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Novel Findings from New Estimation between Green Monetary Policy and Environmental Sustainability in Europe: Does Institutional Quality Matter?

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ABSTRACT

We expand the previous study on the link between green monetary policy index (GMP) and environmental sustainability (ES) by empirically examining the moderating role of institutional quality. Various econometric approaches were employed in the data set of 17 European Union (EU) member nations from 2001 to 2022. As in previous studies, our estimation results demonstrate that promoting green monetary policies can increase overall environmental performance (EPI). Additionally, promoting specific policies such as GMP_Credit_Operations, GMP_Foreign_Asset_Purchases, and GMP_Domestic_Asset_Purchases can also increase one of the three environmental performance aspects. To further discuss the role of GMP, we reveal the impacts of green monetary policies on three dimensions of ES over different time horizons. The results show that GMP has a positive impact, making ES more likely to persist in the long term. Finally, we analyze the interaction between variables representing institutional quality and the impact of GMP on ES. According to our results, nations with well-developed institutional structures may have a greater favourable impact on green monetary strategies.

Keywords: Environmental sustainability, Environmental performance, Institutional quality, Green monetary policy, Global countries
JEL Classifications: C33, F21, G21, O16

1. INTRODUCTION

Adopting sustainable projects is critical in Europe, affecting not just energy production and usage but also industrial, transportation, and agriculture. These fields demand substantial investment, which is difficult to measure because of their complexity and the dearth of trustworthy worldwide data. The estimated yearly funding requirements for low-carbon transitions, specifically for supply-side energy infrastructure and related investments, range from $1.6 trillion to $3.8 trillion between 2016 and 2050 (Richbell and Wood, 2018). According to reports, climate finance has not yet reached these levels. Between 2017 and 2018, the average investment amount was $579 billion, but only $326 billion came from private sector sources and $253 billion from public sector resources (Karam et al., 2019). This emphasizes the importance of the financial industry to budgeting and legislation to achieve a successful and long-lasting transition.

The European Green Deal states that the EU wants to be carbon neutral by 2050. The public and commercial sectors must make considerable expenditures to achieve this change. According to EU projections, by 2030, the energy sector will require an additional €350 billion yearly to achieve a 55 percent decline in carbon emissions. The EU Commission intends to invest €1 trillion in the Green Deal, with funding coming from the €750 billion Next Generation EU Fund and the €21–2027 Multiannual Financial Framework (MFF) in part (Wu and Liu, 2021). Even with this vast sum, there is still a considerable funding deficit of at least €2.5 trillion, which will mostly need to be covered by the private market using the right laws and incentives to encourage ESG investments.

Furthermore, it has recently gained widespread recognition that fundamental changes in financial institutions are caused mainly by climate shifts. The effects of climate shifts are widespread, impacting all economic players in all sectors and geographical locations and frequently exhibiting non-linear dynamics. A significant amount of assurance exists that several transitional and physical hazards will materialize, even while their impact, period, and future routes remain undetermined (Dafermos et al., 2021). The degree and type of future repercussions will be determined by current actions, making this influence mostly irreversible and dependent on short-term actions. Climate hazards can impede the transfer of fiscal policy via capital markets and the banking industry. This is particularly true regarding unexpected discounting of climate-related fiscal hazards and property stranding. As a result, some central banks have started implementing sustainable financial regulations operations to assist businesses and industries in making the transition to a greener economy and to reduce the economic hazards related to climate modification (Dietz, 2022; Okwuise et al., 2023; Thiemann et al., 2023).

The primary duties of a central bank (CB) are handling foreign exchange reserves, implementing fiscal policies, and overseeing high-value payout networks. Those crucial duties, collectively called "monetary policy operations," include allocating funds for collateral and asset purchases by "eligibility criteria." Bank bonds, corporate bonds, and bank loans are private sector instruments that significant CBs accept as security and for purchasing assets. This has become more common, especially after the global economic downturn and the implementation of quantitative easing. For instance, the European Central Bank (ECB) has played a pivotal role in the economic recovery by lending money to EU credit agencies as part of its fiscal measures activities. It has significant holdings in equities via its Asset Purchases Program (APP), launched in October 2014. Ever since, the ECB has implemented multiple Asset Purchase Programs (APPs) that allow it to buy government bonds, covered bonds (CBPP3), and asset-backed securities (ABSPP). The European Central Bank (ECB) added the Corporate Sector Purchase Program (CSPP) to the already-existing APP framework in March 2016 by announcing its objective to buy company securities directly.

Furthermore, it has recently gained widespread recognition that fundamental changes in financial institutions are caused mainly by climate shifts (NGFS 2019). The effects of climate shifts are widespread, impacting all economic players in all sectors and geographical locations and frequently exhibiting non-linear dynamics. A significant amount of assurance exists that several transitional and physical hazards will materialise, even while their impact, period, and future routes remain undetermined. The degree and type of future repercussions will be determined by current actions, making this influence mostly irreversible and dependent on short-term actions. Climate hazards can impede the transfer of fiscal policy via capital markets and the banking industry. This is particularly true regarding unexpected discounting of climate-related fiscal hazards and property stranding. As a result, some central banks have started implementing sustainable financial regulations operations to assist businesses and industries in making the transition to a greener economy and to reduce the economic hazards related to climate modification (Schnabel, 2023).

Below is the arrangement of the remaining sections of this paper. The literature on the variables is covered in Section 2. The study procedures and an explanation of the variables and information are covered in section three. Our findings and discussion are covered in section 4. The last thoughts, the consequences of policy, and the limitations for strategies are shown in Section 5.

2. LITERATURE REVIEW

2.1. Concepts and Theoretical Structure

Scholars, financial companies, administrations, and companies engaged in ecological finance typically agree on certain features, even without an official or widely accepted definition: it includes financial assets, services, and investments that support socially and environmentally responsible practices (Bernini and La Rosa, 2024; Hermundsdottir and Aspelund, 2020; Wiredu et al., 2023). This comprises funding and loans encouraging actions that positively influence the environment, like building environmentally friendly infrastructure, buying environmentally friendly products, and using green technologies. Green technology, sometimes called eco-technology, is characterized as technology that uses creative and long-lasting solutions to address environmental and ecological issues. It can potentially lessen or even reverse the consequences of human activities on the surroundings, offering a beacon of hope for a sustainable future. Investing in public green expenditures, such as public policies that support initiatives aiming at environmental harm reduction and environmental protection (such as pollution reduction), is another aspect of green finance. According to Aleknevičienė and Bendoraitytė (2022), Azad et al. (2022), Dörry and Schulz (2018), and Zadek and Flynn (2014), green investment is a subset of green finance that focuses on allocating capital to enterprises, assets, or initiatives that positively impact the environment or society. It is simply investing in sustainability. "green finance" refers to a broader range of financial activities, goods, and services that support socially and ecologically conscious projects. This includes the operational expenditures associated with environmentally friendly investments, including project planning and land purchase.

The difference between green money and climate finance is another crucial one. A subcategory of green finance known as "climate finance" focuses on mitigating and limiting CO_2 emissions to address the effects of climate shift via adaption plans particularly. Its goal is to make environmental and human systems more resilient to the damaging effects of climate shift. Climate finance uses market-based ecological policy tools to maximize the environmental impact of investment approaches and assist companies in reallocating resources for increased sustainability without sacrificing profitability. Sustainable banking and green banking are terms that are frequently used interchangeably. Though it is a subset of ecological banking, green finance focuses more on coordinating economic operations with sustainability goals by considering ecological, social, and governance aspects. A framework known as ESG (Environment, Social, and Governance) is used more often to assess the ethical and sustainable impact of investments or businesses. According to Hayes, "a company's ability to manage hazards and worries associated with governance, social responsibility, and the environment in its daily activities is measured by its ESG scores." According to this concept, green finance helps the transition to a low-carbon economy by directing financial resources to ecologically friendly activities and initiatives (Agrawal et al., 2023; Cui et al., 2023; Hu et al., 2023; Wu et al., 2024). Green financing is facilitated by financial tools such as impact investments, sustainability-linked loans, green bonds, and insurance policies (Alamgir and Cheng, 2023; Liu and Zhu, 2024; Wu et al., 2024; Ye and Dela, 2023). Its main objective is synchronizing the banking sector with the SDGs and other sustainability goals. According to Lindenberg, there are three main aspects related to sustainable finance:

- The funding of green initiatives by the public and private sectors in fields like water conservation (dams, for example) and biodiversity protection (landscapes, for example) or in the reduction, avoidance, and restitution of environmental harms (energy efficiency, for example). Both capital and project planning expenses are included in this funding
- The funding of public green programs that encourage the execution of initiatives and endeavours to reduce or adjust biological and environmental harm (as well as the associated operating expenses). This could involve policies like feed-in tariffs intended to encourage the adoption of renewable energy sources
- Assisting in creating a green finance structure that creates specific institutional, legal, and economic frameworks and promotes green investments (such as the Green Climate Fund or financial products for ecological assets like sustainable bonds and organized green funds).

Green financing is essential when examining the fundamental elements of a democracy. An economy like this is propelled by inclusive growth, which aims to achieve real economic advancement to advance equal potential and general well-being for people and the environment. In an inclusive economy, economic disparities are lessened, and possibilities for prosperity are broadly distributed among all societal sectors, improving the welfare of disadvantaged or marginalized populations. Instead of just dispersing money following periods of considerable growth, as is frequently the case with traditional economic development, it emphasizes the engagement of all segments of society in the development procedure. The goal of both inclusive economies and green finance is to increase economic resilience from a systemic standpoint. The other significant ecological aspects that support equitable expansion and serve as the foundation of a prosperous society are as follows:

- Real economic progress: gauging the population's well-being to gauge progress beyond GDP per capita. Access, benefit-sharing, equitable and durable possibilities, and creatively striking a balance between preserving cultural standards, ecosystem funds, and social capital are all components of collective well-being. It enhances both the biological yield—the harvestable population expansion of an ecosystem—and the social yield—the harvestable growth in human assets or total value contributed in a community—by considering the expenses associated with the surroundings and society to achieve net advancement
- A circular economy: this model reduces garbage via several reuse stages, unlike the "take-make-use-waste" linear economy. It covers the following types of reuse: product-level (repair or refurbishing), component-level (remanufacturing), and material-level (eco-friendly recycling or upcycling)
- Inclusive policies and institutions include measures intended to promote equitable access to opportunities and benefits, inclusive growth, and the creation of jobs. They also contain steps to encourage a fairer banking industry via monetary legislation and better income distribution via fiscal policy. To improve economic inclusion and lessen disparities, inclusive organizations create the framework of social, legal, and economic structures, regulations, and practices that foster an accessible and equitable financial system.

Environmental and ecological economics are two critical theoretical models that support sustainable financing and an equitable economy. Within sustainability, these disciplines investigate the interaction between the surroundings and the economy. Economic theory emphasizes the protection of natural capital and sees the economy as a component of the larger ecosystem of the earth (Kurniawan and Sugiawan, 2020). It is an interdisciplinary field that looks at the interactions and evolution of natural ecosystems alongside human economies and their social components. Fostering equitable treatment and preserving ecological balance are essential aspects of environmental economics, which aims to create sustainable, just, and ecologically conscious fiscal structures that improve human well-being. The idea that physical capital created by humans may replace natural capital is contested, and it emphasizes how crucial it is to preserve and responsibly manage "ecosystem services"—the advantages ecosystems provide to humans, like clean water, air, and fertilization (Chenoweth et al., 2018; Costanza, 2020; Elliff and Kikuchi, 2015; Langemeyer et al., 2024). When making decisions, sustainable economics puts morals and beliefs ahead of money since it cares about the sustainability of economic activity over the long run and the welfare of subsequent generations.

By weighing the costs and advantages of various approaches, environmental economics investigates how market-based instruments, regulatory measures, and environmental policies might be used to tackle ecological issues (Mazaheri et al., 2022). It focuses on evaluating specific environmental problems and using practical, cost-effective ways to lessen them. Chen claims that the foundation of green economics is the idea that natural resources have a market value and that economic expansion may come with consequences that conventional economic approaches frequently fail to account for. It assesses the trade-offs between environmental preservation and financial growth using techniques such as cost-benefit evaluation. The main goal is to develop commercially viable solutions to environmental issues while integrating biological consequences. This entails putting a financial value on ecological services and products like clean water availability, air quality, carbon-sequestered forest environments, biodiversity, and wildlife protection. Initiatives like carbon prices, the creation of carbon markets (including the trade of carbon credits), and resource allocation optimization for ecological preservation are all based on environmental economics.

The idea of "regenerative economics," essential to a green economy, unites the theories of environmental and environmental economics (Buckton et al., 2023; Fath et al., 2019; Jain, 2021; Niekerk, 2024; Shannon et al., 2022). According to this viewpoint, economics is the investigation of resource allocation and management. Conventional economic models emphasize the scope of fiscal activity, such as monetary transactions, and use economic growth to gauge progress. On the other hand, the green economy emphasizes sustainable development and the standard of human life.

Understanding the planet's regenerative potential—our primary resource—is essential to comprehending the regenerative character of the green economy. This viewpoint calls on us to reduce waste generation and degradation to levels that the earth can sustainably handle and to utilize non-renewable resources at a rate that permits the development of renewable alternatives. As per the United Nations, a green economy is characterized by minimal carbon emissions, effective use of resources, social inclusivity, and fairness in the financial transactions between individuals and the natural world. Regenerative economics, which emphasizes replenishing capital that supports human wellness, is fundamental to this idea. In contrast to conventional economic concepts, the green economy acknowledges the economic significance of green services and natural capital (Boehnert, 2015). It promotes thorough cost accounting systems that appropriately identify ecological impact costs, regardless of whether they result from damage or poor asset maintenance. Growth in employment and income is fueled by expenditures in regenerative economic activities, highlighting the economy's dual dedication to conservation and prosperity.

The macroeconomic strategy of the green economy is centred on attaining inclusive growth, prioritizing expenditures, employment creation, and skill expansion (Adamowicz, 2022; Aslam and Ghouse, 2023; Fan et al., 2022). This approach seeks to decrease resource use and emissions by increasing resource efficiency and improving wellness. The availability of green assets, technology, and financing is essential for advancing the green economy. Fiscal regulations are critical to enabling this shift because they use a range of instruments and strategies to increase efficiency and popularise environmentally friendly manufacturing and responsible consumption. Partnerships are crucial to this development.

2.2. Theoretical Model Development

Equation (1) illustrates the overall quantity of business bonds qualified for a CB buy program (B_T), presented by sustainable bonds for businesses B_G distributed by corporations to finance ecologically beneficial activities, and corporate bonds that are not environmentally friendly or conventional B_N issued by corporations for investment in non-emission or reducing pollution innovations:

$$B_T = B_G + B_N \qquad (1)$$

We determine the proportion of sustainable bonds $x = \frac{B_G}{B_T}$, and the corresponding quantity of non-sustainable bonds $1 - x = \frac{B_N}{B_T}$.

To keep things simple, we suppose that the CB can correctly recognize the kind of bond. While the supposition has no bearing on the article's findings, it prevents addressing a variety of frequently different criteria for every kind of organization and/or asset buy program under assessment, as no worldwide benchmark has yet been developed (OECD 2018).

If sustainable and traditional bonds were excellent alternatives to institutions, manufacturing and spending in both fields would be unaffected if the CB shifted its portfolio component to environmentally friendly bonds while keeping all resources equal. Nevertheless, green and non-green bonds represent two distinct uses of monetary assets and serve as imperfect alternatives for issuing corporations and investors (Flammer, 2021; Gianfrate and Peri, 2019). As a result, we use two different supply functions to simulate both. Green bond yield harms the overall supply of business green bonds: $B_G(\mu_G)$. When the interest level on this class of bonds (μ_G) grows, enterprises' comparative availability of bonds declines because it becomes more expensive for corporations to implement fiscally sustainable initiatives by issuing environmentally friendly bonds. The linear isoelastic formula defined in Eq. (2a) simulates the overall supply function. Likewise, the share supply of sustainable bonds $x(\mu_G)$ is provided by Equation (2b), and the opposite offer function $\mu_G(x)$ is (2c):

$$B_G(\mu_G) = \frac{\alpha}{\mu_G} \Leftrightarrow \qquad (2a)$$

$$x(\mu_G) = \frac{\alpha}{\mu_G B_T} \Leftrightarrow \qquad (2b)$$

$$\mu_G(x) = \frac{\alpha}{x B_T} \qquad (2c)$$

Similarly, the total amount of business non-green bonds in the marketplace is adversely related to non-green bond yield: $B_N(\mu_N)$. Eq. (3a) describes the purpose of the overall supply, which is unitary isoelastic. The corresponding non-green bonds offer about proportion $1–x(\mu_N)$ is Eq. (3b), along with the reverse offer formula $\mu_N(1–x)$ is (3c):

$$B_N(\mu_N) = \frac{\beta}{\mu_N} \Leftrightarrow \qquad (3a)$$

$$1 - x(\mu_N) = \frac{\beta}{\mu_N B_T} \Leftrightarrow \qquad (3b)$$

$$\mu_N(1-x) = \frac{\beta}{(1-x) B_T} \qquad (3c)$$

According to the description, the entire number of business bonds in the marketplace and bond yields must be numbers >0 (B_T, μ_G, $\mu_N > 0$). Equations (2c) and (3c) indicate that the parameters α, β must be positive. They are scaling elements of the whole offers of sustainable and non-sustainable bonds, which serve as proxies for the comparable sector share of the two kinds of bonds under consideration.

2.2.1. Neutral monetary policy

The number of business bonds the CB buys via an extensive buy program is only governed by currency legal aspects, such as inflation objectives (Bacchiocchi et al., 2024). We suppose the delegate CB is the sole investor in company bonds and purchases the whole pool of eligible bonds. As a result, we concentrate solely on the different components of the buying program B_T and investigate the consequences of a CB tactic that incorporates ecological issues (for example, green financial regulations) to evaluate the phenomenon of portfolio re-balancing and its influence on company bond costs.

According to the contemporary portfolio principle, the CB evaluates the mean projected yields of sustainable μ_G and non-sustainable bonds μ_N, their mean deviation is represented correspondingly by $\sigma_G, \sigma_N > 0$, and the disparity between the two forms of company bonds $\sigma_{G,N}$. The disparity $\sigma_{G,N}$ is connected to the correlation value $r_{G,N} = \frac{\sigma_{G,N}}{\sigma_G \sigma_N}$, to be economically significant, the correlation has to be between −1 and +1. As a result, we require that:

$$-1 \le \frac{\sigma_{G,N}}{\sigma_G \sigma_N} \le 1 \quad (4)$$

Based on the CAPM, the desired sector of the CB portfolio $\mu_P(x)$ is a convex mixture of personal productivity, with the masses representing the fraction of sustainable bonds $x \in (0,1)$ and non-sustainable bonds $1-x$ (the supplemental element) in the CB marketplace:

$$\mu_P(x) = x\,\mu_G + (1-x)\mu_N \quad (5)$$

Altering the reverse offer roles of sustainable (2c) and non-sustainable bonds (3c) into Equation (5) and determining the potential variance of the CB portfolio $\sigma_P^2(x)$, dependent on volatility $\sigma i > 0, i = G,N$, and the disparity $\sigma_{G,N}$ of the distinct types of bonds, we get:

$$\begin{cases} \mu_P(x) = \frac{\alpha}{B_T} + \frac{\beta}{B_T} \\ \sigma_P^2(x) = x^2\,\sigma_G^2 + (1-x)^2\,\sigma_N^2 + 2x(1-x)\sigma_{G,N} \end{cases} \quad (6)$$

The framework of Eq. (6) calculates a tuple of scores: the portfolio's predicted yield and variance concerning share x. The CB suffers a mean-variance trade-off when combining/allocating green (x) and non-green ($1-x$) bonds. As a result, business bonds vary in risk-reward ratios based on the creditworthiness of the issuing corporation. While the CB favors resources with the greatest predicted earnings, it also strives to reduce uncertainty regarding business bonds' future returns. Suppose the CB selects the optimal risk-reward level for green and non-green bonds, resulting in a portfolio distribution with the highest return-to-risk ratio (ideal portfolio x^* in the CAPM). In a neutral economic policy setting, the preference formula for risk aversion in CB could be written as a capital distribution line characterized by the following (7):

$$\mu_P(x) = r_F + S_P \sigma_P(x) \quad (7)$$

The CB optimizes the assortment returns $\mu_P(x)$ for a specific portfolio danger $\sigma_P(x)$, in which the reward-to-risk ratio, or SP for short, and $r_F \ge 0$ is the corresponding risk-free asset (the sector related to a property with no risk, such as a short-run US Treasury bond). Equation (7) illustrates the compromise between predicted portfolio return $\mu_P(x)$ and its volatility $\sigma_P(x)$. This so characterizes the CB's risk-averse favorability. The CB is ready for compromise to maintain a collection of investments with higher risk provided it provides a greater average return, which is evident in S_P. As a result, given the limitations in (6), the CB optimizes the reward-to-hazard proportion S_P by identifying the share x that maximizes the asset class's Sharpe value proportion on the Markowitz bullet:

$$\max_x S_P = \frac{\mu_P(x) - r_F}{\sigma_P(x)} \qquad \text{s.t.} \quad (8)$$

limitations in (6)

Remember that $\mu_P(x) \ge r_F$ in (8) demands that:

$$\frac{\alpha + \beta}{B_T} \ge r_F \quad (9)$$

According to the Sharpe ratio requirement (8), it is necessary that $\sigma_P^2(x) > 0$ in (6). Consequently, it must be true that:

$$\sigma_{G,N} > -\frac{x\sigma_G^2}{2(1-x)} - \frac{(1-x)\sigma_N^2}{2x} \quad (10)$$

The issue in (8) can be resolved by addressing the unrestricted optimization challenge.

$$\max_x \frac{\frac{\alpha}{B_T} + \frac{\beta}{B_T} - r_F}{\sqrt{x_G^2\sigma_G^2 + (1-x)^2\,\sigma_N^2 + 2x(1-x)\sigma_{G,N}}} \quad (11)$$

The answers to issue (11) provide the ideal proportions of green and non-green commercial bonds in the marketplace and can be obtained by:

$$x^* = \frac{\sigma_N^2 - \sigma_{G,N}}{\sigma_G^2 + \sigma_N^2 - 2\sigma_{G,N}} \quad (12a)$$

$$1 - x^* = \frac{\sigma_G^2 - \sigma_{G,N}}{\sigma_G^2 + \sigma_N^2 - 2\sigma_{G,N}} \quad (12b)$$

Considering circumstances (4) and (12a), (12b) ∈ (0, 1), the following has to be true:

$$\sigma_N^2 > \sigma_{G,N} \quad (13a)$$

$$\sigma_G^2 > \sigma_{G,N} \quad (13b)$$

We establish the variations of ideal stocks (12a) and (12b) with regard to the structure specifications as follows:

$$\frac{\partial x^*}{\partial \sigma_N^2} = \frac{\sigma_G^2 - \sigma_{G,N}}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^2} > 0 \quad (14a)$$

$$\frac{\partial x^*}{\partial \sigma_G^2} = \frac{\sigma_{G,N} - \sigma_N^2}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^2} < 0 \quad (14b)$$

$$\frac{\partial x^*}{\partial \sigma_{G,N}} = \frac{\sigma_N^2 - \sigma_G^2}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^2} \gtreqless 0 \quad (14c)$$

$$\frac{\partial x^*}{\partial \sigma_N^2 \partial \sigma_G^2} = \frac{\sigma_N^2 - \sigma_G^2}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^3} \gtreqless 0 \quad (14d)$$

$$\frac{\partial x^*}{\partial \sigma_G^2 \partial \sigma_{G,N}} = \frac{2\sigma_{G,N} + \sigma_G^2 - 3\sigma_N^2}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^3} \gtreqless 0 \quad (14e)$$

$$\frac{\partial x^*}{\partial \sigma_N^2 \partial \sigma_{G,N}} = -\frac{2\sigma_{G,N} - 3\sigma_G^2 + \sigma_N^2}{\left(\sigma_G^2 - 2\sigma_{G,N} + \sigma_N^2\right)^3} \gtreqless 0 \quad (14f)$$

Increasing financial risk mitigates the optimal proportion of business bonds in a CB portfolio. Covariance might have a favourable, adverse, or null influence on x^*, according to the distinction between the two deviations.

Given the ideal shares, it is achievable to extract the ideal quantity of green B_G^* and non-green bonds B_N^* in the marketplace:

$$B_G^* = x^* B_T \quad (15a)$$

$$B_N^* = (1-x)^* B_T \quad (15b)$$

The equilibrium bond yields μ_G^* and μ_N^* are found by putting the most suitable quantity of bonds, both green and non-green in the total reverse source characteristics (2c) and (3c):

$$\mu_G^* = \frac{\alpha}{B_G^*} = \frac{\alpha(\sigma_G^2 + \sigma_N^2 - 2\sigma_{G,N})}{B_T(\sigma_N^2 - \sigma_{G,N})} \quad (16a)$$

$$\mu_N^* = \frac{\beta}{B_N^*} = \frac{\beta(\sigma_G^2 + \sigma_N^2 - 2\sigma_{G,N})}{B_T(\sigma_G^2 - \sigma_{G,N})} \quad (16b)$$

These bond rates show the funding expense for every company that issues bonds. Using Eqs. (16a), (16b), the financial institution can adjust the composition x^* of its proportionality sheet to decrease the expense of capital for environmentally friendly firms and boost the expense for non-green enterprises without changing the latter's total measurements (B_T).

2.2.2. Green monetary policy

The reality of climatic outside forces and tangible and shifting hazards associated with climate shift calls market impartiality into question since it may exacerbate pre-existing ineffectiveness that leads to incorrect prices and inadequate resource distribution. The goal of environmentally friendly monetary administration is to accept such externalities and hazards to achieve an optimal allocation of monetary assets while considering climate-related challenges.

The CB aims to rectify its assortment to lower the expense of investment for enterprises that participate in suitable initiatives whereras simultaneously addressing the general aspect of balance sheet B_T. The CB minimizes borrowing costs for ecologically friendly corporations by raising the relative proportion x^* of environmentally friendly bonds while making it more expensive to finance non-green initiatives. This sustainable currency strategy should motivate businesses to invest and transition to environmentally friendly industrial practices. We describe green monetary regulations by implementing a steering/tilting component that controls the CB's holdings (Labidi, 2024; Schoenmaker, 2021).

$$p = \frac{C_N}{C_G} \quad (17)$$

Where C_i, with $i = G,N$ is an artificial measurement of the i-type issuer's environmental impact, such as average emission levels and/or other environmental measurements. It should be noted that The median ecological effect metric of non-green issuers C_N is higher than that of green issuers C_G. This is congruent with paper carried out by Fatica et al. (2021), which found that sustainable bonds distributed by non-financial firms are related to the decline in firm-level carbon emission levels caused by eco-friendly financial commitment initiatives.

The slanted component p in Eq. (17) is always greater than one since it represents the proportion of the two footprint measurements. Furthermore, this ratio outlines the scope of greening financial regulation and considers the extra hazards (physical and transitional) associated with the environmental impact of companies that challenge company bonds to fund non-sustainable initiatives. They: (1) bring more to bad weather occurrences and natural catastrophes, (2) are more exposed to an expanding judicial and administrative environment-friendly structure in which adherence hazards, litigation, and liability expenses connected with expenditures mindful of climate change erode the profitability of companies, (3) become the focus of fiscal strategies that require a decrease in the usage of fossil fuels and the release of carbon (ECB/ESRB, 2021; Alogoskoufis et al., 2021).

Climate dangers are crucial and incorporated through the CB business bond obtain strategies. Because they influence the difference of the associated bonds (σ_N^2), we develop a changed variation ˆ , which considers climate-related hazards in addition to financial risk:

$$\hat{\sigma}_N^2 = p\sigma_N^2 \quad (18)$$

When the steering/tilting factor p exceeds one, the overall danger associated with non-green business bonds rises. In this sense, by incorporating climate-related hazards into portfolio evaluations, the CB embraces the government's downsides and shortcomings. According to the marketplace effectiveness rule, the best choices for portfolios in a green monetary regulation context cover three goals: optimizing earnings, managing risk/volatility, and lowering firms' ecological impact, which is identified similarly to Eqs. (6) and (8) and stated in:

$$\max_x S_P = \frac{\mu_P(x) - r_F}{\sigma_P(x)} \quad \text{s.t.}$$

$$\begin{cases} \mu_P(x) = \dfrac{\alpha}{B_T} + \dfrac{\beta}{B_T} \\ \sigma_P^2(x) = x^2\sigma_G^2 + (1-x)^2\hat{\sigma}_N^2 + 2x(1-x)\sigma_{G,N} \end{cases} \tag{19}$$

and the equivalent answers in (12a) and (12b) with the replacement of $\hat{\sigma}_N^2$ in (18).

Since

$$\frac{\partial x^*}{\partial p} = \frac{\sigma_N^2(\sigma_G^2 - \sigma_{G,N})}{\left(\sigma_G^2 + p\bar{\sigma}_N^2 - 2\sigma_{G,N}\right)^2} > 0 \tag{20}$$

from condition (13b), the CB optimum portfolio has a greater proportion of green bonds (x^*) and a lower proportion of non-green bonds ($1–x^*$). The ideal quantity of both kinds of bonds B_G^* and B_N^* is provided by (15a) as well as (15b), the bond yields μ_G^* and μ_N^* are obtained by (16a) and (16b), after putting $\hat{\sigma}_N^2$ into (18):

$$\mu_G^* = \frac{\alpha}{B_G^*} = \frac{\alpha(\sigma_G^2 + \hat{\sigma}_N^2 - 2\sigma_{G,N})}{B_T(\hat{\sigma}_N^2 - \sigma_{G,N})} \tag{21a}$$

$$\mu_N^* = \frac{\beta}{B_N^*} = \frac{\beta(\sigma_G^2 + \hat{\sigma}_N^2 - 2\sigma_{G,N})}{B_T(\sigma_G^2 - \sigma_{G,N})} \tag{21b}$$

The CB lowers fiscal expenses for ecologically friendly businesses and restricts funding requirements for non-green corporations, hence raising the fictitious green premium (Caramichael and Rapp, 2024), since

$$\frac{\partial\mu_G^*}{\partial p} = \frac{\alpha\sigma_N^2\left(\sigma_{G,N} - \sigma_G^2\right)}{B_T\left(\sigma_{G,N} - p\sigma_N^2\right)^2} < 0 \quad \frac{\partial\mu_N^*}{\partial p} = \frac{\beta\sigma_N^2}{B_T\left(\sigma_{G,N} - \sigma_G^2\right)^2} > 0 \tag{22}$$

3. EMPIRICAL METHODOLOGY

The model employed to examine the connection between environmental performance and green monetary policy is as follows:

$$ES_{it} = \beta_0 + \beta_1 GMP_{i,t} + \beta_2 INC_{i,t} + \beta_3 GE_{i,t} + \beta_5 NR_{i,t} + \beta_5 POP_{i,t} + \beta_6 SAV_{i,t} + \beta_7 INF_{i,t} + \varphi_t + \omega_i + \varepsilon_{ijt}, \tag{1}$$

where *i* represents a country, *t* represents the year corresponding. φ_t denotes the year-fixed effect, and ω_i denotes the country-fixed effects. $\varepsilon_{ijt,}$ is the stochastic term.

3.1. Environmental Performance

Measures such as the Environmental Performance Index (EPI), Health Protection (HLT) and Ecosystem Protection (ECO) can be used to environmentally assess the performance of a particular nation (Hsu and Zomer, 2016)). The EPI is determined utilizing thirty-two indicators spanning ten topics, according to Ahmed et al. (2022) and Ha (2023), who stress the importance of building environmental policies utilizing the multidimensional environmental performance index (YCELP). Environmental Law and Policy at Yale University provided statistics on environmental performance.

3.2. Green Monetary Policy

According to the World Bank, public-private partnership investment in energy is defined as the value of pledges to energy projects that have completed financial closure and directly or indirectly benefit the public.

3.3. Control Variables

The explanatory variables used here are the growth of the economy (*INC)*, the level of democratization (GE), Natural rents (NR), Population (POP), the percentage of Savings (SAV) and Inflation (INFL), grounded on the empirical research, as shown in Table 1. The matrix of each variable's correlations is shown in Table 2. The information of included countried is provided in Table A1 in Appendix

The cross-sectional dependence (CD) test follows Pesaran (2021) to verify the existence of CD in the data. Next, the variable stationarity is assessed by applying Levin et al. (2002) and Im et al. (2003), taking into account the data's cross-sectional dependence. Presented in Table 3, the tests indicate that all variables are stationary after differencing them once. Following the approaches of Beck and Katz (1995), Ha (2022a, 2022b), Thanh et al. (2022), and Le et al. (2022), the panel-corrected standard error (PCSE) model was employed to investigate the linkage, accounting for the CD and stationarity status. Additionally, all explanatory variables are taken with a lag of one period to avoid plausible endogeneity. We also replicate our findings using the feasible generalized least squares (FGLS) and the two-step system GMM, which are applied to manage possible heterogeneity and endogeneity concerns, as suggested by Gala et al. (2018), Thanh et al. (2022), and Sweet and Eterovic (2019). Table 4 reports the results of cointegration test.

4. EMPIRICAL RESULTS

4.1. Environmental Performance and Green Monetary Policy: Benchmark Results

Table 5 demonstrates the impact of green monetary policy on environmental performance, using both PCSE and FGLS. Panel A estimates the impacts on EPI. Among the five dimensions of green monetary policy, three dimensions - GMP, GMP_

Table 1: Variables' definition and statistics summary

Variable	Definition	Measure	Source	Obs	Mean	SD	Min	Max
EPI	Environmental performance index	Scoring from 0 to 100, with a higher score means a better performance.	YCELP	374	48.19	14.14	15.83	77.96
HLT	Environmental health index	Scoring from 0 to 100, with a higher score means a better performance.	YCELP	374	63.01	23.33	8.09	93.14
ECO	Ecosystem vitality index	Scoring from 0 to 100, with a higher score means a better performance.	YCELP	374	49.56	12.85	18.88	69.29
GMP	Green monetary policy (GMP)	Natural logarithm value of per capita total green monetary policy inflow value.	IMF	374	0.02	0.15	0.00	1.00
GMP_CreditGuidance	Credit guidance on GMP		IMF	374	0.01	0.07	0.00	1.00
GMP_Collateral	Green collateral		IMF	374	0.01	0.10	0.00	1.00
GMP_Credit_ Operations	Green credit operations		IMF	374	0.01	0.12	0.00	2.00
GMP_Domestic_ Asset	Green domestic assets		IMF	374	0.01	0.07	0.00	1.00
GMP_Foreign_Asset_ Purchases	Green foreign asset purchase		IMF	374	9.89	1.08	6.63	11.26
INC	Economic growth	GDP per capita (real, constant 2010).	WDI	374	0.98	0.82	-0.76	2.35
GE	Level of democratization	The index of democratization	FSSDA	374	2.30	3.04	0.01	14.21
NR	Natural rents	Percentage of total natural rents (coal, mineral, natural gas, forest rents) to total GDP.	WDI	374	4.37	1.33	0.91	6.26
POP	Population.	Total of population.	WDI	374	25.53	7.53	10.96	51.55
SAV	Saving	Annual saving to total GDP (%).	WDI	374	48.19	14.14	15.83	77.96
INFL	Inflation	Annual inflation rate (%)	WDI	374	63.01	23.33	8.09	93.14

Table 2: Correlation coefficients

	EPI	HLT	ECO	GMP	GMP Credit Guidance	GMP Credit_ Operations	GMP Domestic_ Asset_ Purchases	GMP Foreign_ Asset_ Purchases
EPI	1							
HLT	0.905***	1						
ECO	0.922***	0.817***	1					
GMP	−0.0474	−0.0462	−0.0872	1				
GMP_CreditGuidance	−0.159**	−0.162**	−0.174***	0.467***	1			
GMP_Credit_Operations	−0.0469	−0.0257	−0.0652	0.662***	−0.00762	1		
GMP_Domestic_Asset_Purchases	0.104*	0.0801	0.0587	0.140**	−0.00510	−0.00723	1	
GMP_Foreign_Asset_Purchases	0.0882	0.0691	0.0529	0.467***	−0.00538	−0.00762	−0.00510	1
INC	0.857***	0.964***	0.778***	−0.0442	−0.166**	−0.00411	0.0619	0.0499
GE	0.739***	0.855***	0.595***	−0.00328	−0.0654	0.0110	0.0624	0.00426
NR	−0.342***	−0.248***	−0.324***	−0.0767	−0.0126	−0.0514	−0.0336	−0.0493
POP	−0.0310	−0.159**	−0.00884	0.124*	0.0968	0.0833	−0.00653	−0.00546
SAV	−0.267***	−0.168**	−0.387***	0.131*	0.0624	0.136**	0.0358	0.00255
INFLL	−0.577***	−0.592***	−0.492***	−0.0294	0.113*	−0.0939	−0.0194	−0.0217
	INC	**GE**	**NR**	**POP**	**SAV**		**INFLL**	
EPI								
HLT								
ECO								
GMP								
GMP_CreditGuidance								
GMP_Credit_Operations								
GMP_Domestic_Asset_Purchases								
GMP_Foreign_Asset_Purchases								
INC	1							
GE	0.861***	1						
NR	−0.201***	−0.257***	1					
POP	−0.191***	−0.0197	−0.563***	1				
SAV	−0.107*	0.101	0.301***	0.149**	1			
INFLL	−0.524***	−0.470***	0.326***	−0.121*	−0.0168		1	

Table 3: Cross-sectional dependence and stationarity tests

Variable (in level)	CD-test, Pesaran (2004)	Im-Pesaran-Shin test (Z-bar)	Variable (in difference)	Im-Pesaran-Shin test (Z-bar)
EPI	7.712***	4.135	DEPI	−2.524***
HLT	25.85***	−3.55***	DHLT	−20.20***
ECO	153.85***	−0.36	DECO	−22.84***
GMP	21.66***	−9.66***	DGMP	−25.77***
INC	42.070***	3.007	DINC	−3.698***
GE	14.973***	0.463	DGE	−3.241***
NR	0.103	−4.056***	DNR	−4.653***
POP	7.381***	0.247	DPOP	−3.663***
SAV	32.791***	4.124***	DSAV	−2.238***
INFLL	0.034	9.771	DINFLL	−3.370***

For the CD test, the null hypothesis is "cross-sections are independent." In the context of the CIPS, the null hypothesis is "panels are homogeneous and non-stationary." Meanwhile, for the Levin-Lin-Chu unit root test, the null hypothesis is "panels contain a unit root", with the alternative hypothesis is "panels are stationary"

Table 4: Cointegration test

Model: f (EP and GMP)	Kao test	Pedroni test	Westerlund test
	Dickey-Fuller test	Phillips-Perron t	Variance ratio
EPI	−3.11***	−2.51***	5.26***
HLT	−4.17***	−2.56***	5.11***
ECO	−5.18***	−2.64***	5.24***

Regarding the Kao and Pedroni tests, the null hypotheses are "No cointegration," while the alternative hypotheses are "All panels are cointegrated." Regarding the Westerlund test, the null hypothesis is "No cointegration," while the alternative is "Some panels are cointegrated"

Credit_Operations, and GMP_Foreign_Asset_Purchases - are found to be statistically significant at the 1% level. Notably, GMP_Foreign_Asset_Purchases has the strongest effect on the environmental performance index (EPI), with a coefficient of 6.54 at a 5% significance level. GMP_Credit_Guidance and GMP_Domestic_Asset_Purchases are not significant. The results highlight the importance of green monetary policy in improving EPI. Among control variables, economic growth (INC), democratization level (GE), natural rents (NR), and inflation (INFL) negatively affect EPI at the 1% significance level. In contrast, population (POP) positively impacts EPI, while savings (SAV) negatively impact it, though both are found to be insignificant.

Similarly, in Panel B, both PCSE and FGLS estimates show that the coefficients of GMP, GMP_Credit_Operations, and GMP_Foreign_Asset_Purchases are statistically significant at the 10% level, with GMP_Credit_Operations having the strongest impact on the environmental health index (HLT) with a coefficient of 1.20. However, GMP_CreditGuidance and GMP_Foreign_Asset_Purchases do not exert significant effects on HLT. These results underscore the importance of green monetary policy for the HLT. Control variables such as democratization level (GE), population (POP), savings (SAV), and inflation (INFL) negatively affect the HLT at the 10% significance level. At the same time, economic growth (INC) and natural rents (NR) have insignificant negative impacts. The Ecosystem Vitality Index (ECO) is examined in Panel C in relation to green monetary policy. As for the five GMP components, only GMP_Foreign_Asset_Purchases and GMP_Domestic_Asset_Purchases are significant in both estimates at the 10% levels. While GMP Foreign Asset Purchases promote ECO, GMP Domestic Asset Purchases significantly reduce it. At the 10% level, the following control factors significantly affect the index negatively: population (POP) and inflation (INFL), whereas economic growth (INC), democratization level (GE), and savings (SAV) favorably affect the index. NR is the only control variable that has no significant impact on ECO.

4.2. Robustness Checks

4.2.1. The short−run and long-run influence of green monetary policy

The influence of green monetary policy on both short- and long-term environmental performance is seen in Table 6. At a 10% significance level, the long-term analysis demonstrates that GMP has a considerable beneficial influence on all three environmental performance metrics, with coefficients ranging from 0.88 to 1.72. This suggests that environmental features including ecosystem, health protection, and environmental performance index may be successfully promoted by concentrating on green financing policies. We did not discover a substantial short-term influence of GMP on any of the three associations, in contrast to the long-term connection. It implies that GMP is not immediately evident from actual data. Furthermore, in all three models, the coefficient EC term is substantial and negative, which ranges from -0.33 to -0.38. This result indicates that, over time, between 33 and 38 percent of the disequilibrium brought about by shocks during the preceding period will return to equilibrium.

4.2.2. Mechanism

The EPI centers on two policy objectives: Environmental Health and Ecosystem Vitality. 40 indicators monitored in 11 problem categories are used to measure these, including Air Quality (AIR); Sanitation and Drinking Water (H_2O); Heavy Metals (HMT); Waste Management (WMG); Biodiversity and Habitat (BDH); Ecosystem Services (ECS); Fisheries (FSH); Climate Change Mitigation (CCM); Acid Rain (ACR); Agriculture (AGR); Water Resources (WRS).

The linear effect of GMP on ecological sustainability is shown in Table 7. The results obtained from both PCSE and FGLS approaches are comparable, suggesting a strong analysis of the process. Panel A shows the influence of GMP on four factors: air, sanitation and drinking water (H_2O); heavy metals (HMT); and waste management (WMG); while Panel B looks at the effects of

Table 5: The effects of green monetary policy on environmental performance: Benchmark models

Panel A: EPI										
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
	PCSE					**FGLS**				
	EPI	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**	**EPI**
L.GMP	1.14*					1.14*				
	(0.322)					(0.190)				
L.GMP_CreditGuidance		−2.10					−2.10			
		(2.214)					(2.103)			
L.GMP_Credit_Operations			2.28**					2.28***		
			(0.140)					(0.029)		
L.GMP_Domestic_Asset_Purchases				−0.66					−0.66	
				(1.596)					(2.834)	
L.GMP_Foreign_Asset_Purchases					6.54**					6.54**
					(3.277)					(2.822)
L.INC	−4.86***	−4.67***	−4.95***	−4.77***	−4.68***	−4.86***	−4.67***	−4.95***	−4.77***	−4.68***
	(1.184)	(1.234)	(1.186)	(1.198)	(1.188)	(1.402)	(1.400)	(1.407)	(1.401)	(1.390)
L.GE	−5.94***	−5.73***	−5.90***	−5.85***	−5.78***	−5.94***	−5.73***	−5.90***	−5.85***	−5.78***
	(1.266)	(1.257)	(1.260)	(1.248)	(1.229)	(1.056)	(1.060)	(1.053)	(1.054)	(1.047)
L.NR	−0.45***	−0.45***	−0.45***	−0.45***	−0.46***	−0.45***	−0.45***	−0.45***	−0.45***	−0.46***
	(0.118)	(0.119)	(0.117)	(0.118)	(0.119)	(0.135)	(0.135)	(0.135)	(0.136)	(0.135)
L.POP	0.20	1.14	0.70	0.54	0.02	0.20	1.14	0.70	0.54	0.02
	(3.100)	(3.087)	(3.006)	(3.041)	(3.080)	(4.842)	(4.866)	(4.829)	(4.835)	(4.805)
L.SAV	−0.04	−0.05	−0.04	−0.05	−0.05	−0.04	−0.05	−0.04	−0.05	−0.05
	(0.073)	(0.074)	(0.074)	(0.074)	(0.073)	(0.083)	(0.083)	(0.083)	(0.083)	(0.083)
L.INFLL	−0.51***	−0.51***	−0.50***	−0.51***	−0.53***	−0.51***	−0.51***	−0.50***	−0.51***	−0.53***
	(0.129)	(0.130)	(0.130)	(0.129)	(0.128)	(0.120)	(0.120)	(0.120)	(0.120)	(0.119)
Observations	357	357	357	357	357	357	357	357	357	357
Number of nations	17	17	17	17	17	17	17	17	17	17
Panel B: HLT										
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
	PCSE					**FGLS**				
	HLT	**HLT**	**HLT**	**HLT**	**HLT**	**HLT**	**HLT**	**HLT**	**HLT**	**HLT**
L.GMP	0.08					0.08				
	(0.516)					(0.455)				
L.GMP_CreditGuidance		−0.99					−0.99			
		(0.980)					(0.803)			
L.GMP_Credit_Operations			1.20*					1.20*		
			(0.255)					(0.774)		
L.GMP_Domestic_Asset_Purchases				0.37*					0.37*	
				(0.280)					(0.082)	
L.GMP_Foreign_Asset_Purchases					−0.46					−0.46
					(0.524)					(1.085)
L.INC	−0.45	−0.40	−0.54	−0.43	−0.44	−0.45	−0.40	−0.54	−0.43	−0.44
	(0.464)	(0.457)	(0.489)	(0.454)	(0.452)	(0.536)	(0.534)	(0.536)	(0.535)	(0.535)
L.GE	−1.71***	−1.65***	−1.73***	−1.71***	−1.71***	−1.71***	−1.65***	−1.73***	−1.71***	−1.71***
	(0.444)	(0.449)	(0.442)	(0.450)	(0.450)	(0.404)	(0.404)	(0.401)	(0.403)	(0.403)
L.NR	−0.01	−0.01	−0.00	−0.01	−0.01	−0.01	−0.01	−0.00	−0.01	−0.01

(Contd...)

Table 5: *(Continued)*

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel B: HLT										
	PCSE					FGLS				
	HLT	HLT	HLT	HLT	HLT	HLT	HLT	HLT	HLT	HLT
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
L.POP	−12.22***	−11.92***	−12.11***	−12.20***	−12.16***	−12.22***	−11.92***	−12.11***	−12.20***	−12.16***
	(1.173)	(1.194)	(1.191)	(1.189)	(1.184)	(1.851)	(1.857)	(1.841)	(1.846)	(1.848)
L.SAV	−0.06**	−0.06**	−0.06**	−0.06**	−0.06**	−0.06*	−0.06**	−0.06*	−0.06*	−0.06*
	(0.028)	(0.028)	(0.028)	(0.027)	(0.027)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
L.INFLL	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***	−0.21***
	(0.058)	(0.057)	(0.058)	(0.058)	(0.058)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Observations	357	357	357	357	357	357	357	357	357	357
Number f nations	17	17	17	17	17	17	17	17	17	17
Panel C: ECO										
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
	PCSE					FGLS				
	EPI	EPI	EPI	EPI	EPI	EPI	EPI	EPI	EPI	EPI
L.GMP	−0.90					−0.90				
	(1.197)					(1.303)				
L.GMP_CreditGuidance		−3.15					−3.15			
		(2.284)					(2.299)			
L.GMP_Credit_Operations			0.37					0.37		
			(1.662)					(2.225)		
L.GMP_Domestic_Asset_Purchases				−3.24*					−3.24	
				(1.703)					(3.097)	
L.GMP_Foreign_Asset_Purchases					3.16*					3.16*
					(0.973)					(0.107)
L.INC	−5.91***	−5.87***	−6.03***	−6.06***	−5.96***	−5.91***	−5.87***	−6.03***	−6.06***	−5.96***
	(0.980)	(1.003)	(0.978)	(0.969)	(0.975)	(1.536)	(1.531)	(1.543)	(1.531)	(1.530)
L.GE	−2.42**	−2.30**	−2.49**	−2.46**	−2.45**	−2.42**	−2.30**	−2.49**	−2.46**	−2.45**
	(1.028)	(1.029)	(1.024)	(1.009)	(1.014)	(1.157)	(1.158)	(1.155)	(1.152)	(1.153)
L.NR	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10
	(0.114)	(0.113)	(0.114)	(0.114)	(0.116)	(0.148)	(0.148)	(0.149)	(0.148)	(0.148)
L.POP	12.95***	13.59***	12.71***	12.70***	12.43***	12.95**	13.59**	12.71**	12.70**	12.43**
	(3.572)	(3.635)	(3.556)	(3.533)	(3.586)	(5.304)	(5.320)	(5.295)	(5.285)	(5.291)
L.SAV	0.23***	0.22***	0.23***	0.23***	0.23***	0.23**	0.22**	0.23**	0.23**	0.23**
	(0.072)	(0.073)	(0.073)	(0.072)	(0.072)	(0.091)	(0.091)	(0.091)	(0.091)	(0.091)
L.INFLL	−0.57***	−0.58***	−0.57***	−0.57***	−0.58***	−0.57***	−0.58***	−0.57***	−0.57***	−0.58***
	(0.144)	(0.144)	(0.146)	(0.144)	(0.145)	(0.131)	(0.131)	(0.132)	(0.131)	(0.131)
Observations	357	357	357	357	357	357	357	357	357	357
Number of nations	17	17	17	17	17	17	17	17	17	17

SE in parentheses ***,**,* are 1%, 5%, and 10%

GMP on Biodiversity and Living Environment (BDH), Ecosystem Services (ECS), Fisheries (FSH), Climate Change Mitigation (CCM), Acid Rain (ACR), Agriculture (AGR), and Water Resources (WRS). Of these, only the effect of GMP on WMG is of statistical significance in PCSE estimates for Panel A, and only the effect of GMP on FSH is statistically important in PCSE and FGLS estimates for Panel B, at the 10% level. This implies that the two policy objectives in the EPI will be more successfully attained if the growth of the FSH component is prioritized.

Table 6: The influence of green monetary policy on environmental performance: Short-run and long-run effects

Variables	(1)	(2)	(3)
	EPI	HLT	ECO
		Short-run impact	
EC term	−0.37*	−0.33***	−0.38***
	(0.016)	(0.013)	(0.015)
D.GMP	0.11	0.13	0.14
	(0.04)	(0.001)	(0.019)
		Long-run impact	
GMP	0.88***	0.95***	1.72**
	(0.012)	(0.001)	(0.002)
Observations	357	357	357

The inclusion of institutional quality into the model, as both an independent variable and an interaction term with GMP, is examined in Table 8. Surprisingly, in contrast to previous findings, adding institutional quality dimensions into the model results in the negative impacts of the GMP (independently) environment performance index and its dimension, except for corruption control (CC) and GE variables. Institutional quality variables as independent variables have two distinct effects on EPI. First, VA, RQ, and CC positively affect EPI; while PV, GE, and RL exert a negative effect. The interaction term of institutional quality with the GMP all reported positive coefficients but for the insignificance

Table 7: The linear effects of green monetary policy on environmental performance: Transmission mechanisms

Panel A								
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	PCSE					FGLS		
	AIR	H_2O	HMT	WMG	AIR	H_2O	HMT	WMG
L.GMP	0.14	−0.38	0.63	0.34*	0.14	−0.38	0.63	0.34
	(0.820)	(0.501)	(0.674)	(0.188)	(0.699)	(0.673)	(0.678)	(0.211)
L.INC	−5.39***	12.22***	−4.39***	−0.98***	−5.39***	12.22***	−4.39***	−0.98***
	(0.733)	(0.706)	(0.567)	(0.187)	(0.823)	(0.793)	(0.799)	(0.248)
L.GE	−1.86***	−1.76***	−1.93***	−0.57***	−1.86***	−1.76***	−1.93***	−0.57***
	(0.684)	(0.414)	(0.655)	(0.210)	(0.620)	(0.598)	(0.602)	(0.187)
L.NR	−0.10	0.27***	−0.23***	0.01	−0.10	0.27***	−0.23***	0.01
	(0.062)	(0.058)	(0.069)	(0.024)	(0.080)	(0.077)	(0.077)	(0.024)
L.POP	−24.89***	10.85***	−11.54***	−0.94**	−24.89***	10.85***	−11.54***	−0.94
	(1.977)	(1.886)	(1.274)	(0.391)	(2.843)	(2.740)	(2.758)	(0.857)
L.SAV	−0.08*	−0.06	−0.06	0.04***	−0.08	−0.06	−0.06	0.04***
	(0.046)	(0.040)	(0.043)	(0.012)	(0.049)	(0.047)	(0.047)	(0.015)
L.INFLL	−0.25***	−0.24***	−0.12**	0.00	−0.25***	−0.24***	−0.12*	0.00
	(0.086)	(0.081)	(0.058)	(0.020)	(0.070)	(0.068)	(0.068)	(0.021)
Observations	357	357	357	357	357	357	357	357
Number of nations	17	17	17	17	17	17	17	17

Panel B										
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	PCSE					FGLS				
	BDH	ECS	FSH	ACD	AGR	BDH	ECS	FSH	ACD	AGR
L.GMP	−2.01	1.58	−3.05**	0.02	0.26	−2.01	1.58	−3.05***	0.02	0.26
	(2.051)	(1.406)	(1.367)	(4.022)	(0.371)	(2.562)	(1.401)	(1.081)	(3.602)	(0.652)
L.INC	−16.53***	−14.70***	−2.67*	42.77***	2.26***	−16.53***	−14.70***	−2.67**	42.77***	2.26***
	(1.731)	(1.282)	(1.412)	(4.583)	(0.456)	(3.018)	(1.651)	(1.274)	(4.244)	(0.768)
L.GE	−3.95**	4.17***	−2.60**	−11.85***	−0.87	−3.95*	4.17***	−2.60***	−11.85***	−0.87
	(1.907)	(1.317)	(1.089)	(3.178)	(0.533)	(2.274)	(1.244)	(0.960)	(3.198)	(0.579)
L.NR	0.21	−0.50***	−0.27*	−0.69	0.02	0.21	−0.50***	−0.27**	−0.69*	0.02
	(0.228)	(0.144)	(0.167)	(0.447)	(0.060)	(0.292)	(0.159)	(0.123)	(0.410)	(0.074)
L.POP	31.48***	29.13***	−5.49	−44.72***	−12.32***	31.48***	29.13***	−5.49	−44.72***	−12.32***
	(7.204)	(4.601)	(4.302)	(8.501)	(3.361)	(10.424)	(5.702)	(4.401)	(14.658)	(2.653)
L.SAV	0.44***	0.60***	0.25***	−1.00***	−0.09**	0.44**	0.60***	0.25***	−1.00***	−0.09**
	(0.136)	(0.085)	(0.081)	(0.258)	(0.041)	(0.179)	(0.098)	(0.076)	(0.252)	(0.046)
L.INFLL	−0.99***	−0.14	0.18	−1.54***	−0.00	−0.99***	−0.14	0.18*	−1.54***	−0.00
	(0.264)	(0.132)	(0.126)	(0.448)	(0.057)	(0.258)	(0.141)	(0.109)	(0.363)	(0.066)
Observations	357	357	357	357	357	357	357	357	357	357
Number of nations	17	17	17	17	17	17	17	17	17	17

SE in parentheses ***,**,* are 1%, 5%, and 10%

Table 8: An analysis of the moderating effects of institutional quality on the link between green monetary policy and the environmental performance

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	EPI					
	VA	PV	GE	RQ	RL	CC
L.GMP	−0.15***	−0.17***	−0.15	−0.14***	−0.14***	0.14
	(0.019)	(0.015)	(0.011)	(0.016)	(0.010)	(0.027)
L.InstQ	0.24***	−0.22***	−0.28***	0.29	−0.24***	0.21***
	(0.029)	(0.070)	(0.061)	(0.056)	(0.037)	(0.145)
L.InstQ* GMP	1.23***	1.44**	1.15	1.12***	1.23***	1.11
	(0.012)	(0.122)	(0.212)	(0.014)	(0.03)	(0.118)
L.INC	−0.01*	−0.22***	−0.01*	−0.11*	0.01	−0.01*
	(0.007)	(0.008)	(0.007)	(0.006)	(0.006)	(0.007)
L.GE	0.24***	0.26***	0.13***	0.13***	0.03***	0.03***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
L.POP	−0.13***	−0.24	−0.26	−0.25***	−0.01	−0.03
	(0.051)	(0.043)	(0.053)	(0.056)	(0.034)	(0.045)
L.NR	−0.17***	−0.24***	−0.22	−0.24***	−0.08***	−0.04***
	(0.012)	(0.014)	(0.015)	(0.012)	(0.013)	(0.015)
L.SAV	0.19	−0.23	−0.32***	−0.10	−0.22***	−0.11
	(0.086)	(0.079)	(0.108)	(0.095)	(0.071)	(0.103)
Observations	357	357	357	357	357	357
Number of nations	17	17	17	17	17	17

SE in parentheses ***,**,* are 1%, 5%, and 10%

of GE and CC. Since these coefficients are of large magnitude, they can offset the adverse influence of GMP and institutional quality (independently, if applicable), and induce the enhancement environment performance index.

5. CONCLUSIONS

This study explores the impact of Green Monetary Policy (GMP) on environmental performance (EP) using composite and dimensional indices over the period 2001-2022 in 17 countries. The analysis controls economic growth, democratization levels, natural rents, population, and inflation. The results show that GMP significantly and positively affects the composite performance index of EP and its components EPI, HLT, and ECO. This positive influence is confirmed in the long term, where GMP enhances EP performance, with institutional quality acting as a positive catalyst.

The findings suggest that countries should consider enacting green monetary policies to improve the quality and effectiveness of environmental policies. Green credit guidelines and green foreign asset purchases should be prioritized. Governments and policymakers must invest in and research this area to transition to a green economy. In the presence of good institutional quality, the relationship between GMP and EP tends to yield positive outcomes, as effective policy institutions provide the certainty needed for businesses to invest and adapt their operations, promoting sustainable environmental development.

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APPENDIX

Table A1: Countries in the sample

EU countries		
Austria	Hungary	Portugal
Belgium	Iceland	Slovak Republic
Bulgaria	Ireland	Slovenia
Czech Republic	Italy	Sweden
Denmark	Lithuania	
Spain	Luxembourg	
Estonia	Latvia	
United Kingdom	Malta	
Greece	Netherlands	
Croatia	Poland	