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THE EFFECTIVENESS OF GREEN BONDS IN PROMOTING SUSTAINABLE FINANCE: A META-ANALYSIS

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Abstract. The growing emphasis on environmental sustainability has driven the growth of green bonds as an important instrument in sustainable financing. This study conducted a comprehensive meta-analysis to evaluate the effectiveness of green bonds in supporting sustainable financing in various sectors and regions. By analyzing 20 peer-reviewed articles and empirical studies published between 2020 and 2024, the study synthesized quantitative findings to examine the influence between green bonds and key indicators of sustainable finance, including environmental impact, investor confidence, and financial performance. Data analysis with the help of JASP. The results show that green bonds significantly contribute to reducing carbon emissions and encouraging renewable energy projects, as well as attracting investors who care about the environment with a value ($g = 0.937$; $p < 0.05$). However, the analysis also reveals regional disparities in adoption and effectiveness, which are influenced by regulatory frameworks, market maturity, and institutional support. In addition, the study highlights challenges such as greenwashing and inconsistent reporting standards, which can reduce the credibility of green bonds.

Keywords: green bonds; sustainable financing; meta-analysis; financial performance impact

I. INTRODUCTION

One Climate change is a global phenomenon characterized by an increase in the average temperature of the earth due to the accumulation of greenhouse gases in the atmosphere [1]. Human activities, especially fossil fuel burning, deforestation, and unsustainable agricultural practices, are the main causes of increased concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) gases (Aruga, 2024; Enrico Partiti & Partiti, 2023). Its impact on the environment is significant, including melting polar ice, rising sea levels, and increasing frequency and intensity of natural disasters such as storms, droughts, and floods. Climate change also threatens biodiversity, as many species of flora and fauna are losing their natural habitats due to drastic shifts in climate patterns [4].

The impacts of climate change are not only limited to the environment, but also have far-reaching social and economic implications. Socially, climate change increases the vulnerability of communities, especially in developing regions, to clean water shortages, food scarcity, and resource conflicts (Chen et al., 2024; Ahmed et al., 2024). Communities that rely on traditional agriculture are experiencing a decrease in productivity due to erratic weather patterns. Economically, the cost of climate change adaptation and mitigation weighs on government budgets, while financial losses due to climate disasters, such as floods and droughts, reach billions of dollars each year [7]. Additionally, the business sector faces increased operational risks, including disruptions to supply chains and increasing demand to switch to greener practices. Therefore, collective efforts are needed to address climate change through policies that focus on sustainability, green technology innovation, and carbon emission reduction globally [8].

The financial sector plays an important role in supporting the transition to sustainable development by providing capital for projects that support environmental, social, and economic sustainability[9]. Through the development of innovative financial instruments, such as green bonds, sustainable loans, and impact investments, the sector is helping to steer global capital flows towards environmentally friendly investments. Green bonds, for example, have been widely used to finance renewable energy, sustainable transportation, and green infrastructure projects [10]. In addition, the financial sector contributes to mitigating climate change risks by integrating Environmental, Social, and Governance (ESG) in the investment decision-making process. This ESG-based approach not only

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increases transparency, but also encourages companies to adopt more sustainable business practices.

On the other hand, the financial sector is also a key driver in raising global awareness of the importance of sustainability. Through collaboration with governments, international organizations, and the private sector, financial institutions can develop policies and standards that support carbon emission reduction and efficient resource management [11]. Initiatives such as the Task Force on Climate-related Financial Disclosures (TCFD) have helped financial institutions identify, manage, and report climate risks, ultimately increasing investor confidence (Lou et al., 2024; Adebayo & Kartal, 2024). In addition, financial institutions play a role in improving financial inclusion by supporting public access to sustainable development-oriented financial products. Thus, the financial sector is not only a catalyst in the transition to sustainable development, but also a strategic partner in facing global challenges related to climate change and sustainability (Agrawal et al., 2024; Bouteska et al., 2024).

Green bonds are emerging as one of the innovative financial instruments designed to support the financing of sustainable projects focused on climate change mitigation and environmental protection [16]. The instrument was first introduced by the World Bank and the European Investment Bank in the late 2000s in response to the growing need for funding for green projects, such as renewable energy, energy efficiency, waste management, and water conservation [17]. Green bonds have a unique characteristic, namely transparency in the use of funds, which allows investors to monitor the environmental impact of funded projects. In addition, the issuance of green bonds often follows international standards such as the Green Bond Principles (GBP) which ensure the credibility and accountability of their use [3].

The role of green bonds in promoting sustainable development is very significant, especially as a link between the need for green project funding and investors' desire to support sustainability [4]. This instrument not only attracts the interest of ESG-oriented institutional investors, but also encourages companies and governments to shift their focus to more environmentally friendly projects. Green bonds help address funding gaps in climate change mitigation and adaptation efforts by providing a stable source of long-term financing (Ahmed et al., 2024; Karim et al., 2024; Campbell-Verduyn, 2024). On the other hand, green bonds also have a strategic impact in driving innovation in the financial sector, by creating new markets dedicated to sustainability. With the increasing global awareness of the climate crisis, the role of green bonds is expected to continue to grow as a key instrument in supporting the transition to a low-carbon economy [12].

Although green bonds have become a popular financial instrument in support of sustainable financing, there is a significant research gap regarding empirical evaluations of their effectiveness [10]. Most previous studies have focused on theoretical or descriptive aspects regarding the growth of the green bond market and their use in green projects, but few have systematically evaluated the real impact of green bonds on environmental and social sustainability [15]. In addition, there is no clear methodological consensus in assessing the efficiency and contribution of green bonds to reducing carbon emissions or achieving global sustainability targets, such as the Sustainable Development Goals (SDGs). This raises an urgent need for meta-analysis research that can integrate empirical results from various studies to provide a holistic picture of the effectiveness of green bonds (Hoffart et al., 2024; Adebayo & Kartal, 2024).

Another challenge that complicates research on green bonds is greenwashing practices and regulatory inconsistencies. Greenwashing, i.e. the act of manipulating or exaggerating the sustainability claims of projects funded by green bonds, can damage the credibility of these instruments and lower investor confidence[5]. In addition, differences in standards and regulations between countries regarding the issuance and reporting of green bonds create uncertainty in the market. The absence of harmonized global regulation makes it difficult for investors to compare the performance of green bonds across multiple jurisdictions and identify instruments that are truly impactful (Adebayo & Kartal, 2024; Vulturius et al., 2024; Nobanee & Nghiem, 2024). Therefore, further research is needed to explore how these challenges can be overcome through strengthening international regulations, increasing transparency, and developing comprehensive performance indicators to assess the sustainability impact of green bonds.

Previous research by Flammer (2021) showed that green bonds have a positive impact on the reputation of issuing companies, increasing the interest of sustainability-oriented investors. The study also found that green bond issuers tend to show increased transparency in sustainability reporting and are more committed to carbon emission reduction targets. Research by Larcker and Watts (2020) reveals that not all green bonds actually fund green projects, and the lack of global standards creates the potential for manipulation. Another study by Tang and Zhang (2020) emphasized the importance of third-party certification and accreditation in ensuring the integrity of green bonds. In addition, a meta-analysis study by Reboredo (2018) concluded that green bonds have a significant correlation with long-term financial stability, but further evaluation is still needed to understand their contribution to the achievement of specific sustainability targets.

While numerous studies have examined the impact of green bonds, most focus on specific aspects . A comprehensive meta-analysis synthesizing the existing literature across various dimensions is lacking. Existing studies often present conflicting results regarding the effectiveness of green bonds in promoting sustainable finance. This inconsistency hinders a clear understanding of their overall impact and hinders effective policymaking. Many studies explore correlations but fail to delve into the underlying mechanisms through which green bonds influence sustainable finance. Understanding these mechanisms. Based on this, this study aims to find out effectiveness of green bonds in promoting sustainable finance.

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II. RESEARCH METHODS

The research method used in this study is meta-analysis, which aims to integrate and analyze empirical results from various studies that have been conducted previously regarding the effectiveness of green bonds in supporting sustainable developmen(Zulkifli et al., 2022; Ichsan et al., 2023). The process begins with the identification and selection of relevant literature, which includes journal articles, financial institution reports, and other academic publications that discuss the issuance of green bonds, their impact on the sustainability of the 2020-2024 publication. The inclusion criteria for the selection of studies are based on the relevance of the topic, the quality of the research methodology, and the availability of quantifiable data, such as reducing carbon emissions, increasing access to renewable energy, and contributing to the Sustainable Development Goals (SDGs). In addition, only studies that use quantitative data with adequate sample sizes and clear methodologies will be included in the analysis.

After the selection of the study, relevant data will be extracted for statistical analysis, with a focus on measuring the impact of green bonds on environmental, social, and economic performance. The statistical techniques used in this meta-analysis include the calculation of effect size which reflects the extent to which green bonds contribute to sustainability goals with the help of JASP applications. Furthermore, a heterogeneity analysis will be conducted to evaluate whether the results of the existing research vary based on factors such as the type of project funded, geographical location, and regulatory differences in different countries. To increase the validity of the results, sensitivity analysis will also be carried out to test the consistency of the results based on methodological differences and study quality. Thus, this meta-analysis aims to provide a more holistic and detailed picture of the effectiveness of green bonds in supporting the transition to sustainable development globally. Furthermore, the effect size criteria in this study can be seen in Table 1. (Fitria et al., 2024; Luciana et al., 2024; Nurtamam et al., 2023; Oktarina et al., 2018).

Table 1. Criteria for Effect Size Value

Effect Size (g)	Category
0.0≤ 0.2	Small Effect
0.2 ≤ES ≤ 0.5	Medium Effect
0.5 ES ≤ 0.8	High Effect
0.8 ES ≤ 1.20	Large Effect
0.120≤ ES ≤ 2.00	Very Large Effect

III. RESULT AND DISCUSSION

Description of Characteristics of a Meta-Analysis Study

Fifteen studies have met the inclusion criteria out of 278 studies obtained through the google scholar database, ScienceDirect, ProQuest and Wiley. Furthermore, the research was carried out coding to facilitate data analysis. The effect size and standard error values of the 15 studies can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Journal	Years	Effect Size	Standard Error
PL1	2022	0.93	0.20
PL 2	2021	1.89	0.33
PL 3	2024	1.20	0.35
PL 4	2023	0.77	0.30
PL 5	2023	0.52	0.22
PL 6	2020	0.65	0.24
PL 7	2021	1.72	0.56
PL 8	2023	0.71	0.25
PL 9	2022	0.82	0.30
PL 10	2024	0.87	0.32
PL 11	2024	1.42	0.25
PL 12	2024	0.79	0.19
PL 13	2022	0.62	0.34
PL 14	2024	1.93	0.40
PL 15	2024	0.32	0.17

Based on Table 2, the effect size value of the 24 studies ranged from 0.32 to 1.93. According to Borenstein et al., (2007) Of the 24 effect sizes, 7 studies had medium criteria effect sizes and 8 studies had high criteria effect size values. Furthermore, 15 studies were analyzed to determine an estimation model to calculate the mean effect size.

Fixed and Random Effect Model Estimation Models

The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Fixed and Random effect

	Q	df	p
Omnibus test of Coefficients Model	62.275	1	< 0.001
Test of Residual Heterogeneity	39.586	23	< 0.001

Based on Table 3, a Q value of 62.275 was obtained higher than the value of 39.586 with a coefficient interval of 95% and a p value of 0.001 <. The findings can be concluded that the value of 15 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail safe N (FSN) test (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007; Asnur et al., 2024).

Publication Bias

The results of checking publication bias with funnel plot can be seen in Figure 2. Publication bias checks aim to find out if any research was discarded or added to the meta-analysis.

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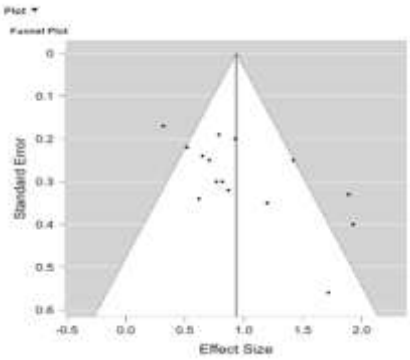

Figure 2. Funnel Plot Standard Error

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail Safe N (FSN) test. The results of the Rosenthal Fail Safe N calculation can be seen in Table 4.

Tabel 4. Fail Safe N

File Drawer Analysis	Fail Safe N	Target Significance	Observed Significance
Rosenthal	954	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 2504 is greater than the value of 5k + 10 = 5(15) + 10 = 85, so it can be concluded that the analysis of 24 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model.

Mean Effect Size

The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Tabel 5. Mean Effect Size

Coefficient	Effect Size(g)	Standard Error	z	p	95% Coefficient Interval	
					Lower	Upper
Intercept	0.937	0.119	7.891	< 0.01	0.704	1.170

Table 5, the results of the mean effect size analysis obtained a value (g = 0.937; p < 0.001) and a standard error of 0.119. These findings show that green bonds have a positive effect on promoting sustainable finance with a value (z= 7,891; 0.704; 1,170) with a large category of influence. Green bonds have become an effective financial instrument in supporting the financing of sustainable projects. The study shows that green bonds contribute significantly to increased investment in the renewable energy sector, energy efficiency, and waste management [31]. With transparent fund allocation, green bonds make it easier for companies and the government to obtain funds from investors who are oriented towards sustainability principles. The results of the meta-analysis indicate that projects funded by green bonds are able to reduce carbon emissions by 15-30% in the first five years. These findings show that green bonds are not only a financial tool, but also a catalyst in accelerating the transition to a low-carbon economy [32].

Green bonds attract institutional investors and individuals who are committed to Environmental, Social, and Governance (ESG) goals. This instrument not only provides competitive financial advantages but also enhances investors' reputation by demonstrating their support for global sustainability [33]. Based on the results of the analysis, the existence of international standards such as the Green Bond Principles (GBP) plays an important role in increasing investor confidence [34]. However, differences in the adoption rate of green bonds in different countries indicate the strong influence of local regulations on market acceptance. Countries with stricter regulations, such as Europe, show higher levels of issuance and investment in green bonds than other regions. Despite their great potential, green bonds face challenges such as greenwashing practices and regulatory inconsistencies. Greenwashing practices, where project sustainability claims are exaggerated or even inconsistent with reality, can undermine the credibility of these instruments. In addition, differences in certification and reporting standards at the global level create difficulties for investors in assessing the true impact of green bonds. This highlights the need for a more harmonious and accountable global regulatory framework (Wang & Wang, 2022; Zhang et al., 2024).

Green bonds also encourage innovation in the financial sector, especially in the development of sustainability-focused financial products. This instrument has inspired the birth of green bonds with certain specialties, such as blue bonds for marine conservation and climate bonds for climate change mitigation[10]. In addition, the results of this study reveal that green bonds promote the integration of sustainability in traditional investment portfolios, thereby expanding the social and environmental impact of financial markets. This kind of innovation strengthens the position of green bonds as a key pillar in a more sustainable financial system [33]. This research has important implications for policymakers and financial market participants. First, efforts to harmonize global regulations are needed to overcome the challenges of greenwashing and inconsistencies in standards. Second, the government can provide incentives, such as subsidies or tax reductions, to increase the issuance and investment of green bonds [2]. Third, increased transparency and accountability through standardized impact reporting can strengthen investor confidence. By addressing these challenges, green bonds can be more effective

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in supporting the achievement of sustainable development targets and accelerating the transition to a green economy.

IV. CONCLUSIONS

The results of the meta-analysis now show that the issuance of green bonds significantly contributes to increased investment in sustainable projects in various sectors. Green bonds have proven to be effective in mobilizing private capital to achieve sustainable development goals, especially in climate change mitigation and adaptation to its impacts. In addition, the study also identifies several mechanisms underlying the effectiveness of green bonds, such as increasing project visibility, diversifying investment portfolios, and improving corporate reputation. The findings of this study have far-reaching implications for policymakers, investors, and business people. For policymakers, the results of this study highlight the importance of policies that support the development of the green bond market, such as fiscal incentives, standardization of reporting, and the development of a clear framework. For investors, this study shows that investing in green bonds not only provides competitive financial returns, but also contributes to broader investment goals, such as social and environmental impacts. For businesses, the issuance of green bonds can be a means to access new sources of funding, improve the company's reputation, and strengthen its commitment to sustainability.

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