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Impact Analysis of Green Bond Issuance on Carbon (CO₂) Emissions: Green Finance Transformation in Developed and Developing Countries

ABSTRACT

This study investigates whether green bond issuance affects carbon emissions in developed and developing countries, an important aspect of climate change mitigation. Empirical evidence remains limited due to short time-series data. Using the Generalized Method of Moments (GMM), the study analyzes dynamic panel data from 16 countries between 2016 and 2021. The findings indicate that green bond issuance significantly reduces carbon emissions in both developed and developing countries, with higher issuance associated with lower emissions. However, the impacts differ across country groups. In developed countries, the benefits of green bonds, including greenium, are mainly captured by large, investment-grade issuers in the banking sector. In contrast, developing countries face challenges such as weak institutional frameworks, minimum issuance volume requirements, and high transaction costs. To enhance the effectiveness of green bonds, governments should address these barriers while improving supporting facilities and infrastructure to accelerate the transition toward a green economy

Kata kunci: Green bonds, carbon emissions, GMM, developed and developing countries
Klasifikasi JEL: O16; G32; Q52; Q54; Q56

INTRODUCTION

A green bond is a debt instrument issued to support environmental projects aiming to mitigate the impact of climate change (World Bank, 2015). Mobilizing climate finance contributes to the mitigation of global warming of up to 1.5°C. Therefore, green bond issuance increases every year, along with awareness about the impact of climate change. Climate Bonds Market Intelligence noted that, in 2021, global green bond issuance set a record at USD 517.4 billion, the highest figure since the

first issuance ten years prior. Amounting 517 billion dollars, green bonds are key in driving financial innovation and sustaining the economy (Ehlers & Packer, 2017; Baker et al., 2018; Zerbib, 2019).

Bond issuance is highly technical and complex, involving different regulatory frameworks, limited traceability and auditability, the risk of settlement failures, and mutual stakeholder distrust. In addition, third-party verification is required to qualify a bond as 'green' to ensure that the fund

proceeds are spent on environmentally beneficial projects (Malamas et al., 2023). The issuance is also influenced by government policies and incentives that support decarbonization efforts. For example, Singapore has implemented policies to subsidize the cost of issuing green bonds, thus encouraging first-time bond issuers to enter the market (Xu, 2020). Aside from that, it is imperative to guarantee that green bond funds are spent on projects that actually contribute to the reduction of carbon emissions. These green projects can be located in developed or developing countries. Projects from the forestry sector in developing countries are particularly important as they contribute significantly to global carbon emissions (IPCC, 2023). Insufficient reporting and a lack of transparency regarding the use of funds can result in losses, which affect the environmental impact of the projects funded through green bonds. Therefore, evaluating the environmental impact of projects funded through green bonds is imperative. A project is considered successful if it has environmental benefits, such as renewable energy (CBI,

2023). The fundamental question is whether green bond issuance impacts carbon emissions in developed and developing countries.

In developing countries, access to affordable financing for environmental projects is a major issue. Green bonds can provide a solution as they attract capital from domestic and international investors, but other obstacles prevent widespread green bond adoption (World Bank, 2019). These include the low awareness and understanding of green finance, lack of capacity and expertise in issuing green bonds, and the lack of supportive regulatory frameworks. To overcome these barriers, technical assistance, capacity building, and policy support are needed, which requires collaboration between governments, financial institutions, and international organizations (IFC, 2018). Indonesia is a developing country that has issued green bonds to fund renewable energy projects, sustainable agriculture, and waste management initiatives (World Bank, 2018). Other countries, such as Brazil, India, and China, have also used green bonds to finance sustainable

development goals (SDGs) as they can attract investment, stimulate economic growth, and address environmental challenges (CBI, 2021)

By contrast, developed countries are one step ahead in driving the growth of the green bond market. Through robust frameworks, standards, and policies, developed countries have created an environment that supports green bond issuance (European Commission, 2021). They have also established standards and certifications of green bonds to increase transparency and credibility in the market. For example, the Climate Bonds Initiative has developed the Climate Bond Standard, which provides guidelines for issuers to demonstrate the environmental integrity of their green bonds. This standard helps investors identify green bonds that meet certain environmental criteria (CBI, 2021).

Green bond issuance requires strict reporting and transparency to guarantee the proper use of the funds and the project's environmental impact. This enables monitoring and evaluation

of the impact of green bond issuance on carbon emissions. Green bond issuers are expected to report the environmental performance and the impact of funded projects regularly. However, in the UN Report at the COP 27 Climate Conference, many European developed countries were found to have manipulated the recording data. The environmental, social, and corporate governance (ESG) standards are relatively new, so many entities greenwash their images, glossing over their promotional practices that protect the environment. For example, they claim a large allocation of funds to portray an image of a 'green' organization with eco-friendly practices. This greenwashing can distort the information about projects funded by green bonds, misleading investors and other stakeholders. Greenwashing may also occur in the context of green bond issuance. For example, an issuer may make misleading or inaccurate claims about the use of funds generated from the issuance of a green bond or the environmental impact of projects funded by green bonds. Such a practice can

damage investors' and the public's confidence in green financial instruments, undermining the integration of the entire green financial markets.

Climate finance tends to flow more to countries with a better capacity to deal with climate change, depriving the most climate-vulnerable countries (Cheng et al., 2022). These climate-vulnerable countries need to receive more climate funding and invest more in green technologies and infrastructure. Governments worldwide must transform and future-proof their economies by driving inclusive and sustainable growth and creating green jobs and investment opportunities. Past research has examined whether green bonds make a difference in bond yields and green bond prices. However, a holistic picture of the impact of bond issuance remains to be seen. Questions that have yet to be answered include (1) what attracts investors and issuers to the green bond market, (2) to what extent the financial incentives, business cases, or institutionalization explain engagement with the green bond market, and (3)

whether countries in the green bond market view green bonds as an important tool to shift capital from less sustainable investments to more sustainable ones (Ehlers & Packer, 2017; Baker et al., 2018; Zerbib, 2019).

The relationship between the issuance of green bonds and carbon emissions results in a mechanism that reduces carbon emissions. This mechanism varies depending on factors such as government policies, financial market conditions, and available infrastructure. Green bond issuance provides a specific source of funding for projects that contribute to carbon emission reduction, such as renewable energy generation, energy efficiency, sustainable transportation, or waste management. In other words, the issuance of green bonds encourages the development and implementation of projects that can reduce carbon emissions both at the firm and sectoral levels. This can be supported by accurate and transparent reporting, which increases the accountability and effectiveness of green bond issuance in reducing carbon emissions.

With the advancement of research in recent years, the green bond approach has become a central instrument in financing investments aiming to achieve SDGs at the global level. Some studies explore the factors that affect the loan size (Chiesa & Barua, 2019; Azhgaliyeva et al., 2020). Others examine the trend in different states of the economy. For example, Josué Banga (2018) points out a rise in green bonds in both developed and developing countries. However, the lack of proper institutional arrangements for green bond management, minimum issuance volumes, and high transaction costs associated with green bond issuance have become major obstacles to green bond development in developing countries. To overcome this challenge, local governments should provide guarantees to local green bond issuers aiming to cover transaction costs associated with the issuance (Banga, 2019)

The challenges and potential of climate change are likely to exacerbate in the future. Effective governance is needed for the management, but data shows that governance and integrity of

records have been suboptimal. Therefore, examining the impact of green bond issuance is crucial because it can contribute to emission reduction and climate change mitigation. Transparency reporting includes the use of funds and the environmental impact achieved, which reflects corporate accountability regarding carbon emission reductions. In addition, information about the environmental impact of green bonds can increase investor confidence, which encourages funds to be allocated to sustainable projects (Claes, 2019; Bose et al., 2018; Östermark, 2020; Wang, 2021), allowing for the development of green financial markets.

Carbon emissions continue to increase yearly, exacerbating the impact of climate change. Therefore, funding to support green sustainable development is increasingly needed. Green bonds offer a new approach to funding environmental projects and driving sustainable development, providing investors an avenue to support green initiatives and accelerate the transition to a greener economy. This study examines the green bond yield in various countries

by examining its issuance impact on the economic transformation. While past studies have observed the development of the green bond market in developed countries, the markets in developing countries have not been fully explored. Hence, their full potential remains underappreciated. According to the Climate Bonds Initiative (2016), only USD 2.2 billion of total flows in the green bond market have been directed towards cities in developing countries, compared to USD 17 billion in developed countries.

This research introduces the idea that Against this backdrop, the current study analyses the impact of green bond issuance on carbon emissions in developed and developing countries. Reporting on the use of green bonds varies in each country because there is no existing standard. Therefore, it is important to fill in this knowledge gap research the specific factors related to green bond issuance that contribute to the reduction of carbon emissions. In addition, there is only limited empirical evidence on the impact of green bond issuance on carbon emissions in developed and developing countries.

Findings in previous studies are also inconclusive, depending on the period and characteristics of the intervention in the study locations. This research aims to fill this gap, hypothesizing that the issuance of green bonds can reduce carbon emissions both in developed and developing countries.

This research gives new contribution for the previous literatures. This study uses data on green bond issuance in developed and developing countries from 2016 to 2021 as an independent variable. The data include carbon emissions, green bond data, renewable energy electricity use, inflation growth and population in developed and developing countries. This research introduces the idea that The estimation results using the Generalized Method of Moments (GMM) show that green bond issuance significantly reduces carbon emissions in both developed and developing countries. The main contribution of this study research to studies of the impact of green bond issuance on economic transformation. They also provide policy recommendations and best practices for

green bond issuers and other stakeholders to reduce carbon emissions further. These recommendations may include measures to improve transparency, accountability, and effective use of green bond funds in order to promote the growth of the green bond market.

Green finance refers to financial products and services that support sustainable and environmentally friendly projects and activities. It covers various forms of financing, including green bonds, green loans, and green investment funds (Liu et al., 2022). Green finance is vital in tackling climate change and driving the transition to a low-carbon and sustainable economy (Ng & Zheng, 2018). One of the main instruments in green finance is green bonds, debt securities whose proceeds are used exclusively to finance or refinance environmentally friendly projects with a positive impact on the environment (Wang & Zhi, 2016). These projects may include renewable energy, energy efficiency, sustainable transportation, and climate adaptation initiatives.

At its inception in the Paris Agreement, green finance did not have standard ESG guidelines for bond funding. However, green bonds have gained significant traction recently, with a record-high issuance of USD 550 billion in 2020 (CBI, 2021). Since green bonds have stricter disclosure requirements than conventional bonds, transparency and accountability in the use of funds are guaranteed. This makes green bonds attractive to investors who prioritize environmental sustainability and seek to align their investments with their values (Löffler et al., 2021). In addition, the aims of green bonds align with SDGs, e.g., achieving affordable and clean energy, sustainable cities and communities, and climate action (CBI, 2021).

The market has grown steadily since its introduction in 2006, with more private entities issuing corporate green bonds. Measuring green finance involves assessing the volume and impact of finances allocated to green projects. One commonly used metric is the size of the green bond market. According to the Climate Bonds Initiative, the global green bond market reached a record high

of USD 1.65 trillion in 2021, which indicates the amount of capital mobilized for green projects. Other measures in green finance include tracking investments in renewable energy, energy efficiency, sustainable infrastructure, and other sectors that benefit the environment. These measurements can be made at the national, regional, or global level to assess the progress and impact of green finance initiatives. However, it is important to note that measuring the impact of green finance is not only measuring financial flows but also evaluating the environmental outcomes and sustainability performance of the financed projects and activities. This can be assessed through various frameworks and standards, such as the Green Bond Principles and SDGs, which focus on green finance initiatives' environmental and social impacts (Gabr & Elbannan, 2023).

According to the World Bank (2015), green bonds are debt instruments that raise specialized capital to support climate-related environmental projects. First incepted in 2007, green bonds have grown at a compound annual growth

rate of over 50%, funding environmental projects worldwide (Kochetygova & Jauhari, 2014). Green Bond's Market Summary shows that green bond sales rose to USD 25.8 billion in the first quarter of 2018 (CBI, 2018). The Green Bond Principles developed by the International Capital Market Association (ICMA) provide guidelines and frameworks for issuing and evaluating green bonds. These documents can provide insight into the contribution of green finance to the reduction of carbon emissions. Green finance also involves the adoption of rigorous standards and certifications to ensure that funded projects meet established environmental criteria. This standard involves environmental impact assessment, measurement of carbon emissions, and transparent reporting. This enables monitoring and evaluation of carbon emissions reduced by green-financed projects.

Through the issuance of green bonds or other sustainable finance instruments, green finance can raise funds from investors interested in sustainable projects. The funds can

finance projects that minimize carbon emissions and accelerate environmental recovery. Likewise, financial support for clean technology's research and development and innovation can promote innovation in green technologies, making it more efficient in reducing carbon emissions in various sectors, such as energy, transportation, and industry. In addition, green finance can also change public behaviour and awareness regarding the importance of reducing carbon emissions. Through campaigns and information related to projects funded by green finance, communities can be more aware of their environmental impact and motivated to adopt a more sustainable lifestyle. Despite the importance of green finance, developing countries still have lower climate finance resources. They need funding for the adaptation of policies to mitigate the impact of climate change.

The Climate Bonds Initiative's database shows that only limited investors and governments in developing countries have issued green bonds. Nevertheless, their participation in guarding the market has been

increasing. The rising trend in the green bond market could be attributed to two factors. The first is the increasing understanding of the link between climate change and financial stability among investors and policymakers (Carney 2016; TCFD 2017), which has led to the adoption of preventive measures, such as assessing financial institutions' exposure to climate risks (Battiston et al., 2017; Mercer, 2015). The assessment aims to examine the financial system's resilience to climate change's impacts. Investors are urged to move from a shareholder model that focuses on profit maximization alone to a stakeholder model that aims to create not only financial but also social and environmental values (Schoenmaker, 2017). This financing impact will work if investment products appeal to investors with a substantial asset base (Reichelt, 2010). Globally, the spending of corporate debt financing on investment products such as green bonds has been surging as it is purposeful financing for global climate mitigation and the achievement of SDGs.

LITERATURE & RESEARCH METHOD

This research uses cross-sectional secondary data from 16 countries, including both developed and developing countries. Meanwhile, time series are data related to the time period to be studied, i.e., from 2016 to 2021. The independent variable in this study is the issuance of green bonds, a standard measure describing the level of financial bonds for green economic development. Green bond issuance has been found to have several effects. The first concerns the advantages of borrowing costs for issuers, with green bonds having lower yield spreads than conventional bonds (Mensi, 2022; CBI, 2022). However, empirical evidence on its direct macro-level impact on carbon emissions remains limited, particularly in a comparative developed-developing country context and under short time-series constraints. This constitutes an important empirical gap, as most prior studies focus on firm-level outcomes or single-country analyse. These gains are related to demand pressures and bond index inclusion (Caramichael, 2022).

Next, green bond issuance can also promote green innovation, contributing to carbon emissions by optimizing resources and efficiency mechanisms. (Fatica, 2021). Green bonds also play a role in financing the transition to a low-carbon economy and driving sustainable growth. This is because the issuance of green bonds has a positive impact on a company, including share price, profitability, operational performance, innovation capacity, and corporate social responsibility (Sartzetakis, 2019).

Accordingly, the primary objective of this study is to empirically examine the impact of green bond issuance on carbon (CO₂) emissions while accounting for macroeconomic and demographic factors, including inflation growth, renewable electricity use, and population size. By applying the Generalized Method of Moments (GMM) to dynamic panel data, this study contributes to the literature by addressing endogeneity concerns and capturing the dynamic relationship between green finance and emissions reduction.

Meanwhile, the control variables used in this study are inflation growth, renewable fuel electricity use, and population size. The issuance of green bonds significantly impacts emission reduction, with the issuance volume influenced by, among others, inflation rates and population (Anamaria, 2021). The development of green bond markets can provide a financing source for renewable energy projects and increase renewable energy capacity (Dragica, 2020). The development of the green bond market is also influenced by population size, with highly populated countries often having higher volumes of green bond issuance (Kostiantyn, 2022).

The green bond data used are issuers of green bonds sourced from Bloomberg data reports. The size of the bond issuance is measured in billion USD. The annual data on electricity use from renewable energy is sourced from Ourworlddata and measured in Terra Watt hour (TWh). Data on the annual percentage rate of inflation is sourced from the World Bank, measured by the annual growth rate of GDP, with an implicit deflator showing the rate of

price change in the economy. Annual data on population is sourced from the World Bank, measured in annual percentage of total population, and is based on the de facto definition of population, counting all residents.

Methodologically, this research extends prior studies by applying both difference and system GMM estimators to a multi-country dataset with limited time dimensions. From a policy and industry perspective, the findings provide evidence-based insights for governments, regulators, and financial institutions on how green bond market development can support climate mitigation strategies and the transition toward a low-carbon economy, particularly in developing countries facing institutional and market barriers. The analytical technique used in this study is the GMM method to analyze the relationship between green bonds and carbon emissions. Based on the theoretical foundation, carbon emissions are affected by the issuance of green bonds. Where $C02_{it}$ is a carbon emission for country 1 in year t . Then $GBit$ is a green bond for country 1 in year t . ε . To

see the effect of green bond issuance on carbon emissions in each period, the

Independent variable was added so that the model built in this study is:

$$CO_{2it} = \delta CO_{2t-1} + \beta_1 GB_{it} + \beta_2 GDPInd_{it} + \beta_3 GDPForest_{it} + \beta_4 GDPKpt_{it} + \beta_5 Population_{it} + \eta_i + \varepsilon_{it} + \xi_{it} + \lambda W u_{it} + \varepsilon_{it}$$

where $u_{it} =$

Tabel 1: Model Econometrics Analysis

No.	Variable Name	Simbol	Units	Data Source
1	CO2 gas emissions	CO2	MtCO2e Units	Our World in Data
2.	Green Bond Issuance	GB	USD (Miliar USD)	Bloomberg
3	GDP in the Industrial sector	GDPin%	Ratio %GDP industry sector	World Bank
4	GDP Forest sector	GDPForest%	Ratio %GDP Forest sector	World Bank
5	GDP per Capita	GDPcpt	GDP per Capita USD (Miliar USD)	World Bank
6	Population	Population	Total Population	World Bank

This method is commonly used in panel data analysis or time-repeating data as it can deal with endogeneity problems and bias in regression models. of green bond studies, the use of GMM can help control biases arising from unobserved variables and interplay factors between green bonds and carbon emissions to see how green bonds affect climate change. The GMM method is often used to refine the Ordinary Least Square (OLS) estimation (ArellanoBond, 1998), whose values are inconsistent and

biased due to the lag of the independent variable related to errors between the independent variables. The estimation used in the GMM method consists of two steps: the first-difference GMM (Arellano-Bond, 1998) and the GMM system. In his research, Bond (2001) stated that the first-difference GMM method is more likely to have a significant bias when the window of the observed time series is small.

RESULTS AND DISCUSSION

This study examines the impact of corporate green bond issuance on carbon emissions using a balanced panel of 16 developed and developing countries over the period 2016–2021, employing a dynamic panel data model estimated through the Generalized Method of Moments (GMM) to address potential endogeneity, unobserved country-specific effects, and the persistence of carbon emissions over time.

The empirical results indicate that green bond issuance has a statistically significant negative effect on carbon emissions, suggesting that increased corporate engagement in green bond financing contributes to the reduction of greenhouse gas emissions, and this relationship remains robust after controlling for the lagged dependent variable, thereby confirming the dynamic nature of emission behavior and the suitability of the GMM approach.

The coefficient of lagged carbon emissions is positive and significant, indicating strong emission persistence, which reflects the structural rigidity of energy systems and industrial

production patterns in both developed and developing countries and implies that environmental outcomes are heavily influenced by historical emission levels. Consequently, green bond financing should be viewed as a long-term policy instrument whose effectiveness depends on sustained and consistent implementation rather than short-term interventions.

The validity and reliability of the estimated model are further supported by diagnostic tests, as the Hansen/Sargan test confirms the appropriateness of the instrumental variables and the Arellano–Bond test shows no evidence of second-order autocorrelation, indicating that the GMM estimates are consistent and reliable.

From an economic and policy perspective, the observed negative relationship between green bond issuance and carbon emissions underscores the effectiveness of market-based financial instruments in promoting environmental sustainability, as green bonds enable corporations to mobilize capital specifically allocated to

environmentally friendly projects, including renewable energy, energy efficiency improvements, clean transportation, and sustainable infrastructure, which directly reduce emissions by lowering dependence on fossil fuels and enhancing production efficiency. While the emission-reducing effect of green bond issuance is evident across both developed and developing countries, differences in its magnitude can be attributed to variations in regulatory frameworks, financial market depth, institutional quality, and technological readiness, with developed countries generally benefiting from more mature green finance ecosystems and clearer taxonomy standards, whereas developing countries may face implementation constraints despite experiencing meaningful emission reductions.

These findings are consistent with existing literature highlighting the role of sustainable finance in achieving climate mitigation goals, particularly as green bonds provide financial incentives rather than compliance-based regulatory

pressure, thereby aligning corporate profitability with environmental responsibility and supporting the transition toward low-carbon economies. Nevertheless, the persistence of carbon emissions identified in the model suggests that green bond issuance alone is insufficient to achieve rapid and substantial emission reductions, and its effectiveness must be reinforced through complementary policies such as carbon pricing mechanisms, stricter environmental regulations, and stronger institutional support for green project verification to prevent greenwashing. Overall, this study contributes to the literature by providing robust empirical evidence using a dynamic panel GMM framework applied to a mixed sample of developed and developing countries, demonstrating that accounting for emission persistence and endogeneity yields more reliable estimates of the environmental impact of corporate green bond issuance and strengthens the case for green finance as a key component of long-term climate policy.

Tabel 2: Deskriptive Analysis

Variable	2017-2021			
	Mean	Std. Dev	Min	Max
Carbon emissions (Ln)	5.49	1.82	1.44	8.59
Green bond issuance (Ln)	20.77	1.30	16.52	24.46
Electricity from renewable energy (Ln)	3.80	2.62	-3.00	7.80
Inflation	2.51	2.26	-2.70	11.38
Population (Ln)	17.74	1.97	14.05	21.07

Table 2 shows the descriptive statistics of the variables. The average value of carbon emissions from all countries is 5.49, with the lowest average carbon emissions coming from Mauritius at 1.44 and the highest average carbon emissions in the USA at 8.59. The average green bond issuance is 20.7, with the lowest issued by Singapore at an average green bond issuance rate of 16.52 and the highest issued by the USA at 24.46. The average amount of electricity from renewable energy is 3.80, with the lowest average use in Brazil at -3.00 and the highest use in France at 7.80. The average inflation growth value was 0.77, with the lowest average inflation growth in Mauritius at -2.70 and the highest in Chile at 11.38. The average population growth value is 17.74, with the lowest average population growth in Mauritius at 14.05 and the highest population growth in China at 21.07.

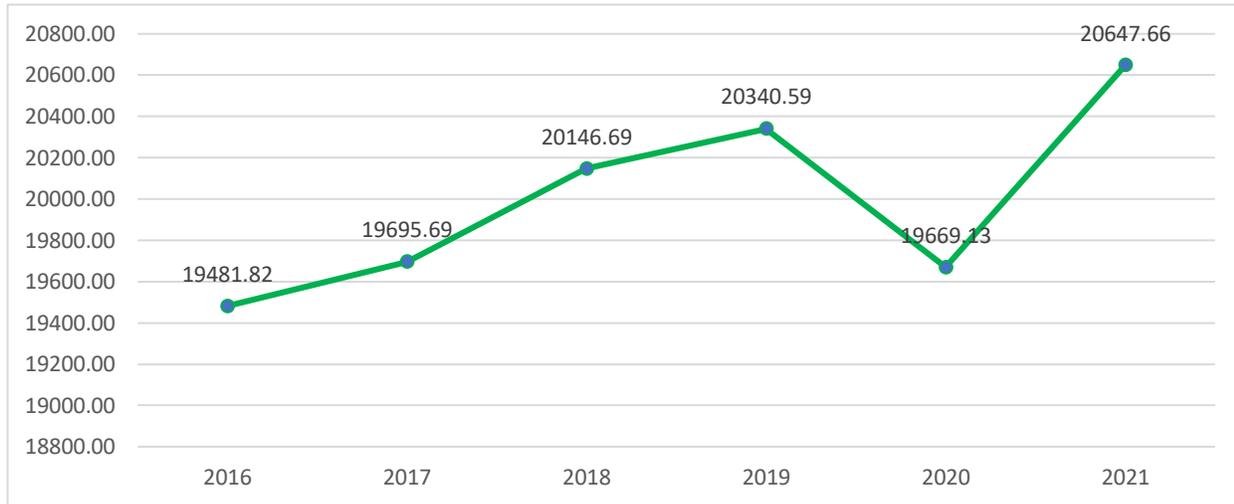
Developing countries have higher average carbon emissions than developed countries. These differences may be due to

higher levels of industrialization, lack of strict environmental regulations, or different economic levels. Stricter environmental policies may be needed in developing countries to reduce carbon emissions. International support and technology transfer can help developing countries in their efforts to reduce emissions. Carbon emissions data may not account for all emission sources. Differences in definitions and measurements between countries may influence the results. Analysis shows that developing countries have higher average carbon emissions compared to developed countries during the 2016-2021 period. This difference is statistically significant. Further studies could explore the factors causing differences in emissions and evaluate the effectiveness of emissions reduction policies in different countries. According to Ourworlddata data report (2023), over six years from 2016 to 2021, the trend of carbon emissions on the global level saw significant increases. In 2020, the trend dipped due to

the COVID-19 pandemic, but as the economy recovered, the emissions soared in 2021. In general, the USA emitted the highest

amount of carbon, followed by India, Japan, China, Germany, South Korea, and Indonesia.

Figure. 1. The trends of carbon emissions from 2016 to 2021 in MtCO₂e (in millions)



Source: Writer (2024)

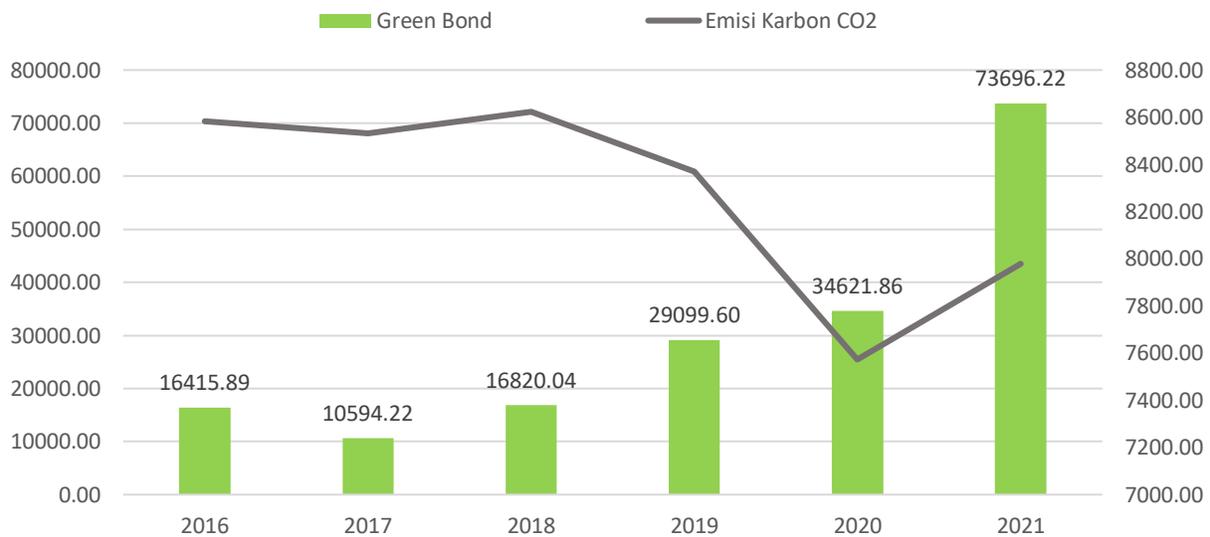
From 2016 to 2019, carbon emissions increased yearly, but the trend dipped in 2020 due to the COVID-19 pandemic. Signals of economic recovery began to be seen in 2021 in all countries. Accordingly, the average carbon emissions increased from 19669.13 MtCO₂e (in millions) in 2020 to 20647.66 MtCO₂e (in millions) in 2021. The difference in average carbon emissions between developed and developing countries highlights the importance of strategies tailored to the needs and

conditions of each country. A collaborative approach and international support are needed to achieve global emissions reduction goals. Developing countries need to develop policies and infrastructure that support green growth. Developed countries need to continue technical and financial support, as well as share knowledge and technology with developing countries. According to a report by the International Energy Agency (IEA), in 2020, carbon emissions on a global scale

decreased due to massive restrictions on community activities in response to the COVID-19 pandemic. In 2021, carbon emissions experienced positive growth for the first time since the COVID-19

outbreak. It should be noted that the trends are different between developed and developing countries in relation to green bond issuance, shown in Figure 2.

Figure 2. The Trend of Carbon Emissions and Green Bond Issuance in Developed Countries between 2016 and 2021 (in millions)



Source: Writer (2024)

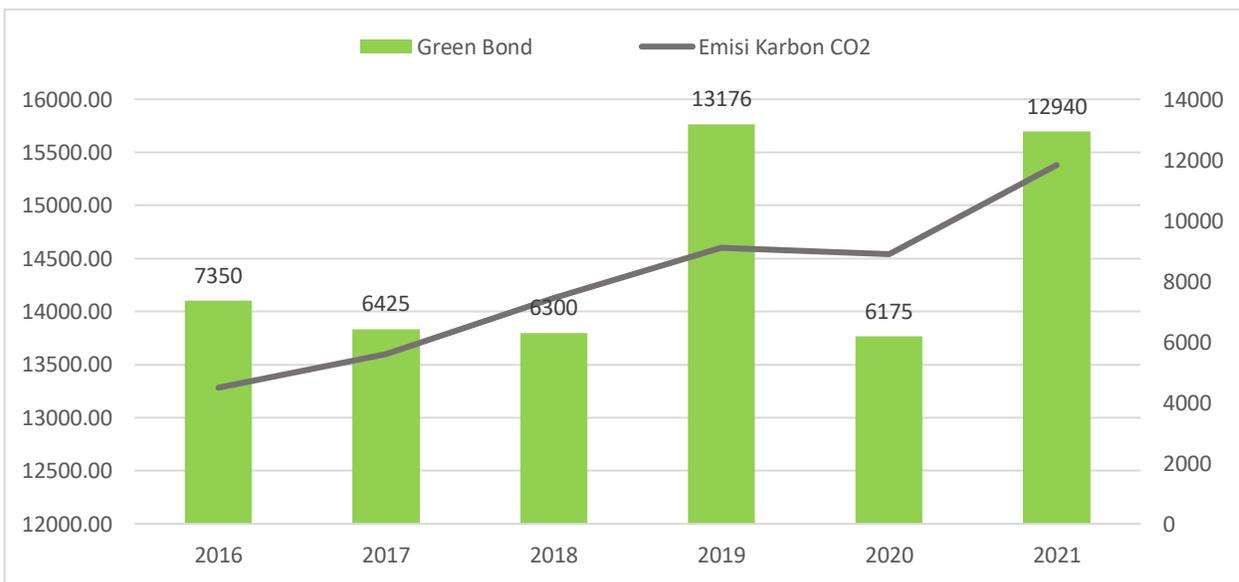
Figure 2. shows the trends of carbon emissions and the issuance of green bonds in the classification of developed countries. According to Ourworlddata (2023), carbon emissions in developed countries decreased from 2016 to 2020, indicating an environmental improvement. This trend was followed by a rising trend of green

bond issuance. The COVID-19 outbreak in 2020 reduced emissions significantly before picking up in 2021. The highest amount of carbon was emitted by the USA and the lowest by Hong Kong. It can be concluded that developed countries have succeeded in reducing their carbon emissions or keeping their emissions stable. This could be attributed

to the adoption of clean technologies, sustainable energy policies, and high awareness of environmental issues. Developed countries have switched from fossil fuel-based energy sources to renewable ones, such as wind, solar, and hydropower. This helps reduce carbon emissions from the energy sector. Regarding environmental policies, developed countries often implement

policies and regulations that support carbon emission reductions, such as carbon taxes, vehicle emission limits, and building energy efficiency standards. In terms of sustainable transportation, developed countries have invested in low-carbon vehicles, such as high-speed trains, and implemented efficient public transportation and incentives for electric cars.

Figure 3. The Trends of Carbon Emissions and Green Bond Issuance in Developing Countries from 2016 to 2021 (in millions)



Source: Writer (2024)

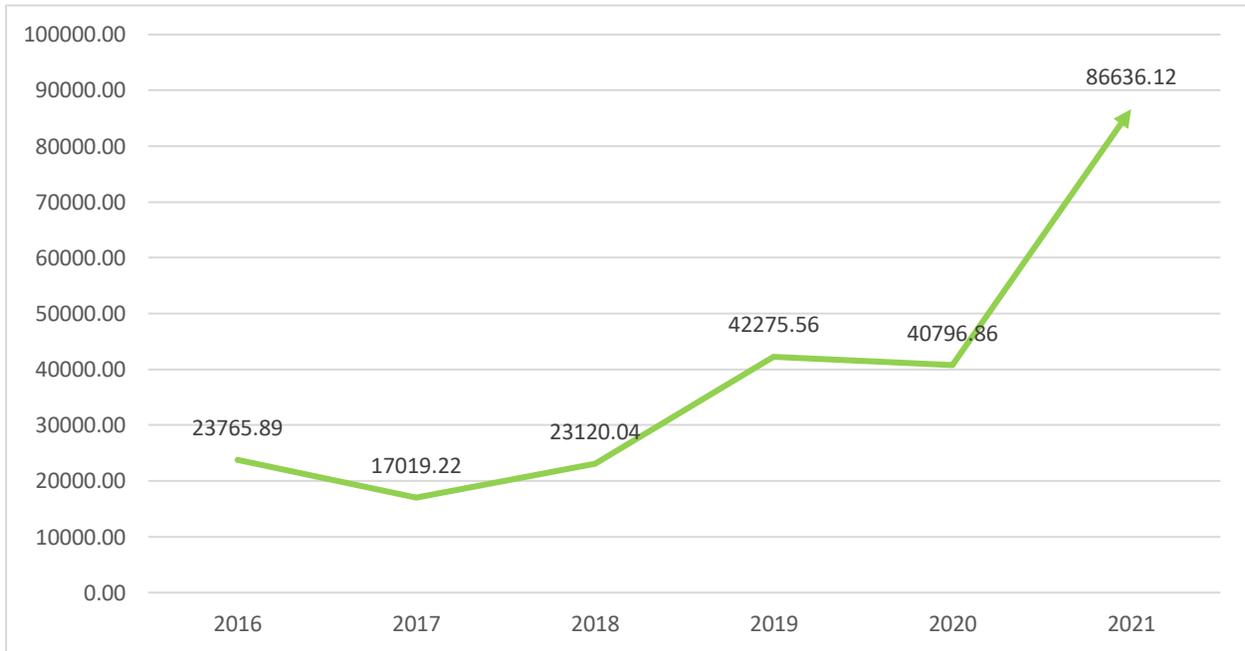
Figure 3. shows the trends of carbon emissions and the issuance of green bonds in developing countries. According to Ourworlddata (2023), the

trend increased from 2016 to 2021, indicating that developing countries continue facing climate change challenges. Accordingly, the trend of

green bond issuance remains inconsistent every year. The rising trend could be attributed to rapid economic growth and continued reliance on fossil fuels, such as coal and oil-based power plants, as a major energy source. Some

developing countries have started to use renewable energy sources to reduce carbon emissions, but the lack of infrastructure and funding remains an obstacle.

Figure 4.4. The Trend of Green Bond Issuance globally from 2016 to 2021 (USD in millions)



Source: Writer (2024)

The independent variable in this study is the issuance of green bonds, indicating the level of financial resources for green economic development. In general, the value of green bond issuance globally increased from 2016 to 2021, as

shown in Figure 4.4. The average issuance of green bonds in 2016 was 23765.89, increasing to 86636.12 in 2021. The control variables in this study are inflation growth, renewably sourced electricity use and population size. Inflation growth is a general increase in

the prices of goods and services in an economy, used as a control variable in this study to ensure that fluctuations in inflation do not affect research results related to the use of renewably sourced electricity and population size. The use of renewably sourced electricity may impact the environment and economy. Likewise, population size within a given area can affect energy consumption and electricity demand. Therefore, these two factors are relevant control variables. In 2016, the issuances in some countries, including Singapore, Japan, Chile, and Mauritius, were low. From 2016 to 2021, the USA became the country with the highest green bond issuance, with an index value of 41922.19 in 2021 (USD in millions).

Meanwhile, the country with the lowest green bond issuance was Austria. This shows that there is still a gap in green bond issuance. In 2020, the gap between the highest and lowest green bond issuance was 23845.85 (USD in millions), which widened in 2021 to 41822.19 (USD in millions).

Both developed and developing countries saw growth in green bond

issuance. However, developed countries remained leaders in terms of volume and value. Meanwhile, developing countries focus more on local environmental issues and use sustainable investment opportunities to advance their green projects. This differentiation of country categories can contribute to achieving global goals to reduce carbon emissions and promote sustainable development. In developed countries, large investment-class issuers within the banking sector primarily benefit from the greenium, i.e., the borrowing cost advantage associated with green bonds (CBI, 2022). On the other hand, developing countries face obstacles in developing green bonds, including a lack of proper institutional arrangements, minimum volume requirements, and high transaction costs (Caramichael, 2022).

This study uses the dynamic panel (GMM), combining time series and cross-sectional data, to analyze the effect of green bond issuance on encouraging green economy policies to reduce carbon emissions. The data used are green bonds, carbon emissions, inflation,

electricity from renewable energy and the country's population from 2016 to 2021.

Tabel 3: Inferential Analysis

	(1)	(2)	(3)
	All Countries	Developing Countries	Developed Countries
Green bond	-0.262*** (0.039)	-0.431*** (0.065)	-0.227*** (0.041)
EV Renewable	-0.002 (0.039)	-0.006*** (0.041)	-0.191** (0.081)
Inflation	-0.027 (0.017)	0.033* (0.016)	-0.046 (0.037)
Population	0.621*** (0.045)	0.786*** (0.069)	0.6299*** (0.044)
AR (1)	0.013	0.070	0.024
AR (2)	0.857	0.121	0.677
Sargan test of overid. Restriction	0.000	0.008	0.000
Hansen test of overid. restrictions	0.243	0.978	0.866
Hansen test GMM	0.064	0.681	0.382
Difference GMM	0.816	1.000	1.000
Hansen test iv	0.170	0.995	0.787
Difference iv	0.463	0.652	0.701
Prob > F	0.000	0.000	0.000

GMM Results Description: Standard errors in parentheses *p<0.1, **p<0.05, *** p<0.01

Source: Writer (2024)

The analysis examines the impact of green bond issuance on carbon emissions in all countries, both developing and developed countries.

Table 3 Column 1 shows the GMM regression results for the all-country model. Column 2 shows the GMM regression results for the developing country model. Column 3 shows the

GMM regression results for developed country models. The regression of the GMM shows that the influence of green bond issuance on carbon emissions in both country groups is proven statistically. The issuance of green bonds can lead to reduced carbon emissions and increased environmental involvement. Companies issuing green bonds experience a decrease in the carbon intensity of their assets, leading to emission reductions (Jin Xing Zheng, 2023; Fatica, 2021).

Green bond issuance is described as a financial bond tool for climate change, interpreted as a financial bond mechanism to finance projects with environmental benefits, including reducing carbon emissions. Green bonds have been shown to impact stock market reactions positively and can lead to improved corporate environmental performance (Caroline, 2019; Elettra Agliardi, 2019). Green bonds play an important role in financing the transition to a low-carbon economy by providing funds for large, long-term infrastructure investments. Therefore, green bonds are

instrumental in climate change mitigation (Sartzetakis, 2021).

This study found a significant relationship between the effect of green bond issuance on carbon emissions. With a significance level of 1 per cent, green bond issuance is significantly and negatively related, indicating that with a 1 per cent increase in green bond issuance in all countries, the impact of carbon emissions is reduced by 0.262 points. More specifically, the reduction in developed countries was by 0.227 points and developing countries by 0.431 points. This finding is in line with research conducted by Jin Xing Zheng (2023) and Liu et al. (2020), which shows that the issuance of green bonds significantly impacts reducing carbon emissions. This finding indicates the effectiveness of financial instruments in reducing environmental impact. The bond issuance raises funds for the implementation of green projects, such as renewable energy, energy efficiency, and sustainable transportation, which subsequently reduce carbon emissions.

Using renewable electricity by combining several sources, including

hydropower, solar, wind, geothermal, biomass, waves, and tides, can help reduce carbon emissions. In all countries, the use of renewably sourced electricity shows a negative value for carbon emissions. However, the impact of using renewable energy sources worldwide may not be significant. Clean sources, such as solar and wind power, have grown rapidly in recent decades and have contributed increasingly to the world's energy supply. However, the impact may not always be significant due to different policies, social and political climates, high initial costs and the ever-dependence on fossil energy sources. In developed countries, the use of renewably sourced electricity shows a negative relationship, with a 95 per cent confidence level in carbon emissions. This illustrates that using renewable electricity will reduce the impact of carbon emissions by 0.191 points. By contrast, in developing countries, the use of renewable electricity has a significance level of 1 per cent, significantly negatively correlated to carbon emission. This indicates an increase of 1 per cent in

renewably sourced electricity will reduce carbon emissions by 0.006 points.

This finding aligns with research conducted by Xixuan Guo (2022), which shows the use of renewable energy as a sustainable and environmentally friendly alternative to fossil fuels. It plays an important role in reducing carbon emissions and mitigating climate change. By switching from fossil fuel-based energy to renewable energy, countries can reduce their dependence on carbon-intensive energy production and reduce greenhouse gas emissions. Renewable energy consumption can also help narrow the gap between production-based and consumption-based carbon emissions, especially in net emissions exporters. This suggests that renewable energy sources can contribute to more sustainable and balanced patterns of carbon emissions in global value chains. Overall, renewable energy is a key component in the transition to low-carbon and sustainable energy systems, and its adoption must be prioritized to mitigate climate change and reduce carbon emissions transfer.

Regarding the impact of inflation growth on carbon emission reduction, measured by economic growth rate, the finding shows that it is significantly negatively related to the reduction of carbon emissions. In the model of all countries and developed countries, inflation growth shows a negative value for carbon emissions, but not significantly. This means that economic growth can contribute to reducing carbon emissions, albeit insignificantly. Inflation-linked bonds, also known as treasury inflation-protected securities, are bonds whose payments are adjusted based on the evolution of a price index, such as the Consumer Price Index. These bonds play an important role in investors' portfolios and are implemented by central banks. This finding aligns with research conducted by Jin Serena Fatica (2020), showing that green bond issuance is linked with a decrease in carbon intensity and emissions more than the issuance of conventional bonds. Green bonds are an emerging conservation financing instrument that promotes environmental engagement. While inflation-linked

bonds primarily focus on managing inflation risk, green bonds are more concerned with environmental sustainability and responsible corporate governance. Therefore, while both types of bonds have unique purposes and implications, they are not directly related to each other in terms of purpose and function (Giovana Cristina da Silva Pereira, 2022).

In developing countries, inflation growth has a confidence level of 90 per cent, indicating that inflation growth will increase carbon emissions; the higher the inflation growth, the greater the increase in carbon emissions. An increase in inflation of 1 per cent will increase carbon emissions for developing countries by 0.033 points. In other words, high or unstable inflation can dampen investor confidence and create an unfavourable investment environment, including investments in green bonds. Therefore, keeping inflation at reasonable levels is important to support investment in sustainable financial instruments such as green bonds. In developing countries, the link between inflation and sustainable funding is often

more complex due to greater economic challenges. It is important to note that green bonds are financial instruments that can support sustainable development, but their success also depends on broader policies and practices. Thus, inflation management and sustainable policies must be carefully integrated in the context of sustainable development in developing countries. The inequality in green bond issuance, especially in sustainable development, remains glaring at the national level in developing countries worldwide.

The study also found that a country's population is significantly related to carbon emissions. With a significance level of 1 per cent, the issuance of green bonds is positively related to carbon emissions. This indicates that with an increase of 1 per cent in population in all countries, carbon emissions in all countries will increase by 0.621 points, with developed countries increasing by 0.629 points and developing countries by 0.786 points. In previous research by Yu Yan (2022) and Rufaro Garidzirai (2020), population

growth has been found to have a significant impact on carbon emissions. In addition, Gregory Casey (2016) also argues that population policies must be considered in mitigating climate change. This means that population growth alone could contribute to half of the increase in emissions by 2025. The impact of population growth on carbon emissions has been studied along with other factors, such as energy use and carbon taxes. The findings show that energy use and population growth positively affect carbon emissions, while carbon taxes reduce carbon emissions (Anqing Shi, 2001).

CONCLUSION

This study analyses the effect of green bond issuance on carbon emissions in developed and developing countries. The issuance of green bonds is the main independent variable, with control variables being inflation growth, the use of renewably sourced electricity, and population. The analysis using the GMM method results in several conclusions.

First, green bond issuance negatively and significantly influences

carbon emissions—the more green bonds issued, the more carbon emissions are reduced. This study confirms the findings in previous studies stating that the increase in green bond issuance has a negative and significant influence on the reduction of carbon emissions. Second, increase in green bond issuance in all countries will reduce the impact of carbon emissions in developed and developing countries. Third, the issuance of green bonds affects all countries, including developed and developing countries, in reducing carbon emissions. However, green bond issuance differs between developed and developing countries. In developed countries, large investment-class issuers within the banking sector primarily benefit from the greenium, or borrowing cost advantage associated with green bonds. Meanwhile, developing countries face barriers to developing green bonds, including a lack of proper institutional arrangements, minimum volume requirements, and high transaction costs.

Lastly, in the green bond industry, there are challenges in determining clear criteria and standards for assessing the

sustainability and environmental impact of projects funded by green bonds. For example, in developed countries, where the amount of green bond issuance is greater than in developing countries, the reduction of carbon emissions tends to be more effective and efficient. Lack of transparency and standards can yield unfavourable results due to uncertainty regarding the extent to which green bonds reduce carbon emissions.

Appendix (Optional)

This section is provided for the author to express his gratitude either for the research funders or the other parties who contribute to research realization.

AUTHOR CONTRIBUTIONS

Conceptualisation, Methodology, Analysis, Original draft preparation. Wijianto^a and Telisa Aulia Falianty^b. Department of Economics, Faculty of Economics and Business, University of Indonesia, Jakarta, Indonesia.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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