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The cautious march of central banks toward climate policy measures

Afroza Sultana

Department of Business Administration, Premier University, Chittagong-4000, Bangladesh.
Email: afrozapuc2018@gmail.com

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ABSTRACT

This study examines central banks' cautious yet evolving approach toward integrating climate-related policy measures within their mandates. An extensive literature search finds that unconventional monetary and collateral-based policies have the possibility of violating the market neutrality rules and may face political resistance. Regarding carbon tax, central banks can play a supportive rather than a pivotal role, and stress-testing, which can be an effective tool to disclose climate risk, is still nascent. Furthermore, a binomial logistic regression model has been employed using three key indicators: green bond issuance, carbon intensity of GDP, and the green macroprudential index, along with GDP and climate vulnerability as control variables across 55 countries. Results show that although central banks are the dominant climate risk regulators in most countries studied, their involvement does not significantly predict superior green financial outcomes. Notably, a negative association is observed between regulatory stringency and central bank enforcement, suggesting that non-central bank institutions may administer mature green regulations. The jackknife method indicates that central banks can be an efficient facilitator of green bond issuance when the data of the United States, the key opponent of green central banking, is excluded from the model. The study recommends a clearly defined mandate for central banks and advocates for coordinated monetary-fiscal strategies to ensure effective and balanced climate action.

Contribution/ Originality: This paper uniquely analyzes whether central banks, as the primary enforcers of climate-related financial regulation, lead to improved green financial outcomes. It is the first research of its kind to reveal that, until now, the involvement of central banks has not significantly enhanced the performance of green financial indicators.

1. INTRODUCTION

Climate change presents significant challenges for individuals, institutions, and society. In line with this, the desire to achieve net-zero carbon emissions by 2050 requires a substantial reduction in global emissions within the next decade (Dombret & Kenadjian, 2021). Many experts argue that relying solely on the market economy to regulate carbon emissions is insufficient, as the private sector continues to sustain a carbon-intensive economic model (Şimandan & Păun, 2021). Besides, there is increasing recognition that climate change and the transition to a low-carbon economy pose systemic macroeconomic and financial stability challenges. As a result, public institutions, including central banks and financial regulators, should take more proactive measures (Campiglio et al., 2018). Central banks, being state institutions, have a legal and ethical responsibility to support efforts to reduce carbon emissions. This involves recognizing financial risks linked to climate change and using their influence to promote sustainable investments that support the shift toward a low-carbon economy (Robins, 2023).

With their regular mandate, central banks supervise government and commercial banks to ensure a stable and efficient financial system that supports economic growth. They regulate interest rates, control the money supply, and handle open market operations to implement monetary policy, manage inflation, and stabilize the currency. Additionally, they provide financial assistance to the government as a lender, which contributes to overall financial stability. Central banks are also responsible for issuing and circulating the national currency, managing foreign exchange reserves, and offering financial guidance. They also regulate payment systems and ensure secure transactions (Campiglio et al., 2018; Dombret & Kenadjian, 2021).

Central banks are increasingly being pressed to consider climate risks as part of their responsibilities, given their potential to impact financial stability (Simon Dikau & Volz, 2021; González & Núñez, 2021; United Nations Environment Programme, 2017). As a result, many central banks integrate climate-related risks into their policy frameworks, incorporate sustainability initiatives into their mandates, and support green finance (Simon Dikau & Volz, 2021; Sultana, 2025). However, central banks' responses vary based on legislative mandates, institutional interpretations, and the country-based political context in which they operate (Robins, 2023).

On the contrary, some scholars argue that involving central banks in efforts to green the economy could undermine their legitimacy, increase politicization, and result in unnecessary interventions. These critics also point out potential adverse outcomes, such as price instability, inflationary pressures, damaged reputations, and worsening economic inequality. Additionally, they warn that over-reliance on monetary expansion, commercial banking regulation, and the emergence of a new type of conservatism in central bank practices could increase public debates (Şimandan & Păun, 2021). Moreover, expanding central banks' mandates may overburden them with additional responsibilities, making it harder to focus on their primary goal of maintaining monetary and financial stability (Campiglio et al., 2018). Considering the probable scenario, 48% of central banks still had not adopted clear sustainability objectives, although many were taking steps to integrate environmental and climate-related risks into their policy frameworks (Simon Dikau & Volz, 2021).

The actions of central banks and financial regulators in supporting a low-carbon transition depend on their specific mandates, how those mandates are interpreted, and their willingness to take action (Campiglio et al., 2018). Given the variations in central bank mandates and traditions among countries, it is crucial to examine the degree to which central banks should align with and assist their governments in achieving sustainability goals (Simon Dikau & Volz, 2021). Considering these dubious suggestions from the two dimensions of literature, the study aims to determine the extent to which the central bank should be involved in this climate-related policy measure. It searches for evidence on whether central banks serve better as the leading regulatory authority for green regulation in the economic sector. Starting with the literature search on the current suggested green central banking policies and practices, it applied a binomial logistic regression to analyze the relationship between green financial indicators' performance and central banks' role as primary regulators across 55 countries. The study will contribute to the existing knowledge of the area by examining central banks' cautious yet evolving approach toward integrating climate policy measures within their mandates.

2. LITERATURE REVIEW

The following sub-sections of the literature review have explored recent themes in green central banking.

2.1. Evaluation of Green and Sustainable Central Banking

Central banks' shift toward a green and sustainable agenda gained significant momentum between the 2010s and early 2020s. The 2015 Paris Agreement highlighted the financial risks associated with climate change, prompting central banks to adjust their roles in managing these risks (United Nations Climate Change, 2015). In 2017, eight central banks and financial supervisors formed The Network for Greening the Financial System (NGFS), which serves as a platform for central banks and supervisors to exchange policies and strategies for addressing

environmental risks, scaling up sustainable finance, and sharing best practices. Many central banks are now considering joining the NGFS to establish common standards in this vital area of central banking (Durrani, Rosmin, & Volz, 2020). In 2020, the Bank for International Settlements (BIS) released a publication titled "Green Swan," which addressed the integration of climate risks into the stability mandates of central banks (Bolton, Després, Pereira da Silva, Samama, & Svartzman, 2020). Between 2020 and 2025, numerous central banks adopted green finance principles, adjusted regulatory frameworks, and aligned monetary policies with sustainability goals. However, the progress varied across institutions; for example, the European Central Bank (ECB) and the Bank of England moved more swiftly toward greener policies compared to the Federal Reserve (Jabko & Kupzok, 2024). This evolution is continuous, with central banks continuing to refine their strategies to address climate risks and support the transition to a low-carbon economy.

2.2. Unconventional Monetary Policy (UMP) and Green Quantitative Easing (Green QE)

According to their mandates, central banks aiming to stimulate economic growth may increase output, leading to accelerated environmental degradation (Merler & Bruegel, 2018). Therefore, central banks are considering aligning their monetary policy tools with environmental sustainability objectives. Before the 2007-2008 global financial crisis, central banks primarily relied on interest rate adjustments to manage economic conditions. However, following the crisis, many central banks adopted unconventional monetary policies (UMP), such as large-scale purchases of financial assets like government and corporate bonds, known as quantitative easing (QE), to provide further economic stimulus (Campiglio et al., 2018).

Green central banking, which this study is interested in, often suggests using UMP to support climate change mitigation efforts. While traditional monetary tools are designed to stabilize economic cycles and promote long-term growth, they are too broad to address environmental goals effectively (Merler & Bruegel, 2018). One such initiative, Green QE, has been adopted by some central banks, including the ECB. As part of its Public Sector Purchase Programme, the ECB allocates approximately 10% of its purchases to bonds issued by supranational entities, such as regional and national development banks (Campiglio et al., 2018).

Green QE is a monetary policy strategy where central banks prioritize purchasing environmentally sustainable assets, such as green bonds, to advance climate-related goals while injecting liquidity into the economy. In contrast to traditional QE, which involves broad asset purchases to stimulate overall economic growth, green QE specifically targets investments that support the transition to a low-carbon economy (Dafermos, Nikolaidi, & Galanis, 2018). This policy aims to mitigate climate-related financial risks, promote sustainable investments, and align monetary policy with environmental sustainability objectives (Matikainen, Campiglio, & Zenghelis, 2017). In response to negative financial disruptions caused by the fossil fuel industry, green QE has proven effective in mitigating output declines and reducing financial instability. This policy aligns with maintaining price stability and can be implemented within the mandates of central banks (Diluiso, Annicchiarico, Kalkuhl, & Minx, 2021).

However, there are ongoing debates about its effectiveness. Critics contend that central banks should maintain neutrality in asset purchases rather than prioritizing specific sectors (Campiglio et al., 2018). The idea of using monetary policy tools to favor green assets over brown assets is seen by some as a violation of the principle of market neutrality (Vestergaard, 2022). Nonetheless, the ECB has suggested moving away from the neutrality principle in favor of a market efficiency approach (European Central Bank (ECB), 2021).

Campiglio et al. (2018) indicated several opponents' views in this regard. His view is that central banks' QE programs are cyclical policy tools that provide temporary economic stimulus. However, using them to drive structural changes toward a low-carbon economy may place additional burdens on central banks, potentially undermining their ability to maintain price stability. Moreover, these purchases have unintentionally benefited large, carbon-intensive companies, as they tend to have more substantial credit ratings. At the same time, many low-carbon businesses are too small to issue corporate bonds. Additionally, some central banks view QE as incompatible with the inclusion of

low-carbon assets in their eligible asset lists, as these assets may not meet the required financial risk standards, raising concerns about the quality of the central bank's portfolio.

A recent study by Ferrari and Landi (2024) examines the transmission mechanisms of Green QE, which shifts the central bank's balance sheet toward green bonds issued by non-polluting firms. The study highlights that Green QE's impact on reducing emissions remains minimal. While some argue that green monetary interventions may encourage investors to participate in green markets only during stable periods, with their effectiveness potentially waning during crises (Aloui, Benkraiem, Guesmi, & Vigne, 2023). Furthermore, central banks' primary goals include stimulating economic activity, boosting the stock market, and restoring confidence in the financial sector, which encompasses both green and brown assets. Focusing exclusively on green assets could undermine the effectiveness of monetary policy in achieving its core objective of stabilizing the financial system, especially in times of crisis (Aloui et al., 2023).

2.3. Climate Financing

The transition to a net-zero carbon economy requires substantial investments, with the financial sector playing a pivotal role in directing resources toward sustainable and green initiatives, which can be called climate financing (Dombret & Kenadjian, 2021). More specifically, climate financing refers to allocating funds to support projects that reduce greenhouse gas emissions and improve resilience against the impacts of climate change. These financial resources come from the public and private sectors and are distributed through various intermediaries (Hong, Karolyi, & Scheinkman, 2020). Central banks are critical in encouraging bankers and asset managers to prioritize investments in climate mitigation instruments and low-emission growth (Sheng, 2015). In line with it, over the past few years, there has been a notable increase in the issuance of green and sustainable bonds, reflecting the growing demand for climate finance products (González & Núñez, 2021).

Notably, green and sustainability bonds are financial instruments designed to raise funds for projects with positive environmental impacts, such as renewable energy, energy efficiency, and sustainable infrastructure. Many countries are implementing green guidelines and issuing green bonds, often with the support of central banks (Dikau & Ryan-Collins, 2017). Central banks can foster green and low-carbon financing by facilitating access to green bond markets, lowering borrowing and issuance costs, and directly investing in green bonds (Durrani et al., 2020). Additionally, they can encourage bankers and asset managers to prioritize investments in climate mitigation and low-emission growth (Sheng, 2015).

2.4. The Brown Haircut and Green Hair Growth

In collateralized loans, a 'haircut' refers to a reduction in the value of an asset used as collateral, which ensures that the lender has enough security in case of default. The size of the haircut typically reflects the asset's risk level. Within central banking, terms like "brown collateral haircuts" and "green hair growth" are emerging to influence investment toward more sustainable practices. Brown collateral haircuts involve applying higher haircuts to carbon-heavy, or "brown," assets. By increasing the haircuts on these assets, central banks reduce their attractiveness as collateral, encouraging a shift toward more sustainable investments. In contrast, "green hair growth" refers to offering lower haircuts for "green" assets aligned with environmental sustainability, such as renewable energy projects or green bonds (McConnell, Yanovski, & Lessmann, 2021).

Jakob Vestergaard (2024) argues that collateral haircuts are a significant policy tool for adopting the green central banking agenda, despite the NGFS's view that they play a limited role. McConnell et al. (2021) identify that, combined with green hair growth, brown collateral haircuts promote carbon-neutral investments while reducing funding for carbon-intensive assets, thereby lowering emissions. Central banks can help mitigate climate change by distinguishing between green and brown collateral when lending to commercial banks. The strategy can reduce borrowing rates for green loans and increase rates for brown loans, encouraging greener investments (McConnell et

al., 2021). However, the concept of green monetary policy using monetary policy tools to favor green assets and penalize brown ones conflicts with the principle of market neutrality. This presents a point of political resistance among central bankers (Vestergaard, 2022).

2.5. Coordination with Fiscal Policy

Central banks primarily focus on monetary policy and financial regulation, while governments and legislative bodies generally manage fiscal policies. Fiscal policies, which include government spending and taxation strategies, aim to influence economic activity (Blinder, 1982). The primary fiscal policy mechanism recommended for addressing climate change is carbon pricing, which can be implemented through a tax on the carbon content of products and services or a cap-and-trade system for emission allowances. Other market-based approaches include subsidies for clean technology and the gradual phasing out of fossil fuel subsidies (Campiglio et al., 2018). In fact, introducing a carbon tax can impact inflation and economic growth, prompting central banks to adjust monetary policies, such as interest rates, to mitigate any negative economic consequences. For example, the Bank of Japan monitors the potential effects of climate policies, including carbon taxes, on inflation and economic stability (Kihara, 2024). Therefore, relying solely on carbon pricing may not be enough to support low-carbon businesses. On the other hand, monetary policy alone is an insufficient substitute for sound fiscal policy; overstating its effectiveness could distance it from the political realm and create unrealistic expectations among the public, seeking practical solutions to climate change (Hansen, 2022). McConnell et al. (2021) suggest that combining a carbon tax and green monetary policy could help governments reduce the necessary carbon tax levels, making the transition to a carbon-neutral economy more politically feasible.

2.6. Macroprudential Policies and Stress Testing

Macro- and microprudential policies, as outlined by the Basel regulatory framework, aim to reduce systemic financial risk and address specific financial risks that financial institutions face. These policies include tools such as reserve restrictions, liquidity mandates, capital requirements, loan-to-value ratio limits, and credit expansion controls. Financial institutions with higher-risk assets may be subject to stricter regulatory standards (Campiglio et al., 2018). There is an ongoing debate among financial authorities and institutions regarding integrating climate-related financial risks into the Basel Framework. The Pillar 1 framework, which mandates a minimum capital requirement, may be challenging to implement due to insufficient historical data on climate-related risks. In contrast, the Pillar 2 approach is seen as more feasible, offering a flexible method for capital assessment through climate scenario analysis and stress testing (Shirai, 2023).

Here, the climate-related stress test is an analytical process carried out by financial institutions and regulators to evaluate the resilience of financial systems to climate-related risks. To assess their effect on financial institutions' balance sheets and operations, these tests simulate potential climate change impacts, including extreme weather events, policy changes, and technological advancements (Durrani et al., 2020). Central banks are increasingly incorporating climate-related stress testing to maintain financial stability. By integrating climate risks into their supervisory frameworks, central banks aim to ensure that financial institutions properly manage and disclose these risks (Network for Greening the Financial System (NGFS), 2021).

2.7. The Dilemma of Role Playing

Federal Reserve Chair Jerome Powell has stressed that the responsibility for climate protection lies with elected governments, not central banks. In a 2021 speech, he stated, "We are not, and we do not seek to be, climate policymakers as such. We have a limited but important role, focused on our existing mandates" (Schroeder, 2021). Supporting his view, some argue that presenting central banks as climate leaders could create unrealistic expectations

(Boneva, Ferrucci, & Mongelli, 2022). Moreover, the involvement of central banks in climate risk raises concerns about their accountability and whether they can justify their actions within their traditional mandates (Siderius, 2022).

On the other hand, in the opinion of Christine Lagarde, President of the European Central Bank, "climate change affects all of our policy areas. The climate change center provides the structure we need to tackle the issue with the urgency and determination that it deserves (Bank for International Settlements, 2021)." supporting her view, it is said that the central bank must also have a responsibility to guide markets toward a scenario that limits global warming to below 2 degrees in order to mitigate long-term climate risks and safeguard the financial system (Thiemann, Büttner, & Kessler, 2023). Besides, as governments struggle to meet global climate targets, new climate advocates may emerge, potentially altering the political landscape of the climate-neutral economy (Siderius, 2022). It is also the view that although the transition to a low-carbon economy is ultimately the duty of elected governments, achieving a smooth transition requires a comprehensive policy approach. This could involve collaboration between central banks and financial regulators to ensure a coordinated effort (Boneva et al., 2022; Campiglio et al., 2018).

3. OBJECTIVES AND HYPOTHESIS

The discussion in the literature review identified differing perspectives on the role of central banking in various recent climate risk management domains, which facilitates the search for concrete evidence of central banks' association with improved green financial performance at the country level. Therefore, the main objective of the study is to examine the relationship between the central banks' primary role in green regulation and the enhancement of green financial indicators. Specifically, the analysis aims to determine whether countries primarily regulated by central banks, as opposed to other authorities, exhibit greater green bond issuance, a higher macroprudential index, and a lower carbon footprint in their gross domestic product. The study establishes the following null and alternative hypotheses for binomial logistic regression.

H_0 = *The green financial indicators do not perform better when regulated by central banks*

H_1 = *The green financial indicators perform better when regulated by central banks.*

4. DATA AND METHODOLOGIES

Binomial logistic regression (LR) has been used, which is one of the most commonly employed approaches for modeling variables when the outcome variable is binary (Hosmer, 2013). The dichotomy here is whether central banks, being the supreme authorities, are associated with the better performance of green financial indicators. The applied ten events per variable (EPV) is a widely accepted minimum standard for sample size concerns in logistic regression research (Collins, Reitsma, Altman, & Moons, 2015; Moons et al., 2014; Pavlou et al., 2015). However, there is also the view that the current evidence supporting EPV guidelines for binary logistic regression is insufficient (Van Smeden et al., 2016). As this study is cross-sectional and searches for an association rather than inferential causation, the ten EPV standards have been adopted, including one independent variable for each of the ten samples.

Appendix 1 presents the list of 55 countries included in the analysis. Considering these 55 countries, three independent variables and two control variables have been finally added. Regarding the sample size, determining the appropriate sample size for cross-country analyses depends on various factors, including the research objectives, the statistical methods employed, and the desired precision of the results, especially when survey data are very constrained (Meuleman & Billiet, 2009). Hence, the new and nascent nature of the study allows for research to be initiated on association rather than causation in this cross-sectional analysis across 55 countries.

The D'Orazio and Popoyan (2019) data source has been used for both dependent and independent variables. This data provides a comprehensive overview of green macroprudential regulations and instruments across various countries as of October 2019. The data is the first of its kind, including information on the climate-related financial regulations implemented, the institutions responsible for their enforcement, official references, and links to the relevant documents. The data were collected from official documents of national central banks and financial

institutions (D'Orazio & Popoyan, 2019). Two independent variables are collected from the International Monetary Fund (2022) and World Bank Group (2023) regarding the volume of green bond issuance (green finance) and the carbon intensity of GDP; these two are vital climate risk measurement indicators (International Monetary Fund, 2022).

Four independent data sources were used, since evidence suggests that the methodology may still be regarded as cross-sectional if the data from each year is evaluated as a separate, independent sample (Levin, 2006; Setia, 2016). The data's numeric coincidence allowed the application to adopt a nominal scale in the analysis. Dependent and independent variables and the respective data sources are described in Table 1.

Table 1. Description of variables.

Dependent variables		
	Descriptions	**Data source**
CB	The Central Bank is the supreme enforcement body. Two options have been considered: 1= Central Banks are the supreme regulatory enforcement body for implementing climate-related financial policy, and 0= Central Banks do not deal with implementing climate-related financial policy.	D'Orazio and Popoyan (2019)
Independent variables		
	Descriptions	Data source
GB	Green Bond. The 10-year average of the issuance of green and sustainability-linked bonds, which are fixed-income instruments mainly intended to finance climate and environmental initiatives, is taken.	International Monetary Fund (2022)
CO_2GDP	CO_2GDP is calculated by dividing total CO_2 emissions by the Gross Domestic Product (GDP), typically expressed in kilograms of CO2 per 2021 PPP $ of GDP.	World Bank Group (2023)
GMI	The green Macroprudential index. The GMI index is created by D'Orazio and Popoyan (2019) which sets the scores as 0= under discussion, 1=voluntary, and 2= mandatory, for implementing green regulation.	D'Orazio and Popoyan (2019)
Control variables		
	Descriptions	Data source
GDP	Gross Domestic Product Growth	World Bank Group (2024)
GVI	The GDL Vulnerability Index (GVI). It is a composite index designed to monitor and project socio-economic vulnerability to climate change.	Global Data Lab (2025)

The basic classification model using binomial logistic regression is:

$$logit(P) = ln(\frac{P}{1-P}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

Where P is the probability of the event outcome (Central bank is the supreme regulatory authority or not), β_0 is the Intercept, and β_1, β_2, β_k, etc, are the coefficients for predictor variables X_1, X_2, X_3, etc.

The specific models being used are:

Model 1: $CB = \beta_0+\beta_1 GB$.

Model 2: $CB = \beta_0+\beta_1 GB+\beta_2 CO_2GDP$.

Model 3: $CB = \beta_0+\beta_1 GB+\beta_2 CO_2GDP+\beta_3 GMI$.

Model 4: $CB = \beta_0+\beta_1 GB+\beta_2 CO_2GDP+\beta_3 GMI+\beta_4 GDP$.

Model 5: $CB = \beta_0+\beta_1 GB+\beta_2 CO_2GDP+\beta_3 GMI+\beta_4 GDP+\beta_5 GVI$.

Model 6: $CB_{JK} = \beta_0+\beta_1 GB+\beta_2 CO_2GDP+\beta_3 GMI+\beta_4 GDP+\beta_5 GVI$.

Model 6 has adopted the *jackknife* robustness test, where one country is removed from the analysis and the model is re-applied to check the robustness of the model in a cross-country study (Wu, 1986). In this stage, data from the United States has been removed to demonstrate that results are not unduly influenced by any single country's data,

as the US has been the largest GB issuing country that does not rely on the central bank for climate policy in the financial sector.

5. FINDINGS AND ANALYSIS

After the final analysis, among the 55 countries, 40 were found to be dependent on central banks for green regulation, while 15 countries were regulated by government-affiliated bodies other than central banks.

Table 2. Descriptive statistics.

Variables	Observations	Mean	Std. dev.	Min.	Max.
CB	55	0.7272	0.4495	0.0000	1.0000
GB	55	6.2922	9.8436	0.0061	47.0954
CO_2GDP	55	0.1612	0.1061	0.0471	0.4978
GMI	55	0.5273	0.8132	0.0000	3.0000
GDP	55	2.2587	1.9141	-1.7191	7.0912
GVI	55	30.3454	12.4874	11.0000	70.0000

Descriptive statistics in Table 2 indicate that approximately 73% of countries in the sample have designated their central banks as the regulatory body for managing climate-related financial indicators (Mean CB = 0.7272). The mean issuance of green and sustainability-linked bonds (GB) was 6.29, although the high standard deviation (9.84) suggests considerable disparity across countries. The average carbon intensity (CO_2GDP) stood at 0.1612, while the mean GMI score was 0.5273, reflecting that green prudential policies remain largely in preliminary or voluntary stages in many jurisdictions. GDP levels varied widely (Mean = 2.26; SD = 1.91), as did GVI scores (Mean = 30.34; SD = 12.49), underscoring heterogeneity in economic size and developmental vulnerability across the sample.

Table 3. Results of binomial regression models.

Independent variables	Dependent variable: Central bank as supreme policy maker					
	(1)	(2)	(3)	(4)	(5)	(6)
GB	0.0219 (0.5415)	0.0228 (0.5371)	0.0206 (0.5650)	0.0264 (0.4862)	0.0385 (0.3649)	0.1001 (0.1645)
CO_2GDP		1.1422 (0.7093)	1.6063 (0.6098)	1.3357 (0.6793)	1.0415 (0.7530)	1.9067 (0.6010)
GMI			-0.3119 (0.3999)	-0.4656 (0.2760)	-0.6955 (0.1860)	-0.9427 (0.1030)
GDP				0.1465 (0.4476)	0.1254 (0.5149)	0.2156 (0.2879)
GVI					0.0287 (0.4286)	0.0393 (0.3159)
Content	0.8537 (0.0173)	0.6684 (0.2723)	0.7820 (0.2077)	0.5532 (0.4317)	-0.1658 (0.8855)	-0.8452 (0.5334)
Chi-Square	0.415 (0.519)	0.559 (0.559)	1.256 (0.740)	1.843 (0.765)	2.505 (0.776)	5.340 (0.376)
McFadden R^2	0.0064	0.0087	0.0195	0.0286	0.0388	0.0864
Log likelihood	-32.0198	-31.9478	-31.5994	-31.3057	-30.9750	-28.23
Observation	55	55	55	55	55	55

Table 3 presents six stepwise logistic regression models. In Model 1, green bond issuance (GB) appears with a small and statistically insignificant positive coefficient (β = 0.0219; p = 0.5415), suggesting that countries with greater climate financing activities are not significantly more likely to designate central banks as climate risk regulators. However, in the Jackknife model 6, the coefficient and significance of GB increase significantly, suggesting a single-country (USA) influence in this regard.

Adding carbon intensity (CO_2GDP) in Model 2 slightly improves the model. While CO_2GDP yielded a positive coefficient across all models, the estimates remained statistically insignificant (e.g., $\beta = 1.1422$ in Model 2; $p = 0.7093$), implying that emissions intensity is not a significant determinant of central bank enforcement status. In Model 3, the Green Macroprudential Index (GMI) is added and shows a negative coefficient ($\beta = -0.3119$; $p = 0.3999$), which increases in magnitude in subsequent models. In the fully specified Model 6, GMI displays the strongest effect ($\beta = -0.9427$; $p = 0.1030$), suggesting that greater regulatory formalism may be inversely related to central bank enforcement. This finding indicates that as green prudential regulation becomes more stringent (from voluntary to mandatory), the likelihood that central banks are the implementing authority decreases. One possible interpretation is that in jurisdictions where climate regulation is more established, enforcement responsibilities may be distributed among other government-affiliated bodies rather than central banks alone.

Model 4 introduced GDP as a measure of economic size. The coefficient remained positive and consistent across models (e.g., $\beta = 0.2156$ in Model 6), yet was not statistically significant ($p = 0.2879$), indicating that economic size is not a strong predictor of regulatory assignment in this context. Similarly, the inclusion of the GDL Vulnerability Index (GVI) in Models 5 and 6 did not yield significant effects (e.g., $\beta = 0.0393$; $p = 0.3159$), although the coefficients were positive, suggesting a tentative association between vulnerability and the assignment of climate regulatory responsibilities to central banks. Model fit, as measured by McFadden R^2, gradually improves from 0.0064 (Model 1) to 0.0864 (Model 6), yet remains below the conventional thresholds for strong explanatory power.

5.1. Cross-Validation Robustness

In Table 4, 10-fold cross-validation has been used in RapidMiner Software as the model validation technique to ensure robust and unbiased performance evaluation. This method involves dividing the dataset into ten equal parts or "folds." In each iteration, one fold is used as the test set while the remaining nine folds are used for training. The process is repeated ten times, with each fold serving as the test set once. The results from all iterations are then averaged to produce a final performance metric. This approach helps in minimizing the variance associated with random data splits and provides a more stable estimate of model accuracy.

Table 4. Cross-validation.

Variables	Coefficients	Std. coefficient	Std. error	Z-value	P-value
GB	0.114	1.085	0.074	1.545	0.122
CO_2GDP	2.327	0.239	3.777	0.616	0.538
GMI	-1.007*	-0.816	0.554	-1.819	0.069
GDP	0.310	0.623	0.190	1.635	0.102
GVI	0.041	0.537	0.036	1.126	0.260
Constant	-1.141	1.351	1.328	-0.859	0.390

Note: * $p<0.10$.

In Table 4 in cross-validation, the direction and magnitude of the coefficients largely mirror those found in the regression models. In this robustness test, the coefficient for GMI remains negative and approaches marginal significance ($\beta = -1.007$; $p = 0.069$), further reinforcing the earlier inference that countries with more advanced green prudential regulation may assign enforcement to institutions other than central banks. Green bond issuance (GB) and GDP continue to exhibit insignificant positive associations.

6. CONCLUSION AND POLICY IMPLICATIONS

The role of central banks in addressing climate-related financial risks remains a subject of ongoing debate. While climate change poses significant risks to macroeconomic stability, the extent to which central banks should intervene in sustainability efforts is contested. Some advocate for an active role, incorporating green monetary policies,

regulatory frameworks, and sustainable finance incentives, while others express caution against overburdening central banks with objectives that may compromise their core mandate of ensuring financial and monetary stability.

The logistic regression models reveal that none of the independent variables, green bond issuance, carbon intensity, GDP, or vulnerability, exerts a statistically significant effect when central banks are the climate risk regulators. However, the GMI consistently showed a negative association, nearing significance in the full model ($p = 0.1030$) and in cross-validation ($p = 0.069$), suggesting an inverse relationship between regulatory maturity and central bank enforcement. Though central banks were the leading regulatory authorities in a higher number of countries, there was no statistically significant evidence that green financial indicators perform better when regulated by central banks. In sum, while macro-financial indicators offer some insight, the designation of regulatory authority likely depends on deeper governance structures, institutional mandates, and political economy factors, which were still beyond the scope of this quantitative model.

Central banks should have clearly defined mandates regarding climate-related interventions. If sustainability objectives are to be incorporated, legislative bodies must explicitly outline their scope to avoid potential conflicts with core responsibilities like price and financial stability. Besides, addressing climate change requires an integrated approach where central banks complement, rather than replace, government-led fiscal policies. Governments should take the lead in implementing carbon pricing, green subsidies, and tax incentives, while central banks can support these efforts through risk assessment frameworks and targeted green finance strategies.

While Green QE can support green finance markets, it must be carefully designed to avoid market distortions and conflicts with monetary policy objectives. Policymakers should ensure that green asset purchases are aligned with financial stability goals and do not compromise market neutrality. Additionally, transparency in financial markets is critical for effective climate risk management. Central banks and financial regulators should enforce mandatory climate-related disclosures to improve risk assessment, pricing accuracy, and informed decision-making for investors and financial institutions. Additionally, policymakers should recognize that different economies have varying levels of financial development and institutional capacity.

Lastly, while central banks have a role in addressing climate risks, their interventions should be carefully balanced to avoid unintended economic consequences. A collaborative, well-coordinated approach between monetary authorities, governments, and financial institutions is essential to achieving a sustainable, low-carbon economic transition while maintaining financial stability. Future studies should include more countries' practices to consider the central banks' role in climate risk management.

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REFERENCES

Aloui, D., Benkraiem, R., Guesmi, K., & Vigne, S. (2023). The European Central Bank and green finance: How would the green quantitative easing affect the investors' behavior during times of crisis? *International Review of Financial Analysis, 85*, 102464. https://doi.org/10.1016/j.irfa.2022.102464

Bank for International Settlements. (2021). *Christine Lagarde: Climate change and central banks – analysing, advising and acting.* Retrieved from https://www.bis.org/review/r210712b.htm

Blinder, A. S. (1982). *Issues in the coordination of monetary and fiscal policy.* National Bureau of Economic Research NBER Working Paper No. 982.

Bolton, P., Després, M., Pereira da Silva, L. A., Samama, F., & Svartzman, R. (2020). *The green swan: Central banking and financial stability in the age of climate change*. Bank for International Settlements, BIS Books No. 31.

Boneva, L., Ferrucci, G., & Mongelli, F. P. (2022). Climate change and central banks: What role for monetary policy? *Climate Policy*, *22*(6), 770-787. https://doi.org/10.1080/14693062.2022.2070119

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change*, *8*(6), 462-468. https://doi.org/10.1038/s41558-018-0175-0

Collins, G. S., Reitsma, J. B., Altman, D. G., & Moons, K. G. M. (2015). Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): The TRIPOD statement. *Journal of British Surgery*, *102*(3), 148-158. https://doi.org/10.1002/bjs.9736

D'Orazio, P., & Popoyan, L. (2019). Dataset on green macroprudential regulations and instruments: Objectives, implementation and geographical diffusion. *Data in Brief*, *24*, 103870. https://doi.org/10.1016/j.dib.2019.103870

Dafermos, Y., Nikolaidi, M., & Galanis, G. (2018). Climate change, financial stability and monetary policy. *Ecological Economics*, *152*, 219-234. https://doi.org/10.1016/j.ecolecon.2018.05.011

Dikau, S., & Ryan-Collins, J. (2017). Green central banking in emerging market and developing country economies. In (pp. 1–50). United Kingdom: New Economics Foundation.

Dikau, S., & Volz, U. (2021). Central bank mandates, sustainability objectives and the promotion of green finance. *Ecological Economics*, *184*, 107022. https://doi.org/10.1016/j.ecolecon.2021.107022

Diluiso, F., Annicchiarico, B., Kalkuhl, M., & Minx, J. C. (2021). Climate actions and macro-financial stability: The role of central banks. *Journal of Environmental Economics and Management*, *110*, 102548. https://doi.org/10.1016/j.jeem.2021.102548

Dombret, A. R., & Kenadjian, P. S. (2021). *Green banking and green central banking (Institute for Law and Finance Series)* (Vol. 24). Berlin/Boston, Germany: De Gruyter.

Durrani, A., Rosmin, M., & Volz, U. (2020). The role of central banks in scaling up sustainable finance—What do monetary authorities in the Asia-Pacific region think? *Journal of Sustainable Finance & Investment*, *10*(2), 92–112. https://doi.org/10.1080/20430795.2020.1715095

European Central Bank (ECB). (2021). *From market neutrality to market efficiency*. Frankfurt am Main, Germany: European Central Bank.

Ferrari, A., & Landi, V. N. (2024). Whatever it takes to save the planet? Central banks and unconventional green policy. *Macroeconomic Dynamics*, *28*(2), 299-324. https://doi.org/10.1017/S1365100523000032

Global Data Lab. (2025). *GDL vulnerability index*. Nijmegen, The Netherlands: Radboud University.

González, C. I., & Núñez, S. (2021). *Markets, financial institutions and central banks in the face of climate change: Challenges and opportunities*. Occasional Paper No. 2126, Banco de España, Madrid, Spain.

Hansen, L. P. (2022). Central banking challenges posed by uncertain climate change and natural disasters. *Journal of Monetary Economics*, *125*, 1-15. https://doi.org/10.1016/j.jmoneco.2021.09.010

Hong, H., Karolyi, G. A., & Scheinkman, J. A. (2020). Climate finance. *The Review of Financial Studies*, *33*(3), 1011-1023. https://doi.org/10.1093/rfs/hhz146

Hosmer, D. W. (2013). *Applied logistic regression*. United States: John Wiley & Sons, Inc.

International Monetary Fund. (2022). *Green debt, climate finance indicators*. Washington, D.C: International Monetary Fund.

Jabko, N., & Kupzok, N. (2024). The crossover between climate politics and central banking: How green central banking emerged in the US, the EU, and the UK. *Politics & Society*, *52*(4), 662-690. https://doi.org/10.1177/00323292241246357

Kihara, L. (2024). *BOJ hopes to keep 2% inflation target while monitoring climate shock risks*. Tokyo, Japan: Reuters.

Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-Based Dentistry*, *7*(1), 24-25. https://doi.org/10.1038/sj.ebd.6400375

Matikainen, S., Campiglio, E., & Zenghelis, D. (2017). The climate impact of quantitative easing. *Policy Paper, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science*, *36*, 1-36.

McConnell, A., Yanovski, B., & Lessmann, K. (2021). Central bank collateral as a green monetary policy instrument. *Climate Policy*, *22*(3), 339-355. https://doi.org/10.1080/14693062.2021.2012112

Merler, S., & Bruegel. (2018). *Green central banking*. Brussels, Belgium: Bruegel.

Meuleman, B., & Billiet, J. (2009). A Monte Carlo sample size study: How many countries are needed for accurate multilevel SEM? *Survey Research Methods*, *3*(1), 45–58. https://doi.org/10.18148/srm/2009.v3i1.666

Moons, K. G. M., de Groot, J. A. H., Bouwmeester, W., Vergouwe, Y., Mallett, S., Altman, D. G., . . . Collins, G. S. (2014). Critical appraisal and data extraction for systematic reviews of prediction modelling studies: The CHARMS checklist. *PLoS Medicine*, *11*(10), e1001744. https://doi.org/10.1371/journal.pmed.1001744

Network for Greening the Financial System (NGFS). (2021). *Progress report on bridging data gaps*. Paris, France: NGFS.

Pavlou, M., Ambler, G., Seaman, S. R., Guttmann, O., Elliott, P., King, M., & Omar, R. Z. (2015). How to develop a more accurate risk prediction model when there are few events. *BMJ*, *351*, h3868. https://doi.org/10.1136/bmj.h3868

Robins, N. (2023). *Sustainable central banking: clear green water between the Fed and the ECB?* London, United Kingdom: LSE Business Review.

Schroeder, P. (2021). *Federal Reserve withdraws from global regulatory climate change group*. Washington, D.C: Reuters.

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. *Indian Journal of Dermatology*, *61*(3), 261-264. https://doi.org/10.4103/0019-5154.182410

Sheng, A. (2015). *Central banks can and should do their part in funding sustainability (Fixing Climate Governance Series Paper No. 1)*. Waterloo, Ontario, Canada: Centre for International Governance Innovation.

Shirai, S. (2023). *Global climate challenges, innovative finance, and green central banking*. ADBI Working Paper No. 1361, Asian Development Bank Institute, Tokyo, Japan.

Siderius, K. (2022). An unexpected climate activist: Central banks and the politics of the climate-neutral economy. *Journal of European Public Policy*, *30*(8), 1588-1608. https://doi.org/10.1080/13501763.2022.2093948

Şimandan, R., & Păun, C. (2021). The costs and trade-offs of green central banking: A framework for analysis. *Energies*, *14*(16), 5168. https://doi.org/10.3390/en14165168

Sultana, A. (2025). Central bank digital currency (CBDC): Reclaim the money supply. *International Journal of Finance & Banking Studies*, *14*(2), 57–72. https://doi.org/10.20525/ijfbs.v14i2.4049

Thiemann, M., Büttner, T., & Kessler, O. (2023). Beyond market neutrality? Central banks and the problem of climate change. *Finance and Society*, *9*(1), 14-34. https://doi.org/10.2218/finsoc.8090

United Nations Climate Change. (2015). *The Paris agreement*. USA: United Nations Climate Change.

United Nations Environment Programme. (2017). On the role of Central Banks in enhancing green finance. In (pp. 1–27). USA: United Nations Environment Programme

Van Smeden, M., De Groot, J. A. H., Moons, K. G. M., Collins, G. S., Altman, D. G., Eijkemans, M. J. C., & Reitsma, J. B. (2016). No rationale for 1 variable per 10 events criterion for binary logistic regression analysis. *BMC Medical Research Methodology*, *16*(1), 163. https://doi.org/10.1186/s12874-016-0267-3

Vestergaard, J. (2022). *How can central banks help mitigate climate change? A money view perspective on green central banking*. SECO Working Paper, No. 3.

Vestergaard, J. (2024). Green central banking: Reorienting finance through a recalibration of monetary policy. *Climate Policy*, *24*(7), 924-933. https://doi.org/10.1080/14693062.2024.2353118

World Bank Group. (2023). *Carbon intensity of GDP*. India: World Bank Open Data.

World Bank Group. (2024). *GDP growth*. India: World Bank Open Data.

Wu, C.-F. J. (1986). Jackknife, bootstrap and other resampling methods in regression analysis. *The Annals of Statistics*, *14*(4), 1261-1295. https://doi.org/10.1214/aos/1176350142

Appendix 1. Countries that are included in the analysis.

1. Argentina	15. France	29. Malta	43. Saudi Arabia
2. Australia	16. Germany	30. Mexico	44. Singapore
3. Austria	17. Greece	31. Mongolia	45. Slovakia
4. Bangladesh	18. Hungary	32. Morocco	46. Slovenia
5. Belgium	19. India	33. Netherlands	47. South Africa
6. Brazil	20. Indonesia	34. Nigeria	48. South Korea
7. Canada	21. Ireland	35. Norway	49. Spain
8. China	22. Italy	36. Pakistan	50. Sweden
9. Colombia	23. Japan	37. Peru	51. Switzerland
10. Croatia	24. Kenya	38. Poland	52. Turkey
11. Czech Republic	25. Lao PDR	39. Portugal	53. United Kingdom
12. Denmark	26. Latvia	40. Republic of Cyprus	54. United States
13. Estonia	27. Lithuania	41. Romania	55. Vietnam
14. Finland	28. Luxembourg	42. Russian Federation	