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GOVERNMENT ENVIRONMENTAL EXPENDITURE AND CLIMATE-DRIVEN RISK: THE MODERATING ROLES OF GOVERNMENT EFFECTIVENESS AND CONTROL OF CORRUPTION

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ABSTRACT

Research Originality – Previous studies have largely discussed government environmental expenditure and governance as separate determinants of environmental outcomes. Less attention has been paid to how governance influences the effectiveness of environmental spending in reducing climate-driven risk.

Research Objectives – This study examines whether Government Effectiveness and Control of Corruption moderate the relationship between government environmental expenditure (GEX) and climate-driven risk.

Research Methods – We use an unbalanced panel of 93 countries covering the period from 2013 to 2021. Panel data regressions are estimated using robust standard errors, with interaction terms included to capture the moderating effects of the two governance indicators.

Empirical Results – The results show that higher GEX is significantly associated with lower climate-driven risk. In the baseline estimations, the interaction terms for Government Effectiveness and Control of Corruption indicate that stronger governance tends to reinforce the risk-reducing effect of environmental spending. These results, however, become statistically insignificant when the models are estimated using more conservative clustered standard errors.

Implications – The findings suggest that the effectiveness of environmental spending depends not only on the number of public resources allocated but also on the institutional setting in which those resources are managed. Increasing environmental budgets without improvements in government effectiveness and corruption control may therefore produce limited results.

Keywords: Government Environmental Expenditure; Climate-Driven Risk; Government Effectiveness; Control of Corruption.

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INTRODUCTION

Climate-driven hazards have evolved from primarily environmental concerns into systemic risks to global fiscal and macroeconomic stability. These risks include transition risks, which can affect public finances, and physical risks, which can damage infrastructure and assets (Pardal, 2024). Such pressures can increase the cost of financing public debt (Chen et al., 2025) and contribute to budgetary deficits, potentially exacerbating socioeconomic disparities (Gao, 2024). Against this backdrop, government environmental expenditure (GEX) represents a direct policy instrument for climate adaptation and mitigation, with the broader objective of strengthening resilience to climate-related shocks.

However, closer examination of the empirical literature reveals that the effectiveness of GEX is highly context-dependent and remains unclear. Studies have shown that a higher share of environmental expenditure can contribute to reductions in greenhouse gas emissions (Varadi et al., 2024) and local air pollution (Jiang & He, 2024), as well as help address climate variability through green funding (Haris et al.,

2025). However, these findings may not be readily generalizable across countries. The effectiveness of GEX is highly heterogeneous and influenced by country income levels (Halkos & Paizanos, 2013; Oluklulu & Kasal, 2025), levels of economic development (Hazem et al., 2023), and regional economic structures (Donkor et al., 2022).

This complexity is further compounded by evidence of spatial spillovers, whereby environmental spending in one jurisdiction can influence environmental outcomes in neighboring jurisdictions, creating dynamics of policy competition and learning (Bolea et al., 2024; Sun et al., 2024). This contextual dependence and the mixed empirical evidence suggest that the quantity of spending alone may be an incomplete predictor of climate-related outcomes. The quality of the institutional environment in which fiscal policy is implemented may play a crucial role.

Abundant evidence suggests that governance quality is a fundamental explanatory factor underlying the heterogeneity of environmental policy outcomes. Poor governance, particularly corruption, acts as a corrosive force that systematically undermines the effectiveness of environmental policies. Corruption has been shown to exacerbate the risks and impacts of climate disasters (Zhou et al., 2024), hinder the pace of green growth (Tawiah et al., 2024), weaken the assertiveness of climate policies (Rafaty, 2018), and directly lead to the misallocation of critical environmental resources (Xie et al., 2023). Conversely, a strong institutional framework is fundamental to the success of environmental interventions. Previous studies generally associate stronger control over corruption with lower emissions and improved environmental outcomes (Uddin et al., 2023; Basheer et al., 2024; Omri & Boubaker, 2024). To achieve environmental goals, government effectiveness, reflected in the bureaucratic capacity and quality of policy implementation, is essential (Granberg, 2018; Uddin et al., 2023). Furthermore, effective and accountable governance contributes to building public trust and support for environmentally relevant policies that are typically politically difficult, such as higher public expenditure and carbon taxes (Hoffmann et al., 2022; Muhammad et al., 2022; Lim, 2023; Levis & Smith, 2024).

These two strands of literature have evolved in parallel, but a key research gap remains at the intersection of GEX and governance. The existing literature generally treats GEX and governance as independent explanatory variables but rarely examines their interactive effects. An important question is how the quality of governance systematically moderates the effectiveness of environmental spending to reduce climate risks. Without a clear understanding of these moderating mechanisms, we risk producing incomplete policy recommendations that focus only on “how much to spend” and not on the more important question of “how to ensure that funds are spent effectively.”

To fill this gap, this study aims to empirically investigate the moderating effects of government effectiveness and control over corruption on the relationship between GEX and climate-induced risks. In particular, we ask: to what extent does the effectiveness of GEX in reducing climate risks depend on government effectiveness and the level of corruption control in a country? This study makes an important contribution by using panel data from 93 countries over the period 2013–2021. We propose a more sophisticated model of fiscal policy effectiveness based on the theory of institutional economics. Specifically, this study provides cross-country quantitative evidence on the role of governance as a moderator of the relationship between environmental expenditure and climate-driven risk. The findings suggest that increasing environmental spending alone may not be sufficient to reduce climate risk without improving governance quality.

The rest of the article is structured as follows. Section 2 reviews the literature in more detail and develops the research hypotheses. Section 3 presents the methodological design, data, variables, and model specifications. Section 4 presents and discusses the results of the empirical analysis. Finally, Section 5 summarizes the main results, discusses the policy implications, and indicates directions for future research.

LITERATURE REVIEW

Government environmental expenditure refers to government funding allocated to preventing, reducing, and remedying environmental damage. Green investment can take many forms, including investments in green infrastructure (such as waste treatment facilities), subsidies to incentivize the use of

APPLICATIONS FOR PRACTICE

- Spending on environmental protection has been shown to reduce the risks associated with climate change. However, the success of this spending depends heavily on the quality of governance.
- Environmental funds have a much greater impact in countries with effective governments and low levels of corruption. Good governance ensures that funds are used effectively for their intended purposes.
- Therefore, simply increasing environmental budgets is not enough. Policymakers must combine these investments with robust reforms to enhance government performance and reduce corruption, thereby improving the effectiveness of efforts to address the climate crisis.

environmentally friendly technologies, operational costs for environmental monitoring and enforcement, and public education programs.

The environment is a public resource and thus subject to market failure, which means that there are insufficient private-sector incentives to protect it. This provides a rationale for government investment in environmental protection. Therefore, public intervention is necessary as a long-term investment to prevent more costly environmental disasters in the future and protect citizens' health and well-being from the effects of pollution.

The effectiveness of government environmental spending differs widely across the world. Funding commitments continue to grow in countries such as Turkey and Romania; however, spending patterns differ and do not always generate commensurate impacts (Soare et al., 2020; Yildirim et al., 2023). Although government environmental spending can be effective in reducing emissions, its effectiveness remains limited in some countries, such as the United States (Shabman, 2017). In China, low efficiency and pollution impacts can offset the welfare gains from such spending. The success of such spending largely depends on the sources of funding (with tax revenues being more effective than natural resource rents), efficiency policies such as the removal of fossil fuel subsidies, and the ability to attract foreign investment (Zhang et al., 2019). The main problem is the distribution of resources, which are often not directed at priority environmental objectives. Thus, success is not defined by the size of the budget but by the synergy of strategic resource allocation, effective policies, and stringent oversight to ensure a tangible environmental impact (Zhang et al., 2019; Yaroshevych et al., 2021).

Building on this rationale, GEX is a crucial fiscal policy instrument for directly addressing climate-related risks. This argument is based on the capacity of GEX to operate through a number of mutually reinforcing causal pathways. The first pathway is mitigation, through which public funds are directed towards reducing greenhouse gas emissions at their sources. Empirical evidence from countries and regions consistently shows that environmental spending reduces greenhouse gas emissions in general (Varadi et al., 2024), CO₂ emissions in particular (Hazem et al., 2023; Onyinyechi & Olasupo, 2022), and other pollutants such as SO₂ (Halkos & Paizanos, 2013; Jiang & He, 2024). This evidence supports the underlying mechanism. Mitigation measures are at the core of green fiscal policy (Oluklulu & Kasal, 2025) and directly reduce the severity of future climate hazards.

The second pathway involves adaptation and resilience building. Such spending supports physical infrastructure and social systems that make communities less vulnerable to unavoidable climate impacts. This includes investment in urban flood risk management (Aziz et al., 2024) and sustainable financing schemes for stormwater management (Zhao et al., 2019). GEX enhances adaptive capacity and therefore reduces the vulnerability component in calculations of climate risk (Jaiwant et al., 2024). Moreover, the local governments' ability to manage environmental expenditure effectively in the face of climate extremes is an important component of this response (Benito et al., 2023).

The third pathway is catalytic and systemic. Investment in GEX can generate spillover effects beyond the initial public investment. Green public procurement is a form of GEX that can provide incentives for private sector innovation and reduce its environmental footprint (Even-Tov et al., 2025). Moreover, green spending, financing, and revenues have been shown to contribute to the reduction of environmental and climate variability when combined with technological innovation (Haris et al., 2025). GEX enables green investments and public-private partnerships that are necessary for the low-carbon transition both nationally and locally (Granberg, 2018). The evidence base is converging around multiple mechanisms, including direct mitigation, resilience-building, and systemic catalysis (Donkor et al., 2022), supported by empirical findings from a range of contexts. Based on this, the basic hypothesis of this study is as follows:

H1: Government environmental expenditure is negatively associated with climate-driven risk.

However, beyond this direct relationship, the effect of GEX on climate-driven risk may vary depending on the institutional environment in which fiscal policy is implemented (Halkos & Paizanos, 2013; Donkor et al., 2022; Oluklulu & Kasal, 2025). The translation of GEX into concrete climate risk reduction is not an automatic process but is critically mediated by the quality of a country's governance.

In this study, two dimensions of governance—government effectiveness and control over corruption—are therefore considered as moderators that determine the 'rate of return' of each GEX unit in achieving environmental goals. Government effectiveness serves as an efficiency multiplier and reflects perceptions of the quality of public services, the quality of the civil service, and the degree of independence from political pressure. In countries with strong institutions, GEX funds are more likely to be well managed and channeled toward projects with the greatest impact. Empirical studies show that regulatory quality and government effectiveness help reduce emissions (Handoyo, 2024; Uddin et al., 2023).

Efficient local governments are also important for supporting low-carbon transitions (Xu et al., 2023) and for ensuring more efficient spending on the environment (Benito et al., 2023). Furthermore,

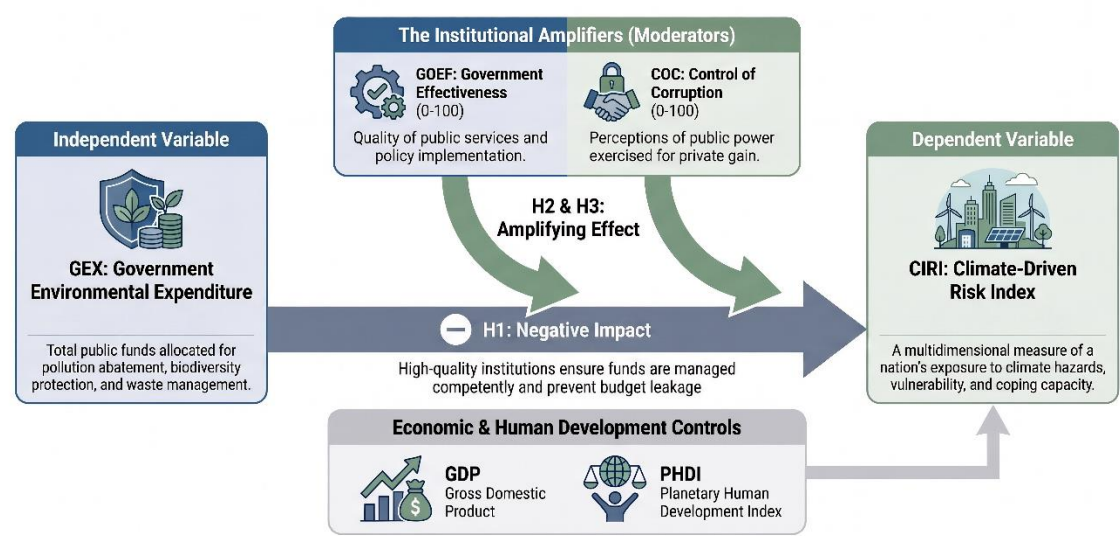
institutional effectiveness can create public trust, which is needed to garner support for costly environmental policy. Greater trust in government institutions has been found to promote support for climate policies (Kulin & Johansson Sevä, 2020; Lee et al., 2020; Hoffmann et al., 2022; Lim, 2023) and pro-environmental behavior (Levis & Smith, 2024). Furthermore, the effectiveness of policy tools such as carbon taxes is closely related to government accountability, which affects public acceptance (Muhammad et al., 2022). However, the relationship is not straightforward, and some studies have found negative correlations between indicators of government effectiveness and environmental performance, which highlights the necessity to understand the relative importance of specific dimensions of governance (Handoyo, 2024; Oyewo et al., 2024).

At the same time, control over corruption helps safeguard budgetary integrity by preventing leakages and the misuse of public funds, which can weaken the effectiveness of GEX. Corruption systematically undermines the climate agenda through a number of channels. It directly amplifies the risks and effects of climate disasters (Zhou et al., 2024); it is a major detractor of green growth (Tawiah et al., 2024); it weakens environmental policy robustness (Rafaty, 2018); and it encourages resource misallocation that actually raises emissions (Xie et al., 2023). In a stronger institutional environment, effective control over corruption can help ensure that GEX reaches its full potential by reducing the diversion and misuse of public resources. Corruption control has been found to be effective in significantly reducing carbon emissions (Omri & Boubaker, 2024; Oyewo et al., 2024; Uddin et al., 2023), curtailing the environmental effects of energy consumption (Lee et al., 2020), and improving overall environmental quality across climate change, air quality, and waste management (Basheer et al., 2024; Van Hung & Doanh, 2025). Additionally, controlling corruption may mitigate the negative impacts of other problems, such as income inequality (Wang et al., 2024) and the environmental consequences of financial development (Farouq & Sulong, 2023).

Thus, government effectiveness determines a country's ability to translate GEX into outcomes, while control over corruption determines the integrity of the process. These two factors together form the institutional capacity that determines whether GEX will succeed or fail in reducing climate risks. In a strong institutional environment characterized by high effectiveness and low corruption, the negative effect of GEX on climate risks is expected to be significantly amplified. Therefore, government effectiveness and control over corruption function as moderating mechanisms that condition the magnitude of the relationship between environmental spending and climate risk reduction, meaning that their presence either strengthens or weakens how effectively financial allocations translate into risk mitigation. Consequently, the following hypothesis is proposed:

- H2: Government effectiveness positively moderates the negative relationship between Government Environmental Expenditure and Climate-Driven Risk
- H3: Control over corruption positively moderates the negative relationship between Government Environmental Expenditure and Climate-Driven Risk

Figure 1 Conceptual Research Framework



Source: Processed by the authors

Figure 1 illustrates the conceptual framework developed to examine the empirical dynamics among the variables in this study. The framework posits a direct relationship in which GEX acts as the independent variable influencing Climate-Driven Risk (CIRI) as the dependent variable (tested in H1). Furthermore, to

account for the heterogeneous impacts of fiscal policy across different institutional settings, the model integrates two key dimensions of governance. They are Government Effectiveness (GOEF) and Control over Corruption (COC) as moderating variables that condition the strength of the relationship between GEX and climate risk (tested in H2 and H3, respectively). Additionally, Gross Domestic Product (GDP) and the Planetary Human Development Index (PHDI) are incorporated as control variables to account for national economic scale and human-environmental development levels.

METHODS

This study utilizes an unbalanced panel dataset comprising 93 countries over the period from 2013 to 2021. To provide a clear and transparent overview of the research scope, the selected sample encompasses a geographically and economically diverse group of nations, representing a comprehensive mix of both developed and developing economies across major global regions. The distribution of the 93 sample countries included in this study is detailed in Table 1.

Table 1 Distribution of the 93 Sample Countries by Region

Region / Continent	Number of Countries	List of Countries Included in the Sample
Europe & Eurasia	39	Albania, Austria, Azerbaijan, Belgium, Bulgaria, Croatia, Cyprus, Czech Rep., Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russian Federation, Slovak Rep., Slovenia, Spain, Sweden, Switzerland, Türkiye, Ukraine, United Kingdom
Asia & Middle East	23	Afghanistan, Armenia, Bahrain, Bangladesh, Bhutan, Cambodia, Indonesia, Israel, Japan, Jordan, Kazakhstan, Kyrgyz Rep., Lebanon, Malaysia, Mongolia, Myanmar, Nepal, Oman, Philippines, Singapore, Thailand, United Arab Emirates, Uzbekistan
Africa	14	Angola, Botswana, Burkina Faso, Burundi, Côte d'Ivoire, Egypt, Kenya, Liberia, Namibia, Senegal, South Africa, Tanzania, Uganda, Zambia
Americas & Oceania	17	Argentina, Australia, Bahamas, Brazil, Canada, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Jamaica, New Zealand, Nicaragua, Panama, Papua New Guinea, Uruguay
Total	93 Countries	Unbalanced panel data spanning across developed and developing economies (2013–2021)

Source: Processed by the authors

The selection of these countries was primarily determined by data availability across all primary, moderating, and control variables during the 2013–2021 study window. Data were compiled from several credible institutional data sources. The variables in this study are operationalized as described in Table 2.

Table 2 Operationalization of Research Variables

Variable Role	Notation	Variable Name	Operational Definition	Data Source
Dependent	CIRI	Climate-Driven Risk	Measures a country's exposure and vulnerability to climate-driven risks, incorporating three dimensions: climate-driven hazards and exposure, vulnerability, and lack of coping capacity. Measured using the Climate-driven INFORM Risk Index, ranging from 0 to 10, with higher values indicating higher climate-driven risk.	IMF Climate Change Dashboard – Climate-driven INFORM Risk Index
Independent	GEX	Government Environmental Expenditure	Government expenditure allocated to environmental protection under the Classification of the Functions of Government (COFOG), including activities such as pollution abatement, waste management, biodiversity and landscape protection, and other environmental protection activities. Measured as a percentage of GDP.	IMF Government Finance Statistics (GFS) – COFOG, Environmental Protection
Moderator	COC	Control of Corruption	Captures perceptions of the extent to which public power is exercised for private gain, including petty and grand corruption and state capture. Measured using the WGI percentile rank, ranging from 0 (lowest) to	World Bank – Worldwide Governance Indicators (WGI)

Table 2 Operationalization of Research Variables (Continued)

Variable Role	Notation	Variable Name	Operational Definition	Data Source
Moderator	GOEF	Government Effectiveness	100 (highest), with higher values indicating stronger control over corruption. Captures perceptions of the quality of public services and the civil service, independence from political pressures, quality of policy formulation and implementation, and the credibility of government commitments. Measured using the WGI percentile rank, ranging from 0 (lowest) to 100 (highest), with higher values indicating greater government effectiveness.	World Bank – Worldwide Governance Indicators (WGI)
Control	GDP	Gross Domestic Product	Represents the economic size of a country. Measured as the natural logarithm of GDP in current US dollars.	World Bank – World Development Indicators (WDI), GDP (current US\$)
Control	PHDI	Planetary Pressures-adjusted Human Development Index	Measures human development after adjusting the Human Development Index (HDI) for planetary pressures associated with carbon dioxide emissions per capita and material footprint per capita. Higher values indicate higher human development after accounting for planetary pressures.	UNDP – Human Development Reports (PHDI Dataset)

Source: Processed by the authors

In an effort to improve model specification and to address concerns about omitted variable bias, this study includes GDP and Planetary Pressures-adjusted PHDI as control variables. We include GDP to capture the economic size and level of development of a country, as wealthier countries generally have greater fiscal capacity to invest in environmental protection and to absorb climate-induced shocks. Meanwhile, PHDI is included to account for broader dimensions of human development while considering ecological pressures. This is important because societies with higher levels of human development and better health standards may exhibit different levels of vulnerability and resilience to environmental risks. The proposed hypotheses is tested using a panel data regression model in this study. Three specific models were constructed to analyze the direct relationship and the moderating effects.

Model 1: to test H1 regarding the direct effect of GEX on CIRI.

$$CIRI_{i,t} = \beta_0 + \beta_1 GEX_{it} + \beta_2 GDP_{it} + \beta_3 PHDI_{it} + \varepsilon_{it} \quad (1)$$

Model 2: to test H2 regarding the moderating effect of GOEF in the relationship between GEX and CIRI.

$$CIRI_{i,t} = \beta_0 + \beta_1 GEX_{it} + \beta_2 GDP_{it} + \beta_3 PHDI_{it} + \beta_4 GOEF_{it} + \beta_5 (GEX_{it} \times GOEF_{it}) + \varepsilon_{it} \quad (2)$$

Model 3: to test H3 regarding the moderating effect of COC in the relationship between GEX and CIRI.

$$CIRI_{i,t} = \beta_0 + \beta_1 GEX_{it} + \beta_2 GDP_{it} + \beta_3 PHDI_{it} + \beta_4 COC_{it} + \beta_5 (GEX_{it} \times COC_{it}) + \varepsilon_{it} \quad (3)$$

Where ε_{it} represents the error term. Model 2 features *GOEF* as the moderator, interacting with GEX to test how bureaucratic capability and institutional quality condition the relationship between environmental spending and climate-driven risk. The moderating variable in Model 3 is *COC*. The interactive effect between *COC* and *GEX* indicates the extent to which the protection of budget integrity and the prevention of public fund leakage improve the effectiveness of environmental expenditure in reducing risk. We estimated a pooled Ordinary Least Squares (OLS) regression with heteroskedasticity-robust standard errors. The models were tested for diagnostic adequacy and robustness to determine the reliability of the empirical results. The Variance Inflation Factor (VIF) was used to assess multicollinearity and collinearity among the explanatory variables.

As a temporal robustness check, a one-year lagged specification was used to address concerns about possible reverse causality between government environmental spending and climate-driven risk. This specification does not fully eliminate concerns about endogeneity, but it allows us to assess whether the main results are robust to using expenditure in the previous period. This method accounts for the inherent lag of public fiscal policy transmission, as the budget allocations require time to be implemented and to generate effects on structural changes. It is also consistent with the annual appropriations and multi-year budgeting cycles of the sample countries, under which expenditures in previous periods may influence

subsequent environmental outcomes. As an additional robustness test to assess the consistency of the main findings, two-way clustered standard errors at the country and year levels were used.

RESULT AND DISCUSSION

To provide a preliminary profile of the data distributions and characteristics across the 93 sample countries from 2013 to 2021, Table 3 reports the descriptive statistics for all variables examined in this study, including the number of observations, the mean, standard deviation, minimum, and maximum values.

Table 3 Descriptive Statistics of Research Variables

Variable	Obs	Mean	Std. dev.	Min	Max
GEX	690	0.47	0.38	0.003	1.87
GDP	690	25.58	1.73	21.39	29.28
PHDI	690	0.70	0.08	0.42	0.82
CIRI	690	3.02	1.45	0.30	7.30
GOEF	690	63.91	25.54	3.80	100
COC	690	59.85	28.96	0.95	100

Source: Processed by the authors

The total number of observations varies across the different models depending on whether the panel data is balanced or unbalanced, as shown in Table 3. The number of observations for the core variables is consistent at 690. Government Environmental Expenditure (GEX) has a mean of 0.47, a standard deviation of 0.38, and minimum and maximum values of 0.003 and 1.87, respectively. These variable measures fiscal expenditure on environmental protection. The relatively large standard deviation indicates substantial variation in environmental expenditure across countries. The Climate-Driven Risk Index (CIRI) shows an average of 3.02 and a standard deviation of 1.45 (ranging from 0.30 to 7.30). The governance indicators, Government Effectiveness (GOEF) and Control of Corruption (COC), have mean scores around 63.91 and 59.85, respectively, with substantial variations ranging from almost zero to the maximum percentile rank of 100. Lastly, the average values of the control variables, GDP (natural logarithm) and the Planetary Human Development Index (PHDI), are 25.58 and 0.70, respectively.

As the first diagnostic analysis, the multicollinearity test was conducted to establish a strong empirical basis for the research model. The Pearson correlation matrix (Table 4) shows a significantly negative correlation between Government Environmental Expenditure (GEX) and Climate-Driven Risk (CIRI) ($r = -0.57$), providing preliminary evidence consistent with the core hypothesis. Furthermore, the two moderating variables, Government Effectiveness (GOEF) and Control of Corruption (COC), were positively correlated at a high level ($r = 0.9233$). The high correlation suggests that the two variables capture closely related dimensions of governance.

Table 4 Correlation Matrix Between Variables (Pearson Correlation Matrix)

	GEX	GDP	PHDI	CIRI	GOEF	COC
GEX	1.00					
GDP	0.37	1.00				
PHDI	0.43	0.38	1.00			
CIRI	-0.57	-0.26	-0.60	1.00		
GOEF	0.60	0.47	0.55	-0.80	1.00	
COC	0.58	0.37	0.43	-0.75	0.92	1.00

Source: Processed by the authors

Table 5 reports VIF values below the traditional threshold of 10, indicating that severe multicollinearity is unlikely within each estimated model. Because of the high correlation between GOEF and COC ($r = 0.92$), the two governance dimensions are estimated in separate models to mitigate concerns about collinearity. This strategy, however, does not eliminate all concerns about model specification and may involve a trade-off with potential omitted-variable bias, as the two dimensions of governance are closely related.

The hypothesis testing results, based on the panel data regression analysis presented in Appendix 1, provide empirical evidence relevant to the proposed conceptual framework. Model 1 shows that climate-driven risk is negatively and significantly associated with GEX ($\beta = -1.5$, $p < 0.01$). However, in Models 2 and 3, the coefficient of GEX captures the conditional effect of environmental expenditure when the respective governance moderator equals zero. Therefore, the main effect coefficient of GEX in the interaction models should not be interpreted in isolation from the interaction terms.

The results provide strong support for H1. The baseline interaction models further indicate that governance may condition the relationship between GEX and climate-driven risk. The coefficients of $GEX \times GOEF$ and $GEX \times COC$ are negative and statistically significant in the baseline specifications, suggesting that higher levels of government effectiveness and control over corruption strengthen the negative marginal

association between GEX and climate-driven risk. These baseline results offer initial support for H2 and H3. However, the robustness analysis shows that the statistical significance of these moderating effects varies across estimation methods. The R-squared increases from 0.49 in Model 1 to 0.72 in Model 2 and 0.68 in Model 3, suggesting that the specifications with governance variables and their interaction terms have greater explanatory power.

Table 5 Multicollinearity Test Results (VIF)

Variable	Model 1	Model 2	Model 3
	VIF (1/VIF)	VIF (1/VIF)	VIF (1/VIF)
PHDI	1.33 (0.75)	1.51 (0.66)	1.38 (0.72)
GEX	1.31 (0.76)	1.63 (0.61)	1.66 (0.60)
GDP	1.25 (0.80)	1.33 (0.75)	1.28 (0.78)
GOEF		2.01 (0.50)	
COC			1.65 (0.61)
Mean VIF	1.30	1.62	1.49

Source: Processed by the authors

To verify the validity of the findings, a series of robustness tests was conducted, yielding a more nuanced picture. This moderation finding is also supported by the one-year lagged specification used as a temporal robustness check, in which both interaction coefficients are significant. However, the moderating effects lose statistical significance when estimated with two-way clustered standard errors at the country and year levels ($p > 0.10$). It is worth noting, however, that the direction and magnitude of the interaction coefficient are consistent across all models. In general, these results can be interpreted as follows: the direction of the moderating effects of governance is robust; however, their statistical significance is sensitive to the estimation method employed. Overall, the findings provide robust support for H1 but only partial support in the baseline specifications for H2 and H3, as the moderating effects are not robust to two-way clustered standard errors at the country and year levels.

The findings provide evidence of the negative relationship between GEX and the aggregate CIRI. This result supports the baseline H1 and is consistent with the wider literature suggesting that public environmental spending can contribute to reducing environmental and climate-related risks. The CIRI encompasses multiple aspects of climate-related risk, including climate-induced hazards and exposure, vulnerability, and lack of coping capacity. However, as the present analysis uses the aggregate CIRI score as the dependent variable, the results should be interpreted as evidence of an association with overall climate-driven risk, rather than evidence that GEX independently reduces each underlying component of the index. To identify which specific dimension underlies the observed relationship, separate analyses would be required at the component level.

The negative relationship observed here is largely consistent with previous studies associating environmental expenditure with reduced greenhouse gas emissions (Varadi et al., 2024), CO₂ emissions (Hazem et al., 2023; Onyinyechi & Olasupo, 2022), and other pollutants such as SO₂ (Halkos & Paizanos, 2013; Jiang & He, 2024). Previous research also identifies several plausible channels through which environmental expenditure may contribute to lower climate-related risk, including direct emission abatement, investment in adaptive infrastructure such as flood-risk management (Aziz et al., 2024), and catalytic effects on private-sector green innovation through instruments such as public procurement (Even-Tov et al., 2025). These mechanisms offer a theoretical and empirical context for interpreting the current findings. However, the present study does not directly test these mechanisms or the individual components of the CIRI separately.

The main contribution of this study is that the negative relationship between GEX and climate risk is not uniform but appears to be moderated by the quality of the institutional environment. In particular, the interaction results suggest that the relationship between GEX and climate-driven risk becomes more negative as GOEF or COC increases, although the statistical significance of these moderating effects is sensitive to the estimation method. Both COC and GOEF are measured using percentile ranks ranging from 0 to 100. It is important to recognize that these measures are relative rather than absolute. For example, a score of 80 does not mean that a country has an effectiveness score of 80 out of 100, but simply that the country is perceived to have higher governance effectiveness than 80% of the other countries in the global dataset. The interaction effects are theoretically consistent with the proposition that the effectiveness of GEX is conditional on the institutional performance of countries. Government effectiveness may therefore

be an institutional condition that facilitates the translation of environmental expenditure into reduced climate-driven risk (Benito et al., 2023; Granberg, 2018). Moreover, good governance enhances public trust, a crucial driver of support for often expensive and politically challenging climate policies (Hoffmann et al., 2022; Levis & Smith, 2024; Lim, 2023).

Simultaneously, control over corruption can serve as a safeguard for budgetary integrity. Corruption consistently erodes the climate agenda by raising the risks and impacts of disasters (Zhou et al., 2024), hampering green growth (Tawiah et al., 2024), undermining policy decisiveness (Rafaty, 2018), and misallocating critical resources (Xie et al., 2023). In contrast, a stronger institutional environment may help environmental expenditure translate more effectively into environmental outcomes, consistent with previous studies linking corruption control to lower emissions and better environmental quality (Basheer et al., 2024; Omri & Boubaker, 2024; Uddin et al., 2023). Therefore, the moderation findings may help explain some of the heterogeneity in the effectiveness of GEX reported in prior studies, such as differences related to country income levels and regional economic structures (Donkor et al., 2022; Halkos & Paizanos, 2013; Oluklulu & Kasal, 2025).

A major finding of the robustness analysis is that the moderating effects ($GEX \times GOEF$ and $GEX \times COC$) are not statistically significant when tested using the two-way clustered standard errors at the country and year levels ($p > 0.10$). This specification allows for dependence among observations within the same country over time as well as common shocks across countries within the same year, thereby providing more conservative inference. Accordingly, these moderation results should be interpreted with caution; while the directional signs remain stable, the evidence indicates that institutional conditioning is highly sensitive to stringent econometric specifications, highlighting a key avenue for future causal identification studies. The loss of significance here does not necessarily imply the absence of a moderating relationship; rather, it indicates that the statistical evidence for the moderating effects is sensitive to the estimation method and the associated treatment of within-country and cross-country dependence.

For example, using data from our dataset, advanced economies such as Finland and Denmark have very high and stable governance scores over the 2013–2021 period, with GOEF and COC consistently ranging between 96 and 100, and very low climate-driven risks (CIRI around 1.0 to 1.7). In stark contrast, Indonesia, which represents an emerging economy context in our sample, shows a more variable governance trajectory, with GOEF ranging between 42.86 and 64.29, COC between 29.38 and 45.24, and the CIRI at higher levels ranging from 4.3 to 4.7. The stark cross-national variation illustrates that the relationship between environmental expenditure, governance, and climate-driven risk may differ substantially across institutional contexts. These descriptive contrasts highlight the substantial cross-country heterogeneity in governance and climate-induced risk. However, they should not be read as identifying the statistical mechanism that causes the loss of significance under two-way clustered standard errors. Overall, the results of the moderation analyses of the present study provide a preliminary explanation for the heterogeneity in the effectiveness of GEX reported in the prior literature.

CONCLUSION

This study aims to examine the moderating role of governance quality, proxied by Government Effectiveness and Control over Corruption, on the nexus between GEX and CIRI. The study reports several important findings based on panel data from 93 countries over the period 2013–2021. First, the results consistently show a statistically significant negative association in the baseline specification between GEX and climate-driven risk. This finding supports the relevance of environmental expenditure as an important fiscal instrument associated with climate-risk mitigation and adaptation.

Second, the baseline results indicate that the relationship between GEX and climate-driven risk may be conditional on government effectiveness and control of corruption. However, these moderating effects should be interpreted as suggestive rather than definitive because the interaction terms are no longer statistically significant with two-way clustered standard errors.

These findings have important practical implications from the national fiscal perspective, especially in an emerging economy such as Indonesia, where public environmental expenditure may serve as an important fiscal instrument amid variations in governance quality, as reflected in government effectiveness and control over corruption scores. The empirical evidence shows that accelerating national commitments to climate resilience and the low-carbon transition through state budget allocations and other fiscal instruments should be accompanied by improvements in governance quality, rather than focusing solely on increasing environmental expenditure. Fiscal policy should be closely linked to continuous strengthening of bureaucratic capacity and safeguards for public financial integrity so that public funds are used as efficiently as possible in risk reduction. Whether environmental spending can effectively address systemic climate vulnerabilities will depend in part on ensuring that green allocations are protected from institutional leakages and managed by capable public institutions.

The policy implications of these findings are clear: simply increasing budget allocations for the environment without simultaneously pursuing governance reforms is an insufficient and suboptimal approach to addressing the climate crisis. Policymakers need to ask not just "how much to spend" but, more importantly, "how to ensure that spending is effective." Efforts to improve bureaucratic capacity and strengthen control over corruption should be seen as part of climate policy itself.

The present study is subject to the limitation that the statistical significance of the moderating effects is sensitive to the most conservative model specifications. In addition, while the lagged specification provides a partial response to concerns about reverse causality, concerns about endogeneity remain because the study does not employ a formal causal identification strategy. Future research could therefore deepen this analysis by employing alternative methodologies, extending the data span, or investigating other dimensions of institutional quality. Qualitative case studies at the country level could also yield richer insights into the particular mechanisms through which environmental governance and spending interact to build climate resilience.

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Appendix 1 Regression Results and Robustness Test

	Baseline OLS (Robust SE)			Lagged Robustness Test (Robust SE)			Two-Way Clustered SE		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
<i>GEX</i>	-1.58 (-12.48)***	0.66 (1.44)	0.48 (1.67)*	-1.07 (-10.04)***	0.72 (1.55)	0.41 (1.18)	-1.58 (-5.01)***	0.66 (0.79)	0.48 (0.74)
<i>GDP</i>	0.043 (2.18)**	0.15 (9.09)***	0.10 (5.93)***	0.01 (0.470)	0.10 (5.09)***	0.08 (3.66)***	0.04 (0.83)	0.15 (3.43)***	0.10 (2.21)*
<i>PHDI</i>	-7.19 (-12.92)***	-4.21 (-9.07)***	-5.74 (-12.72)***	-7.88 (-13.86)***	-5.87 (-10.53)***	-6.74 (-13.26)***	-7.18 (-5.33)***	-4.21 (-3.77)***	-5.74 (-5.23)***
<i>GOEF</i>			-0.03 (-13.17)***			-0.02 (-8.74)***			-0.03 (-5.57)***
<i>GEX x GOEF</i>			-0.01 (-2.82)***			-0.015 (-2.64)***			-0.01 (-1.46)
<i>COC</i>				-0.02 (-11.52)***			-0.017 (-8.59)***		-0.02 (-4.74)***
<i>GEX x COC</i>				-0.01 (-3.75)***			-0.013 (-2.67)***		-0.01 (-1.60)
<i>_cons</i>	7.61 (14.08)***	4.21 (9.22)***	5.80 (12.27)***	8.61 (16.14)***	6.00 (10.88)***	6.97 (13.14)***	7.61 (5.47)***	4.21 (3.54)***	5.80 (4.70)***
<i>F</i>	244.46	638.16	442.80	226.49	366.78	304.66	215.24	353.88	296.67
<i>R-Square</i>	0.4849	0.7212	0.6844	0.4498	0.6131	0.5971	0.4849	0.7212	0.6844

Notes: t-statistics are reported in parentheses. The final three specifications use two-way clustered standard errors at the country and year levels. *** p<0.01,**p<0.05,*p<0.10.

Source: Processed by the authors