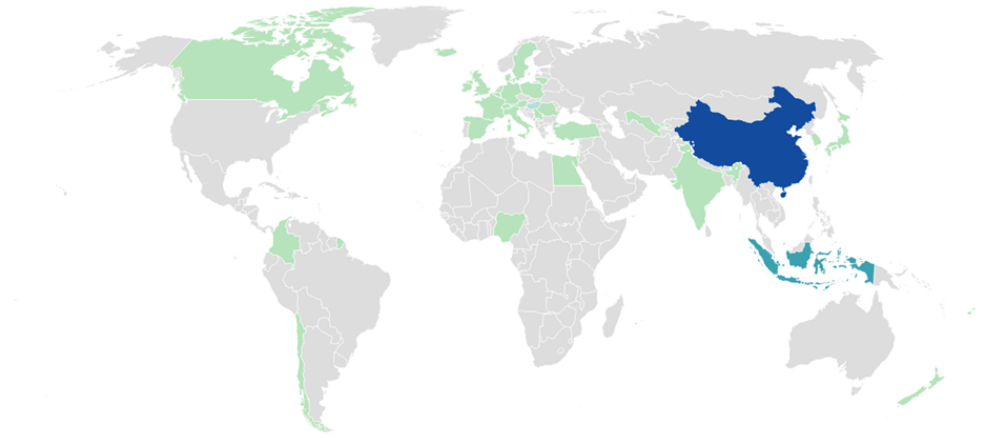
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a) Yearly Distribution of Sovereign Green Bonds



b) Country-level Distribution of Sovereign Green Bonds

Figure 1: **Yearly and Country Level Distribution**. Figure 1 a shows the yearly distribution of all sovereign green bonds as well as for fixed (of floating) coupon type. Figure 1 b shows the country level distribution of sovereign green bonds.

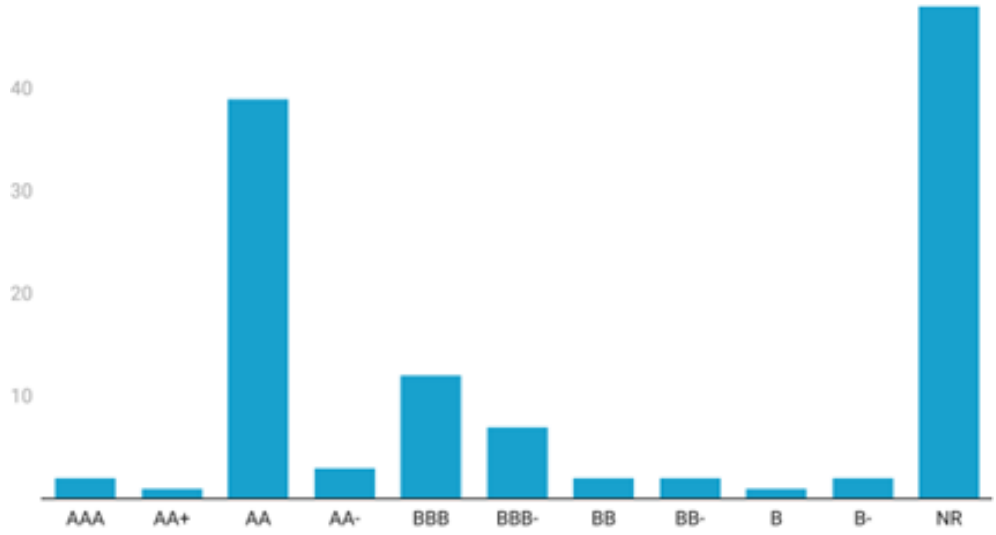
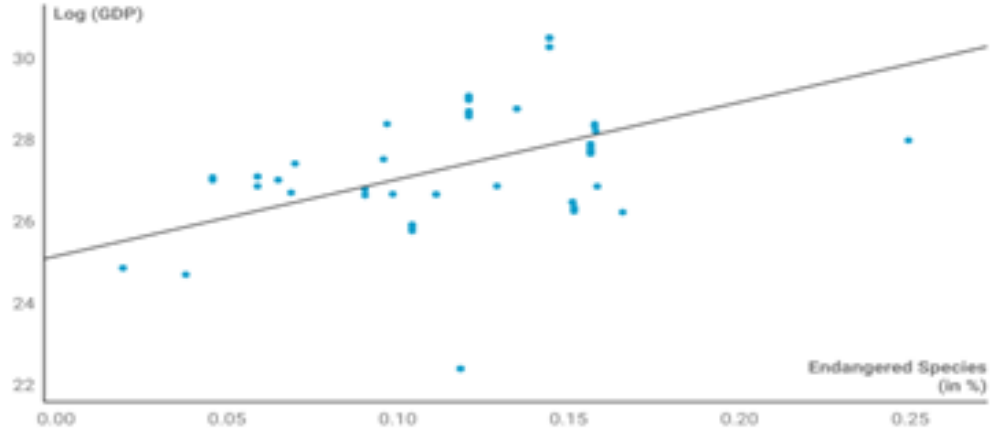
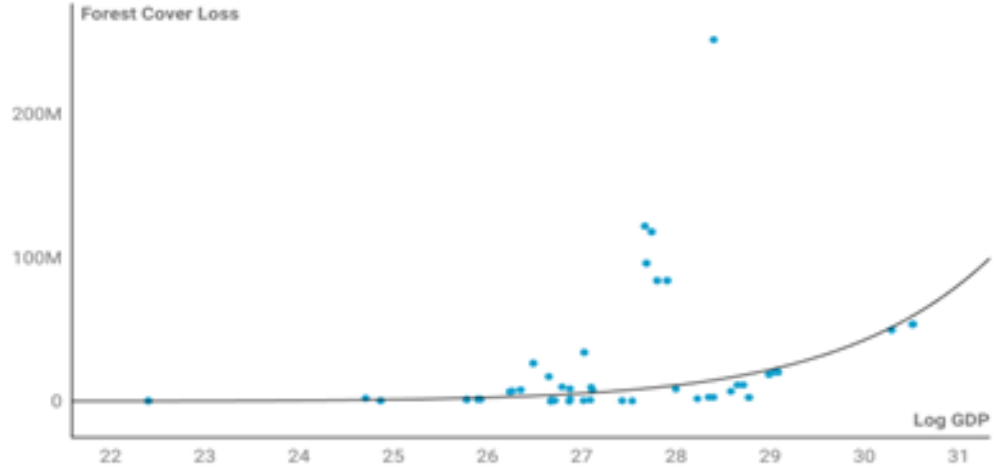


Figure 2: Credit Ratings of Sovereign Green Bonds. This figure shows the distribution of credit ratings of sovereign green bonds. 37 % green bonds are not rated, and among the rated bonds, 30% are rated AA.



a) Log GDP vs Biodiversity Risk



b) Log GDP vs Natural Capital Risk

Figure 3: Biodiversity and Natural Capital Risk versus Gross Domestic Product (GDP). This figure compares the biodiversity risk and natural capital risk with the natural logarithm of GDP. The biodiversity risk is measured as the ratio of endangered species (Endangered Species) to total number of species in a country in particular year. The natural risk is measured as forest cover loss (as % of territorial

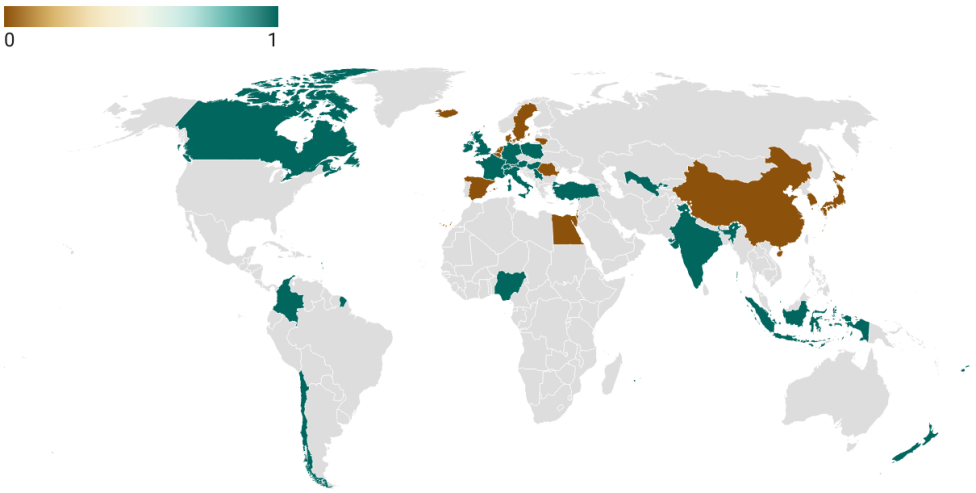


Figure 4: **Sustainable Forestry using Sovereign Green Bonds**. This figure shows the countries which use the green bond proceeds for sustainable forestry projects compare to countries which use the green bond proceeds for other projects.

Table 1
Sovereign Green Bond Characteristics

Panel A: Coupon-Type

Coupon Type	Frequency	Percentage
Fixed/Floating	151	69.91
Zero Coupon	65	30.09
Total	216	100

Panel B: Green Certification

Certified	Freq.	Percent	Cum.
N	2	1.32	1.32
Y	149	98.68	100
Total	151	100	

Panel C: Bond Maturity

Maturity Type	Frequency	Percent
Maturity	146	96.69
Callable	5	3.31
Total	151	100

Panel D: Summary Statistics

Variable	Mean	Standard Deviation	Max
Yield	4.373	2.645	18.138
Amount Issued (in million USD)	3,151	6,125	37,861
Coupon	3.437	2.817	16.25
Fixed	0.947	0.225	1
Certified	0.987	0.115	1
Option	0.033	0.180	1

Notes: **Sovereign Green Bond Characteristics**. This table provides the bond characteristics of sovereign green bonds. Panel A shows the distribution of coupon types used in sovereign green bonds. As green reports are available only for fixed/floating coupon type bonds and not for zero coupon (or strip) bonds, the paper focuses on the former. Panel B provides the distribution of green certification of these bonds. Panel C provides distribution based on maturity type. Panel D provides the summary statistics of these bonds. Yield is offering yield to maturity measured in percentage. Amount Issued is the amount issued by the sovereign using a green bond, measured in million USD. Coupon is the coupon of a bond, measured in percentage. Fixed is an indicator variable that takes the value 1 if a bond is fixed income, and 0 for a floating bond. Certified is an indicator variable that takes the value 1 if the bond is certified by Climate Bond Initiative (CBI) or affiliated certifying agencies. Option is an indicator variable that takes the value 1 if a bond is option embedded; otherwise, it takes the value 0. Further details on variable definition are provided in Appendix A.

Table 2
Biodiversity and Natural Capital Risk Indicators

Biodiversity Risk

Indicator	Mean	Standard Deviation	Maximum
Endangered Species	12.975	3.457	24.948
Biodiversity Regulation Index	0.284	0.452	1
Biodiversity Degradation Index	0.068	0.252	1

Natural Capital Risk

Indicator	Mean	Standard Deviation	Maximum
Natural resources depletion (% of GNI)	1.216	1.83	14
Net forest depletion (% of GNI)	4.2	19.7	1
Annual freshwater withdrawals, total (% of internal resources)	1.33	8.957	77.5

Notes. **Biodiversity and Natural Capital Risk Indicators**. This table provides the summary statistics of biodiversity and natural capital risk measures. Biodiversity Risk is measured as the ratio

of endangered species (Endangered Species) to total number of species in a country in particular year, stringency of regulation of biodiversity risk (Biodiversity Regulation Index), and stringency of regulation on biodiversity degradation (Biodiversity Degradation Index). Natural Capital Risk is measured as natural resources depletion as percentage of gross national income, net forest depletion as percentage of gross national income, annual fresh water withdrawals as percentage of internal resources. Further details on variable definition are provided in Appendix A.

Table 3
Sovereign Green Projects: Disclosure and Category

Panel A: Distribution of Disclosures on Sovereign Green Bonds

Index	Type of Report	# Numbers
1	Impact Reports	118
2	Allocation reports	115
3	External Review	103
4	ESG Framework	85
5	Prospectus	39
6	Term Sheet	19

Panel B: Sovereign Green Project Category

Green Project Category	# Numbers	Percentage
Biodiversity	116	77
Natural Resources and Management	82	54
Energy Efficiency	136	90
Pollution Prevention and Control	92	61
Climate Change Adaptation	109	72
Circular Economy	89	59
Renewable Energy	144	95
Green Buildings	95	63
Clean Transportation	146	97
Sustainable Water Management	113	75

Notes: **Sovereign Green Projects: Disclosure and Categor**y. Panel A shows the distribution of reports provided by the sovereigns' issuing green bonds. In the green reports, sovereign issues ESG framework, allocation reports, impact reports, prospectuses, external review, and term sheets. The ESG framework provides a description of the green categories and the project's intended purpose. Second Opinion Report (SPO) provided by the auditor to verify whether those projects are aligned with green bond principles (developed by ICMA). Impact report provides details on the impact of these projects measured as carbon emissions avoided, electricity generation using renewable sources, and similar measures. Allocation reports provide the details on capital allocation for the green projects using the bond proceeds. The Term Sheet

provides the final contractual terms related to the bond. These reports are hand-collected and used to develop a structured database on green projects using Artifical Intelligence (AI) model as suggested in Aswani (2024). This database is matched at the bond level. Panel B shows the distribution of green project categories provided in the ESG Framework as per green bond guidelines suggested by ICMA.

Table 4
Is Sovereign Sustainable Bond Pricing Associated with Biodiversity and Nature Capital Loss?

Panel A: *Primary Market Bond Yield and Biodiversity Loss*

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield	(6) Yield	(7) Yield	(8) Yield	(9) Yield
Endangered Species	1.526			1.526			1.51		
	(6.760)			1(0.940)			1(0.940)		
Biodiversity Regulation Index		-0.308			-0.308			-0.521	
		(0.515)			(0.506)			(0.706)	
Biodiversity Degradation Index			0.303			0.303			-0.007
			(0.978)			(0.463)			(0.702)
Observations	127	127	127	127	127	127	127	127	127
R-squared	0	0.003	0.001	0	0.003	0.001	0.063	0.07	0.063
Bond Level Controls	No	No	No	No	No	No	Yes	Yes	Yes
Error Clustering	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: *Primary Market Bond Yield and Natural Capital Depletion*

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield	(6) Yield	(7) Yield	(8) Yield	(9) Yield
Natural Resources Depletion (in %)	1.001***			1.001***			0.987***		
	(0.085)			(0.096)			(0.095)		
Natural Forests Depletion (in %)		0.320**			0.320***			0.321***	
		(0.140)			(0.036)			(0.037)	
Fresh Water Withdrawal (in %)			0.064***			0.064***			0.061***
			(0.024)			(0.008)			(0.008)
Observations	127	127	127	127	127	127	127	127	127
R-squared	0.523	0.04	0.054	0.523	0.04	0.054	0.53	0.102	0.111
Bond Level Controls	No	No	No	No	No	No	Yes	Yes	Yes
Error Clustering	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes. **Sovereign Bond Pricing and Biodiversity/Natural Capital Risk**. This table shows the regression results of the association between bond yield and biodiversity and natural capital risk in the primary market. Panel A shows the regression of bond yield on biodiversity risk measures. Panel B shows the regression of bond yield on natural capital risk measures. In Panel A, Columns (1) – (3) show the regression results without controlling for bond level controls and without error clustering at the country level. Columns (4) – (6) show the results with country-level error clustering but without controlling for bond-level controls. Columns (7) – (9) show the results with bond-level controls as well as with country-level error clustering.

Biodiversity Risk is measured as the ratio of endangered species (Endangered Species) to total number of species in a country in particular year, stringency of regulation of biodiversity risk (Biodiversity Regulation Index), and stringency of regulation on biodiversity degradation (Biodiversity Degradation Index). In Panel B, Columns (1) – (3) show the regression results without controlling for bond level controls and without error clustering at the country level. Columns (4) – (6) show the results with country-level error clustering but without controlling for bond-level controls. Columns (7) – (9) show the results with bond-level controls as well as with country-level error clustering. Natural Capital Risk is measured as natural resources depletion as percentage of gross national income, net forest depletion as percentage of gross national income, and annual fresh water withdrawals as percentage of internal resources. Bond level controls comprise - logarithm of amount issued, indicator variable for whether bond is fixed income or floating (Fixed), indicator variable for whether the bond is callable or not (Option), and years in maturity of the bond (Maturity). Details of the variables are provided in Appendix A. *, **, *** show the statistical significance at 10 %, 5 %, and 1% levels.

Table 5
Secondary Market of Sovereign Sustainable Bond and Biodiversity & Natural Capital Risk

Panel A: *Liquidity Un-adjusted Bond Yield and Biodiversity & Natural Capital Risk*

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield	(6) Yield
Endangered Species	8.875					
	(18.456)					
Biodiversity Regulation Index		-0.521				
		(1.267)				
Biodiversity Degradation Index			-0.146			
			(1.526)			
Natural Resources Depletion (in %)				1.303**		
				(0.500)		
Natural Forests Depletion (in %)					0.404***	
					(0.088)	
Fresh Water Withdrawal (in %)						0.070***
						(0.020)
Observations	3,681	3,681	3,681	3,681	3,681	3,681
R-squared	0.059	0.058	0.057	0.087	0.066	0.065
Bond Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: *Liquidity Adjusted Bond Yield (LAY) and Biodiversity Risk*

VARIABLES	(1) LAY	(2) LAY	(3) LAY	(4) LAY	(5) LAY	(6) LAY
Endangered Species	21.398***	15.537***				
	(4.654)	(3.403)				
Biodiversity Degradation Index			1.195**	1.679***		
			(0.542)	(0.188)		
Biodiversity Regulation Index					1.333***	1.083**
					(0.271)	(0.427)
Observations	1,890	1,489	1,890	1,489	1,890	1,489
R-squared	0.191	0.150	0.015	0.080	0.080	0.078
Bond Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country Controls	No	Yes	No	Yes	No	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: *Liquidity Adjusted Bond Yield (LAY) and Natural Capital Risk*

VARIABLES	(1) LAY	(2) LAY	(3) LAY	(4) LAY	(5) LAY	(6) LAY
Natural Resources Depletion (in %)	0.574**	0.524***				
	(0.257)	(0.168)				
Natural Forest Depletion (in %)			0.786*	0.831**		
			(0.428)	(0.380)		
Fresh Water Withdrawl (in %)					1.111	0.932
					(0.732)	(1.059)
Observations	1,890	1,489	1,890	1,489	1,890	1,489
R-squared	0.078	0.134	0.003	0.061	0.025	0.072
Bond Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country Controls	No	Yes	Yes	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes

Notes. **Secondary Market of Sovereign Sustainable Bond and Biodiversity & Natural Capital Risk** This table shows the regression results of the association between secondary market bond yield and biodiversity & natural capital risks. Panel A reports the results of illiquidity un-adjusted yield on biodiversity & natural capital risks. Panel B reports the results of illiquidity adjusted yield on biodiversity risk factors. Panel C reports the results of illiquidity adjusted yield on natural capital risk factors. Illiquidity adjusted yield (LAY) is residual from panel regression of bond yield on illiquidity risk. The illiquidity risk is measured as the absolute value of bid yield minus ask yield ($|BidYield - AskYield|$). Yield is the monthly offer yield to maturity, measured in percentage. Biodiversity Risk is measured as the ratio of endangered species (Endangered Species) to total number of species in a country in particular year, stringency of regulation of biodiversity risk (Biodiversity Regulation Index), and stringency of regulation on biodiversity degradation (Biodiversity Degradation Index). Natural Capital Risk is measured as natural resources depletion as percentage of gross national income, net forest depletion as percentage of gross national income, annual freshwater withdrawals as percentage of internal resources. All regressions have bond-level controls and country-level error clustering. Bond level controls comprise - logarithm of amount issued, indicator variable for whether the bond is fixed income or floating (Fixed), indicator variable for whether the bond is callable or not (Option), and years in maturity of the bond (Maturity). Details of the variables are provided in Appendix A. *, **, *** shows the statistical significance at 10 %, 5 %, and 1% level.

Table 6
Sovereign's Green Intentions and Bond Pricing

Panel A: *Bond Pricing and Sovereign Green Intention to Mitigate Biodiversity and Natural Capital Risk*

	Primary Market				Secondary Market			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
VARIABLES	Yield	Yield	Yield	Yield	Yield	Yield	Yield	Yield
Biodiversity	-0.399		-0.720		-1.802		-2.929	
	(0.875)		(0.902)		(2.659)		(3.371)	
Natural Resources		0.813		1.032		0.485		0.994
		(0.689)		(0.788)		(1.304)		(1.706)
Observations	130	130	130	130	3,690	3,690	3,690	3,690
R-squared	0.0036	0.0238	0.0705	0.0971	0.009	0.001	0.079	0.06
Bond Level Controls	No	No	Yes	Yes	No	No	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: *Biodiversity Risk, Green Intentions, and Secondary Market Bond Pricing*

VARIABLES	(1) Yield	(2) Yield	(3) Yield
Biodiversity	-3.056	-3.411	-3.000
	(6.385)	(3.893)	(3.587)
Endangered Species	22.470		
	(35.870)		
Endangered Species x Biodiversity	-3.692		
	(36.840)		
Biodiversity Index Regulation		-2.835	
		(3.817)	
Regulation x Biodiversity		3.077	
		(3.724)	
Biodiversity Index Degradation			-1.091
			(3.334)
Degradation x Biodiversity			-0.0695
			(2.099)
Observations	3,681	3,681	3,681
R-squared	0.086	0.082	0.079
Bond Level Controls	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes

Panel C: *Natural Capital Risk, Green Intentions, and Secondary Market Bond Pricing*

VARIABLES	(1) Yield	(2) Yield	(3) Yield
Natural Resources	0.448	1.386	2.258
	(1.555)	(1.602)	(2.685)
Natural Resources Depletion (in %)	1.05		
	(1.575)		
Resources Depletion x Natural Resources	0.248		
	(1.412)		
Natural Forest Depletion (in %)		0.469***	
		(0.044)	
Forest Depletion x Natural Resources		0.103	
		(1.153)	
Fresh Water Withdrawal (in %)			0.078***
			(0.009)
Water Withdrawal x Natural Resources			-0.033
			(0.054)
Observations	3,681	3,681	3,681
R-squared	0.089	0.072	0.079
Bond Level Controls	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes

Notes. **Green Intentions and Sovereign Bond Pricing.** This table provides the regression results of bond yield on sovereign's green intentions related to biodiversity and natural capital risk. Panel A shows the regression results of sovereign yield on green intentions measured as a vector of indicator variables- *Biodiversity* and *Natural Resources*. *Biodiversity* is an indicator variable which takes value 1 if the sovereign's green project is related to biodiversity; otherwise, 0. *Natural Resources* is an indicator variable which takes value 1 if the sovereign's green project is related to risk to natural resources management; otherwise, 0. ESG framework report by green bond issuing sovereign provides the intentions to allocate the capital in the green projects aligned with green bond principles. Yield is monthly offer yield to maturity, measured in percentage. Biodiversity Risk is measured as the ratio of endangered species (Endangered Species) to total number of species in a country in particular year, stringency of regulation of biodiversity risk (Biodiversity Regulation Index), and stringency of regulation on biodiversity degradation (Biodiversity Degradation Index). Natural Capital Risk is measured as natural resources depletion as percentage of gross national income, net forest depletion as percentage of gross national income, and annual freshwater withdrawals as percentage of internal resources. All regressions have bond level controls and country-level error clustering. Bond level controls comprise - logarithm of amount issued, indicator variable for whether bond is fixed income or floating (Fixed), indicator variable for whether the bond is callable or not (Option), and years in maturity of the bond (Maturity). Details of the variables are provided in Appendix A. *, **, *** shows the statistical significance at 10 %, 5 %, and 1% level.

Table 7
Green Efforts, Green Intentions, and Sovereign Bond Yield

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield
Number of Green Projects (per USD)	-0.004*	-0.012***	-0.015***	0.087	-0.023***
	(0.002)	(0.003)	(0.004)	(0.068)	(0.006)
Biodiversity				0.711	
				(0.700)	
Biodiversity X Number of Green Projects				-0.100	
				(0.066)	
Natural Resources					-0.214
					(0.549)
Natural Resources X Number of Green Projects					0.010*
					(0.006)
Observations	63	63	63	63	63
R-squared	0.040	0.200	0.373	0.400	0.404
Bond Controls	No	Yes	Yes	Yes	Yes
Country-level Controls	No	No	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes

Notes. **Green Efforts, Green Intentions, and Sovereign Bond Pricing.** This table provides the regression results of bond yield on sovereign's green efforts related to biodiversity and natural capital risk. Columns (1) - (3) reports the regression results of yield on green efforts (*Green Efforts*) with and without bond-level and country-level controls. Columns (4) - (5) report the results of yield on the interaction of green intentions and green efforts. *Green Efforts* is measured as number of green projects developed by the sovereign using the sustainable debt proceeds i.e., number of green projects per USD of proceeds amount. The green intentions is measured as a vector indicator variables - *Biodiversity* and *Natural Resources*. Biodiversity is an indicator variable which takes value 1 if the sovereign's green project is related to biodiversity; otherwise, 0. Natural resources is an indicator variable which takes value 1 if the sovereign's green project is related to risk to natural resources management; otherwise, 0. All regressions have bond level controls and country-level error clustering. Bond level controls comprise - logarithm of amount issued, indicator variable for whether bond is fixed income or floating (Fixed), indicator variable for whether the bond is callable or not (Option), and years in maturity of the bond (Maturity). Details of the variables are provided in Appendix A. *, **, *** shows the statistical significance at 10 %, 5 %, and 1% level.

Table 8
Kunming-Montreal Convention and Sovereign Green Bonds

Panel A: *Kunming-Montreal Convention, Sovereign Green Bond Yield, and Biodiversity & Natural Capital Risk*

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield	(5) Yield	(6) Yield	(7) Yield
Kunming	-0.203	6.918***	0.324	-0.155	-0.130	-0.151	-1.355**
	(0.567)	(1.139)	(0.941)	(0.694)	(0.377)	(0.777)	(0.601)
Endangered Species		14.73**					
		(5.447)					
Kunming x Endangered Species		-54.64***					
		(5.723)					
Biodiversity Index Regulation			0.415				
			(0.374)				
Kunming x Biodiversity Index Regulation			-1.500*				
			(0.821)				
Biodiversity Index Degradation				1.433**			
				(0.494)			
Kunming x Biodiversity Index Degradation				-2.300***			
				(0.482)			
Natural Resources Depletion					1.377***		
					(0.177)		
Kunming x Natural Resources Depletion					-0.481**		
					(0.155)		
Fresh Water Withdrawl							0.054***
							(0.008)
Kunming x Fresh Water Withdrawl							3.400***
							(0.267)
Observations	130	127	127	127	127	127	127
R-squared	0.061	0.148	0.082	0.075	0.561	0.102	0.427
Bond Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: *Kunming-Montreal Convention, Green Intentions, and Sovereign Green Bond Yield*

VARIABLES	(1) Yield	(2) Yield
Kunming	0.466**	-0.0195
	(0.147)	(0.216)
Biodiversity	0.365	
	(0.216)	
Kunming x Biodiversity	-0.529	
	(0.371)	
Natural Resources		0.482**
		(0.168)
Kunming x Natural Resources		0.254
		(0.142)
Observations	130	130
R-squared	0.928	0.930
Bond Controls	Yes	Yes
Country	Yes	Yes
Error Clustering	Yes	Yes

Notes. **Kunming-Montreal Convention and Sovereign Green Bonds**. This table reports whether the regression results of sovereign bond yield on biodiversity & natural capital risks changed after Kunming-Montreal Convention. Panel A reports the regression results of bond yield on biodiversity & natural capital risks post Kunming-Montreal Convention. The coefficient of interaction term of each risk factor with Kunming-Montreal Convention (*Kunming*) is of interest. *Kunming* is indicator variable which takes value 1 if the bond is issued post 19th December, 2022; otherwise 0. *Biodiversity Risk* is measured as the ratio of endangered species (Endangered Species) to total number of species in a country in particular year, stringency of regulation of biodiversity risk (Biodiversity Regulation Index), and stringency of regulation on biodiversity degradation (Biodiversity Degradation Index). *Natural Capital Risk* is measured as natural resources depletion as percentage of gross national income, net forest depletion as percentage of gross national income, and annual freshwater withdrawals as percentage of internal resources. Panel B reports whether the regression results of yield on green intentions changed post Kunming-Montreal Convention. The green intentions is measured as a vector indicator variables - *Biodiversity* and *Natural Resources*. Biodiversity is an indicator variable which takes value 1 if the sovereign's green project is related to biodiversity; otherwise, 0. Natural resources is an indicator variable which takes value 1 if the sovereign's green project is related to risk to natural resources management; otherwise, 0. Bond controls comprise bond maturity, amount issued, indicator variable for fixed coupon, and indicator variable for option embeddedness. Country controls comprise natural logarithm of GDP and Debt to GDP ratio. The specification also includes clustering the error at country level. Details of the variables are provided in Appendix A. *, **, *** are significance level at 10%, 5%, and 1%.

Table 9
Environmental Performance of Sovereign Green Bond Issuers

Panel A: *Distribution of Carbon Commitments*

Carbon Commitments of Green Bond Issuers			
Commitments	Number of Bonds	Percent	Cumulative
Carbon neutral(ity)	59	39.07	39.07
Climate neutral	13	8.61	47.68
Emissions intensity target	2	1.32	49.01
Emissions reduction target	8	5.3	54.3
Net zero	67	44.37	98.68
Other	2	1.32	100
Total	151	100	

Panel B: *Carbon Intensity of Green Bond Issuers: Are Net-Zero Committers Doing Better?*

	(1)	(2)	(3)	(4)
VARIABLES	ΔCarbon Intensity	ΔCarbon Intensity	ΔCarbon Intensity	ΔCarbon Intensity
Interim Target	-0.092	-0.07		
	(0.207)	(0.152)		
Net Zero Target			-0.174	-0.104
			(0.223)	(0.166)
Constant	0.278	-1.939**	0.509	-1.841**
	(0.264)	(0.848)	(0.389)	(0.863)
Observations	23	23	23	23
R-squared	0.284	0.658	0.3	0.662
Bond Controls	Yes	Yes	Yes	Yes
Country Controls	No	Yes	No	Yes

Notes. **Environmental Performance of Sovereign Green Bond Issuers**. This table shows the regression results of environment performance of green bond issuing sovereigns. Panel A reports the distribution of carbon emissions related commitments of green bond issuers. Panel B reports the regression results of change in carbon emissions intensity on interim target and net zero target indicator variables. Δ is difference between third year from issuance and the year of issuance. Interim Target is an indicator variable which takes value 1 if the sovereign has the interim target year for reducing emissions; otherwise, 0. Net Zero Target is an indicator variable which takes value 1 if the sovereign has the net zero target year for reducing emissions; otherwise, 0. Bond controls comprise bond maturity, amount issued, indicator variable for fixed coupon, and indicator variable for option embeddedness. Country controls comprise natural logarithm of GDP and Debt to GDP ratio. Details of the variables are provided in Appendix A. *, **, *** are significance level at 10%, 5%, and 1%.

Table 10
Sustainable Forestry and Sovereign Green Bond Issuance

Panel A: *Sustainable Forestry Projects by Sovereign Green Bond Issuers*

Sustainable Forestry	Freq.	Percent	Cum.
0	92	60.93	60.93
1	59	39.07	100
Total	151	100	

Panel B: *Need of Sustainable Forestry for Sovereign Green Bond Issuers*

	Country Comparison		Pre and Post Green Bond Issuance			
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Forest Area (%)	Forest Cover Loss	Forest Area (%)	Forest Cover Loss	Forest Area (%)	Forest Cover Loss
Sustainable Forestry Country	2.551**	159,156.029**				
	(0.047)	(7,173.653)				
Post-Green Bond Issuance			6.920***	-17,261.821	0.209*	-68,358.027***
			(2.145)	(46,255.929)	(0.114)	(20,550.373)
Observations	544	544	320	320	320	320
R-squared	0.005	0.031	0.020	0.000	0.997	0.944
Country	No	No	No	No	Yes	Yes
Year	Yes	Yes	No	No	No	No
Error Clustering	Yes	Yes	Yes	Yes	Yes	Yes

Notes. **Sustainable Forestry and Sovereign Green Bond Issuance**. Panel A shows the distribution of bonds targetting sustainable forestry projects using the proceeds amount. Panel B Columns (1) - (2) report the regression results of forest area percentage of land (Forest Area (%)) and forest cover loss in hectares (Forest Cover Loss) on countries which target sustainable forestry projects using the green bonds proceeds versus the countries which issued green bonds but did not target sustainable forestry projects. Panel B Columns (3) - (6) report the regression results of forest area percentage of land (Forest Area (%)) and forest cover loss in hectares (Forest Cover Loss) on post green bond issuances in countries which target sustainable forestry projects using the green bond proceeds. Columns (3) -(4) show results without country fixed effects and columns (5) -(6) show results with country fixed effects. *Sustainable Forestry Country* is an indicator variable which takes value 1 if the country has issued atleast one green bond to support the projects related to sustainable forestry and 0 for countries which issued green bonds for other projects. *Post-Green Bond Issuance* is the indicator variable which takes the value 1 for years post green bond issuance supporting sustainable forestry projects; otherwise 0. Empirical specification also includes error clustering at country level and year level. Details of the variables are provided in Appendix A. *, **, *** are significance level at 10%, 5%, and 1%.

Table 11
Sustainable Development Goals (SDGs) and Sovereign Green Bond Pricing: External Validity of Green Intentions

Panel A: *Distribution of SDG 14 ("Life Below Water") and SDG 15 ("Life over Land")*

SDG 14	Freq.	Percent
0	84	55.63
1	67	44.37
Total	151	100

SDG 15	Freq.	Percent
0	32	21.19
1	119	78.81
Total	151	100

Panel B: *Impact of SDGs on Sovereign Green Bond Pricing*

VARIABLES	(1) Yield	(2) Yield	(3) Yield	(4) Yield
SDG_14	0.525		-0.227	
	(0.662)		(0.536)	
SDG_15		-0.911		-0.976
		(1.162)		(1.257)
Observations	3,690	3,690	130	130
R-squared	0.066	0.076	0.061	0.078
Bond Controls	Yes	Yes	Yes	Yes
Error Clustering	Yes	Yes	Yes	Yes

Notes. **Sustainable Development Goals (SDGs) and Sovereign Green Bond Pricing**. Panel A shows the distribution of bonds based on "Life on Land" (sustainable development goal (SDG) 15) and "Life below Water" (sustainable development goal (SDG) 14). SDG 14 covers biodiversity issues and SDG 15 covers natural resources management issues. Adoption of these SDGs helps to test the impact of green intentions on bond pricing. Panel B reports the regression results of these SDGs on sovereign green bond pricing. Panel B Columns (1) - (2) reports the impact of these SDGs on secondary market yield and Columns (3) - (4) reports the impact of these SDGs on primary market yield. Bond controls comprise bond maturity, amount issued, indicator variable for fixed coupon, and indicator variable for option embeddedness. Empirical specification also includes error clustering at country level and year level. Details of the variables are provided in Appendix A. *, **, *** are significance level at 10%, 5%, and 1%.

Appendix A

Index	Variable Name	Definition	Source
1	Annual freshwater withdrawals, total (% of internal resources)	Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source. Withdrawals can exceed 100 percent of total renewable resources where extraction from nonrenewable aquifers or desalination plants is considerable or where there is significant water reuse. Withdrawals for agriculture and industry are total withdrawals for irrigation and livestock production and for direct industrial use (including withdrawals for cooling thermoelectric plants). Withdrawals for domestic uses include drinking water, municipal use or supply, and use for public services, commercial establishments, and homes.	World Bank
2	Adjusted savings: natural resources depletion (% of GNI)	Natural resource depletion is the sum of net forest depletion, energy depletion, and mineral depletion. Net forest depletion is unit resource rents times the excess of roundwood harvest over natural growth. Energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). It covers coal, crude oil, and natural gas. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). It covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	World Bank
3	Adjusted savings: net forest depletion (% of GNI)	Net forest depletion is calculated as the product of unit resource rents and the excess of roundwood harvest over natural growth.	World Bank
4	Terrestrial and marine protected areas (% of total territorial area)	Terrestrial protected areas are totally or partially protected areas of at least 1,000 hectares that are designated by national authorities as scientific reserves with limited public access, national parks, natural monuments, nature reserves or wildlife sanctuaries, protected landscapes, and areas managed mainly for sustainable use. Marine protected areas are areas of intertidal or subtidal terrain–and overlying water and associated flora and fauna and historical and cultural features–that have been reserved by law or other effective means to protect part or all of the enclosed environment. Sites protected under local or provincial law are excluded.	World Bank
5	Endangered Species (% of total Species)	Endangered Species Score: computed as the share of endangered species (% of all species)	IUCN Red List of Threatened Species
6	Biodiversity Index Regulation	Identify biodiversity-related sentences in IMF reports using regular expression searches for the same biodiversity dictionary. Then manually classify the sentences into degradation or regulation. If a report contains at least one biodiversity degradation / regulation sentence, Giglio et al (2023) assign a score of '1' to the country; otherwise, 0.	IMF
7	Biodiversity Index Degradation		IMF
8	Yield	Bond yield, measured in %.	Bloomberg and LSEG
9	Coupon	Coupon of the issued bond. Measured in Percentage.	Bloomberg and LSEG
10	Amount Issued	Amount issued using the sovereign green bond.	Bloomberg and LSEG
11	Maturity	Difference of years between maturity date and issue date.	Bloomberg and LSEG
12	Biodiversity	Indicator variable which takes value 1 if the green-bond issuing sovereign intend to begin a biodiversity project using the bond proceeds; otherwise 0.	Green Bond Disclosures
13	Natural Resources	Indicator variable which takes value 1 if the green-bond issuing sovereign intend to begin a natural resources management project using the bond proceeds; otherwise 0.	Green Bond Disclosures
14	Illiquidity	Absolute value of bid yield minus ask yield. The yield is measured in percentage.	Bloomberg
15	Green Efforts	Number of green projects implemented per dollar value of proceeds.	Green Bond Disclosures and Bloomberg
16	Forest Area	Forest area as percentage of habitable land.	World Bank
17	Forest Cover Loss	The loss of forest cover in hectares.	World Bank
18	Gross Domestic Product (GDP)	The gross domestic product (GDP) of a country, measured in USD.	World Bank
19	Terms of Trade	The terms of trade of a country, measured in percentage.	World Bank
20	Debt to GDP Ratio	The ratio of debt to GDP of a country.	World Bank
21	Kunming	An indicator variable that takes the value 1 if a bond is issued after 19th December 2022; otherwise 0.	Bloomberg and LSEG
22	Interim Target	An indicator variable that takes the value 1 if a sovereign has an interim target (year) for carbon neutrality; otherwise, 0.	
23	Net Zero Target	An indicator variable that takes the value 1 if a sovereign has an net-zero target (year) for carbon neutrality; otherwise, 0.	
24	Sustainable Forestry Country	An indicator variable that takes the value 1 if a sovereign used green bond proceeds for a sustainable forestry project; otherwise, 0.	Green Bond Disclosures and Bloomberg
25	Post-Green Bond Issuance	An indicator variable that takes the value 1 if the year is the same or post-green bond issue year for the green bond issuing sovereigns who invested on sustainable forestry projects; otherwise, 0.	Green Bond Disclosures and Bloomberg
26	SDG_14	An indicator variable that takes the value 1 if the green-bond issuing sovereign has adopted sustainable development goal (SDG) 14 i.e., "Life below Water" ; otherwise, 0.	Green Bond Disclosures
27	SDG_15	An indicator variable that takes the value 1 if the green-bond issuing sovereign has adopted sustainable development goal (SDG) 15 i.e., "Life on Land" ; otherwise, 0.	Green Bond Disclosures