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GREEN, SOCIAL, AND SUSTAINABLE BONDS IN THE CONTEXT OF SELECTED MACROECONOMIC INDICATORS

ABSTRACT: This article examines the relationships and possible connections between public finance and environmentally-driven financing. Green, social, and sustainable bonds represent one of the most significant financial innovations of the 21st century, offering a pathway for mobilizing private and public capital to support environmental and social projects. Traditional sources of financing, such as foreign direct investment, official development assistance, and domestic tax revenues, have proven insufficient to meet these vast needs; and generating a positive impact on public finances; consequently, innovative financial instruments capable of channeling private and institutional capital toward sustainable projects are currently gaining prominence. The aim of this article is to analyze the volume of issued green, social, and sustainable bonds in relation to GDP and GDP per capita, and to identify outliers that significantly deviate from the overall data trend using regression models. The article focuses on analyzing time trends in the green, social, and sustainable bond market based on data from 2015–2023, and employs quantitative statistical methods to assess the extent to which selected indicators of GDP and GDP per capita influence the volume of issued bonds. These relationships were examined through regression models. Previous research on this topic has typically focused on only one type of bond in relation to its determinants rather than all three; therefore, we consider the present article unique, despite the fact that it examines only GDP and GDP per capita. The article highlights current challenges associated with the issuance of the analyzed bonds in relation to sustainable finance, public finance, as well as the limitations of capital markets.

KEYWORDS: *capital market; green bonds; social bonds; sustainable bonds; sustainable finance*

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INTRODUCTION

Currently, global annual climate finance flows are insufficient to meet the rising ambitions of states and public sector for climate change mitigation worldwide. Despite persistent global efforts of public sector, climate change—primarily driven by carbon dioxide (CO_2) emissions—continues to intensify, posing acute risks to ecosystems. The consequences of this crisis include escalating global warming, pressure on public finances heat-related illnesses, wildfires, and significant loss of life (Nikhil et al., 2026). More and more countries are prioritizing green and low-carbon development as a key initiative, with achieving carbon neutrality becoming a central development goal of public sector and finance. Green innovation, which acts as a key mechanism for green transition, has subsequently become a target within government incentive frameworks and public spending programs (Chen et al., 2026). Many countries have introduced various (fiscal) macroeconomic instruments, such as environmental protection tax (EPT), resource tax, and carbon emissions trading system (ETS). However, these policies have two limitations: First, their reliance on repressive measures to pressure heavily polluting or high-emitting enterprises leads to narrow coverage and insufficient incentives for green transition. Second, a clear reliance on mandatory fiscal or financial policies cannot effectively mobilize market-driven engagement in green transition initiatives. Given these limitations, alternative instruments have received significant attention. Recently, market-based green fiscal instruments have become key complements to stimulate the low-carbon transition. Among them, the Government Green Bond (GGB) program has been introduced as a new macro policy instrument to finance environmental infrastructure and activate the green investment market.

The 2015 Paris Agreement revitalized global efforts to address climate change by calling for sustained reductions in carbon emissions and a transition to a low-carbon economy. Achieving these goals requires financing that extends far beyond the reach of public resources (Maisuradze et al., 2020), with capital markets becoming central to mobilizing private investments into environmental and social projects.

Sustainable debt markets—encompassing Environmental, Social, and Governance (ESG) criteria—have grown and gained global significance due to a combination of contextual factors (e.g., the pandemic, the increasing impact of climate change, and social justice

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movements) and favorable market conditions, such as the low global interest rates observed until 2022 and heightened investor interest (ECLAC, 2022).

In line with this, corporations have begun adopting sustainable business practices to secure legitimacy and strengthen their market position, thereby contributing to the broader sustainable goals of the economy (Saha et al., 2023). Globally, business models are shifting as sustainability becomes an increasing necessity for both firms and financial institutions. Consumers prefer to engage with socially responsible companies (Kumar & Hosh, 2022) and favor businesses aligned with their values, ethical standards, and sustainability goals (Aziz & Alshdaifat, 2024; Ogiemwonyi, Alam et al., 2023).

Consequently, there has been rapid growth in demand from investors and global institutions for ESG-linked investment opportunities. Green, Social, Sustainable, and Sustainability-Linked Bonds (GSSS) have emerged as a key asset class within the broader spectrum of ESG assets (OECD, 2024). In this context, Green, Social, and Sustainability (GSS) bonds have become a crucial mechanism in debt capital markets, facilitating the flow of funds toward sustainable outcomes while meeting the growing demand for responsible investment opportunities (Deo & Varua, 2026). Emerging taxonomies and regulations, which are gradually being integrated into the legislation of many countries, also contribute to the effective use of these instruments (OECD, 2024). For these reasons, it is essential to conduct a deeper investigation into these types of bonds and to define both their prospects and their limitations.

This scientific article provides a basis for discussion within the government's decision-making sphere. Based on the analysis conducted, it addresses certain questions regarding the impact of green and social investments on the state of public finances. The results of the analysis clearly demonstrate that public policies should address this issue in greater detail, including in relation to potential increased legislative support and positive public regulation. It should be noted, however, that it is essential to maintain ideological neutrality in this case as well and to view this type of investment (from the perspective of public policy decision-makers) merely as another option for stabilizing public finances.

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THEORETICAL FRAMEWORK

Several authors have addressed the relationship between the public economy, public finance, investment, and environmental aspects. C. Carraro, A. Favero, and E. Massetti (2012) had already assessed the impact of investment and public finance in a green, low-carbon economy. Other authors who have examined the relationship between public finance, public policy, and government regulations in relation to investment include X. Liao and X. Shi (2018). A.A. Romano and G. Scandurra (2017) examined green investments and public policies. Their analysis, conducted in developing and developed countries between 2004 and 2011, consisted of two steps: In the first step, the authors examined several sectors of green policy (regulatory policies, fiscal incentives, and public investments), while in the second step, they analyzed the specific policies adopted by individual countries. Their findings confirmed that not all policies support investment in renewable energy sources and that their effectiveness depends on a country's level of development. More recent studies include those by Q. J. Wang, H. J. Wang, and Ch. P. Chang (2022), N. Wang and Y. Ch. Chang (2014), who examined the development of policy instruments that support low-carbon governance. The authors analyzed these instruments across five dimensions in relation to key policies in the area of low-carbon governance.

Alongside equity, debt capital—as a repayable financial source from external origins—represents the second fundamental component of a company's financial structure (Musa et al., 2025). In addition to traditional credit sources such as bank loans, advanced economies with well-developed capital markets make extensive use of bonds as alternative financing models (Hillier, 2025), a practice that has led to their growth in recent years.

The Green Bond Principles (2021) characterize green bonds as any type of bond instrument where the proceeds or an equivalent amount are used exclusively to partially or fully finance or refinance new and/or existing eligible green projects, and which are aligned with the four core components of the Green Bond Principles (i.e., use of proceeds, process for project evaluation and selection, management of proceeds, and reporting). They may be issued by governments (Steelyana et al., 2023), corporations, or other entities to support investment projects whose primary objective is sustainability, while providing investors with regular or fixed payments (Nikhil et al., 2026). Based on the foregoing, the rise of these

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innovative instruments in the field of sustainable finance has been stimulated, directing capital toward environmentally beneficial projects (Arshad et al., 2024).

The Social Bond Principles (ICMA, 2023) define social bonds as any type of bond instrument where the proceeds or an equivalent amount are used exclusively to partially or fully finance or refinance new and/or existing eligible social projects (Grygieńć & Rymsza, 2015), and which are aligned with the four core components of the Social Bond Principles (i.e., use of proceeds, process for project evaluation and selection, management of proceeds, and reporting). The proceeds from these bonds are utilized to fund projects with a defined social impact (Faresta et al., 2025). Their social impact is determined through the mitigation of negative social impacts and/or the achievement of positive social outcomes (Park, 2018).

Social bonds provide investors with the opportunity to improve the social profile of their portfolios and achieve measurable impact by investing in social projects and companies. By substituting a portion of fixed-income holdings, investors can achieve a portfolio with a higher level of sustainability while maintaining similar risk-return characteristics (Nordea, 2023).

The Sustainability Bond Guidelines (ICMA, 2021) characterize sustainability bonds as any type of bond instrument where the proceeds or an equivalent amount are used exclusively to finance or refinance a combination of both green and social projects. Sustainability bonds are aligned with the four core components of the Green Bond Principles and the Social Bond Principles (i.e., use of proceeds, process for project evaluation and selection, management of proceeds, and reporting), with the former being particularly relevant to underlying green projects and the latter to underlying social projects. This approach acknowledges that certain social projects may yield environmental co-benefits, and conversely, that some green projects may generate social co-benefits.

The fundamental taxonomy for green, social, and sustainability bonds is the Climate Bonds Taxonomy (2021), which identifies the activities and projects necessary to ensure a low-carbon economy; this was later expanded to include the methodology known as the Climate Bond Resilience Taxonomy (CBRT, 2024).

Green, social, and sustainable bonds provide access to new capital funds, enhance visibility in global financial markets, and signal a commitment to sustainability. Their role in

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financing sustainable development should therefore not be viewed as an isolated solution, but as part of a broader ecosystem of financial innovation, governance reform, and global cooperation. For emerging economies, the way forward lies in balancing ambition with credibility through the issuance of bonds that not only attract capital but also deliver genuine, measurable, and lasting sustainability outcomes (Ndukaji, 2025).

According to Varney (2025), green bonds, supported by dynamic policy innovations, are not only financial instruments (Sahin et al., 2025) but also strategic means to achieve long-term sustainability and climate goals. For policymakers, the results highlight the need to adopt flexible, transparent and harmonised regulatory frameworks that encourage private sector involvement while preserving market integrity (Bhattacharya et al, 2022). Political stability, at first glance, strengthens investor confidence and enhances policy continuity, thereby supporting green investments. Nevertheless, in several politically stable countries, short-term economic needs often outweigh long-term climate goals, leading to significantly high CO_2 emissions. This trade-off is particularly evident in developing countries, where the high costs of climate action often force governments to prioritise industrial growth over long-term sustainability (Nikhil, 2026). The role of the state and policy frameworks, including regulatory standards, tax incentives, and clear definitions of “green” projects, are key to creating an environment that supports the issuance of green bonds. A strong policy foundation provides both issuers and investors with the clarity and confidence needed to engage in green finance (Fatica & Panzica, 2021). In the case of green bonds, the effectiveness of policies aimed at supporting the green bond market depends not only on the formal regulatory environment but also on informal social norms. Policies such as tax incentives, green certification standards, and institutional support mechanisms are institutional innovations that can help build a stable green bond market (Varney, 2025).

METHODOLOGY

The objective of this article is to analyze the volume of issued green, social, and sustainable bonds in relation to GDP and GDP per capita, and to identify outliers that significantly deviate from the overall data trend using regression models. The article focuses on analyzing time trends in the green, social, and sustainable bond market and quantitatively assesses the

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extent to which selected GDP and GDP per capita indicators influence the volume of bonds issued.

The analysis is based on data for the years 2015–2023, sourced from the International Capital Market Association (ICMA) in collaboration with the Luxembourg Stock Exchange, with volumes measured in billions of USD. The data were aggregated on an annual basis and cover more than 60 countries, allowing for a representative overview of the development of this bond market. Bonds are considered green, social, or sustainable only after undergoing a review by an independent external reviewer regarding their environmental or social characteristics. In this article, the year of issuance is defined as the year in which this review took place.

The dataset is supplemented with macroeconomic indicators—specifically GDP and GDP per capita—for the respective years, sourced from World Bank data. While the comprehensive research underpinning this article also analyzed the impact of inflation and carbon dioxide (CO_2) emissions on bond issuance volumes, this article specifically presents results pertaining only to GDP and GDP per capita.

GDP per capita is defined as the gross domestic product divided by the mid-year population. GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are expressed in current U.S. dollars.

GDP at purchasers' prices is the sum of gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Dollar figures for GDP are converted from domestic currencies using single-year official exchange rates. For countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used.

We decided to test the macroeconomic indicators in question due to the fact that large countries (e.g. India or China) may have huge total GDP, but due to their large populations they may achieve low GDP per capita. Conversely, smaller countries with highly

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productive economies (e.g. Ireland) may show high values per capita with a relatively smaller total economy. The results presented in the present article also indicate that both indicators show different dependencies in relation to the bonds under study.

The analysis of the relationship between GDP and the volume of issued green, social, and sustainable bonds was conducted based on the 2024 study, The Role of Green Bonds in Financing Sustainable Energy. The study demonstrated a positive correlation between the analyzed variables. Based on the aforementioned findings, we have formulated the following hypotheses:

H1: The volume of issued green, social, and sustainable bonds is higher in countries with a higher Gross Domestic Product (GDP).

H2: The volume of issued green, social, and sustainable bonds is higher in countries with a higher level of economic development, expressed by the GDP per capita indicator.

H3: Based on the regression model and standardized residuals, at least one outlier that *significantly* deviates from the overall data trend will be identified for each year.

For the purposes of analyzing the bonds in question, we employed quantitative statistical methods that enabled a deeper examination of this specific bond market and an understanding of the relationship between the volume of issued green, social, and sustainable bonds and the selected indicators (GDP and GDP per capita). The data were processed using the MS Excel statistical software and its Data Analysis module. Selected artificial intelligence tools were used to support data processing and interpretation. The study also utilized qualitative methods, such as analysis, synthesis, induction, deduction, abstraction, and comparison.

Descriptive statistics were utilized to summarize the fundamental characteristics of the observed indicators. We tracked the average volumes of bond issuances by year, country, and continent, including minimum, maximum, and median values. This approach provided an overview of the overall market development. To observe the dependence between two quantitative indicators, the Pearson correlation method was employed. This method was used to examine the relationship between the volume of issued green, social, and sustainable bonds and both GDP and GDP per capita.

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Following the entry into force of the Paris Agreement on Climate Change on November 4, 2016, we considered data from the years 2017–2023 in the second part of the analysis. For the purposes of the analysis, incomplete and erroneous data were cleaned. In cases where no issuance occurred in a given year, the volume of bonds was recorded as zero. Correlations were specifically performed on data from the years 2017, 2021, and 2023. These years were selected as reference points to represent key developmental phases of the green, social, and sustainable bond market.

For a deeper analysis of the relationship between economic indicators and the volume of bond issuances, we employed simple linear regression analysis. The regression models examined the impact of GDP and GDP per capita on the volume of issued green, social, and sustainable bonds. The significance of the regression model was assessed using the F-test statistic, which evaluates the significance of the model as a whole at a significance level of $\alpha = 0.05$. The relationship between the variables was modeled using a simple linear regression equation of the following form:

$$y = ax + b,$$

where a represents the slope coefficient and b the constant. The independent variable (x) represents the selected indicator, and the dependent variable (y) represents the volume of the analyzed bonds issued. Subsequently, predicted values for the volumes of the analyzed bonds issued were identified. The residual is the difference between the actual and predicted issuance value. To identify extreme values (outliers), the residuals were standardized according to the relationship:

$$u_i = \frac{x_i - \bar{x}}{s_x},$$

where x_i is the residual value, $\bar{x}$ is the mean value of the residuals, and s_x is the sample standard deviation of the residuals.

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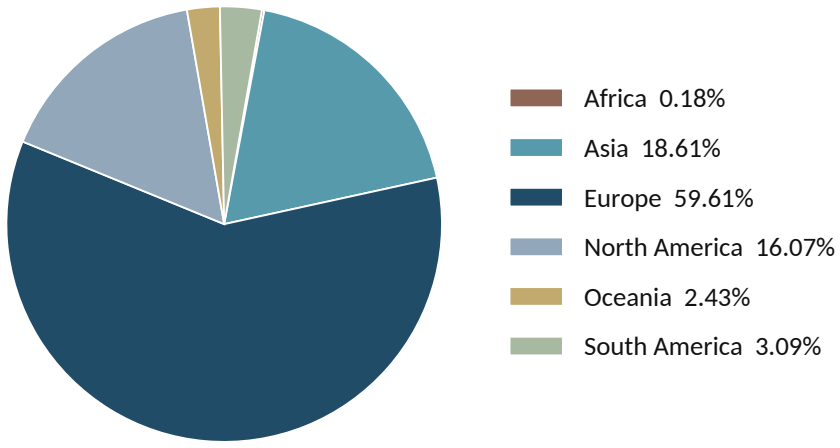
RESULTS

Trend analysis in global green, social, and sustainable bond volumes

The first issuances of green, social, and sustainable bonds were recorded in 2015. By 2022, these bonds accounted for 13% of total global bond issuances. According to available data from the ICMA and the Luxembourg Stock Exchange, issuances were carried out between 2015 and 2023 across six continents: Africa, Oceania, Asia, Europe, North America, and South America. Together, these regions issued green, social, and sustainable bonds with an approximate value of 3,968.03 billion USD over the monitored period.

Figure 1 illustrates the distribution of the total volume of green, social, and sustainable bond issuances among the individual continents for the monitored period.

Figure 1: Distribution of the total volume of green, social, and sustainable bond issuances among individual continents for the years 2015–2023



Source: *Own processing based on ICMA data.*

Europe holds a dominant position in the market, accounting for the largest share of total emissions with a value of approximately 2,365.52 billion USD. This is followed by Asia and North America, with total emissions of approximately 738.52 billion USD and 637.58 billion USD, respectively. The other continents (Africa, Oceania, and South America) contributed only marginally to the total volume.

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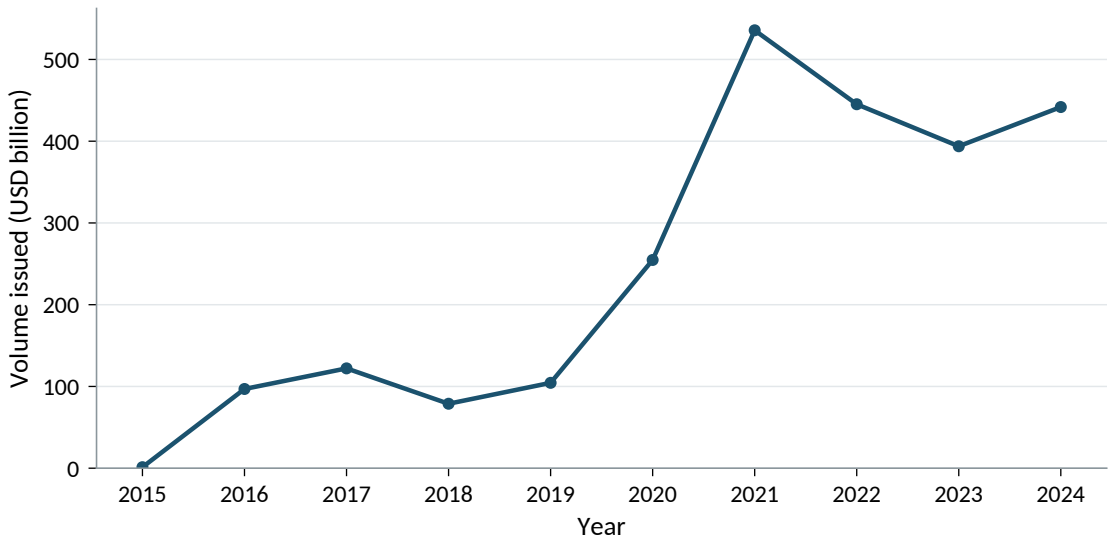
Green bonds issued during the monitored period totaled more than 2,474.66 billion USD. Descriptive statistics were conducted on a sample of 1,857 global issuances. The volume of individual issuances ranged from 0.00 billion USD to 117.57 billion USD. The average issuance volume reached 1.33 billion USD, while the median stood at 0.36 billion USD. Specifically, 928 out of the total 1,857 issuances (nearly half) had a volume lower than the median, and more than half of the observations had a volume lower than the average.

This indicates that the examined population is dominated by small and medium-sized issuance volumes, while a decisive share of capital may be concentrated among a smaller number of large issuers. Figure 2 illustrates the time trend of the volume of issued green bonds.

Figure 2: Time series of the volume of issued green bonds 2015–2024



Source: *Own processing based on ICMA data.*

The skewness coefficient reached a value of 13.96, and the kurtosis coefficient reached a value of 238.38, indicating the presence of extremely high values in the dataset. Slovak green bond issuances from 2021 (Slovenská sporiteľňa) and 2023 (Tatra banka) were issued with total volumes of 1.16 billion USD and 1.27 billion USD, respectively. In terms of distribution, these issuances are significantly above the median and close to the overall average. Given the large disparities between issuances and the presence of several very high values, Slovak issuances can be classified as higher-volume, yet still within the broader average.

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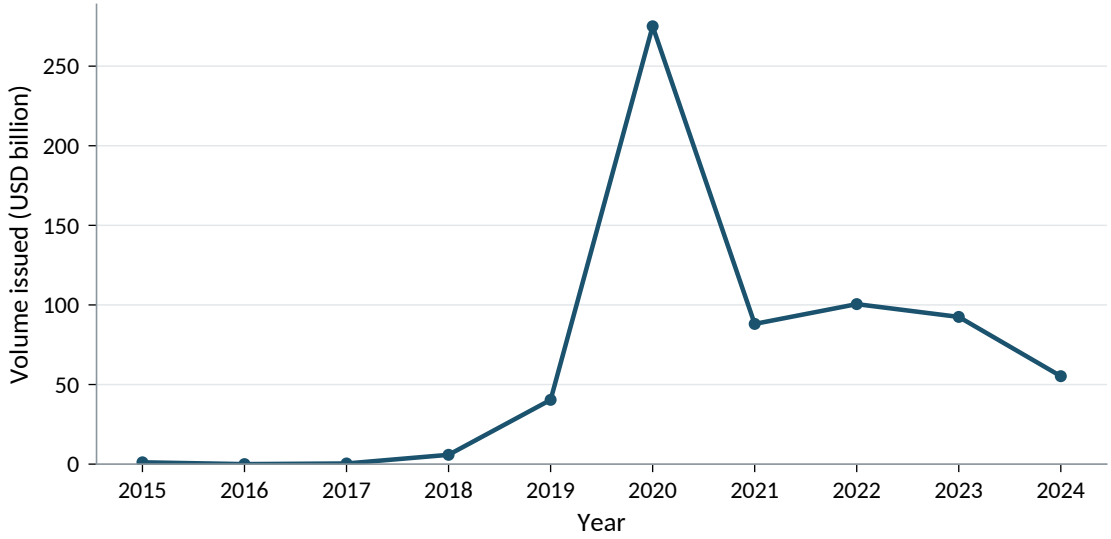
The total volume of social bonds amounted to 659.09 billion USD. Descriptive statistics were conducted on a sample of 317 issuances, which ranged from 0.00 USD to 142.85 billion USD. The average issuance volume was 2.08 billion USD; however, the median value was only 0.33 billion USD. This implies that the majority of issuances had a relatively low value, and the average was influenced by a few extremely high-value issuances. Figure 3 illustrates the time trend of the volume of issued social bonds.

Figure 3: Time series of the volume of issued social bonds, 2015–2024



Source: *Author's own analysis based on ICMA data.*

Sustainable bonds reached a total volume of 545.19 billion USD, based on a sample of 543 tracked issuances, representing the smallest segment of the bonds analyzed. The average issuance volume reached 1 billion USD. As in the previous cases, the median for this type of bond was significantly below the mean, at 0.4 billion USD. Three-quarters of the issuances were below the threshold of 0.89 billion USD. Figure 4 illustrates the time trend of the volume of issued sustainable bonds.

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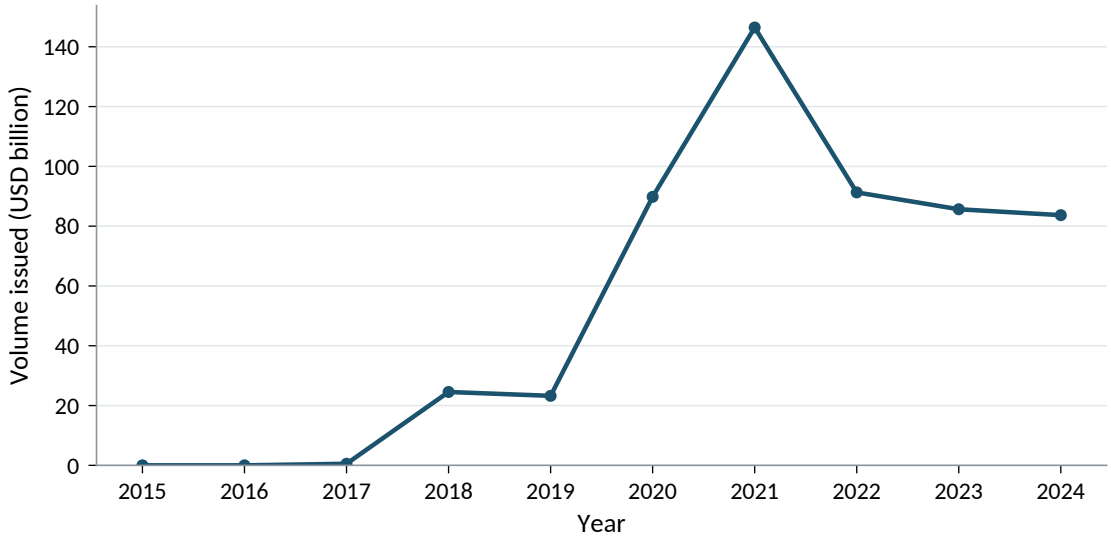
Figure 4: Time series of sustainable bond issuance volume, 2015–2024



Source: *Author's own analysis based on ICMA data.*

Once again, the occurrence of isolated, extremely high-volume issuances can be observed, while small and medium-sized issuances remain dominant. The data distribution is strongly right-skewed, as confirmed by high values for both skewness (6.16) and kurtosis (48.14).

Analysis of the relationship between GDP and the volume of issued green, social, and sustainable bonds

The positive impact of GDP on green bond issuance, according to Ozyesil & Tembelo (2025), is based on the assumption that economic strength facilitates greater activity in the green bond market. A higher level of GDP allows countries to allocate more resources to sustainable projects, thereby creating a favorable environment for green bond issuance. Increased renewable energy capacity and a higher level of GDP positively influence green bond issuance, suggesting that economic strength and investments in renewable energy infrastructure drive demand for green bonds. These results highlight the role of economic prosperity and renewable energy initiatives in fostering the growth of green bond markets. Economic prosperity and stability are essential for the growth of green bond markets, as larger and more stable economies are better able to support large-scale green projects (Flammer, 2021). These facts point to the factors influencing green bond issuance, emphasizing the key role of interest rates, renewable energy capacity, carbon emission reduction, and GDP (Hachenberg & Schiereck, 2018).

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Based on the above, in accordance with the established methodology, we analyzed the volume of green, social, and sustainable bonds in relation to GDP. Based on the cited studies and assumptions, we formulated the following hypothesis:

H1: The volume of green, social, and sustainable bond issuances is higher in countries with a higher Gross Domestic Product (GDP).

The analysis was performed on a sample of 147 observations from the years 2017, 2021, and 2023. The underlying assumption was the existence of a positive relationship between GDP and the volume of issued green, social, and sustainable bonds, with the expectation that countries with higher GDP would issue a larger volume of these bonds. Table 1 displays the results of the Pearson correlation.

Table 1: Results of Pearson's correlation between GDP and the volume of green, social, and sustainable bonds issued

Year	Pearson's correlation coefficient	Test statistics	Number of samples analyzed
2017	0.086498956	0.716897897	20
2021	0.510499889	5.41E-06	71
2023	0.308022857	0.020915401	56

Source: *Author's own analysis based on ICMA data.*

The Pearson correlation analysis between GDP and the volume of green, social, and sustainable bond issuances revealed a positive relationship, the strength of which varied across the observed years. In 2017, the correlation was very weak (0.0865), whereas in 2021 it reached a moderate intensity (0.5105), and in 2023 it was slightly weaker (0.3080). These results suggest that in the selected years, the hypothesis held that economically stronger countries tend to issue a larger volume of the monitored bonds. This phenomenon was most pronounced in 2021. Based on these results, we verified

H3: Based on the regression model and standardized residuals, at least one outlier will be identified in each year that *significantly* deviates from the overall data trend.

The values of the regression model test statistics (p-values) demonstrated a statistically significant relationship between the volume of tracked bond issuances and GDP in 2021 (5.41E-06) and 2023 (0.02). In 2017, the statistical significance of the model was not confirmed.

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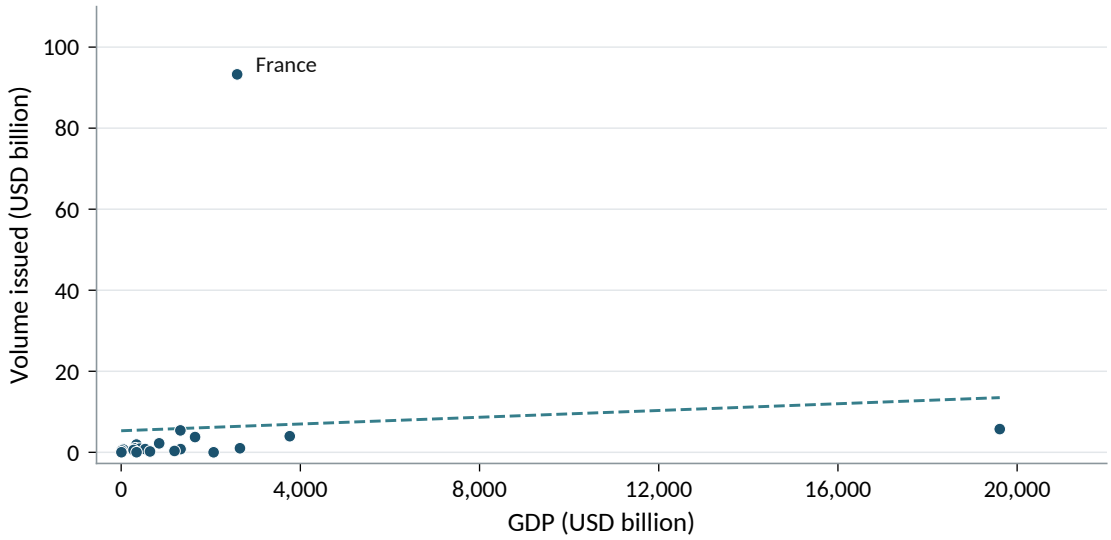
Within the regression model, outliers were identified that significantly deviated from the overall data trend. In 2017, one dominant observation was recorded—France—with an issuance volume of 93.27 billion USD, which significantly exceeded the values of other countries (Figure 5).

Figure 5: Outlier analysis in the regression model between GDP and the volume of green, social, and sustainable bonds issued in 2017



Source: *Author's own analysis based on ICMA data.*

In 2021, significant deviations from the model were recorded in the United Kingdom, France, Italy, Japan, and China, which issued bonds in volumes of 118.10 billion USD, 96.38 billion USD, 77.94 billion USD, 53.59 billion USD, and 10.13 billion USD, respectively (Figure 6).

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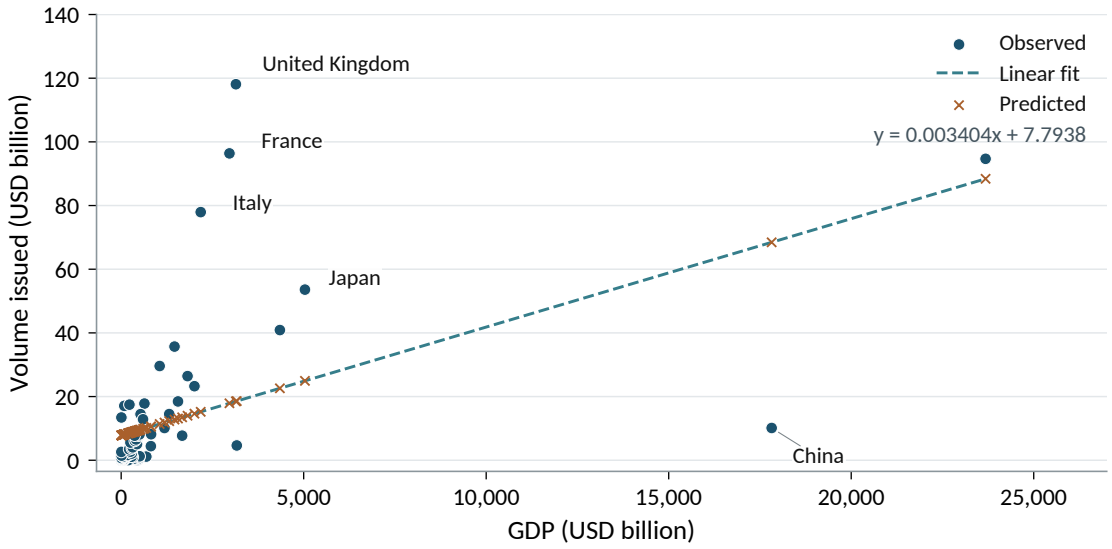
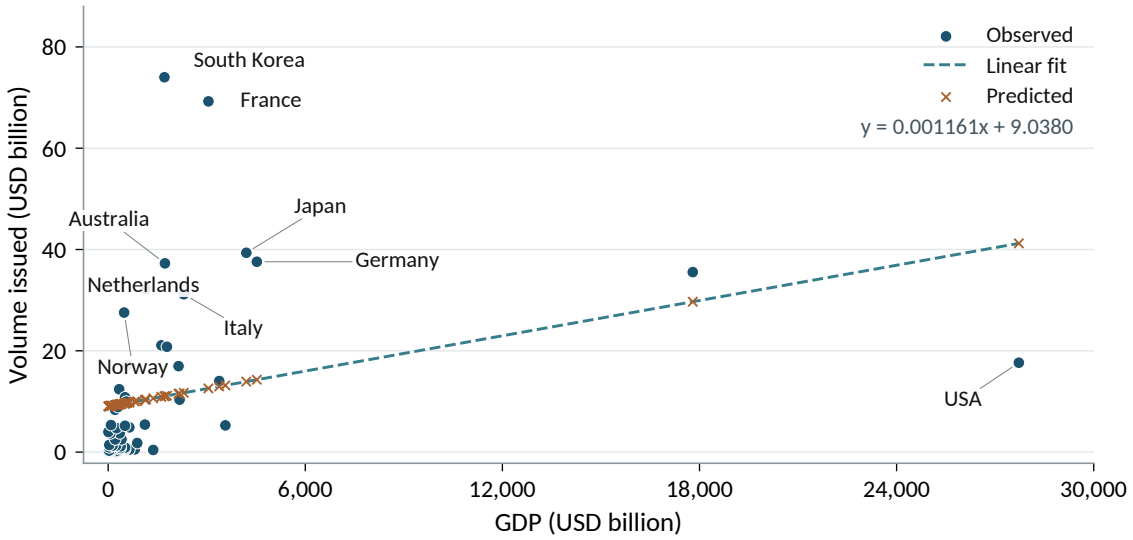
Figure 6: Outlier analysis in the regression model between GDP and the volume of green, social, and sustainable bonds issued in 2021



Source: *Author's own analysis based on ICMA data.*

In 2023, South Korea, France, Australia, Japan, the United States, Germany, the Netherlands, Italy, and Norway stood out as significant outliers (Figure 7). Their issuances of green, social, and sustainable bonds amounted to $74.01 billion, $69.25 billion, $37.27 billion, $39.35 billion, $17.65 billion, $37.58 billion, $32.2 billion, $31.17 billion, and $27.56 billion, respectively.

Figure 7: Analysis of outliers in the regression model between GDP and the volume of issued green, social, and sustainable bonds for 2023



Source: *Author's own analysis based on ICMA data.*

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The overall analysis results demonstrate the existence of a positive relationship between GDP and the volume of issued green, social, and sustainable bonds, with this relationship being statistically significant in 2021 and 2023. In these years, Hypothesis H1 was confirmed. In 2017, H1 was not confirmed.

Analysis of the relationship between GDP per capita and the volume of issued green, social, and sustainable bonds

Another macroeconomic factor analyzed was GDP per capita. It was assumed that countries with higher GDP per capita would be more active bond issuers, particularly in the field of green and social financing. At the same time, the hypothesis was based on the premise that this indicator of economic maturity and standard of living can influence the issuance of green, social, and sustainable bonds through higher investment awareness, demand for sustainable solutions, and more developed financial institutions (Hachenberg & Schiereck, 2018). Based on the above and in accordance with the presented methodology, we tested the hypothesis H2:

H2: The volume of green, social, and sustainable bond issuances is higher in countries with a higher economic level, expressed through the GDP per capita indicator.

A total of 147 samples from 2017, 2021, and 2023 were analyzed. Table 2 shows the results of the Pearson correlation for the relationship between the volume of issued monitored bonds and the level of GDP per capita.

Table 2: Results of the Pearson correlation between GDP per capita and the volume of issued green, social, and sustainable bonds

Year	Pearson's correlation coefficient	Test statistics	Number of samples analyzed
2017	0.123091277	0.605149829	20
2021	0.249234831	0.03608102	71
2023	0.079969821	0.557955148	56

Source: *Author's own analysis based on ICMA data.*

Correlation analysis between GDP per capita and the volume of issued green, social, and sustainable bonds showed a positive, yet relatively very weak relationship in all years. The highest correlation was recorded in 2021 (0.2492). However, even this value still represents

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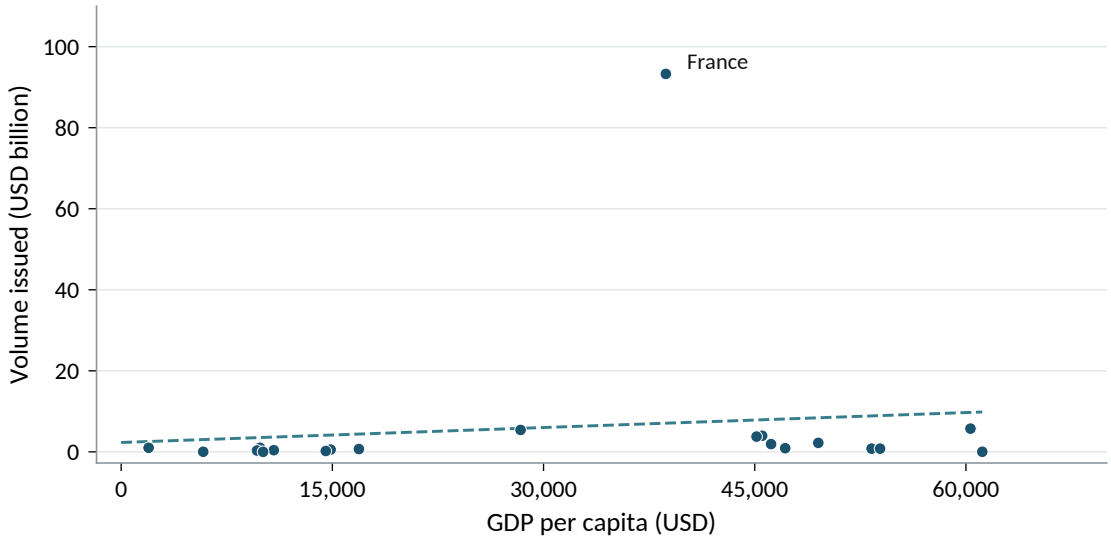
only a weak correlation between the analyzed variables. In the other years, the correlation coefficients were even lower. In 2017, the Pearson correlation coefficient reached a value of 0.1231, and in 2023, only 0.0800. Observations from the analyzed model suggest that GDP per capita may not be a sufficiently strong predictive factor for issuance activity in the field of green, social, and sustainable bonds.

The relationship between GDP per capita and the volume of issued green, social, and sustainable bonds proved to be statistically insignificant in two of the observed years (2017 and 2023). An exception was the year 2021, in which statistical significance of the model was recorded with a p-value of 0.036. This observation suggests that in 2021, a certain degree of dependence existed between a country's economic maturity and its sustainable issuance activity. In 2017 and 2023, the p-values were higher than the significance level (α=0.05), which means that the identified correlations cannot be considered statistically convincing.

Further analysis revealed several outliers that deviated from the trend in the model. In 2017, one significantly high issuance was recorded, which belonged to France (Figure 8). This value was also observed as the only residual in the observed year. The issuance exceeded the predicted volume based on the GDP per capita value by nearly 86.2 billion USD.

Figure 8: Analysis of outliers in the regression model between GDP per capita and the volume of issued green, social, and sustainable bonds for 2017



Source: *Author's own analysis based on ICMA data.*

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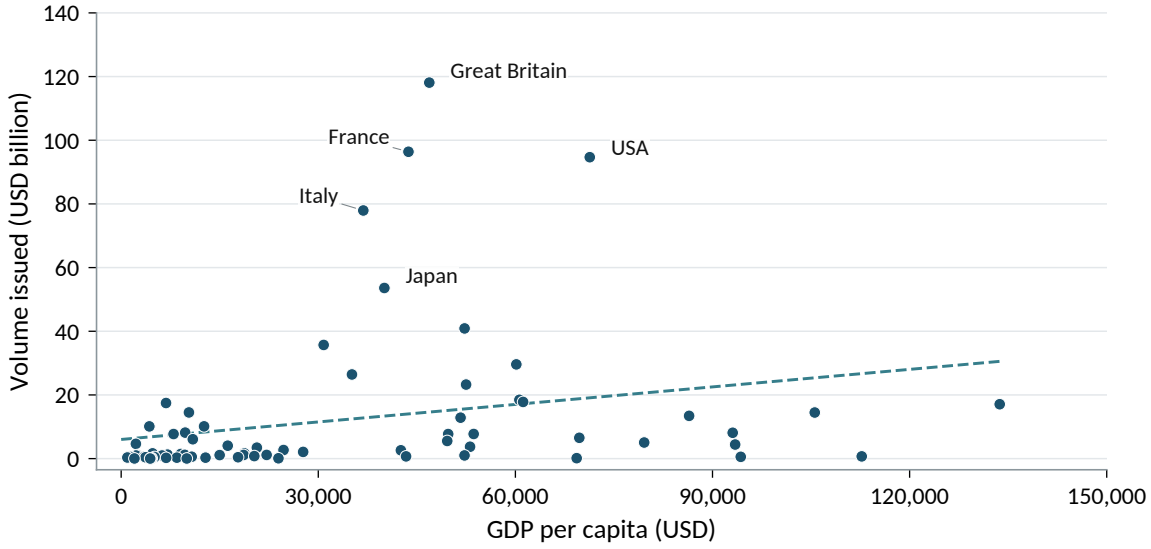
The year 2021 brought several outlier observations. Among the five most significant were the issuances of the United Kingdom, France, Italy, the USA, and Japan (Figure 9).

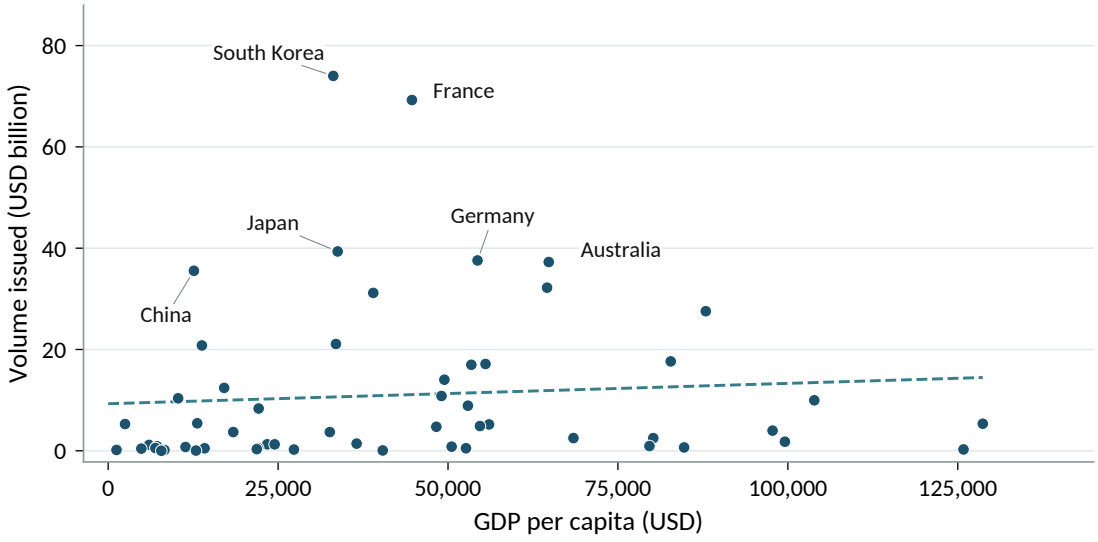
Figure 9: Analysis of outliers in the regression model between GDP per capita and the volume of issued green, social, and sustainable bonds for 2021



Source: *Author's own analysis based on ICMA data.*

In 2023, a larger number of outliers was again recorded. Among the most significant extreme values were the issuances of South Korea and France. Japan, Germany, Australia, and China can also be classified as significant deviations from the model (Figure 10).

Figure 10: Outlier analysis in the regression model between GDP per capita and the volume of green, social, and sustainable bonds issued in 2023



Source: *Author's own analysis based on ICMA data.*

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Although it was assumed that GDP per capita as an indicator of economic maturity would be a stronger factor influencing a country's issuance activity, the results did not unequivocally confirm this hypothesis. Hypothesis H2 was only partially confirmed. Only in 2021 was the relationship between GDP per capita and the analyzed issuances statistically significant. In the other years, the hypothesis was not confirmed. Slovakia, which in both analyzed years (2021 and 2023) moved close to the predicted values, could in the future draw inspiration from active issuers such as France or South Korea, where sustainable financing is firmly anchored in broader economic and environmental policy. Based on the stated results, we confirm Hypothesis H3, because based on the regression model, at least one outlier was identified in each year that significantly deviated from the overall data trend.

DISCUSSION

The results of the analysis demonstrated a causal relationship between investment in this specific area and its impact on public finances and the country’s key macroeconomic indicators. It is evident that there is a reciprocal causal relationship between public policy and this specific aspect of the economic investment landscape. In this case, it can be concluded that the environmental policies of individual countries and the EU directly and indirectly influence green investments, which in turn directly influence cross - cutting government policies - specifically in the areas of public finance and, consequently, social policy. As already mentioned, all public policies in this area should be based on a purely rational and pragmatic approach, free from ideological considerations. Public policy decisions in this area must necessarily take a balanced approach. They must take into account not only the benefits but also the costs that environmental decisions entail in economic terms.

Based on the analysis of outliers in the regression model between GDP per capita and the volume of issued green, social, and sustainable bonds, residuals were detected – the differences between the actual and predicted value of the issuance of green, social, and sustainable bonds based on the GDP value. To more precisely identify outliers, standardized residuals were used, which express the relative deviation from the regression model adjusted for the data scale. Values exceeding +2 were considered potential outliers. Table 3 lists the countries that, in 2021, significantly deviated from the regression model predictions based on standardized residuals.

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Table 3: Residual analysis for the regression model of GDP level and the volume of issued green, social, and sustainable bonds

Year	Country	Projected issue volume (USD)	Standardized residuals (absolute value)	Actual issue amount (USD)	Difference in value (USD)
2021	Great Britain	18.49 bn	4.927520115	118.10 bn	99.61 bn
2021	France	17.89 bn	3.882853802	96.38 bn	78.49 bn
2021	Italy	15.21 bn	3.102973611	77.94 bn	62.73 bn
2021	China	68.45 bn	2.885030807	10.13 bn	(58.32) bn
2021	Slovakia	8.20 bn	0.348661095	1.16 bn	(7.05) bn

Source: *Author's own analysis based on ICMA data.*

The countries United Kingdom, France, and Italy significantly exceeded the predicted issuance volume, which was reflected in their high positive standardized residual values. The United Kingdom exceeded its predicted volume of issued green, social, and sustainable bonds by 99.61 billion USD. France, with the second-highest standardized residual value (3.88), exceeded its predicted volume in 2021 by 78.49 billion USD. Italy achieved the third-highest value of issued bonds relative to the predicted volume. Conversely, China, despite its high GDP, issued 58.32 billion USD less than expected and was identified with a negative standardized residual value. Based on the above, it can be argued that the size of the economy alone does not determine the issuance volume of the bonds under study; other relevant factors may include, for example, the structure of the financial system, the composition of issuers, regulatory measures, and national sustainable finance policies.

In 2021, Slovakia reached a standardized residual of 0.35, which suggests that the volume of issued green, social, and sustainable bonds was very close to the value predicted by the regression model based on GDP. The actual issuance volume reached 1.16 billion USD, while the model expected 8.20 billion USD—the difference thus represented approximately -7.05 billion USD. Although this absolute difference is relatively significant, given the large range of values in the dataset and the high variance among countries, it is still considered a standard observation.

Table 4 illustrates the countries that, based on the analysis of standardized residuals, deviated most significantly from the regression model predictions in 2023.

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Table 4: Residual analysis for the regression model of GDP level and the volume of issued green, social, and sustainable bonds

Year	Country	Projected issue volume (USD)	Standardized residuals	Actual issue amount (USD)	Difference in value (USD)
2023	South Korea	11.03 bn	4.045463215	74.01 bn	62.98 bn
2023	France	12.58 bn	3.639694918	69.25 bn	56.67 bn
2023	Slovakia	9.19 bn	0.508849336	1.27 bn	(7.92) bn

Source: *Author's own analysis based on ICMA data.*

In the observed year, two significant outliers were identified based on the analysis of standardized residuals. South Korea (standardized residual 4.05) and France (standardized residual 3.64) achieved strong positive values. Their actual volume of issued green, social, and sustainable bonds significantly exceeded the values predicted by the regression model. In the case of South Korea, it was 62.98 billion USD more than the model predicted. In the case of France, the value was 56.67 billion USD higher. In both cases, these were countries that issued significantly more bonds than would correspond to their economic performance measured by GDP. Slovakia in 2023 showed a standardized residual of 0.51, which means that the actual volume of issued green, social, and sustainable bonds was slightly lower than predicted by the regression model based on GDP. The model expected an issuance volume of approximately 9.19 billion USD, while only 1.27 billion USD was actually issued. The absolute difference thus represented –7.92 billion USD. Based on the mentioned results, we can confirm that H3 was also confirmed.

For the purpose of better understanding the analyzed data, a linear regression was performed between the volume of issued green, social, and sustainable bonds and the level of GDP excluding significant deviations (outliers). From the data corresponding to 2021, 5 observations were excluded (United Kingdom, France, Italy, Japan, China), and from the data corresponding to 2023, 9 observations were excluded (South Korea, France, Japan, Australia, USA, Germany, Netherlands, Italy, Norway). Thus, 66 and 47 samples were monitored, respectively. The regression model from 2021 demonstrated a strong positive correlation between the analyzed variables (Pearson correlation coefficient = 0.8581) and very high statistical significance (test statistic = 3.40315E-20). Moreover, 73.6% of the variability of the dependent variable (volume of issued monitored bonds) is explained by the independent

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variable (GDP). Even in 2023, the regression model revealed a strong positive correlation between the monitored variables (Pearson correlation coefficient = 0.7167) and high statistical significance (test statistic = 1.46E-08). The explanatory power of the model is lower than that of the previous model. The coefficient of determination (R^2) reached a value of 0.5137, which means that the model can explain approximately 51.4% of the variability of the volume of monitored bonds using the level of GDP. This result points to the relatively good explanatory power of the model.

The overall results of the analysis demonstrate the existence of a positive relationship between GDP level and the volume of monitored bonds, with this relationship being statistically significant in 2021 and 2023. In these years, hypothesis H1 was confirmed; in 2017, H1 was not confirmed. Models from which significant deviations were removed demonstrated an even greater degree of correlation and statistical significance. At the same time, the results suggest that while Slovakia moved in accordance with its economic potential regarding its issuance activity, there is room to strengthen its position in the market for green, social, and sustainable bonds. It can draw inspiration, for example, from the ambitious green and social policy of France, which repeatedly exceeded the model's expectations.

The residual analysis for the regression model of GDP per capita and the volume of examined bonds for 2021 is presented in Table 5. When analyzing the relationship between GDP per capita and the volume of issued green, social, and sustainable bonds in 2021, several countries significantly deviating from the trend were identified, specifically the United Kingdom with a standardized residual value of 4.55, France with a value of 3.62, and the USA with a value of 3.32. These values represented strong positive deviations from the model, meaning that compared to their economic level, they issued a substantially higher volume of monitored bonds than would be expected. With a standardized residual value of 2.86, Italy can also be added to the aforementioned countries, as it issued 65.16 billion USD more than was predicted based on the country's GDP per capita. For comparison, Slovakia issued 8.92 billion USD less than the model predicted. With a standardized residual value at the level of 0.39, it thus falls among the standard deviations of the model.

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Table 5: Residual analysis for the regression model of GDP per capita and the volume of issued green, social, and sustainable bonds

Year	Country	Projected issue volume (USD)	Standardized residuals (absolute value)	Actual issue amount (USD)	Difference in values (USD)
2021	Great Britain	14.62 bn	4.545331664	118.10 bn	103.48 bn
2021	France	14.04 bn	3.616887496	96.38 bn	82.34 bn
2021	USA	19.10 bn	3.319502151	94.67 bn	75.57 bn
2021	Italy	12.78 bn	2.86211875	77.94 bn	65.16 bn
2021	Slovakia	10.08 bn	0.391783149	1.16 bn	(8.92) bn

Source: *Author's own analysis based on ICMA data.*

The residual analysis for 2023 is captured in Table 6. The most significant countries in terms of deviation from the model were South Korea and France. They reached standardized residual values of 3.89 and 3.57, respectively. In both cases, the actual volume of issued green, social, and sustainable bonds was several times higher than the model prediction, which points to a high degree of engagement in the area of sustainable financing. The actual issuance volume of South Korea exceeded the predicted volume by 63.39 billion USD. In the case of France, the actual issuances were approximately 58.16 billion USD higher than the predictions.

Table 6: Residual analysis for the regression model of GDP per capita level and the volume of issued green, social, and sustainable bonds

Year	Country	Projected issue volume (USD)	Standardized residuals (absolute value)	Actual issue amount (USD)	Difference in value (USD)
2023	South Korea	10.62 bn	3.885988517	74.01 bn	63.39 bn
2023	France	11.09 bn	3.565462651	69.25 bn	58.16 bn
2023	Slovakia	10.27 bn	0.551950144	1.27 bn	(9.00) bn

Source: *Author's own analysis based on ICMA data.*

Although it was assumed that GDP per capita as an indicator of economic maturity would be a stronger factor influencing a country's issuance activity, the results did not unequivocally confirm this hypothesis. Hypothesis H2 was only partially confirmed. Only in 2021 was the relationship between GDP per capita and the analyzed issuances statistically significant. In the other years, the hypothesis was not confirmed. Slovakia, which in both analyzed years (2021

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and 2023) moved close to the predicted values, could in the future draw inspiration from active issuers such as France or South Korea, where sustainable financing is firmly anchored in broader economic and environmental policy and, to a certain extent, may be linked to sovereign green bond programs, sustainable finance taxonomies, disclosure requirements for institutional investors, public investment strategies, and other national regulatory initiatives.

Regarding the results, we can confirm that the findings are in some cases consistent with conducted research (Ozyesil & Tembelo, 2025; Flammer, 2021; Hachenberg & Schiereck, 2018), but at the same time, they expand upon them with a broader context, as these studies examined only one type of bond—for example, green bonds over time—whereas in our research, we examined three types of bonds: green, social, and sustainable bonds.

RESEARCH LIMITATIONS

Given the examined factors influencing the volume of issued green, social, and sustainable bonds, it is necessary to define several limitations of this scientific article. The dataset within the descriptive statistics, based on average bond issuance volumes by year, country, and continent—including minimum, maximum, and median—was limited to the period from 2015 to 2024, which may not capture long-term trends, yet it allowed for an overview of the overall market development, the regression analysis concludes with the year 2023. It is also necessary to highlight the limitations inherent in the GDP and GDP per capita indicators themselves. While the macroeconomic indicators examined capture the economic scale and average level of a country, they do not account for differences in capital market development, the composition of bond issuers, sovereign green bond programs, sustainable finance taxonomies, disclosure requirements, institutional investor demand, or the overall regulatory environment. Consequently, countries with comparable GDP levels exhibit significantly different issuance volumes for the bonds under study—for instance, France, South Korea, and the United Kingdom appear as positive outliers, while China appears as a negative outlier, relative to predictions based on GDP.

In further analysis, we relied on data for the years 2017, 2021, and 2023 and observed two determinants influencing the issuance volume of the examined bonds: GDP and GDP per capita. The initial assumption was the existence of a positive relationship between GDP and GDP per capita and the volume of issued green, social, and sustainable bonds, with the

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expectation that countries with higher GDP would issue a greater volume of these bonds. Given the aforementioned limitations, it should also be emphasized that the estimated relationships may, in part, reflect missing institutional, regulatory, and financial market characteristics that are not captured by the macroeconomic indicators under examination. Although the dataset is comprehensive, it is also limited to the examined number of factors and countries. However, regarding the subject research, we expanded the scope of the study to examine three types of bonds—green, social, and sustainable. While previous studies have examined more factors, they have always focused on only one type of bond. Due to the relatively new nature of the topic, where it is still problematic to track time series and predict developments, it will be possible in the future to track longer time series and to rely on a broader sample of countries issuing the selected bonds. Studies that compare countries issuing different volumes of the examined bonds over time will clarify the unique dynamics of the challenges that markets for green, social, and sustainable bonds will face worldwide.

CONCLUSION

The main scientific contribution of this article lies in a more comprehensive quantification of the interrelationships between public policies, public finances, macroeconomic indicators, and green and social investments. In this context, the identified impacts should be viewed from a product-oriented rather than a contextual perspective. The results of the analysis demonstrate causal relationships; however, it is not possible to confirm that investing in green bonds has a positive impact on public finances and the economy solely because of their green focus. This is a trending topic that is artificially prioritized by public policy; with the support of public regulations, it creates conditions for positive impacts in this area (though negative impacts in many others). From the perspective of practical recommendations, it is important to emphasize that these investments should not be viewed from an ideological standpoint - as is currently preferred by public policies in the collective West - but rather simply as another option for investing one’s free capital.

Growing awareness of climate change and social inequality has changed attitudes toward investing, thereby supporting the growth of social, sustainable, and ecological investments. At the heart of this significant shift in the world of finance are green, social, and sustainable bonds—financial instruments designed to fund environmental, social, or

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sustainable projects. Their rapid rise underscores their impact; the global issuance of the examined bonds has increased sharply in recent years. The analyzed data show that the volume of issued green, social, and sustainable bonds is influenced to a certain extent by economic maturity as measured by GDP and GDP per capita. Correlation analysis between GDP and the volume of green, social, and sustainable bond identified statistically significant associations in the relevant years and issuance showed a positive relationship, the strength of which varied across individual years. In 2017, the correlation was very weak (0.0865), while in 2021 it reached moderate intensity (0.5105), and in 2023 it was slightly weaker (0.3080). These results suggest that in the selected years of 2021 and 2023, the hypothesis that economically stronger countries tend to issue a larger volume of the monitored bonds held true. Based on the above, we can conclude that H1 was only partially confirmed.

Based on the analysis performed, we must conclude that GDP per capita may not be a sufficiently strong predictive factor of issuance activity in the area of green, social, and sustainable bonds globally. The relationship between GDP per capita and the volume of issued green, social, and sustainable bonds proved to be statistically insignificant in two observed years (2017 and 2023); in 2021, the statistical significance of the model was shown (p-value 0.036). Based on the foregoing, it can be stated that in 2021, there was a certain degree of dependence between a country's economic maturity measured by GDP per capita and its sustainable issuance activity, but hypothesis H2 was only partially confirmed. Based on the regression model, at least one outlier was identified in each year that deviated significantly from the overall data trend, and therefore we can confirm hypothesis H3.

Green, social, and sustainable bonds represent a way to connect finance with goals in the areas of environment, social responsibility, and sustainability, and their significant volume in the observed period suggests their benefits manifesting in various areas—from supporting specific projects with a positive impact on the environment and quality of life, through benefits for the issuers themselves, to a broader significance on the economic and legislative level. The main advantage of these bonds is precisely that they allow capital to be directed where it is most needed from the perspective of sustainability.

The development of taxonomies and regulations, which are gradually being integrated into legislation in many countries, contributes to the effective use of these instruments, as seen in the volume of issuances over time. The activities of the European Central Bank (ECB)

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to incorporate climate change into its monetary policy, the introduction of Chinese green bond principles, or the Inflation Reduction Act in the USA are just a few examples. On the other hand, for private issuers, these bonds represent an opportunity to strengthen their reputation, transparency, and accountability in an environment where investors increasingly consider the non-financial characteristics of these bonds. An undeniable benefit is better access to capital, while simultaneously building long-term relationships with sustainably oriented investors. The benefit for the state is primarily the ability to finance strategic public, as well as private, projects. Limits and constraints in the studied area may take the form of relatively low social awareness and low political engagement in the field of sustainable finance, which may manifest, for example, in weak pressure on issuers and limitations on the demand side of the capital market for these bonds. Likewise, there is a lack of standardization and limited knowledge of this instrument among investors.

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