

Secondary Publication



Horn, Matthias; Dabbous, Amal; Oehler, Andreas; u. a.

Determinants and effects of green bond issuance : Environmental awareness, ecological budget, biodiversity, oil and lithium

Date of secondary publication: 29.08.2025

Version of Record (Published Version), Article

Persistent identifier: urn:nbn:de:bvb:473-irb-109937x

Primary publication

Horn, Matthias; Dabbous, Amal; Oehler, Andreas; u. a. (2026): Determinants and effects of green bond issuance : Environmental awareness, ecological budget, biodiversity, oil and lithium, in: Ecological economics : the transdisciplinary journal of the International Society for Ecological Economics, Amsterdam [u.a.]: Elsevier, Vol. 239, Nr. 108753, pp. 1–14, doi: 10.1016/j.ecolecon.2025.108753.

Legal Notice

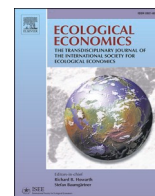
This work is protected by copyright and/or the indication of a licence. You are free to use this work in any way permitted by the copyright and/or the licence that applies to your usage. For other uses, you must obtain permission from the rights-holders.

This document is made available under a Creative Commons license.



The license information is available online:

<https://creativecommons.org/licenses/by/4.0/legalcode>



ANALYSIS

Determinants and effects of green bond issuance: Environmental awareness, ecological budget, biodiversity, oil and lithium

Matthias Horn^{a,*}, Amal Dabbous^b, Andreas Oehler^c, Florian Göbel^a

^a Bamberg University, Bamberg, Germany

^b Saint-Joseph University of Beirut, Lebanon

^c Chair of Finance, Bamberg University, Bamberg, Germany



ARTICLE INFO

JEL:

Classification: Q01

Q50

Q57

Q58

Keywords:

Green Bond

Environmental Awareness

Biodiversity

Biocapacity

Ecological Footprint

Energy Metals

Energy Commodities

ABSTRACT

This study explores the determinants of green bond issuance and its environmental impacts. The empirical analysis employs a panel dataset from 29 OECD countries for the period 2014–2020 and two main models. The first model identifies determinants of green bond issuance, revealing that higher environmental awareness, GDP per capita, oil prices, a higher degree of urbanization, and lower lithium prices are associated with a higher volume of issued green bonds. The second model employs several indicators of environmental performance as dependent variables. The main independent variables are the issued green bond volume, environmental awareness, GDP per capita, environmental policy stringency, renewable energy capacity, and the share of protected areas. The results show that green bond volume, stringent environmental policy, and higher environmental awareness are positively related to the ecological budget and biodiversity while reducing the ecological footprint. Channels for this impact are positive relationships between green bond funding and renewable energy capacity and the share of protected areas. Governments should therefore not only promote the issuance of green bonds, which are essential to raise the financial resources needed to finance environmentally friendly projects, but also offer tax and investment incentives, provide technical assistance, and simplify procedures for project implementation. In addition, resources should be devoted to raising environmental awareness among the population.

1. Introduction

Recent findings show that Earth is now well outside of the safe operating space for humanity (Richardson et al., 2023). Hence, a green transition is necessary (World Economic Forum, 2021). Importantly, this green transition includes two aspects. A decrease of the ecological footprint (decrease of emissions to mitigate climate change and ecological erosion) and an increase of biodiversity and biocapacity to raise the resilience and productivity of the ecological assets. This green transition requires annual investments of at least USD 285 billion (United Nations Environment Programme, 2022). However, there is a significant financing gap that is the subject of ongoing policy debate (Karolyi and Tobin-de la Puente, 2023; Seidl et al., 2024).

One proposed solution for closing the financing gap is the introduction of green finance products to mobilize funds from the private sector (Sharma et al., 2022). Green finance refers to “the provision of financial resources to support environmentally sustainable projects and

initiatives, such as renewable energy, energy efficiency, and sustainable transportation” (Agrawal et al., 2024). Green finance is mostly used to finance environmentally friendly activities and is a crossing point between environmentally friendly projects and the financial sector (Mitchell et al., 2024; Scholtens, 2017). Agrawal et al. (2024) argue that to foster green growth, industries will have to use green finance by investing in carbon emissions reductions and ecology. Financing through debt instruments is expected to have a much greater impact on the green transition than equity investments (Hoepner and Schneider, 2024). The development of green bonds has received considerable attention from policymakers, investors, and researchers in recent years. As argued by Zhou et al. (2020), green bonds can play an important role in ensuring the balance between environmental improvement and economic development. Given the increasing importance of green bonds for a sustainable green transition and the environment, this study examines the key factors influencing the issuance of green bonds and investigates whether the issuance of green bonds has an impact on changes in

* Corresponding author at: Finance, Bamberg University, Kaerntenstr. 7, 96045 Bamberg, Germany.

E-mail address: matthias.horn@uni-bamberg.de (M. Horn).

biodiversity, ecological footprint, and ecological budget (which is biocapacity minus ecological footprint). As such, the aim of the study is to answer two key research questions: RQ1: What are the determinants of green bond issuance? RQ2: What are the environmental impacts of the volume of green bonds issued? In doing so, this study addresses several gaps in the literature, which are outlined below.

Regarding RQ1, i.e. factors considered to impact green bond issuance, this study includes oil and lithium prices, environmental awareness, economic growth, and urbanization. Energy commodities and metal prices have become crucial with the necessary transition of the global economy to clean energy. Due to its important role in the development of new technologies such as electric vehicles and solar panels, lithium is now considered a “super commodity” and is referred to as “the white oil or white gold” (Voskoboynik and Andreucci, 2022; Wojewska et al., 2024).¹ In addition, policymakers are designing policies to move away from the use of oil to renewable energy, e.g. the Renewable Energy Directive of the European Commission. While previous work has mainly focused on the volatility transmissions between green investments, energy, and metal prices (see e.g. Goutte and Mhadhbi, 2024; Gustafsson et al., 2022), a potential link between lithium and oil prices and the volume of issued green bonds has not been thoroughly investigated.

Investors with environmental preferences are more likely to invest in green bonds to support environmental projects (He and Shi, 2023). Dabbous et al. (2023) show that environmental awareness influences people's environmental behavior. Ioannidis et al. (2023) show that higher levels of knowledge and education increase willingness to pay more for renewable energy. In addition, few studies (Al Masud, 2023; Ioannidis et al., 2023) have examined the impact of public environmental awareness on green lifestyles, renewable energy use, and demand for low environmental risk assets (Ardia et al., 2023; Horn et al., 2025; Pastor et al., 2022; Pelster et al., 2024). However, Chatzistamoulou and Koundouri (2022) point out that there is a gap in the literature regarding the impact of environmental awareness on environmental efficiency. We are not aware of any study that has yet examined the influence of individual environmental awareness on green bond issuance, biodiversity, or ecological budget.

RQ2 considers that although increased financing is a necessary condition for the green transition, it is still unclear how effective green financing instruments are in terms of reducing ecological footprints and increasing biocapacity and biodiversity (Harrer et al., 2024). Agrawal et al. (2024) argue that green finance will help mobilize the financial resources needed to mitigate climate risk, and this can increase technological innovation and the issuance of greener products, ultimately promoting environmental sustainability. The literature examining the relationship between finance and ecology is still limited (Meo and Abd Karim, 2022) and to date, no previous studies have examined the influence of green finance on biodiversity, ecological footprint, and ecological budget, and a gap in the literature persists (Tamula et al., 2024).

This study answers the two research questions and fills the above-mentioned gaps in the literature. Specifically, for RQ1, we adopt a macro perspective to examine the impact of changes in oil and lithium prices on green bond volumes and investigate whether environmental awareness, economic growth, and urbanization influence green bond issuance. To answer RQ2, we analyze whether the volume of green bonds issued has an impact on biodiversity, ecological footprint, and ecological budget, taking into account the impact of environmental awareness, economic growth, and environmental policy stringency.

The empirical analysis is based on a panel dataset with annual data for the period 2014–2020 from 29 countries that are members of the

Organization for Economic Co-operation and Development (OECD). We focus on OECD countries for several reasons, including the active role of the OECD and its member countries in climate change mitigation, the harmonized database and OECD datasets, and the high relative homogeneity among OECD countries. The data period is determined by data availability. Sufficient green bond data is not available before 2014 and several data series are only available until 2020, e.g. the Environmental Policy Stringency Index. Two models are tested: the first examines the determinants of green bond issuance and includes lithium and oil prices, environmental awareness, economic development, and urbanization as main independent variables. The second model analyzes the impact of green bond issuance volume, environmental awareness, economic growth, and environmental policy stringency on the ecological budget, ecological footprint, and biodiversity. In a second step, we also include the renewable energy capacity and the share of protected areas as independent variables to analyze their role as a channel for the impact of the issued green bond volume on the ecological budget, ecological footprint, and biodiversity.

The fixed effects model with Driscoll-Kraay standard errors that are robust to cross-sectional and time dependence (Hoechle, 2007) is used to derive the results. As a robustness check for Model 1, we split the dataset into ecological creditors and ecological debtors and repeat the regression analysis for each group separately. In addition, we run the regressions with lagged independent variables. Finally, to address concerns about reverse causality, we regress the returns of lithium and oil on the volume of green bonds. To examine whether green bond issuance is related to ecological footprint and biocapacity, we rely on several measures. As a robustness check and in order to delve deeper into the question of which specific environmental issues are impacted by green bond financing, we use the individual indicators of Yale University's Environmental Performance Index (EPI).

The contributions to the literature are manifold. First, this study contributes to the green bond literature by finding that green bond issuance depends on price fluctuations of oil and lithium. These relationships have not been previously explored and provide valuable insights for policymakers and investors. Second, this study advances the literature on green bonds and biodiversity by including environmental awareness as a factor driving green bond issuance and potentially improving biodiversity and ecological budgets, and by exploring the ecological effect of environmental policy stringency. In doing so, we shed light on the importance of these two factors and demonstrate the complementarity needed between both the government, through environmental regulations, and individuals, through their increased environmental awareness, to enhance biodiversity and ecological budget and promote green bond issuance. Third, this work contributes to the environmental management literature by showing how nations can leverage green bond issuance, environmental policy stringency, and environmental awareness to ensure better biodiversity and ecological budget. Finally, the results of this study will greatly assist scholars, managers, and policymakers in combating biodiversity loss and reducing ecological footprints by identifying the factors needed to promote the issuance of green bonds.

The remainder of this study is organized as follows. Section 2 presents the theoretical background and literature review and derives the hypotheses. Section 3 describes the data used and the methodology employed. Section 4 explains the results and presents a discussion of the findings. Section 5 concludes and presents the policy implications, limitations, and future directions.

2. Literature review and hypotheses development

We divide the relevant literature into two categories. First, we briefly introduce the two most relevant theoretical frameworks for our research questions. Second, we review previous studies on green bonds to derive hypotheses on the determinants and effects of green bond issuance.

¹ We also considered other energy metals such as aluminum, cobalt, copper, indium, lead, nickel and zinc in our analysis. However, we did not find a significant influence of these metals and therefore do not present the results of their analysis in the remainder of this paper.

2.1. Theoretical background

The institutional perspective theory is related to both research questions. According to this theory, the behavior of firms and their ability to innovate, finance, and use green products depends on the institutional environment in which they operate. Regulations, laws, and policies established by formal institutions can influence and shape the behavior of firms (Welter and Smallbone, 2011). In this sense, we can argue that the effectiveness of the design and implementation of environmental regulations will influence firms' environmentally friendly behaviors, such as issuing and investing in green bonds, as well as establishing new practices and processes to protect biodiversity and reduce the ecological footprint. Furthermore, another perspective of this theory highlights the importance of informal institutions such as beliefs and values in influencing firms' behavior (Welter and Smallbone, 2011). Thus, this theory helps to explain the potential role of environmental awareness in promoting the issuance of green bonds by firms as well as the adoption of environmentally friendly practices that lead to higher biodiversity.

The second theory is the diffusion of innovation theory, suggesting that innovation is an essential component of economic growth and will ultimately increase environmental sustainability (Feng et al., 2022). Innovation can drive the development and issuance of new products and technologies that are environmentally friendly, as well as lead to the establishment of new environmental policies and business models that promote environmental sustainability. Since higher green bond volumes are associated with new environmentally friendly business models, we should expect that increasing green bond volumes promote environmental sustainability, i.e., biodiversity and ecological budget.

2.2. Determinants of green bond issuance

2.2.1. Environmental awareness and green bond issuance

Environmental awareness such as public concern, interest, and knowledge of environmental issues has a strong influence on peoples' environmental behavior (Dabbous et al., 2023) and investors' preferences (Tan and Zhu, 2022). Increasing environmental awareness is associated with higher demand for environmental-friendly assets (Ardia et al., 2023; El Ouadghiri et al., 2021; Horn et al., 2025; Pastor et al., 2022; Pelster et al., 2024). The increasing demand for sustainable investments is an important factor driving the growing popularity of green finance (Mertzanis, 2024) in general and the demand for green bonds in particular (Mertzanis, 2023). Green bonds are a key instrument for financing environmentally friendly projects to e.g. mitigate climate change or increase biodiversity (Mertzanis, 2023; Shah et al., 2024). As investors seek investment opportunities that align with their values (Eyraud et al., 2013; Mertzanis, 2023), investors with environmental preferences are more likely to invest in green bonds to support environmental projects (He and Shi, 2023). Hence, it is unsurprising that investor demand for sustainable energy projects is an important determinant of green bond issuance (Prajapati et al., 2021). *Based on these relations, we hypothesize that increasing environmental awareness will increase the volume of green bond issuance (H1).*

2.2.2. Economic growth and green bond issuance

Rising energy consumption as a significant part of economic growth is associated with energy transition (Dabbous et al., 2025; Irfan et al., 2023). As the Gross Domestic Product (GDP) comprises several economic components, it is a valid measure of economic growth (Irfan et al., 2023). Eyraud et al. (2013) found that green investment is stimulated by economic growth, and higher income levels are related to increased investments in green technologies. Thus, increasing GDP per capita influences the growth of green investment in the long run. In line with this, clean energy investments have been boosted by economic growth (Pata et al., 2023; Shah et al., 2024). Furthermore, GDP has a positive impact on eco-innovation (Amara et al., 2023), such as green energy and

technological innovation (Irfan et al., 2023). Wang et al. (2021) observe that GDP per capita has a marginally significant positive effect on pro-environmentally behavior, which could also have an influence on green investment through adjusted investor preferences. *Referring to these findings, we expect that GDP has a positive influence on the volume of green bond issuance (H2).*

2.2.3. Urbanization and green bond issuance

Urbanization is considered an important driver of carbon emissions, energy consumption, and environmental degradation (Alhassan, 2021; Chen et al., 2020; Wang et al., 2021). However, urban areas are changing. He et al. (2017) and Zhang et al. (2017) found that urbanization has different effects on carbon emissions depending on the stage of development and technological progress. Moreover, Irfan et al. (2023) found that urbanization positively impacts energy transition in the short and long term. These results are supported by Ye and Rasoulinezhad (2023), who find that urbanization has a positive effect on sustainable natural resource use in the long run. He and Shi (2023) describe in more detail how this development can take place. The air pollution in urban areas can raise public concern and increase environmental awareness. Both can lead to a higher demand for green bonds due to green preferences (El Ouadghiri et al., 2021; He and Shi, 2023) because investors expect to improve the environment by funding green projects (Jo and Kim, 2022). As air pollution worsens, investors become more supportive of green bonds and environmentally friendly projects receive more funding (He and Shi, 2023). *Thus, we expect a higher degree of urbanization to increase the volume of green bonds issued (H3).*

2.2.4. Oil prices and green bond issuance

Oil is responsible for over 32 % of greenhouse gas emissions (IEA, 2024). Hence, a transition to more sustainable energy sources is needed (Su et al., 2023). This demand for sustainable energy sources leads to the emergence of green bonds as a crucial financial instrument for funding the sustainable transition (Su et al., 2023). However, there is a substitution effect between the oil market and the green bond market, i.e., high oil prices could encourage green investments such as renewable energy investments since they become more cost-effective alternatives relative to traditional fossil fuel technologies (Ahmed, 2024; Eyraud et al., 2013; Lv et al., 2021; Su et al., 2023; Wei et al., 2023). In addition, Fahmy (2022) shows that higher oil prices encourage companies to use clean and sustainable energy sources. Since a large share of green bond funding is used to finance renewable energy projects, higher green bond issuance boosts the installation of green energy solutions (Su et al., 2023; Tolliver et al., 2020). Azhgaliyeva et al. (2022) underline the assumption that high oil prices stimulate green energy investment as a substitute for crude oil by showing that oil supply and demand shocks are important determinants of the likelihood of corporate green bond issuance. *Therefore, we expect a positive influence of oil prices on the issued volume of green bonds (H4).*

2.2.5. Lithium prices and green bond issuance

He et al. (2021) point out that renewable energy projects are more dependent on critical metals / rare earths, e.g. lithium, than fossil fuel projects. Lithium is therefore crucial to the viability of these projects. An increase in the price of lithium increases the project costs (Sohag et al., 2023). If green projects were more expensive, alternatives based on fossil fuels would be cheaper and used as substitutes. This would reduce the probability of green bond issuance since fewer green projects need to be funded. *Accordingly, we expect that lithium prices have a negative influence on the issued volume of green bonds (H5).*

2.3. Effects of green bond issuance

2.3.1. Green bond issuance and ecological footprint

It is well documented that green bond funding is often used for financing renewable energy projects (Alharbi et al., 2023; Wang and

Taghizadeh-Hesary, 2023). Increasing the share of renewable energy has a direct negative impact on carbon emissions (Agan, 2024; Rasoulinezhad and Taghizadeh-Hesary, 2022; Shah et al., 2024). Furthermore, some green bonds are issued to support waste and pollution control and to improve energy efficiency (Mamun et al., 2022). Therefore, projects funded by green bonds additionally reduce the emissions of other greenhouse gases. Support for a direct relationship between increasing green bond issuance and decreasing greenhouse gas emissions is provided by several studies (Qin et al., 2022; Tariq and Hassan, 2023). Chang et al. (2022) show that the issued green bond volume is negatively related to countries' ecological footprint. *Therefore, we expect that a higher issued volume of green bonds reduces the ecological footprint (H6).*

2.3.2. Green bond issuance and biodiversity

Conservation spending is an efficient tool to protect biodiversity (Waldron et al., 2017; for a review on conservation finance see Cosma et al., 2023). However, there is a substantial gap between the financial resources required for biodiversity and ecosystem services and the currently available funds (Karolyi and Tobin-de la Puente, 2023; Seidl et al., 2024; United Nations Environment Programme, 2022). The main reason for this gap is the missing “monetization” of biodiversity, i.e. investments in biodiversity hardly generate a direct financial return for investors (Flammer et al., 2023). Although some green bonds may be used for funding protected areas, we expect the main positive effect of green bonds on biodiversity via a reduction in emissions. Reducing emissions and mitigating climate change should slow down the loss of biodiversity (Sala et al., 2000). *Hence, we expect a positive impact of the issued green bonds volume on biodiversity (H7).*

2.3.3. Green bond issuance, green innovation and ecological budget

To increase the ecological budget, it is not sufficient to solely install renewable energy plants. Instead, it is also necessary to make existing technology more efficient and environmentally friendly (Li et al., 2024). Of course, these technological innovations need to be financed as well. Therefore, it is not surprising that green bond funding is positively related to green technology innovation (Chang et al., 2022; Cheng and Wu, 2024; Shah et al., 2024). Through this channel, clean energy R&D investments have a positive influence on the ecological budget (Kartal et al., 2023). *Combining the latter with (H6) and (H7), we expect a positive impact of the issued green bonds volume on the ecological budget (H8).*

3. Data and methodology

3.1. Data

The dataset covers yearly data from 29 OECD countries² for the period 2014–2020. The volume of green bond issues is provided by the Climate Bonds Initiative. To make the issued green bond volume comparable among countries, it is divided by a country's population and logarithmized (log Green Bond Volume per capita).

For capturing environmental awareness, we rely on the logarithmized Environmental Awareness Index (EAI) of Dabbous et al. (2023) (see also Horn et al., 2025; Pelster et al., 2024). The EAI is based on more than 300 keywords that are first translated into each country's official language and then used to gather the search volume of these keywords on Google via Google Trends. The search volume is available for all OECD countries. Hence, we can compute an individual EAI for each country. We take the average of the twelve monthly observations to compute the yearly EAI.

The Global Footprint Network provides two ecological resource accounting measures to determine the demand for and supply of nature.³

“On the demand side, the Ecological Footprint adds up all [...] the ecological assets that a given population [...] requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber, and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions. On the supply side, a [...] nation's biocapacity represents the productivity of its ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land). These areas, especially if left unharvested, can also serve to absorb the waste we generate, especially our carbon emissions from burning fossil fuel.” A country's ecological budget is its biocapacity minus its ecological footprint. Countries with a positive ecological budget are called ecological creditors. Countries with a negative ecological budget are ecological debtors.

The Environmental Policy Stringency Index (EPS) is retrieved from the OECD library. It is a country-specific composite index of the stringency of environmental policy. It is defined “as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior.” (OECD, 2024). The index uses 13 environmental policy instruments related to climate and air pollution to measure the degree of stringency. It ranges from 0 (not stringent) to 6 (highest degree of stringency).

The remaining control variables on a country level are the logarithmized gross domestic product per capita (GDP) in constant 2015 US\$ (source: World Bank), the degree of urbanization (source: World Bank), and the logarithmized crowdfunding volume (source: Centre for Alternative Finance at Cambridge University).

Yearly returns of lithium and oil are computed with the end-of-year prices. These data are from [investing.com](https://www.investing.com) (lithium prices) and Thomson Reuters Datastream (S&P GSCI-Crude Oil Index Spot).

Two major project categories for which green bond financing can be used are renewable energy projects and terrestrial and aquatic conservation areas. We use data from the International Renewable Energy Agency on the logarithmized installed renewable energy capacity in country i in year t in gigawatts ($Renew_{i,t}$) and from the World Database on Protected Areas on terrestrial and marine protected areas as a percentage of total territorial area ($Protected_{i,t}$) to assess the impact of green bond funding on these two project categories.

3.2. Methodology

The empirical model for analyzing the determinants of the issued green bond volume and for answering RQ1 is as follows:

$$GBV_{i,t} = \beta_{1i} * EAI_{i,t} + \beta_{2i} * GDP_{i,t} + \beta_{3i} * Urbanization_{i,t} + \beta_{4i} * Oil_{t-1} + \beta_{5i} * Lithium_{t-1} + \gamma_i * CountryControls_{i,t} + \alpha_i + u_{i,t} \quad (1)$$

The dependent variable is $GBV_{i,t}$, i.e. the logarithmized green bond issuance per capita in country i in year t . The main independent variables are $EAI_{i,t}$, the logarithmized Environmental Awareness Index for country i in year t , $GDP_{i,t}$, the logarithmized GDP per capita, $Urbanization_{i,t}$ refers to the degree of urbanization, Oil_{t-1} is the return of oil, $Lithium_{t-1}$ is the return of lithium.

The control variables are grouped in $CountryControls_{i,t}$. Previous studies have shown that the effects of issued green bond volume are country-specific (Chang et al., 2022; Mamun et al., 2022). Issued green bond volume has a more pronounced effect in countries with higher emissions (Alharbi et al., 2023). Therefore, we include $Footprint_{i,t}$ (the total ecological footprint of country i in year t) and $Biocapacity_{i,t}$ (refers to the total biocapacity of country i in year t) as control variables. Furthermore, the relation between the issued green bond volume and its effects on the ecological budget is subject to country-specific environmental policy (Tariq and Hassan, 2023). Sohaq et al. (2024) argue that environmental policies influence individual behavior by advocating sustainable practices and environmental policies have emerged as essential elements in the strategic agendas of nations (Ma et al., 2023). Therefore, $EPS_{i,t}$ (the Environmental Policy Stringency Index) is

² From the original 32 OECD countries, Czechia, Estonia, and the Slovak Republic are excluded since no Green Bonds were issued.

³ <https://www.footprintnetwork.org/our-work/ecological-footprint/>

included in the control vector. We also add the logarithmized crowdfunding volume ($Crowdfunding_{i,t}$) of country i in year t to cover the country-wide risk attitude towards risky financial assets.

As robustness checks for these analyses regarding RQ1, we split the dataset into ecological creditors and ecological debtors and repeated the regression analysis for both groups separately. Moreover, we use a country's energy intensity as an alternative measure of $Footprint_{i,t}$. The data is provided by the World Bank. Furthermore, we replace $Biocapacity_{i,t}$ with the IUCN Red List Index ($RLI_{i,t}$) of threatened species. Additionally, we run the regressions with lagged independent variables. Lastly, there might be concerns regarding reverse causality, i.e. that higher green bond volumes lead to more or larger green projects that might influence lithium and oil returns (Yousaf et al., 2024). To address these concerns, we regress the lithium and oil returns on $GBV_{i,t}$ and $GBV_{i,t-1}$, respectively.

The empirical model for analyzing the effects of green bond issuance volume (RQ2) is as follows:

$$Y_{i,t} = \beta_{1i} * GBV_{i,t-2} + \beta_{2i} * EAI_{i,t-1} + \beta_{3i} * GDP_{i,t} + \beta_{4i} * EPS_{i,t-1} + \beta_{5i} * Renew_{i,t} + \beta_{6i} * Protected_{i,t} + \alpha_i + u_{i,t} \tag{2}$$

Where the dependent variable $Y_{i,t}$ is a stand-in for $Footprint_{i,t}$, $EcologicalBudget_{i,t}$, the Biodiversity and Habitat Index ($BDH_{i,t}$) of the Environmental Performance Index (EPI), or the individual indicators of the EPI.

The main independent variables are $GBV_{i,t-2}$, $EAI_{i,t-1}$, $GDP_{i,t}$, $EPS_{i,t}$, the logarithmized installed renewable energy capacity in country i in year t in gigawatts ($Renew_{i,t}$), and the terrestrial and marine protected areas as a percentage of total territorial area ($Protected_{i,t}$).

We apply a stepwise regression approach in which we first run model (2) without $Renew_{i,t}$ and $Protected_{i,t}$. By adding these variables and comparing the regression coefficients of $GBV_{i,t-2}$ between both steps, we can assess whether $Renew_{i,t}$ and $Protected_{i,t}$ act as channels for the impact of $GBV_{i,t-2}$.

We run a Hausman (1978) test on model (1) that confirms that the fixed effects model is appropriate ($\chi^2 = 58$ with p value = .00). Additionally, the respective VIFs of the independent variables are lower than 2.⁴ However, modified Wald tests for groupwise heteroscedasticity clearly show that the errors exhibit groupwise heteroscedasticity ($\chi^2 = 7290$ with $\text{Prob} > \chi^2 = 0.00$). The results are very similar for model (2). To address these characteristics of our dataset, we rely on panel regressions with Driscoll-Kraay standard errors and country-fixed effects that are robust to cross-sectional and temporal dependence (Hoechle, 2007).

An overview of all variables and data sources is presented in Table 1. Descriptive statistics are provided in Table 2. The negative mean ecological budget (- 1.45) is in line with the well-known over-exploitation of ecological resources. Issued green bond volume ranges between a few cents and 1287 USD per capita and year with a mean value of about 50 USD. Lithium (oil) returns are very volatile, ranging from - 50 to 242 (- 46 to 45) percent.

4. Results and discussion

4.1. Determinants of green bond issuance

Table 3 presents full-sample results of panel regressions with issued green bond volume per capita as the dependent variable. The five regression models provide good explanatory power with an R^2 of 32 to 38 %. The results strongly support H1 to H5. In column 1, we include environmental awareness, biocapacity, ecological footprint,

Table 1
Variables and data sources.

Abbreviation	Full name	Definition	Source
$BDH_{i,t}$	Biodiversity and Habitat Index (BDH)	Biodiversity and Habitat Sub Index (BDH) of the Environmental Performance Index (EPI) by Yale University. It is computed using different weights for seven indicators as follows: Terrestrial Biome Protection (national) (22.2 %), Terrestrial Biome Protection (global) (22.2 %), Marine Protected Areas (22.2 %), Protected Areas Rep. Index (14 %), Species Habitat Index (8.3 %), Species Protection Index (8.3 %), Biodiversity Habitat Index (3 %).	Yale University, Environmental Performance Index. https://epi.yale.edu/
$Biocapacity_{i,t}$	Biocapacity	Biocapacity represents the productivity of its ecological assets. If not harvested, these areas can also be used to absorb the waste produced.	Global Footprint Network https://www.footprintnetwork.org/our-work/ecological-footprint/
$Crowdfunding_{i,t}$	Crowdfunding Volume	Measures the crowdfunding volume per year in millions of dollars. We use logarithmized values in the regressions.	Crowdfunding data retrieved from several reports published by the Centre for Alternative Finance at Cambridge University https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/
$EAI_{i,t}$	Environmental Awareness Index	Measures Google search volume of more than 300 keywords per country to proxy environmental awareness of the population. We use logarithmized values in the regressions.	Google trends and own calculations
$EcologicalBudget_{i,t}$	Ecological Budget	The ecological budget is calculated by subtracting the ecological footprint from the biocapacity. Countries with positive (negative) ecological budgets are called	Global Footprint Network https://www.footprintnetwork.org/our-work/ecological-footprint/

(continued on next page)

⁴ The detailed results table covering the VIFs is available from the authors upon request.

Table 1 (continued)

Abbreviation	Full name	Definition	Source
		ecological creditors (debtors)	
$EnergyIntens_{i,t}$	Energy Intensity	Energy intensity is used as a proxy for energy efficiency and represents the ratio between energy supply and gross domestic product measured at purchasing power parity.	World Bank https://databank.worldbank.org/metadataglossary/world-developments/series/EG.EGY.PRIM.PP.KD
$EPS_{i,t}$	Environmental Policy Stringency Index	Country-specific composite index of the stringency of environmental policy.	OECD https://stats.oecd.org/Index.aspx?DataSetCode=EPS
$Footprint_{i,t}$	Ecological Footprint	Sum of all ecological assets that a given population requires to produce the natural resources it consumes and to absorb its waste, especially carbon emissions.	Global Footprint Network https://www.footprintnetwork.org/our-work/ecological-footprint/
$GBV_{i,t}$	Green Bond Issuance per capita	Volume of green bond issues per capita in country i in year t in USD. We use logarithmized values in the regressions.	Data for the volume of green bonds per year in a country in USD is retrieved from Climate Bonds Initiative. https://www.climatebonds.net/market/data/
$GDP_{i,t}$	Gross Domestic Product per capita	Gross Domestic Product per capita in constant 2015 USD. We use logarithmized values in the regressions.	World Bank https://data.worldbank.org/indicator/NY.GDP.PCAP.KD
$Lithium_t$	Yearly return of lithium	Yearly returns of lithium are computed with end of year prices	investing.com
Oil_t	Yearly return of Crude Oil	Yearly returns of oil are computed with end of year prices	Thomson Reuters Datastream (S&P GSCI-Crude Oil Index Spot)
$Protected_{i,t}$	% of protected areas	Terrestrial and marine protected areas in % of total territorial area.	World Database on Protected Areas (WDPA) via World Bank https://data.worldbank.org/indicator/ER.PTD.TOTL.ZS
$Renew_{i,t}$	Installed renewable energy capacity	Installed renewable energy capacity in country i in year t in GW. We use logarithmized values in the regressions.	International Renewable Energy Agency and United Nations World Population Prospects - OurWorldinData.org https://ourworldindata.org/renewable-energy
$RLI_{i,t}$	IUCN Red List Index	Index based on the list of threatened species published by the IUCN.	UNEP https://www.unep.org/SDG/en/Indicator?id=69
$Urbanization_{i,t}$	Urbanization	Degree of urbanization.	World Bank https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

Table 2

	Mean	Std. Dev.	Min	Max	N
$BDH_{i,t}$	72.75	13.86	10.28	91.27	145
$Biocapacity_{i,t}$	4.28	4.25	0.62	15.11	163
$Crowdfunding_{i,t}$	11.51	2.14	17.75	0	163
$EAI_{i,t}$	9.99	0.65	7.27	11.30	163
$EcologicalBudget_{i,t}$	1.45	3.86	15.29	7.44	163
$EnergyIntens_{i,t}$	3.67	1.70	1.21	12.92	163
$EPS_{i,t}$	3.08	0.87	0.78	4.89	163
$Footprint_{i,t}$	5.73	3.06	2.19	29.33	163
$GBV_{i,t}$	3.91	2.03	2.31	7.16	163
$GDP_{i,t}$	10.55	0.52	9.14	11.38	163
$Lithium_{i,t}$	0.19	0.92	0.50	2.42	163
$Oil_{i,t}$	0.02	0.32	0.46	0.45	163
$Renew_{i,t}$	6.93	0.85	4.98	9.00	163
$Protected_{i,t}$	19.55	11.91	0.20	55.07	163
$RLI_{i,t}$	0.89	0.10	0.62	0.99	163
$Urbanization_{i,t}$	80.11	10.38	54.27	98.08	163

environmental policy stringency, and GDP per capita per country as independent variables. In this model, the issued green bond volume significantly increases with higher environmental awareness and higher GDP per capita at the one and 5 % levels, respectively. This is in line with H1 and H2. Environmental awareness appears essential to promote green bond issuance. By revealing that higher environmental awareness can materialize into an increase in the volume of green bonds, we extend the findings of He and Shi (2023) and Dabbous et al. (2023) who argue that environmental awareness can influence peoples' environmental behavior. Further, our results show that the issuance of green bonds is higher in countries with higher GDP per capita.

In column 2, the degree of urbanization and the crowdfunding volume per country are added as further independent variables. As expected in H3, the degree of urbanization is positively related to the issued green bond volume. Moreover, the magnitude of the coefficients of environmental awareness and GDP per capita become smaller. Nevertheless, they stay statistically significant at the five and 10 % level, respectively. Studies by He and Shi (2023) and El Oudghiri et al. (2021) indicate that more urbanization leads to higher pollution levels, which increase environmental awareness and ultimately the demand for green bonds. We extend these studies by establishing the direct link between higher urbanization and green bond issuance.

Column 3 additionally includes the yearly oil price return and provides support for H4 that higher oil prices are associated with a higher green bond volume issuance. The relation is significant at the 1 % level. The coefficients of environmental awareness and GDP per capita remain statistically significant at the 5 % level and further support H1 and H2.

In column 4, the yearly lithium price return replaces the oil price return as an independent variable. The lithium price return is negatively related to the green bond volume issuance with a statistical significance at the 1 % level. This is strong support for H5. Furthermore, the inclusion of the lithium return makes the statistical significance of environmental awareness and GDP per capita disappear.

We report the results of the full regression model in column 5. GDP per capita, the degree of urbanization, oil and lithium returns have a significant impact on the issued green bond volume, supporting H2 to H5.

We interpret these regression results as follows. Ceteris paribus, higher environmental awareness among the population, and a higher GDP are associated with a higher green bond volume. These relations can be driven by several aspects, e.g. a higher willingness of (retail) investors to fund green projects and more possible buyers and customers of green products and services. Since the urban population is on average more environmentally aware and as urbanization is positively related to GDP, urbanization is also positively associated with green bond volume and decreases the magnitude and statistical significance of the influence of environmental awareness and GDP. The positive relation between oil

Table 3
Determinants of issued green bond volume.

	(1)	(2)	(3)	(4)	(5)
$EAI_{i,t}$	8.80*** (0.96)	5.62** (1.56)	5.60** (2.25)	3.70 (2.41)	4.16 (2.82)
$GDP_{i,t}$	14.01** (5.55)	12.05* (5.11)	13.18** (4.62)	10.12 (5.31)	11.38* (5.33)
$Urbanization_{i,t}$		1.01* (0.50)	0.88 (0.47)	0.99* (0.46)	0.91* (0.46)
Oil_{t-1}			0.69*** (0.13)		0.47*** (0.12)
$Lithium_{t-1}$				0.28*** (0.08)	0.21* (0.10)
$Biocapacity_{i,t}$	0.27 (0.39)	0.32 (0.35)	0.33 (0.34)	0.23 (0.30)	0.26 (0.31)
$Footprint_{i,t}$	0.39 (0.23)	0.33 (0.19)	0.34 (0.20)	0.33 (0.20)	0.34 (0.20)
$EPS_{i,t}$	0.27 (0.67)	0.38 (0.64)	0.57 (0.63)	0.46 (0.61)	0.57 (0.63)
$Crowdfunding_{i,t}$		0.04 (0.24)	0.05 (0.26)	0.02 (0.25)	0.01 (0.27)
α	229.90*** (56.78)	259.32** (82.36)	260.18** (78.25)	216.43** (84.52)	227.87** (87.99)
R^2	0.32	0.35	0.37	0.37	0.38
N	163	163	163	163	163

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R^2 for panel regression analysis with model (1) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing $GBV_{i,t}$ on model (1) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 8.80 with a p -value < .01 for $EAI_{i,t}$ as an independent variable.

prices and green bond volume could be related to several motives. For instance, high oil prices can generate financial market turmoil which can make investors more risk-averse and push them to invest in safer assets like green bonds (Arif et al., 2022; Tiwari et al., 2023). As argued by Bondia et al. (2016) and Xia et al. (2019), higher oil prices can encourage investors to seek more sustainable and eco-friendly alternatives. However, we think the most likely explanation is that higher oil prices make green projects more profitable due to higher opportunity costs when green projects are not realized. When oil prices are high, higher environmental awareness and GDP act as catalysts for green projects. In contrast, when lithium prices are high, many green projects are unprofitable due to high investment costs. In this case, high environmental awareness and GDP hardly matter, since developers will not realize the projects and, therefore, do not need to finance them via green bonds.

We subject these results to a robustness check and split the country observations into ecological creditors and ecological debtors. A t -test between ecological creditors and debtors shows that the issued amount of green bonds is significantly higher among ecological creditors.⁵ This is somewhat surprising since ecological debtors should have stronger incentives to increase their ecological budget in order to achieve long-term economic growth. Given these differences between ecological creditors and debtors, we repeat the regressions of Table 3 for these two samples and report the results in Table 4. The positive influence of environmental awareness, GDP, and urbanization on green bond issuance is predominantly found among ecological debtors. With the absence of existing studies in the literature exploring these relationships, the results could be explained as follows. The outcomes obtained make sense since the population of the ecological debtors will probably suffer stronger from further decreases in biodiversity and the negative impacts of a higher global temperature while the population of ecological creditors could benefit from competitive advantages due to their ecological resources. Hence, the urgency for green projects and for funding these projects is higher among ecological debtors. The influence of oil and lithium prices stays robust and similar among ecological

debtors and creditors. This supports our interpretation that the channels of the influence of oil prices are the investment and opportunity costs of green projects. These economic relationships are equal among ecological debtors and creditors.

In further analyses presented in Table A2 in the appendix, we lag the independent variables of the regressions summarized in Table 3. The significance of all coefficients, except the one for lithium returns, disappears and the R^2 decreases considerably. We interpret this as further support that the lithium price is essential for developers of green projects. High lithium prices reduce the number of green projects due to high costs that make the projects unprofitable.

As a further robustness check, the measures for biocapacity and ecological footprint are replaced by alternative measures, the red list index and a country's energy intensity, respectively. The regressions are run with the full sample. The results presented in Table 5 show that our previous results on the influence of environmental awareness, GDP, the degree of urbanization, and oil and lithium prices on issued green bond volume are robust to alternative biodiversity and emission measures.

One of our key findings is that high lithium prices reduce green bond issuance, probably because of high costs that would make the green projects unprofitable. It is worth discussing whether this relation can also be subject to reverse causality, i.e. that a high amount of green bond financing increases the lithium price. We run regressions with lithium returns as the dependent variable and the total issued green bond volume in all OECD countries per year as the independent variable. A second regression employs the lagged total green bond volume as the independent variable. In none of these regressions do we observe significant relations (see Table A3 in the appendix). This is also the case when oil returns are used as dependent variables. Hence, we do not find evidence that green bond funding has a significant influence on lithium and oil prices. While previous studies discussed that energy metal costs are crucial to the viability of renewable energy projects (Sohag et al., 2023) and some like Chen et al. (2022) and, Sohag et al. (2023) established a weak contagion effect between mineral markets and green investments, to our knowledge no comparable empirical evidence is depicted exploring the relationship between oil and lithium prices and green bonds issuance. This study therefore offers a novel result and finds empirical indications that oil and lithium prices have a direct effect on

⁵ See Table A1 in the appendix

Table 4
Determinants of issued green bond volume – Subsamples of Ecological Creditors and Ecological Debtors (robustness check).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$EAI_{i,t}$	6.15 (3.63)	5.47* (2.55)	1.77 (3.60)	2.18 (2.98)	6.87** (2.31)	6.84* (2.88)	5.11 (3.17)	5.55 (3.58)
$Biocapacity_{i,t}$	0.24 (0.78)	0.57 (0.82)	0.20 (0.82)	0.41 (83)	1.35 (2.14)	1.41 (2.10)	1.76 (2.03)	1.69 (2.07)
$Footprint_{i,t}$	0.19 (0.86)	0.69 (0.79)	0.34 (0.86)	0.62 (0.83)	0.15 (0.30)	0.14 (0.29)	0.13 (0.31)	0.12 (0.30)
$EPS_{i,t}$	1.75 (1.20)	1.14 (1.12)	1.13 (1.04)	0.87 (1.10)	0.90 (0.76)	1.02 (0.77)	0.87 (0.78)	0.96 (0.80)
$GDP_{i,t}$	4.08 (10.68)	10.46 (11.64)	4.94 (9.28)	8.79 (10.52)	12.55* (5.19)	13.49** (4.85)	10.56 (5.60)	11.74* (5.85)
$Urbanization_{i,t}$	0.02 (0.42)	0.14 (0.40)	0.30 (0.45)	0.15 (0.45)	1.16* (0.56)	1.03* (0.52)	1.13* (0.53)	1.04* (0.52)
$Crowdfunding_{i,t}$	0.10 (0.09)	0.08 (0.06)	0.16 (0.12)	0.13 (0.09)	0.06 (0.32)	0.07 (0.34)	0.02 (0.34)	0.04 (0.35)
Oil_{t-1}		0.73*** (0.14)		0.46* (0.23)		0.67*** (0.12)		0.47** (0.14)
$Lithium_{t-1}$			0.30** (0.11)	0.24** (0.09)			0.27** (0.10)	0.20 (0.14)
α	108.40 (93.00)	156.29 (109.04)	93.70 (68.97)	126.61 (87.73)	281.36** (91.93)	280.08** (89.58)	239.15* (98.18)	249.30* (103.92)
R ²	0.54	0.58	0.60	0.61	0.36	0.37	0.37	0.38
Subsample	Ecological Creditors	Ecological Creditors	Ecological Creditors	Ecological Creditors	Ecological Debtors	Ecological Debtors	Ecological Debtors	Ecological Debtors
N	40	40	40	40	123	123	123	123

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (1) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing $GBV_{i,t}$ on model (1) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 6.15 with a p-value >.10 for $EAI_{i,t}$ as an independent variable.

Table 5
Determinants of issued green bond volume – alternative measures for $Biocapacity_{i,t}$ and $Footprint_{i,t}$ (robustness check).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$EAI_{i,t}$	5.55** (2.27)	5.64* (2.35)	5.71* (2.38)	3.62 (2.49)	3.89 (2.41)	3.98 (2.44)	4.10 (2.86)	4.35 (2.80)	4.46 (2.81)
$Biocapacity_{i,t}$		0.11 (0.34)			0.01 (0.32)			0.03 (0.32)	
$RLI_{i,t}$	6.11 (7.50)		20.48 (14.83)	2.23 (8.15)		13.54 (12.02)	4.84 (7.47)		17.28 (12.99)
$Footprint_{i,t}$	0.30* (0.16)			0.30 (0.17)			0.31 (0.17)		
$EnergyIntens_{i,t}$		1.01 (0.58)	1.21 (0.69)		0.83 (0.63)	0.97 (0.72)		0.88 (0.62)	1.06 (0.72)
$EPS_{i,t}$	0.55 (0.63)	0.70 (0.66)	0.71 (0.65)	0.45 (0.61)	0.54 (0.65)	0.55 (0.65)	0.55 (0.62)	0.66 (0.66)	0.68 (0.66)
$GDP_{i,t}$	12.87** (4.48)	10.37* (4.93)	10.04* (4.93)	9.88 (5.13)	7.77 (5.64)	7.56 (5.61)	11.11* (5.15)	8.90 (5.47)	8.66 (5.42)
$Urbanization_{i,t}$	0.90* (0.45)	0.83 (0.48)	0.85 (0.47)	1.00* (0.44)	0.95* (0.48)	0.96* (0.48)	0.92* (0.44)	0.87 (0.47)	0.88 (0.47)
$Crowdfunding_{i,t}$	0.06 (0.26)	0.05 (0.28)	0.04 (0.28)	0.01 (0.25)	0.02 (0.27)	0.02 (0.27)	0.01 (0.27)	0.00 (0.29)	0.00 (0.29)
Oil_{t-1}	0.69*** (0.14)	0.67*** (0.12)	0.69*** (0.13)				0.47*** (0.11)	0.47*** (0.10)	0.48*** (0.11)
$Lithium_{t-1}$				0.28*** (0.07)	0.27** (0.07)	0.27*** (0.07)	21* (0.10)	0.20* (0.10)	20* (0.10)
α	261.85** (76.67)	223.85** (91.26)	238.89** (87.61)	214.83** (81.86)	188.35* (96.73)	199.15* (92.63)	228.64** (86.96)	197.99* (98.16)	211.75* (95.80)
R ²	0.37	0.36	0.37	0.37	0.37	0.37	0.38	0.37	0.37
N	163	163	163	163	163	163	163	163	163

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (1) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing $GBV_{i,t}$ on model (1) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 5.55 with a p-value < .05 for $EAI_{i,t}$ as an independent variable.

the green bond market.

In the light of the institutional perspective theory, our results underline the importance of informal institutions such as beliefs and values in influencing firms' behavior. We observe a significant role of environmental awareness in promoting the issuance of green bonds. However, our results do not support the notion that environmental

regulations will influence firms' behavior regarding the issuance of green bonds.

4.2. Effects on ecological footprint, biodiversity, and ecological budget

Having established that higher environmental awareness, GDP,

Table 6

Does the issued green bond volume have an impact on renewable energy capacity and the share of protected areas?

	(1) <i>Renew_{i,t}</i>	(2) <i>Protected_{i,t}</i>
<i>GBV_{i,t-1}</i>	0.05*** (0.01)	0.46* (0.22)
α	6.79*** (0.04)	18.44 (1.06)
R ²	0.25	0.06
N	134	134

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (2) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing the installed renewable energy capacity (*Renew_{i,t}*) on the issued green bond volume (*GBV_{i,t-1}*) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 0.05 with a p-value < .01 for *GBV_{i,t-1}* as an independent variable.

degree of urbanization, and oil prices and lower lithium prices are associated with higher issued green bond volume, we are interested in the effects of green bond funding.

Results of the univariate panel regressions presented in Table 6 show that higher issued green bond volume in year t-1 is associated with higher installed renewable energy generation capacity and an increasing share of protected areas in year t. Our findings complement those of Taghizadeh-Hesary et al. (2023) who show that an increase in green bond issuance is associated with higher renewable energy consumption.

Table 7 contains the results of panel regressions with ecological budget, footprint, and biodiversity (*BDF_{i,t}*) as dependent variables. In columns 1, 3, and 5, the independent variables are the issued green bond volume, environmental awareness, environmental policy stringency, and GDP per capita. The green bond volume variable is lagged by two years. We assume that this is the minimum amount of time that it takes for green projects to unfold a real impact. Environmental awareness and environmental policy stringency are lagged by one year for the same reason. Changes in these lags by one period alter the magnitudes of the coefficients a bit, however, the results stay qualitatively the same. In columns 2, 4, and 6, we add the installed renewable energy generation capacity and the share of protected areas as independent variables, each lagged by one year.

The results support H6 to H8. Results in column 1 show that the issued green bond volume is positively related to the ecological budget with a statistical significance at the 1 % level (H8). This is driven by a reduction in the ecological footprint (H6, see column 3).⁶ Hence, our results are in line with those of Chang et al. (2022). Furthermore, findings in column 5 show that higher green bond volume issuance is associated with higher biodiversity in the following years (H7). Our results match to a certain level Agrawal et al. (2024), who argue that green finance is of major importance in addressing climate change concerns and achieving a sustainable future. However, our results go a step further by revealing that green bonds may enhance biodiversity and reduce the ecological footprint. With a statistical significance at the 1 % level, environmental awareness is positively related to biodiversity and negatively to ecological footprint. The latter is not surprising since environmental awareness goes hand in hand with environmental-friendly behavior. In addition, more stringent environmental policies increase biodiversity.

A look at columns 2 and 4 reveals that renewable energy generation capacity has a positive impact on the ecological budget and a negative

impact on the footprint. Furthermore, the coefficients of *GBV_{i,t-2}* become smaller in magnitude compared to the respective coefficients in columns 1 and 3. This indicates that the installation of renewable energy capacity is a major mechanism through which green bond financing decreases the ecological footprint and ultimately increases the ecological budget.

Moreover, we find negative correlations between GDP and ecological budget and positive correlations between GDP and ecological footprint. It seems plausible that the economic growth of some industries comes along with more emissions and a larger ecological footprint. However, the results also indicate that this type of economic growth reduces the ecological budget, which can harm long-term economic growth when a country's ecological resources are exhausted.

The Environmental Performance Index is a composite of 40 individual indicators. The scale of each indicator ranges from 0 (worst) to 100 (best). We rerun regression model (2) with these 40 indicators as dependent variables to identify the domains that contribute to the ecological footprint reduction and biodiversity increase. We find significant relations for 8 out of 40 indicators.⁷ The respective results are presented in Table 8.

If the issued green bond volume, environmental awareness, or environmental policy stringency is significantly related to an indicator, then the relation is always positive. This shows that the influence of all three variables is as expected and that they are three pillars for a healthier environment. Higher amounts of green bond funding are related to lower F-Gas growth rate (*FGA_{i,t}*) and greenhouse gas emissions per capita (*GHP_{i,t}*), i.e. can mitigate climate change. Moreover, higher issuance of green bonds can improve environmental health by reducing ocean plastic pollution (*OCP_{i,t}*), lead exposure (*PBD_{i,t}*), SO₂ exposure (*SOE_{i,t}*), unsafe sanitation (*USD_{i,t}*), and unsafe drinking water (*UWD_{i,t}*). Furthermore, ecosystem vitality is enhanced by decreasing the SO₂ growth rate (*SDA_{i,t}*) when green bond funding rises. The influence of higher environmental awareness is comparable to the influence of more green bond funding except for the SO₂ growth rate, which is unrelated to environmental awareness. More stringent environmental policy is associated with reduced lead exposure and SO₂ exposure. Although these results are somewhat explorative, one can think of projects funded by green bonds or behaviors established because of environmental awareness that can cause these effects. Nevertheless, we take the results with a grain of salt and abstain from taking these relationships for granted. The key takeaway of the results in Table 8 is that green bond funding and environmental awareness can increase environmental performance in many domains, which ultimately improves the ecological budget and biodiversity.

Results presented in Table 9 show results for the full regression model (2), i.e., in comparison to Table 8, we have added the installed renewable energy capacity (*Renew_{i,t-1}*) and the share of terrestrial and marine protected areas of the total territorial area (*Protected_{i,t-1}*). Since green bond financing increases the latter two variables, the results in Table 9 provide indications through which channels green bond financing improves environmental performance. Compared to Table 8, the coefficient of the issued green bond financing becomes smaller in magnitude in every column. Simultaneously, the coefficient of *Renew_{i,t-1}* is positive with a statistical significance at least at the 10 % level in the regressions with *GHP_{i,t}*, *OCP_{i,t}*, *SDA_{i,t}*, *SOE_{i,t}*, and *UWD_{i,t}* as dependent variables. Similarly, *Protected_{i,t-1}* has a positive coefficient with a statistical significance at least at the 5 % level in the regressions with *GHP_{i,t}*, *OCP_{i,t}*, *PBD_{i,t}*, *SDA_{i,t}*, *SOE_{i,t}*, *USD_{i,t}*, and *UWD_{i,t}* as dependent variables. Therefore, it is very likely that an increase in the issued green bond volume leads to more installed renewable energy generation

⁶ In untabulated results we do not find a significant influence of the green bond volume on biocapacity.

⁷ We omit the indicator for protected areas (*PAR_{i,t}*) due to endogeneity effects with the share of protected areas *Protected_{i,t-1}*. However, we indeed find a significant positive relation between the issued green bond volume and *PAR_{i,t}*.

Table 7
The impact of the issued green bond volume on ecological budget, ecological footprint, and biodiversity.

	(1) <i>EcologicalBudget_{it}</i>	(2) <i>EcologicalBudget_{it}</i>	(3) <i>Footprint_{it}</i>	(4) <i>Footprint_{it}</i>	(5) <i>BDH_{it}</i>	(6) <i>BDH_{it}</i>
<i>GBV_{it}</i> 2	0.05*** (0.01)	0.04*** (0.00)	0.03** (0.01)	0.02 (0.01)	0.36** (0.09)	0.28* (0.10)
<i>EAI_{it}</i> 1	2.03* (0.91)	1.70 (0.94)	3.24*** (0.65)	2.67*** (0.57)	14.67*** (3.03)	12.51** (3.29)
<i>EPS_{it}</i> 1	0.17 (0.09)	0.13 (0.07)	0.22* (0.09)	0.14 (0.08)	2.13** (0.59)	1.88** (0.64)
<i>GDP_{it}</i>	3.42*** (0.71)	3.56** (0.83)	2.50*** (0.38)	2.69*** (0.55)	0.91 (6.56)	0.08 (5.54)
<i>Renew_{it}</i> *10 ⁻²		0.42*** (0.08)		0.70*** (0.08)		2.95 (1.70)
<i>Protected_{it}</i> *10 ⁻²		0.00 (0.00)		0.00 (0.00)		0.05 (0.04)
α	13.90 (16.29)	16.01 (17.42)	12.54 (10.32)	9.13 (11.48)	90.62 (92.34)	76.55 (84.98)
R ²	0.53	0.54	0.54	0.57	0.21	0.22
N	106	106	106	106	95	95

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (2) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing *EcologicalBudget_{it}* on model (2) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 0.05 with a p-value < .01 for *GBV_{it}* 2 as an independent variable.

Table 8
The impact of the issued green bond volume on indicators of the EPI.

	(1) <i>FGA_{it}</i>	(2) <i>GHP_{it}</i>	(3) <i>OCPI_{it}</i>	(4) <i>PBD_{it}</i>	(5) <i>SDA_{it}</i>	(6) <i>SOE_{it}</i>	(7) <i>USD_{it}</i>	(8) <i>UWD_{it}</i>
<i>GBV_{it}</i> 2	0.88** (0.23)	0.17** (0.06)	0.33** (0.10)	0.10*** (0.02)	0.60*** (0.11)	0.40** (0.13)	0.04** (0.01)	0.05*** (0.01)
<i>EAI_{it}</i> 1	14.86* (6.87)	7.03*** (0.50)	24.17*** (1.55)	4.53*** (0.80)	6.80 (5.86)	13.07*** (1.03)	3.53*** (0.69)	2.20*** (0.22)
<i>EPS_{it}</i> 1	4.32* (1.79)	0.06 (0.35)	0.84 (0.55)	1.24*** (0.10)	2.79 (2.20)	2.11*** (0.37)	0.07 (0.08)	0.18 (0.13)
<i>GDP_{it}</i>	59.61 (36.16)	5.44 (2.56)	10.72 (9.30)	5.59 (4.42)	12.17 (9.09)	15.11 (10.22)	2.68 (1.39)	1.85 (1.37)
α	721.88 392.27	104.92** (30.73)	1141.02*** (102.16)	24.82 (51.30)	301.41* (122.42)	253.08** (113.07)	28.71 (20.88)	47.94** (16.44)
R ²	0.14	0.32	0.65	0.41	0.06	0.49	0.35	0.34
N	106	106	106	106	106	106	106	106

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (2) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing *FGA_{it}* on model (2) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 0.88 with a p-value < .05 for *GBV_{it}* 2 as an independent variable.

capacity and protected areas, ultimately leading to reduced emissions, a reduced footprint, a higher ecological budget, and more biodiversity.

Our findings provide support to innovation theory since higher green bond volumes seem to be used for financing new environmentally friendly business models, specifically renewable energy generation. In addition, the results are in line with the institutional perspective theory since more stringent environmental policy is related to more biodiversity and a reduced ecological footprint.

5. Conclusion, implications, limitations, and future directions

With growing environmental concerns and the challenges posed by the loss of natural capital, biodiversity, and the increasing ecological footprint, countries are seeking sustainable solutions and promoting green initiatives (Horn, 2024). The issuance of green bonds seems to be of great importance, as green bonds help to finance environmentally friendly projects and promote sustainable development. However, several gaps have been identified in the literature regarding the main determinants of green bond issuance and the environmental impact of the volume of green bonds issued. This study provides a novel macro perspective by using a panel dataset with annual data from 29 OECD

countries for the period 2014–2020. Two models are tested.

The first model examines the determinants of green bond issuance. The main findings are that the issued volume of green bonds increases significantly with higher environmental awareness, higher GDP per capita, and higher urbanization. Higher oil prices are associated with higher green bond issuance, while the latter is negatively related to the lithium price. When the sample is divided into environmental creditors and debtors, the positive impact of environmental awareness, GDP, and urbanization on green bond issuance is found mainly among environmental debtors. The impact of oil and lithium prices remains robust and similar for ecological debtors and creditors.

The second model analyzes the effects of the issued green bond volume on biodiversity, ecological budget, and the ecological footprint as well as the channels through which the effects take place. The volume of issued green bonds is positively related to the ecological budget, reduces the ecological footprint, and is associated with higher biodiversity in subsequent years. Two channels through which green bond financing develops its positive environmental impact are the installation of renewable energy generation capacities and the establishment of new protected areas. Stricter environmental policies and higher environmental awareness also reduce the ecological footprint and increase

Table 9
The impact of the issued green bond volume on indicators of the EPI – channels.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>FGA_{it}</i>	<i>GHP_{it}</i>	<i>OCPI_{it}</i>	<i>PBD_{it}</i>	<i>SDA_{it}</i>	<i>SOE_{it}</i>	<i>USD_{it}</i>	<i>UWD_{it}</i>
<i>GBV_{it 2}</i>	0.72 (0.34)	0.12** (0.04)	0.20*** (0.02)	0.07** (0.02)	0.29 (0.15)	0.27*** (0.04)	0.04* (0.02)	0.03*** (0.00)
<i>EAI_{it 1}</i>	9.35 (7.85)	5.22*** (0.42)	19.39*** (2.65)	3.28** (1.04)	18.13** (5.31)	8.58*** (1.68)	3.19*** (0.69)	1.60*** (0.33)
<i>EPS_{it 1}</i>	3.69 (1.81)	0.34 (0.46)	0.23 (0.59)	0.88*** (0.15)	5.70** (2.03)	1.05 (0.73)	0.02 (0.08)	0.04 (0.11)
<i>GDP_{it}</i>	56.81 (31.54)	5.48** (1.65)	10.97 (6.30)	6.07 (3.32)	9.62 (7.03)	15.63* (6.78)	2.77* (1.13)	1.88 (0.99)
<i>Renew_{it 1}</i>	7.40 (7.41)	1.71*** (0.28)	4.40*** (0.86)	0.84 (0.42)	8.98*** (1.79)	3.93* (1.55)	0.25 (0.12)	0.56** (0.15)
<i>Protected_{it 1}</i>	0.12 (0.23)	0.04** (0.01)	0.13** (0.04)	0.07*** (0.01)	0.48*** (0.07)	0.14** (0.05)	0.02** (0.00)	0.02*** (0.00)
α	683.28 348.70	98.48** (20.12)	1125.09*** (78.89)	23.34 (39.98)	326.50** (109.06)	239.93* (77.75)	29.30 (17.98)	49.98** (12.67)
R ²	0.15	0.38	0.75	0.51	0.25	0.61	0.37	0.41
N	106	106	106	106	106	106	106	106

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (2) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing *FGA_{it}* on model (2) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 0.72 with a p-value > .10 for *GBV_{it 2}* as an independent variable.

biodiversity.

The results of this study have important implications. First, green bond issuers are urged to make decisions that take into account fluctuations in both oil and lithium prices. For example, when oil prices rise, green bond issuers in oil-importing countries are advised to diversify their energy portfolios and may respond by issuing larger volumes of green bonds, as suggested by Su et al. (2023). Second, the results confirm that green bond volume, environmental awareness, and environmental policy stringency have a positive impact on ecological budget and biodiversity, suggesting the need to consider these variables when formulating policies to mitigate negative environmental impacts. Furthermore, the results show that these three variables act as complements rather than substitutes. In light of these findings, countries are encouraged to promote the issuance of green bonds, which are essential to raise the financial resources needed to finance environmentally friendly projects. One way to achieve this goal is to offer tax and investment incentives, provide technical assistance, and simplify procedures. Third, the findings indicate that in order to protect biodiversity and preserve natural habitats, this action should be accompanied by both increased environmental awareness and stricter environmental policies to achieve higher results. Therefore, governments, businesses, and individuals should devote resources and efforts to raising environmental awareness among the population. Finally, countries need to design and implement strong environmental regulations. One way to do this is to provide financial incentives for high-emitting companies and individuals to use clean technologies, such as electric vehicles or solar panels.

This study may have some limitations. One is the limited number of data points. Because of this caveat, we take the results with a grain of salt and refrain from making statements about the economic magnitude of the relationships. Nevertheless, we would like to emphasize that the data sets analyzed are the most detailed with the longest history available. While our study is certainly only an initial step in the research on green bond issuance, it already highlights interesting relationships and avenues for further research. The relationships identified are highly statistically significant, economically sound, and consistent with our hypotheses derived from related studies. This makes us confident that

the identified determinants of green bond issuance volume, ecological budget, and biodiversity are important. However, we leave it to further research to estimate the elasticities of the relationships when more data is available. Further research could also introduce some additional variables as determinants of the volume of green bonds issued, such as the bond yield, which is considered important by practitioners (Rasoulinezhad, 2022), but for which we had no data.

Finally, as in this study, further research will face the challenge that data on biodiversity, as well as data on biodiversity funding, are difficult to obtain from different, unrelated sources and are notoriously incomplete (Harrer et al., 2024). Naturally, some projects take longer than others to show positive effects on biodiversity. In addition, it is difficult to allocate funds to countries, e.g. funds provided by a European government to an international non-profit organization for services in a transboundary protected area in Africa. It is therefore important that more studies look at these issues to get a clearer and more reliable picture. Our study is only one piece of this puzzle and should be seen as an inspiration and a call for further research.

CRedit authorship contribution statement

Matthias Horn: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Amal Dabbous:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Andreas Oehler:** Writing – review & editing, Methodology, Conceptualization. **Florian Göbel:** Writing – review & editing, Writing – original draft, Investigation, Data curation.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Appendix A. Appendix

Table A1
t-test regarding $GBV_{i,t}$ between ecological debtors and ecological creditors.

	Mean	Std. Dev.	N
Ecological debtors	3.60	2.14	123
Ecological creditors	4.87	1.22	40
Difference	1.27***		
t-statistic	3.55		

Table A2
Determinants of issued green bond volume.

	(1)	(2)	(3)	(4)	(5)
$EAI_{i,t-1}$	1.79 (2.49)	0.86 (2.56)	1.09 (1.98)	1.21 (2.98)	1.29 (2.70)
$GDP_{i,t-1}$	25.27* (11.08)	22.59* (10.24)	22.82* (10.32)	20.35 (10.89)	20.51 (11.11)
$Urbanization_{i,t-1}$		0.75* (0.32)	0.64* (0.28)	0.46 (0.35)	0.42 (0.32)
Oil_t			0.45 (0.57)		0.17 (0.33)
$Lithium_t$				0.43*** (0.08)	0.41** (0.10)
$Biocapacity_{i,t-1}$	0.05 (0.18)	0.02 (0.23)	0.02 (0.22)	0.21 (0.31)	0.20 (0.30)
$Footprint_{i,t-1}$	0.17 (0.11)	0.15 (0.12)	0.06 (0.23)	0.22** (0.08)	0.18 (0.14)
$EPS_{i,t-1}$	1.69*** (0.27)	1.73*** (0.21)	1.69*** (0.23)	2.02*** (0.28)	1.99*** (0.29)
$Crowdfunding_{i,t-1}$		0.06 (0.15)	0.02 (0.21)	0.03 (0.13)	0.02 (0.15)
α	273.23** (96.23)	296.88** (93.90)	293.81** (94.59)	252.78** (97.27)	253.12* (100.27)
R ²	0.06	0.08	0.08	0.13	0.13
N	134	134	134	134	134

Notes: The table presents the estimated coefficients, Driscoll-Kraay standard errors figuring in parentheses, and R² for panel regression analysis with model (1) and country-fixed effects. The symbols ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10 % levels, respectively. Example: Regressing $GBV_{i,t}$ on model (1) with panel regressions and Driscoll-Kraay standard errors (see column (1)) generates a coefficient of 1.79 with a p-value > .10 for $EAI_{i,t}$ as an independent variable.

Table A3
Does issued green bond volume have an impact on lithium and oil prices?

	$Lithium_t$	$Lithium_t$	Oil_t	Oil_t
$TotalGBV_{i,t}$	4.98 (4.85)		0.88 (1.84)	
$TotalGBV_{i,t-1}$		7.66 (7.27)		1.40 (2.37)
α	0.81 (0.65)	0.96 (0.78)	0.14 (0.25)	0.15 (0.26)
Adjusted R ²	0.01	0.02	0.15	0.15
N	7	6	7	6

Notes: The table presents the estimated coefficients, standard errors figuring in parentheses, and R² for OLS regression analysis. None of the coefficients is statistically significant at the 1 %, 5 %, or 10 % level. Example: Regressing lithium prices on the total green bond volume of year t in trillion USD (see column (1)) generates a coefficient of 4.98 with a p-value > .10 for the total green bond volume as an independent variable.

References

Agan, B., 2024. Sustainable development through green transition in EU countries: new evidence from panel quantile regression. *J. Environ. Manag.* 365, 121545. <https://doi.org/10.1016/j.jenvman.2024.121545>.
Agrawal, R., Agrawal, S., Samadhiya, A., Kumar, A., Luthra, S., Jain, V., 2024. Adoption of green finance and green innovation for achieving circularity: an exploratory review and future directions. *Geosci. Front.* 15 (4), 101669. <https://doi.org/10.1016/j.gsf.2023.101669>.

Ahmed, W.M.A., 2024. Attention to climate change and eco-friendly financial-asset prices: a quantile ARDL approach. *Energy Econ.* 136, 107696. <https://doi.org/10.1016/j.eneco.2024.107696>.
Al Masud, M.I., 2023. The Impact of Adult Awareness of Climate Change on Renewable Energy Consumption in the United States. Working Paper Texas Tech University.
Alharbi, S.S., Al Mamun, M., Boubaker, S., Rizvi, S.K.A., 2023. Green finance and renewable energy: a worldwide evidence. *Energy Econ.* 118, 106499. <https://doi.org/10.1016/j.eneco.2022.106499>.
Alhassan, H., 2021. The effect of agricultural total factor productivity on environmental degradation in sub-Saharan Africa. *Sci. Afr.* 12, e00740. <https://doi.org/10.1016/j.sciaf.2021.e00740>.

- Amara, D.B., Qiao, J., Zada, M., 2023. How to reconcile the climate change issue with economic growth? Spatial dual mediating effects of carbon emissions and foreign investment. *J. Clean. Prod.* 411, 137285. <https://doi.org/10.1016/j.jclepro.2023.137285>.
- Ardia, D., Bluteau, K., Boudt, K., Inghelbrecht, K., 2023. Climate change concerns and the performance of green vs. Brown Stocks. *Manag. Sci.* 69 (12), 7607–7632. <https://doi.org/10.1287/mnsc.2022.4636>.
- Arif, M., Naem, M.A., Farid, S., Nepal, R., Jamash, T., 2022. Diversifier or more? Hedge and safe haven properties of green bonds during COVID-19. *Energy Policy* 168, 113102. <https://doi.org/10.1016/j.enpol.2022.113102>.
- Azhgaliyeva, D., Kapsalyamova, Z., Mishra, R., 2022. Oil price shocks and green bonds: an empirical evidence. *Energy Econ.* 112, 106108. <https://doi.org/10.1016/j.eneco.2022.106108>.
- Bondia, R., Ghosh, S., Kanjilal, K., 2016. International crude oil prices and the stock prices of clean energy and technology companies: evidence from non-linear cointegration tests with unknown structural breaks. *Energy* 101, 558–565. <https://doi.org/10.1016/j.energy.2016.02.031>.
- Chang, L., Taghizadeh-Hesary, F., Chen, H., Mohsin, M., 2022. Do green bonds have environmental benefits? *Energy Econ.* 115, 106356. <https://doi.org/10.1016/j.eneco.2022.106356>.
- Chatzistamoulou, N., Koundouri, P., 2022. Sustainability transition through awareness to promote environmental efficiency. In: Terzioglu, M.K. (Ed.), *Advances in Econometrics, Operational Research, Data Science and Actuarial Studies: Techniques and Theories*. Springer International Publishing, Cham, pp. 345–362.
- Chen, J., Wang, L., Li, Y., 2020. Research on the impact of multi-dimensional urbanization on China's carbon emissions under the background of COP21. *J. Environ. Manag.* 273, 111123. <https://doi.org/10.1016/j.jenvman.2020.111123>.
- Chen, Y., Zhu, X., Chen, J., 2022. Spillovers and hedging effectiveness of non-ferrous metals and sub-sectoral clean energy stocks in time and frequency domain. *Energy Econ.* 111, 106070. <https://doi.org/10.1016/j.eneco.2022.106070>.
- Cheng, Z., Wu, Y., 2024. Can the issuance of green bonds promote corporate green transformation? *J. Clean. Prod.* 443, 141071. <https://doi.org/10.1016/j.jclepro.2024.141071>.
- Cosma, S., Rimo, G., Cosma, S., 2023. Conservation finance: what are we not doing? A review and research agenda. *J. Environ. Manag.* 336, 117649. <https://doi.org/10.1016/j.jenvman.2023.117649>.
- Dabbous, A., Croutzet, A., Horn, M., 2025. Achieving Energy Resilience: The Joint Role of Environmental Policy Stringency and Environmental Awareness. *Research in International Business and Finance* 74, p. 102692. <https://doi.org/10.1016/j.ribaf.2024.102692>.
- Dabbous, A., Horn, M., Croutzet, A., 2023. Measuring environmental awareness: an analysis using google search data. *J. Environ. Manag.* 346, 118984. <https://doi.org/10.1016/j.jenvman.2023.118984>.
- El Ouadghiri, I., Guesmi, K., Peillex, J., Ziegler, A., 2021. Public attention to environmental issues and stock market returns. *Ecol. Econ.* 180, 106836. <https://doi.org/10.1016/j.ecolecon.2020.106836>.
- Eyraud, L., Clements, B., Wane, A., 2013. Green investment: Trends and determinants. *Energy Policy* 60, 852–865. <https://doi.org/10.1016/j.enpol.2013.04.039>.
- Fahmy, H., 2022. The rise in investors' awareness of climate risks after the Paris agreement and the clean energy-oil-technology prices nexus. *Energy Econ.* 106, 105738. <https://doi.org/10.1016/j.eneco.2021.105738>.
- Feng, Y., Lai, K.H., Zhu, Q., 2022. Green supply chain innovation: emergence, adoption, and challenges. *Int. J. Prod. Econ.* 248, 108497. <https://doi.org/10.1016/j.ijpe.2022.108497>.
- Flammer, C., Giroux, T., Heal, G., 2023. Biodiversity finance. In: NBER Working Paper No. 31022. <https://www.nber.org/papers/w31022>.
- Goutte, S., Mhadhbi, M., 2024. Analyzing crisis dynamics: how metal-energy markets influence green electricity investments. *Energy Econ.* 134, 107614. <https://doi.org/10.1016/j.eneco.2024.107614>.
- Gustafsson, R., Dutta, A., Bouri, E., 2022. Are energy metals hedges or safe havens for clean energy stock returns? *Energy* 244, Part A, 122708. <https://doi.org/10.1016/j.energy.2021.122708>.
- Harrer, T., Silvola, H., Lehner, O.M., 2024. *Measuring biodiversity: Mission impossible? In: Lehner, O.M., Harrer, T., Silvola, H., Weber, O. (Eds.), The Routledge Handbook of Green Finance*. Routledge, Abingdon, New York, pp. 357–373.
- Hausman, J.A., 1978. Specification tests in econometrics. *Econometrica*. *J. Econom. Soc.* 46 (6), 1251–1271. <https://doi.org/10.2307/1913827>.
- He, X., Shi, J., 2023. The effect of air pollution on Chinese green bond market: the mediation role of public concern. *J. Environ. Manag.* 325, Part B, 116522. <https://doi.org/10.1016/j.jenvman.2022.116522>.
- He, Z., Xu, S., Shen, W., Long, R., Chen, H., 2017. Impact of urbanization on energy related CO₂ emission at different development levels: regional difference in China based on panel estimation. *J. Clean. Prod.* 140, 1719–1730. <https://doi.org/10.1016/j.jclepro.2016.08.155>.
- He, R., Zhong, M., Huang, J., 2021. The dynamic effects of renewable-energy and fossil-fuel technological progress on metal consumption in the electric power industry. *Res. Policy* 71, 101985. <https://doi.org/10.1016/j.resourpol.2021.101985>.
- Hoechle, D., 2007. Robust standard errors for panel regressions with cross-sectional dependence. *The Stata J.* 7 (3), 281–312. <https://doi.org/10.1177/1536867X0700700301>.
- Hoepner, A.G.F., Schneider, F., 2024. Exit vs voice vs denial of (re)entry: assessing investor impact mechanisms on corporate climate transition across asset classes. Working Paper. <https://doi.org/10.2139/ssrn.4193465>.
- Horn, M., 2024. The European green deal, retail investors and sustainable investments: a perspective article covering economic, behavioral, and regulatory insights. *Curr. Res. Environ. Sustain.* 7, 100241. <https://doi.org/10.1016/j.crsust.2024.100241>.
- Horn, M., Oehler, A., Dabbous, A., Croutzet, A., 2025. The Relation between Environmental Awareness and Stock Returns. *International Review of Economics and Finance* 103, 104383. <https://doi.org/10.1016/j.iref.2025.104383>.
- IEA, 2024. Causes and Effects of Climate Change. <https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer> (accessed 21 May 2025).
- Ioannidis, F., Kosmidou, K., Papanastasiou, D., 2023. Public awareness of renewable energy sources and circular economy in Greece. *Renew. Energy* 206, 1086–1096. <https://doi.org/10.1016/j.renene.2023.02.084>.
- Irfan, M., Rehman, M.A., Razzaq, A., Hao, Y., 2023. What drives renewable energy transition in G-7 and E-7 countries? The role of financial development and mineral markets. *Energy Econ.* 121, 106661. <https://doi.org/10.1016/j.eneco.2023.106661>.
- Jo, H., Kim, H.E., Sim, M., 2022. Environmental preference, air pollution, and fund flows in China. *Pac.-Basin Financ. J.* 72, 101723. <https://doi.org/10.1016/j.pacfin.2022.101723>.
- Karolyi, G.A., Tobin-de la Puente, J., 2023. Biodiversity finance: a call for research into financing nature. *Financ. Manag.* 52 (2), 231–251. <https://doi.org/10.1111/fima.12417>.
- Kartal, M.T., Pata, U.K., Destek, M.A., Caglar, A.E., 2023. Environmental effect of clean energy research and development investments: evidence from Japan by using load capacity factor. *J. Clean. Prod.* 416, 137972. <https://doi.org/10.1016/j.jclepro.2023.137972>.
- Li, T., Yue, X.G., Qin, M., Norena-Chavez, D., 2024. Towards Paris climate agreement goals: the essential role of green finance and green technology. *Energy Econ.* 129, 107273. <https://doi.org/10.1016/j.eneco.2023.107273>.
- Lv, C., Bian, B., Lee, C.C., He, Z., 2021. Regional gap and the trend of green finance development in China. *Energy Econ.* 102, 105476. <https://doi.org/10.1016/j.eneco.2021.105476>.
- Ma, R., Abid, N., Yang, S., Ahmad, F., 2023. From crisis to resilience: strengthening climate action in OECD countries through environmental policy and energy transition. *Environ. Sci. Pollut. Res.* 30 (54), 115480–115495. <https://doi.org/10.1007/s11356-023-29970-z>.
- Mamun, M.A., Boubaker, S., Nguyen, D.K., 2022. Green finance and decarbonization: evidence from around the world. *Financ. Res. Lett.* 46, Part B, 102807. <https://doi.org/10.1016/j.frl.2022.102807>.
- Meo, M.S., Abd Karim, M.Z., 2022. The role of green finance in reducing CO₂ emissions: an empirical analysis. *Borsa Istanbul Rev.* 22 (1), 169–178. <https://doi.org/10.1016/j.bir.2021.03.002>.
- Mertzanis, C., 2023. Energy policy diversity and green bond issuance around the world. *Energy Econ.* 128, 107116. <https://doi.org/10.1016/j.eneco.2023.107116>.
- Mertzanis, C., 2024. Central bank policies and green bond issuance on a global scale. *Energy Econ.* 133, 107541. <https://doi.org/10.1016/j.eneco.2024.107541>.
- Mitchell, J., Sigurjónsson, Þ.O., Kavadis, N., Wendt, S., 2024. Green bonds and sustainable business models in Nordic energy companies. *Curr. Res. Environ. Sustain.* 7, 100240. <https://doi.org/10.1016/j.crsust.2023.100240>.
- OECD, 2024. Environmental policy: environmental policy stringency index. In: *OECD Environment Statistics (database)*, 2024. <https://doi.org/10.1787/2bc0bb80-en> (accessed on 29 September).
- Pastor, L., Stambaugh, R.F., Taylor, L.A., 2022. Dissecting green returns. *J. Financ. Econ.* 146 (2), 403–424. <https://doi.org/10.1016/j.jfineco.2022.07.007>.
- Pata, U.K., Alola, A.A., Erdogan, S., Kartal, M.T., 2023. The influence of income, economic policy uncertainty, geopolitical risk, and urbanization on renewable energy investments in G7 countries. *Energy Econ.* 128, 107172. <https://doi.org/10.1016/j.eneco.2023.107172>.
- Pelster, M., Horn, M., Oehler, A., 2024. Who cares about ESG? *J. Clim. Financ.* 8, 100045. <https://doi.org/10.1016/j.jclimf.2024.100045>.
- Prajapati, D., Paul, D., Malik, S., Mishra, D.K., 2021. Understanding the preference of individual retail investors on green bond in India: an empirical study. *Invest. Manag. Financ. Innov.* 18 (1), 177–189. [https://doi.org/10.21511/imfi.18\(1\).2021.15](https://doi.org/10.21511/imfi.18(1).2021.15).
- Qin, M., Su, C.W., Zhong, Y., Song, Y., Lobont, O.R., 2022. Sustainable finance and renewable energy: promoters of carbon neutrality in the United States. *J. Environ. Manag.* 324, 116390. <https://doi.org/10.1016/j.jenvman.2022.116390>.
- Rasoulizadeh, E., 2022. Identification of the success factors of the green bond market for sustainable development in the COVID-19 era. *Energy Research Letters* 3, 1–4. <https://doi.org/10.46557/001c.29979>.
- Rasoulizadeh, E., Taghizadeh-Hesary, F., 2022. Role of green finance in improving energy efficiency and renewable energy development. *Energ. Effic.* 15, 14. <https://doi.org/10.1007/s12053-022-10021-4>.
- Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Coenwll, S., Donges, J.F., Drücke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kumm, M., Mohan, C., Noguez-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Wang-Erlandsson, L., Weber, L., Rockström, J., 2023. Earth beyond six of nine planetary boundaries. *Sci. Adv.* 9 (37). <https://doi.org/10.1126/sciadv.adh2458>.
- Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Hueneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Global biodiversity scenarios for the year 2100. *Science* 287 (5459), 1770–1774. <https://doi.org/10.1126/science.287.5459.1770>.
- Scholten, B., 2017. Why finance should care about ecology. *Trends Ecol. Evol.* 32 (7), 500–505. <https://doi.org/10.1016/j.tree.2017.03.013>.
- Seidl, A., Cumming, T., Arlaud, M., Crossett, C., van den Heuvel, O., 2024. Investing in the wealth of nature through biodiversity and ecosystem service finance solutions. *Ecosyst. Serv.* 66, 101601. <https://doi.org/10.1016/j.ecoser.2024.101601>.

- Shah, S.S., Murodova, G., Khan, A., 2024. Achieving zero emission targets: the influence of green bonds on clean energy investment and environmental quality. *J. Environ. Manag.* 364, 121485. <https://doi.org/10.1016/j.jenvman.2024.121485>.
- Sharma, G.D., Sarker, T., Rao, A., Talan, G., Jain, M., 2022. Revisiting conventional and green finance spillover in post-COVID world: evidence from robust econometric models. *Glob. Financ. J.* 51, 100691. <https://doi.org/10.1016/j.gfj.2021.100691>.
- Sohag, K., Sokolova, Y., Vilamova, S., Blueschke, D., 2023. Volatility transmission from critical minerals prices to green investments. *Res. Policy* 82, 103499. <https://doi.org/10.1016/j.resourpol.2023.103499>.
- Sohag, K., Islam, M.M., Hammoudeh, S.M., 2024. From Policy Stringency to Environmental Resilience: Unraveling the Dose-Response Dynamics of Environmental Parameters in OECD Countries. Working Paper. <https://doi.org/10.2139/ssrn.4607562>.
- Su, Y.H., Rizvi, S.K.A., Umar, M., Chang, H., 2023. Unveiling the relationship between oil and green bonds: Spillover dynamics and implications. *Energy Econ.* 127, Part A, 107043. <https://doi.org/10.1016/j.eneco.2023.107043>.
- Taghizadeh-Hesary, F., Phoumin, H., Rasoulizhad, E., 2023. Assessment of role of green bond in renewable energy resource development in Japan. *Res. Policy* 80 (1), 103272. <https://doi.org/10.1016/j.resourpol.2022.103272>.
- Tamula, K.E., Navidad, N.C., Peregrino, T.D., Abing, M.J.J., Teves, M.R., Capulong, C., Laygan, R.M., 2024. The effect of green bonds on natural capital protection: worldwide evidence. *J. Econ. Res Soc. Sci.* 8 (2). <https://doi.org/10.18196/jerss.v8i2.21604>.
- Tan, Y., Zhu, Z., 2022. The effect of ESG rating events on corporate green innovation in China: the mediating role of financial constraints and managers' environmental awareness. *Technol. Soc.* 68, 101906. <https://doi.org/10.1016/j.techsoc.2022.101906>.
- Tariq, A., Hassan, A., 2023. Role of green finance, environmental regulations, and economic development in the transition towards a sustainable environment. *J. Clean. Prod.* 413, 137425. <https://doi.org/10.1016/j.jclepro.2023.137425>.
- Tiwari, A.K., Abakah, E.J.A., Yaya, O.S., Appiah, K.O., 2023. Tail risk dependence, comovement and predictability between green bond and green stocks. *Appl. Econ.* 55 (2), 201–222. <https://doi.org/10.1080/00036846.2022.2085869>.
- Tolliver, C., Keeley, A.R., Managi, S., 2020. Policy targets behind green bonds for renewable energy: do climate commitments matter? *Technol. Forecast. Soc. Chang.* 157, 120051. <https://doi.org/10.1016/j.techfore.2020.120051>.
- United Nations Environment Programme (UNEP), 2022. *The State of Finance for Nature in the G20: Leading by example to close the investment gap*.
- Voskoboynik, D.M., Andreucci, D., 2022. Greening extractivism: environmental discourses and resource governance in the 'Lithium triangle'. *Environ. Plan. E: Nat. Sp.* 5 (2), 787–809. <https://doi.org/10.1177/25148486211006345>.
- Waldron, A., Miller, D.C., Redding, D., Mooers, A., Kuhn, T.S., Nibbelink, N., Roberts, J. T., Tobias, J.A., Gittleman, J.L., 2017. Reductions in global biodiversity loss predicted from conservation spending. *Nature* 551, 364–367. <https://doi.org/10.1038/nature24295>.
- Wang, Y., Taghizadeh-Hesary, F., 2023. Green bonds markets and renewable energy development: policy integration for achieving carbon neutrality. *Energy Econ.* 123, 106725. <https://doi.org/10.1016/j.eneco.2023.106725>.
- Wang, W.Z., Liu, L.C., Liao, H., Wie, Y.M., 2021. Impacts of urbanization on carbon emissions: an empirical analysis from OECD countries. *Energy Policy* 151, 112171. <https://doi.org/10.1016/j.enpol.2021.112171>.
- Wei, P., Qi, Y., Ren, X., Gozgor, G., 2023. The role of the COVID-19 pandemic in time-frequency connectedness between oil market shocks and green bond markets: evidence from the wavelet-based quantile approaches. *Energy Econ.* 121, 106657. <https://doi.org/10.1016/j.eneco.2023.106657>.
- Welter, F., Smallbone, D., 2011. Institutional perspectives on entrepreneurial behavior in challenging environments. *J. Small Bus. Manag.* 49 (1), 107–125. <https://doi.org/10.1111/j.1540-627X.2010.00317.x>.
- Wojewska, A.N., Staritz, C., Tröster, B., Leisenheimer, L., 2024. The criticality of lithium and the finance-sustainability nexus: supply-demand perceptions, state policies, production networks, and financial actors. *Extr. Ind.Soc.* 17, 101393. <https://doi.org/10.1016/j.exis.2023.101393>.
- World Economic Forum, 2021. What is 'nature positive' and why is it the key to our future? <https://www.weforum.org/agenda/2021/06/what-is-nature-positive-and-why-is-it-the-key-to-our-future/> (accessed 19 September 2024).
- Xia, T., Ji, Q., Zhang, D., Han, J., 2019. Asymmetric and extreme influence of energy price changes on renewable energy stock performance. *J. Clean. Prod.* 241, 118338. <https://doi.org/10.1016/j.jclepro.2019.118338>.
- Ye, X., Rasoulizhad, E., 2023. Assessment of impacts of green bonds on renewable energy utilization efficiency. *Renew. Energy* 202, 626–633. <https://doi.org/10.1016/j.renene.2022.11.124>.
- Yousaf, I., Mensi, W., Vo, X.V., Kang, S.H., 2024. Dynamic spillovers and connectedness between crude oil and green bond markets. *Res. Policy* 89, 104594. <https://doi.org/10.1016/j.resourpol.2023.104594>.
- Zhang, N., Yu, K., Chen, Z., 2017. How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. *Energy Policy* 107, 678–687. <https://doi.org/10.1016/j.enpol.2017.03.072>.
- Zhou, X., Tang, X., Zhang, R., 2020. Impact of green finance on economic development and environmental quality: a study based on provincial panel data from China. *Environ. Sci. Pollut. Res.* 27, 19915–19932. <https://doi.org/10.1007/s11356-020-08383-2>.