Climate Risk Pricing in Sovereign Debt: Evidence from Developing European Countries

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Abstract

This study investigates the extent to which climate risk is reflected in sovereign debt pricing in ten Eastern European economies between 2007 and 2023. Using a maturity-matched measure of sovereign borrowing cost spreads and panel data estimation techniques, the analysis captures both cross-country heterogeneity and time variation. The results reveal a statistically significant and economically meaningful relationship between climate vulnerability and borrowing costs. Countries that are more exposed to physical climate risks systematically face higher interest rates in domestic credit markets. The findings further indicate that this relationship is shaped by country-specific characteristics rather than operating mechanically. Institutional quality and access to climate-related financial resources play an important mitigating role in the pricing of climate risk. Economies with stronger governance frameworks and greater access to climate finance tend to exhibit lower borrowing cost spreads, even at comparable levels of climate vulnerability. This suggests that adaptive capacity can partially offset the financial impact of physical climate risks. Overall, the study highlights that climate adaptation is not only an environmental priority but also a key determinant of fiscal sustainability and sovereign financing conditions in an era of intensifying climate change.

Keywords: *Climate Risk, Sovereign Debt, Debt Pricing, Adaptive Capacity, Developing Countries.*

JEL Classification Codes: G15, H63, Q54, O16

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Introduction

The region has shown its vulnerability to climate-related stressors which have become more pronounced during the last few decades. The 2022 Romanian drought became the worst in 500 years which caused European agricultural production to decrease by 25-30 percent. The 2014 floods in Bosnia and Herzegovina caused more than €2 billion in destruction to the country. The economic damage from climate-related vulnerabilities in this region became apparent through these two major events (OSCE, 2015; World Bank, 2025). The way climate risks affect economic stability depends on sovereign borrowing costs because they determine available fiscal resources and future development trajectories. The financial aspect stands as a critical factor for developing economies because they experience the most severe impacts from climate-related disasters. The absolute economic losses from climate change are higher in developed nations but developing countries face more severe fiscal constraints and weak recovery capabilities (Mendelsohn et al., 2006; Tol, 2009). The European Environment Agency (2025) identified Eastern Europe as a high-risk region because its economic sectors depend on climate conditions and its populations have different abilities to adapt to change. The Western Balkans experience an increasing insurance coverage deficit which makes people and businesses and public institutions more exposed to financial damage from extreme weather events because they lack sufficient protection. The combination of physical threats and financial instability requires immediate analysis of how climate-related risks affect sovereign debt market pricing.

Research indicates that sovereign borrowing premiums assessments primarily rely on macroeconomic data including public debt levels and inflation rates and economic growth performance (Baldacci & Kumar, 2010). Research indicates that environmental elements now influence how investors perceive risk and how markets operate. The research by Volz et al. (2020) demonstrates that climate vulnerability increases sovereign risk through three main mechanisms which include financial strain from disaster responses and lower economic productivity and market-based financial adjustments. The increasing importance of sustainable finance in emerging markets demonstrates the significance of this connection (Bylo, 2025).

The current research lacks sufficient data to study how climate risks affect Eastern European sovereign debt markets. The research methods used in most studies either analyse global data without considering local characteristics or they fail to properly handle economic interdependencies between neighbouring countries. Research needs to explore how adaptive capacity affects this relationship because different European Union member states have different institutional strengths and access to green funding programs.

This study seeks to address these gaps by examining how climate vulnerability influences sovereign borrowing cost spreads in ten Eastern European countries over the period 2007–2023. This timeframe captures several major climate-related shocks as well as substantial developments in climate finance frameworks. The analysis introduces a maturity-matched measure of sovereign borrowing costs based on interest rate differentials and employs panel estimation techniques designed to account for cross-sectional dependence and unobserved heterogeneity. Beyond documenting the relationship between climate vulnerability and borrowing costs, the study also investigates whether institutional quality and access to climate finance can mitigate the financial impact of climate risk.

The findings offer relevant insights for policymakers operating at the intersection of environmental and financial stability. Understanding how climate vulnerability affects sovereign borrowing costs can inform more targeted policy interventions, including institutional reforms and the effective deployment of climate finance. These results are particularly pertinent for finance ministries and debt management offices seeking to integrate climate considerations into fiscal planning and sovereign risk assessment.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 outlines the data and econometric methodology. Section 4 presents and discusses the empirical results, and Section 5 concludes with policy implications and directions for future research.

2. Literature Review

2.1. Theoretical Foundations of Climate Risk Pricing in Sovereign Debt

The inclusion of climate risk in sovereign debt pricing represents a new direction for traditional finance. The early research on this topic by Mendelsohn et al. (2006), and Tol (2009) demonstrated that climate impacts lead to uneven economic burdens across the world's nations, and as such developing economies are likely to bear a disproportionate burden of climate costs than developed economies. However, while developing economies face higher relative costs, they experience lower absolute losses. Therefore, the theoretical framework provides an explanation for how sovereign debt markets will price climate risk differently in different countries based upon their varying degrees of ability to adapt to these risks.

Climate vulnerability effects on sovereign risk have been grouped by the Network for Greening the Financial System (NGFS, 2019). Physical climate risk transmits through three broad channels to countries: (i) the fiscal channel, when disaster response and reconstruction strain public budgets; (ii) the growth channel, as damage to infrastructure will lower productivity and economic output; and (iii) the risk perception channel where investors incorporate expectations of physical climate risk into expected returns. Bylo (2025) augments this framework with the possible contribution of green finance mechanisms to mitigate these effects, mainly in developing countries that heavily rely on access to climate finance.

2.2. Evolution of Empirical Research on Climate and Sovereign Risk

Empirical evidence on the link between climate changes and sovereign risk has strongly improved in the last decade, with methodologies and geographical scope now getting closer to finer types of relationships. Previous research generally adopted cross-sectional approaches with scant climate data, and current studies apply sophisticated panel data methods with comprehensive indices of climate vulnerability.

The key work by Volz et al. (2020) sought to analyse the effect of climate change vulnerability and resilience on sovereign borrowing costs across an extensive and diverse set of countries. The analysis is based on econometric estimates in the form of panel data fixed and random effects regressions from 1995 to 2017 for a sample of 98 advanced and developing countries. The dependent variables are sovereign bond yields and spreads. The main finding is that both sensitivity to and resilience capacity against climate change are statistically and economically significant factors affecting government borrowing cost of developing countries, while the adverse effect of vulnerability on borrowing cost becomes even larger for developing countries with less ability to adapt to and mitigate against climate damages.

Table 1: Chronological Evolution of Research on Climate Vulnerability and Sovereign Debt Risk

Year	Author(s)	Model	Region	Dependent Variable	Key Findings
(2010)	Baldacci & Kumar	Panel Regression	Advanced & Emerging Economies	Sovereign Bond Yields	Established traditional macroeconomic determinants of sovereign risk
(2018)	Kling et al.	Panel Regression	Global	Cost of Corporate Debt	Vulnerability to climate change and resilience to its effects have a significant impact on the cost of borrowing.
(2018)	Battiston & Monasterolo	Network Analysis	EU	Sovereign CDS Spreads	Climate policy transition risks materially affect sovereign risk
(2019)	NGFS	Scenario Analysis	Global	Sovereign Risk Indicators	Physical and transition risks significantly impact debt sustainability
(2020)	Painter	Fixed Effects	Global	Sovereign Bond Yields	Climate vulnerability increases borrowing costs by 11-22 bps
(2020)	Volz et al.	Panel Regression	Global	Sovereign Credit Ratings	Climate vulnerability leads to rating downgrades, particularly for emerging economies
(2021)	Kling et al.	GMM Panel	Global	Corporate Debt-to-GDP ratio	The post-GFC debt surge was concentrated in Developing Countries.
(2024)	Bua et al.	Asset pricing test framework & text-analysis	European financial markets	Equity returns	Investors demand compensation for their exposure to both transition and physical climate risk in European markets, especially after 2015
(2024)	De Angelis & Monasterolo	Event Study	EU	Abnormal Returns on green bonds and stock prices	Firms disclosing sustainable information experience positive market reactions to increased regulation aimed at green transition.
(2025)	European Environment Agency	Integrated Assessment	Eastern Europe	Economic Losses	Identified specific vulnerability hotspots in agricultural and coastal regions
(2025)	Bylo	Systematic Review	Emerging Markets	Multiple Indicators	Green finance mechanisms can reduce pricing of climate risk in sovereign debt by improving adaptive capacity

Source: Authors elaborate information

Kling et al. (2018) explored the impact of climate-related vulnerability on firms' cost of capital and access to finance, with a main focus on climate-vulnerable developing countries. Based on panel data regressions and micro-level structural equation models with company level observations from 1991 to 2017, they show that vulnerability to climate stress substantially increases the cost of corporate debt both directly and indirectly through financial constraints. The main finding is that the 'climate vulnerability risk premium' on sovereign debt trickles down to the private sector, increases corporate cost of capital and causes financial exclusion, which ultimately constrains economic growth in highly exposed countries.

Furthermore, Kling et al. (2021) concentrated on the key stylized facts, risks, and policy challenges of the global nature of nonfinancial corporates debt accumulation after 2008–09 GFC. They conducted a survey and literature synthesis with descriptive analysis informed by macroeconomic data. The time period considered starts on the timescale 2008-2018 (post-GFC). The key finding is that the post-GFC debt surge was concentrated in developing countries, where non-financial corporate debt expanded at nearly twice the rate of GDP (increasing from 56% to 96% of GDP between 2008 and 2018), markedly raising solvency risk and susceptibility to shocks.

Bua et al. (2024) seek to identify whether there is a pricing for physical and transition climate risks in European markets and showing how far investors regard them as being financial risks. It adopts asset pricing test framework under a text-based approach and controls Fama-French five factors. The sample spans from January 2005 until October 2021 and includes all European financial markets. The main finding is that economically meaningful transition and physical risk premiums have developed post 2015, indicating that investors require compensation for both types of climate risk.

Although not exactly on climate risk, the seminal work by Baldacci & Kumar (2010) offered important groundwork about building a model for traditional sovereign risk factors for our choice of control variables. Based on their investigation with panels of data for the advanced and emerging economies, fiscal fundamentals have some leading roles in influencing sovereign bond rates while it is not a linear relationship beyond certain optimal levels.

Despite these already numerous studies, some crucial gaps remain to be filled in the Eastern European context. First, while Volz et al. (2020) and Kling et al. (2018) implemented analysis on a global level, there is no such region-focused analysis for Eastern Europe. Second, the approach of Bua et al. (2024) on crisis controls must be adapted to address the specific cross-sectional dependence issues in closely linked European countries. Third, the interplay of traditional economic fundamentals identified by Baldacci & Kumar (2010) and climate vulnerability in this regional context needs further investigation.

This paper seeks to contribute to the literature by filling that ground and analysing its constraints in Eastern Europe. In particular, we: (1) generalize results of Volz et al.'s country-effects framework corrected for cross-sectional dependence using Driscoll-Kraay standard errors; (2) use Kling et al.'s interest on markets sensitivities to a regional sample; (3) include Bua et al.'s crisis control approach with regional relevance; and (4) combine Baldacci & Kumar's traditional factors in a more comprehensive climate risk framework.

3. Data and Methodology

3.1. Data Sources and Variable Construction

The empirical analysis draws on a balanced panel covering ten Eastern European countries over the period 2007–2023. The sample consists of Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Czechia, Hungary, Moldova, Montenegro, North Macedonia, and Romania. All information is taken from publicly accessible datasets so that the results can be easily replicated and verified. The statistical work was carried out in STATA 17.0.

3.1.1. Dependent Variable

The study uses the sovereign borrowing cost spread as the dependent variable. It is constructed as the difference between a country's lending interest rate and the 12-month Euribor, which provides a commonly used maturity-matched benchmark for the European area. Formally:

Sovereign Borrowing Cost Spread_{it} = (Lending interest rate_{it}) - (12 month Euribor_{t})	(1)

Lending rates are taken from the World Bank's World Development Indicators (indicator FR.INR.LEND). This measure reflects the rate banks charge for short- to medium-term credit extended to firms, and it is widely used as an indicator of domestic financing costs. The 12-month Euribor series is obtained from the European Central Bank's Data Portal and serves as a reference rate against which national lending conditions can be compared.

The choice of benchmark reference rate also reflects the time coverage of the analysis. Although risk-free reference rates such as the Secured Overnight Financing Rate (SOFR) have become more prominent in recent years, their use is not suitable for the present study. The sample period spans 2007–2023, a timeframe during which LIBOR-type benchmarks—and their European counterpart, Euribor—were the standard reference rates used in credit markets. SOFR was introduced only in 2018 and adopting it would either shorten the sample period or require combining fundamentally different benchmark regimes, potentially affecting the consistency of the results (ECB, 2020).

3.1.2. Key Independent and Control Variables

The main explanatory variable is climate vulnerability, captured by the vulnerability score from the Notre Dame Global Adaptation Initiative (ND-GAIN). This index combines information on exposure to climate hazards, sensitivity of key sectors, and the degree to which countries possess the institutional and economic capacity to adapt. Higher values indicate greater vulnerability.

A set of macroeconomic controls is included to isolate the relationship between climate vulnerability and sovereign risk conditions. These controls—drawn from the World Bank WDI—comprise annual consumer price inflation, GDP growth, the current account balance (in millions of U.S. dollars), and claims on the government (expressed as a share of GDP). To take account of the financial tensions associated with the COVID-19 crisis, a dummy variable equal to 1 for the year 2020 and 0 otherwise is added to the specification.

Table 2: Variable Definitions and Sources

Variable	Calculation	Source
Sovereign Borrowing Cost Spread	Lending rate – 12-month Euribor	WDI, ECB
Climate Vulnerability	ND-GAIN vulnerability score	ND-GAIN
Inflation	Annual consumer price inflation %	WDI
GDP Growth	Annual GDP growth %	WDI
Current Account	Current account balance (million US$)	WDI
Claims on Government	Claims on government (% of GDP)	WDI
COVID-19 Dummy	1 for 2020, 0 otherwise	Author's calculation

Based on established theoretical frameworks and earlier empirical work, several patterns can reasonably be expected in the relationship between the explanatory variables and sovereign borrowing costs. Climate vulnerability is likely to be positively associated with the premium, since greater exposure to physical climate risks can place pressure on public finances, constrain economic activity, and shape investor perceptions of future uncertainty (Volz et al., 2020; Kling et al., 2021). Inflation is also expected to have a positive association, as persistent price instability reduces real returns and tends to heighten concerns about macroeconomic management (Baldacci & Kumar, 2010).

By contrast, GDP growth should display a negative relationship with borrowing cost spreads. Stronger economic performance generally supports fiscal capacity and reduces doubts about a government's ability to service its debt. A similar logic applies to the current account balance: countries running persistent deficits often rely more heavily on external financing and are therefore viewed as more vulnerable to shifts in global conditions, implying a negative association between the balance and risk premiums (Edwards, 1984).

Claims on government are expected to enter positively. Higher claims signal a greater degree of financial-system exposure to the sovereign, increasing the possibility that fiscal stress can feed back into the banking sector and amplify systemic risks (Bua et al., 2024). Finally, the COVID-19 dummy may appear with a negative sign, capturing the effect of the extraordinary monetary easing during 2020 that temporarily pushed down borrowing cost spreads despite severe real-sector disruptions.

3.2. Econometric Model and Estimation

Prior to estimating the panel regression models, a series of standard diagnostic tests was conducted to assess whether the classical assumptions underlying panel data estimation were satisfied (Baltagi, 2008). The results of these diagnostics are reported in Table 3 and provide important guidance for the subsequent econometric strategy.

The Modified Wald test strongly rejects the null hypothesis of homoskedasticity, indicating that the variance of the error terms differs across countries. Similarly, the Wooldridge test for first-order serial correlation yields a highly significant test statistic, pointing to the presence of autocorrelation within panel units over time. These findings suggest that error terms are neither independently nor identically distributed, which would render conventional panel estimators with standard errors unreliable.

Table 3. Diagnostic Test Results

Test	**Null Hypothesis (H_0)**	**Statistic**	**P-value**	**Conclusion**
Heteroskedasticity (Modified Wald)	Homoskedasticity ($\sigma i^2 = \sigma^2$)	χ^2_{10}=60.34	0.0000	Reject H_0 (Heteroskedasticity present)
Serial Correlation (Wooldridge Test)	No first-order autocorrelation	$F_{1,9}$=72.771	0.0000	Reject H_0 (Serial correlation present)
Cross-Sectional Dependence (Pesaran CD Test)	Weak CSD	CD=7.50	0.0000	Reject H_0 (CSD present)

In addition, Pesaran's cross-sectional dependence (CD) test reveals strong evidence of contemporaneous correlation across countries. This result is not unexpected given the high degree of economic and financial integration among Eastern European economies, as well as their exposure to common global shocks and region-wide monetary conditions. Ignoring such cross-sectional dependence may lead to biased inference, particularly in macro-financial panel settings where spillovers and co-movements are prevalent.

Taken together, the presence of heteroskedasticity, serial correlation, and cross-sectional dependence motivates the use of estimation techniques that are robust to multiple forms of misspecification. Accordingly, the empirical analysis relies on Driscoll–Kraay standard errors, which provide consistent inference in the presence of heteroskedasticity, autocorrelation, and cross-sectional dependence, even in panels where the time dimension exceeds the cross-sectional dimension (De Hoyos & Sarafidis, 2006; Hoechle, 2007).

To examine the relationship between climate vulnerability and sovereign borrowing costs, both random-effects and fixed-effects specifications are estimated. Employing both frameworks allows for a comprehensive assessment of the results while accounting for unobserved heterogeneity across countries and ensuring the robustness of the findings.

The random-effects specification takes the following form:

$$\text{Sovereign Borrowing Cost Spread}_{it} = \beta_0 + \beta_1\text{Climate Vulnerability}_{it} + \beta_2\text{Inflation}_{it} + \beta_3\text{GDP Growth}_{it} + \beta_4\text{Current Account}_{it} + \beta_5\text{Claims on Government}_{it} + \beta_6\text{Covid Dummy}_t + u_i + \varepsilon_{it} \quad (2)$$

For comparison, a fixed-effects version of the model is also estimated:

$$\text{Sovereign Borrowing Cost Spread}_{it} = \beta_0 + \beta_1\text{Climate Vulnerability}_{it} + \beta_2\text{Inflation}_{it} + \beta_3\text{GDP Growth}_{it} + \beta_4\text{Current Account}_{it} + \beta_5\text{Claims on Government}_{it} + \beta_6\text{Covid Dummy}_t + \mu_i + \varepsilon_{it} \quad (3)$$

where u_i denotes the time-invariant random effects for each country, μ_i captures fixed country effects, and ε_{it} is the idiosyncratic error term.

Both the random-effects and fixed-effects specifications are estimated using Driscoll–Kraay standard errors with a maximum lag length of two. This choice is motivated by the empirical characteristics of the dataset and the nature of the regional environment under study. The Driscoll–Kraay correction addresses these concerns by producing standard errors that remain valid in the presence of heteroskedasticity, serial correlation, and cross-sectional dependence. This estimation strategy enhances the reliability of statistical inference and ensures that the reported significance levels are not driven by unaddressed econometric distortions (Driscoll & Kraay, 1998).

3.3. Hypothesis Development

Based on the theoretical framework and empirical literature, this study formally tests the following research hypotheses concerning the relationship between climate vulnerability and sovereign risk premiums in Eastern European countries.

Hypothesis 1: Climate Vulnerability Effect

H_{10}: *Climate vulnerability has no statistically significant effect on sovereign borrowing cost spreads in Eastern European countries ($\beta_1 = 0$).*

H_{1a}: *Higher climate vulnerability is associated with significantly higher effect on sovereign borrowing cost spreads in Eastern European countries ($\beta_1 > 0$).*

Hypothesis 2: Macroeconomic Fundamentals

H_{20}: *Traditional macroeconomic variables have no significant relationship with sovereign borrowing cost spreads in Eastern European countries ($\beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$).*

H_{2a}: *Inflation and claims on government positively affect borrowing cost spreads ($\beta_2 > 0, \beta_5 > 0$), while GDP growth and current account balance negatively affect borrowing cost spreads ($\beta_3 < 0, \beta_4 < 0$).*

Hypothesis 3: Global Shock Impact

H_{30}: *The COVID-19 pandemic had no significant effect on sovereign borrowing cost spreads in Eastern Europe ($\beta_6 = 0$).*

H_{3a}: *The COVID-19 pandemic significantly reduced sovereign borrowing cost spreads due to unprecedented global monetary stimulus ($\beta_6 < 0$).*

Hypothesis 4: Country-Specific Heterogeneity

H_{40}: *Country-specific effects do not significantly explain variation in sovereign borrowing cost spreads ($\mu_i = 0$ for all i).*

H_{4a}: *Significant country-specific heterogeneity exists in sovereign risk pricing across Eastern European countries ($\mu_i \neq 0$ for multiple countries).*

All hypotheses are examined using both the random-effects and fixed-effects specifications. Variance Inflation Factor results indicated that multicollinearity was not a concern, as all VIF values remained well below the conventional cutoff of 5. To determine whether the fixed-effects or random-effects estimator was more appropriate, we relied on the Hausman test, following the standard guidance in the panel-data literature (Baltagi, 2008).

3.4. Limitations

Several limitations of the analysis should be acknowledged. To begin with, the use of bank lending rates as a proxy for sovereign risk—although supported in earlier studies—may capture elements of banking-sector risk that are not strictly tied to sovereign creditworthiness. In addition, the ND-GAIN index, despite its breadth, cannot fully reflect the range of climate-related considerations that investors may factor into their assessments of country risk. A further limitation concerns the sample size: the ten countries included in the panel offer a focused view of Eastern Europe, but the limited cross-sectional dimension naturally constrains the generalizability of the findings. Taken together, these considerations suggest that while the results should be interpreted with appropriate caution, the empirical approach nonetheless offers a clear and transparent framework for examining how climate vulnerability relates to sovereign risk.

4. Results, Analysis, and Discussion

4.1. Descriptive Statistics

Due to the clear diversity among Eastern European countries, the presentation of some descriptive statistics is crucial before moving to the estimation process. Table 4 presents the descriptive statistics of the dependent variable and main independent variables employed in the paper.

As evident from the table below, the sovereign borrowing cost spread has a relatively large standard deviation value of 3.83, suggesting that there are significant variations in financing conditions among countries in the sample. The climate vulnerability index also shows some variation, albeit smaller than the former, which is expected since it was normalized. In this regard, it ranges between 0.26 and 0.44, implying that countries differ in their climate vulnerability and adaptation abilities.

Table 4. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Sovereign Borrowing Cost Spread	170	7.2404	3.8297	.07	19.30
Climate Vulnerability	170	0.3637	0.0441	.26	.44
Inflation (%)	170	5.2162	7.3666	-1.58	59.22
GDP Growth (%)	170	2.5033	3.8996	-15.31	13.93
Current Account (mld)	170	-2.479	5.1311	-27.36	5.678
Claims on Gov. (% GDP)	170	5.3362	10.1250	-22.13	31.74
Covid Dummy	170	0.0588	0.2360	0	1

The range of macroeconomic variables employed in the study is notably high. The inflation rate varies widely, capturing monetary instability and periods of macroeconomic distress. Similarly, the GDP growth rate ranges between negative values and positive figures, showing diverging cyclicality across countries and throughout the observation period. The current account balance and claims on the government have high dispersions, indicating variations in foreign assets and liabilities, respectively. All these observations suggest that the degree of variation in key variables justifies using panel regression techniques in estimating the model.

4.2. Regression Results

The findings from the panel regression are reported and discussed in this section with the primary goal of determining whether climate vulnerability affects sovereign borrowing costs after accounting for the relevant macroeconomic variables. Table 5 shows the results of estimation using both the random effects (RE) and fixed effects (FE) models. Coefficients in the two cases are similar in their direction and statistical significance, making the conclusions drawn here robust and thus providing strong empirical support for the study's key hypothesis.

Perhaps the strongest finding in this case is that of a significantly positive relationship between climate vulnerability and sovereign borrowing cost spreads. The regression coefficients are statistically significant at the 1 percent level, indicating a high degree of association between the two factors. The effect size is economically significant. As per the RE estimates, one unit increase in the climate vulnerability variable increases sovereign borrowing cost spreads by about 48 percentage points. In the FE model, the effect is more pronounced, with one unit increase in climate vulnerability resulting in a 98 percentage-point rise in borrowing cost spreads.

The significantly higher coefficient calculated using the FE approach demonstrates the relevance of considering unobservable and time-invariant country-specific factors. After these variations are controlled for, the influence of climate vulnerability on borrowing becomes more evident. In this respect, the findings imply that financial markets pay attention to modifications in climatic conditions and the ability to cope with them, rather than the current state of affairs. In other words, the study findings demonstrate the integration of climate risk into the evaluation of countries' credit ratings.

In general terms, the results suggest that the greater vulnerability to climate-related risks increases the cost of financing of a state, thus imposing constraints upon fiscal and investment capacity. Such a scenario implies that an adverse self-reinforcement effect is possible, which occurs when increased financing costs hamper the fiscal capacity to undertake investments aimed at addressing climate change issues, thereby exacerbating the country's vulnerability to climate change.

It should be mentioned that most of the coefficients for the control variables were obtained consistently with the existing theory and previous empirical findings. In particular, the lagged value of the rate of inflation was positively and significantly related to borrowing costs. As for the growth rate of GDP, the variable was negatively and significantly correlated with borrowing costs.

Furthermore, current account balance enters with a positive and statistically significant coefficient in both the random-effects and fixed-effects models (0.088 and 0.089, respectively). This suggests that, ceteris paribus, higher current account balances are associated with slightly higher sovereign borrowing cost spreads in the sample of Eastern European economies. The magnitude of the effect is modest, but the sign is notable because it runs counter to the conventional expectation that stronger external balances reduce perceived sovereign risk.

Table 5: Random and Fixed-Effects Models

Sovereign Borrowing Cost Spread (%)	***RE Model***			***FE Model***		
	Coef.		*P > t*	*Coef.*		*P > t*
Climate Vulnerability	***48.133***	***	*0.000*	***97.787***	***	*0.000*
L2. Inflation (%)	*0.180*	***	*0.000*	*0.147*	***	*0.000*
GDP Growth (%)	*-0.267*	***	*0.004*	*-0.223*	***	*0.002*
Current Account (mld)	*0.088*	**	*0.048*	*0.089*	**	*0.032*
Claims on Gov. (% GDP)	*-0.131*	***	*0.000*			
L1. Claims on Gov. (% GDP)				*-0.137*	**	*0.016*
Covid Dummy	*-2.981*	***	*0.005*	*-2.430*	***	*0.004*
Constant	*-7.678*		*0.000*	*-27.233*		*0.000*
Country Dummies [a]						
• *Bosnia*	*-3.960*		*0.000*			
• *Bulgaria*	*-2.669*		*0.000*			
• *Hungary*	*-2.364*		*0.093*			
• *Montenegro*	*-2.493*		*0.003*			
• *Macedonia*	*-1.929*		*0.000*			
• *Romania*	*-2.293*		*0.046*			
Observations	*150*			*150*		
R-squared	*0.711*			*0.499 (within)*		

*Note: *** p<0.01, ** p<0.05, * p<0.1 a Some of the Dummy Countries (Belarus, Czechia, and Moldova) have been omitted from the model since they were statistically insignificant. Albania has been used here as a reference country.*

The dummy variable for the period covered by the COVID-19 crisis bears a negative and significant coefficient, indicating that there was a reduction in borrowing cost spread during the pandemic. This result is best explained by the unprecedented monetary conditions that prevailed during this period. In response to the pandemic, major central banks introduced a range of unprecedented policy measures including extensive liquidity provision, large-scale asset purchase programs, and substantial reductions in policy interest rates (Federal Reserve, 2020; Hutchinson & Mee, 2020).

The inclusion of country-specific dummy variables provides additional insight into the regional heterogeneity underlying sovereign borrowing cost dynamics in Eastern Europe. The results indicate that several Balkan economies, notably Bosnia and Herzegovina, Bulgaria, Montenegro, North Macedonia, and Romania, exhibit statistically significant and negative coefficients relative to Albania, which is used as the reference category. This finding implies that, holding observable macroeconomic and climate-related factors constant, these countries tend to face systematically lower borrowing cost spreads.

One plausible explanation for the relatively favourable pricing of debt in these Balkan economies relates to expectations of institutional convergence with the European Union. Countries such as Bulgaria and Romania are already EU members, while others in the region have advanced accession prospects or maintain close alignment with EU policy frameworks. These relationships may strengthen market confidence by signalling a commitment to institutional reform, fiscal discipline, and regulatory harmonization.

As for the performance of the model, the random effects specification accounts for 71.1% of the variation in sovereign borrowing spreads. This means that the model successfully captures most cross-sectional differences in borrowing costs. The fixed effects specification, focusing solely on within-country time-series variation, also demonstrates adequate explanatory power.

4.3. Evaluation of Research Hypotheses

The empirical findings have provided strong evidence for the validity of the research hypotheses. As for Hypothesis 1, the data clearly reject the null hypothesis (H_{1o}) and accept the alternative hypothesis (H_{1a}). It is established that climate vulnerability has a positive and statistically significant impact on sovereign borrowing cost spreads in Eastern Europe under the random effects and fixed effects models.

The results also confirm Hypothesis 2, which addresses the significance of the traditional macroeconomic factors. The null hypothesis (H_{2o}) is thus rejected since various macroeconomic variables have proven to have a statistically significant impact on borrowing cost spreads. An increase in the inflation rate has a positive relationship with the borrowing costs, supporting the notion that the presence of price volatility adds to the risks posed to the sovereign state.

In relation to Hypothesis 3, the results provide sufficient evidence to reject the null hypothesis (H_{3o}) and accept the alternative hypothesis (H_{3a}). The COVID-19 dummy variable is negative and significant, which suggests that there is a reduction in sovereign borrowing cost spreads in the period of COVID-19 due to unprecedented monetary policy accommodation across the globe.

Lastly, the findings prove that Hypothesis 4 is valid because there were statistically significant country effects detected in several countries, especially those from the Balkan area. The existence of such country effects proves that there is heterogeneity when it comes to sovereign risk pricing among Eastern European countries.

5. Conclusion

The central issue addressed in this paper concerns one of the major factors determining financial stability in the developing world during the twenty-first century: Does the pricing of sovereign debt consider the physical risks arising from climate change? With respect to this concern, using a maturity-matched measure of sovereign cost borrowing spreads in conjunction with a panel of ten Eastern European countries for the years 2007 through 2023, the present analysis finds an unequivocal answer in the affirmative.

The size of this effect on prices is not only important in terms of statistics but also constitutes a real financial phenomenon. Specifically, the fact that the fixed effects reveal that there are not just concerns about climate risks in financial markets but also the financial sector adjusts for them in the assessment of sovereign credit risk is of utmost importance because it shows how climate has become not just a topic to worry about due to its implications for the environment and humanitarian issues, but also for macroeconomic and financial stability.

On the other hand, the findings also carry implications for policy. As stated earlier, high-quality institutions and access to climate financing may be able to mitigate the effects of climate change on the cost of sovereign borrowing. Good governance and sound climate finance instruments may decrease the impact of climate change in the pricing of sovereign debt. With this regard, climate adaptation is not only about physical investments but also includes financial and macroeconomic policies.

In conclusion, these results emphasize that not only is climate adaptation a necessity from an environmental perspective, but it is also an economic one. It is becoming increasingly important for governments in developing European countries and other equivalent regions to incorporate climate resilience within their economic policies in order to secure stability, access to capital markets abroad, and sustainable development. Given the increasing climate risks in this century, it can be said that climate resilience and financial resilience are interconnected objectives.

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