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When do carbon emissions matter for sovereign ratings? Governance and the pricing of transition risk

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ABSTRACT

This paper investigates whether sovereign credit ratings uniformly price carbon transition risk. Using a panel of 145 countries from 2002 to 2024, we show that rating agencies penalize CO2 emissions only in countries with strong institutional quality. In weak governance nations, carbon exposure remains unpriced. This asymmetry suggests that sovereign transition risk is conditional on state capacity: high emissions threaten creditworthiness only when governments can credibly implement decarbonization policies. Our findings, which are robust to alternative proxies, estimators, and lagged effects, highlight that domestic governance is a crucial mechanism in the financial pricing of sovereign climate risk.

1. Introduction

Climate change is increasingly relevant for sovereign credit risk. A growing literature shows that climate vulnerability and environmental exposure can affect sovereign creditworthiness and raise government borrowing costs (Beirne et al., 2021; Cevik and Jalles, 2020). Forward-looking analyses also suggest that insufficient alignment with international climate targets may lead to future sovereign downgrades (Klusak et al., 2023). Yet the empirical evidence still provides only a partial view of how climate-related risks are incorporated into sovereign ratings.

Most existing studies implicitly treat climate transition risk as being priced uniformly across countries. Under this view, greater carbon intensity should mechanically weaken sovereign creditworthiness because it increases exposure to carbon pricing, regulation, technological obsolescence, and transition-related macroeconomic adjustment. This assumption, however, overlooks a key political economy condition: carbon exposure becomes a material transition risk only when governments are able to implement credible and binding decarbonization policies. Where institutional capacity is weak, the probability that emissions will trigger costly regulatory adjustment is lower, and long-horizon environmental liabilities may remain secondary to more immediate macroeconomic and political risks.

This paper argues that the effect of carbon emissions on sovereign ratings is therefore conditional rather than uniform. While the role of institutional quality in shaping sovereign ratings is well established (Afonso et al., 2011; Teixeira et al., 2018), much less is known about whether governance conditions the way credit rating agencies assess carbon exposure. We address this gap by examining the interaction between per capita CO2 emissions and governance quality in a global panel of sovereigns. Our central argument is that rating agencies penalize carbon exposure only when governance is strong enough to make climate transition policies credible. In this sense, sovereign transition risk is not priced mechanically; it is priced through state capacity.

Using an unbalanced panel of countries over the period 2002–2024, we estimate fixed-effects models that interact carbon emissions

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with a composite Governance Index. The results show that carbon emissions do not exert a uniform negative effect on sovereign ratings. Instead, the marginal effect of emissions becomes increasingly negative as institutional quality improves, and turns statistically significant at higher levels of governance. This pattern is robust to alternative estimators, including Driscoll-Kraay standard errors, as well as to alternative governance dimensions, a different rating agency (Moody's), and an alternative greenhouse gas proxy (methane emissions).

The paper contributes to the literature in two ways. First, it advances research on climate finance and sovereign risk by showing that the pricing of transition risk depends on domestic institutional conditions. Second, it adds to the literature on sovereign rating determinants by showing that environmental exposure affects sovereign creditworthiness through its interaction with governance, rather than as a standalone risk factor.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data and empirical strategy. Section 4 presents the main results. Section 5 reports robustness tests. Section 6 concludes.

2. Hypothesis development

The climate finance literature increasingly suggests that environmental risks may affect sovereign creditworthiness. In the standard view, countries with higher carbon emissions are more exposed to future carbon pricing, tighter environmental regulation, and transition-related adjustment costs, which may weaken their fiscal and macroeconomic outlook and, in turn, their sovereign ratings (Beirne et al., 2021). This leads to a baseline expectation of a negative association between carbon intensity and sovereign credit ratings.

Hypothesis 1 (H1). *Higher carbon intensity is negatively associated with sovereign credit ratings.*

However, this baseline view assumes that climate transition risk is priced uniformly across countries. Such an assumption may be overly mechanical. Carbon exposure does not automatically translate into sovereign transition risk; rather, it becomes economically relevant when governments are able to implement credible and binding decarbonization policies. Institutional quality is therefore likely to shape whether credit rating agencies perceive emissions as a material source of sovereign risk.

This argument is consistent with the broader literature showing that governance is a central determinant of sovereign credit ratings (Afonso et al., 2011; Teixeira et al., 2018). It is also in line with recent evidence suggesting that the role of ESG and climate-related factors in sovereign risk assessment is heterogeneous across countries rather than uniform (Pineau et al., 2022; Naifar, 2024). In weak-governance countries, high emissions may not trigger a substantial rating penalty because the probability of strict policy enforcement is limited, while more immediate macroeconomic and political risks dominate rating decisions. By contrast, in countries with stronger institutions, climate commitments are more likely to be translated into enforceable policy actions, making carbon-intensive economies more exposed to transition-related adjustment costs.

Accordingly, we expect institutional quality to moderate the relationship between carbon intensity and sovereign credit ratings.

Hypothesis 2 (H2). *The negative association between carbon intensity and sovereign credit ratings becomes stronger as institutional quality improves.*

3. Data and model

3.1. Data

To empirically test our hypotheses, we construct an unbalanced panel dataset comprising 145 countries over the period 2002–2024. Our dependent variable is the sovereign credit rating assigned by Standard & Poor's (S&P). Following the standard literature (Afonso et al., 2011), we convert alphanumeric ratings into a linear numerical scale, where higher values indicate better creditworthiness. For robustness, we alternatively employ Moody's sovereign ratings.

Our main independent variable for environmental exposure is carbon intensity, measured as CO2 emissions per capita. As an alternative proxy, we utilize methane emissions. To capture institutional quality, we compute a composite *Governance Index* by taking the simple average of the Worldwide Governance Indicators (WGI) provided by the World Bank, encompassing control of corruption, rule of law, government effectiveness, and political stability. Finally, to isolate the climate-governance interaction from structural economic dynamics, we introduce a set of macroeconomic control variables typically assessed by CRAs, sourced from the World Development Indicators (WDI): GDP growth, inflation, unemployment rate, and the share of renewable energy consumption.

Table A1 in the Appendix reports the descriptive statistics and distributional properties for all variables used in the empirical analysis. The statistics are computed on the main estimation sample of 145 countries and 3335 country-year observations. Detailed definitions and data sources for all variables are provided in Table A2 in the Appendix. Furthermore, the full list of the 145 sovereign nations included in our empirical sample, along with their ISO3 codes, is reported in the Appendix.

3.2. Empirical methodology

We estimate the interactive effect of carbon intensity and governance on sovereign ratings using a Two-Way Fixed Effects (TWFE) panel data model. The baseline econometric specification is formulated as follows:

$$Rating_{it} = \alpha + \beta_1 CO2_{it} + \beta_2 Gov_{it} + \beta_3 (CO2_{it} \times Gov_{it}) + \gamma' X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

where $Rating_{it}$ is the sovereign rating of country i in year t. $CO2_{it}$ represents carbon intensity, and Gov_{it} is the institutional quality index. Our primary coefficient of interest is β_3, which captures the moderating role of governance. The vector X_{it} contains the macroeconomic controls.

We select the TWFE model as our baseline empirical framework because it isolates the within-country relationship over time by controlling for time-invariant country-specific heterogeneity (through country fixed effects μ_i) and common global shocks (through year fixed effects λ_t). This dual control is critical to ensure that our results are not driven by omitted variable bias or global macroeconomic cycles. Finally, ϵ_{it} is the idiosyncratic error term. To ensure the robustness of our statistical inference, standard errors are clustered at the country level. Furthermore, in advanced robustness checks, we employ Driscoll-Kraay standard errors to explicitly account for cross-sectional dependence and spatial correlation across sovereign bond markets.

4. Empirical results

4.1. Baseline results and the moderating role of governance

Table 1 reports the baseline results on the relationship between carbon intensity, governance, and sovereign credit ratings. All specifications are estimated using a Two-Way Fixed Effects (TWFE) framework, which allows us to isolate the within-country relationship over time while controlling for time-invariant country-specific heterogeneity and common global shocks. Column 1 presents the fixed-effects specification without the interaction term. The coefficient on CO2 emissions per capita is negative and statistically significant (-0.045, $p < 0.01$), indicating that, on average, more carbon-intensive countries tend to receive lower sovereign ratings. This finding is consistent with Hypothesis 1 and with the conventional view that environmental exposure may weaken sovereign creditworthiness (Beirne et al., 2021; Klusak et al., 2023; Erhart et al., 2026). However, our results refine this view by showing that such pricing is not uniform but depends on institutional quality, which makes transition policies credible.

Column 2 introduces the interaction between carbon emissions and the governance index. Once this interaction is included, the results point to a more nuanced mechanism. The interaction term is negative and highly significant (-0.051, $p < 0.01$), indicating that the adverse effect of carbon emissions on sovereign ratings becomes stronger as institutional quality improves. In this specification, the constitutive term for CO2 emissions (0.064) captures the effect of emissions when the governance index is equal to zero; therefore, it should not be interpreted in isolation. The relevant quantity is the marginal effect of carbon emissions, which varies with the level of governance according to the following expression:

Table 1
Carbon intensity, governance, and sovereign ratings.

	(1) Baseline	(2) FE Model	(3) Lagged (1-yr)	(4) Driscoll-Kraay
co2_per_capita	−0.045***	0.064***		0.064**
	(0.014)	(0.022)		(0.029)
gov_index	−2.654	−2.136		8.839***
	(2.326)	(2.090)		(1.967)
co2_per_capita * gov_index		−0.051***		−0.051**
		(0.015)		(0.021)
L.co2_per_capita			0.053***	
			(0.019)	
L.gov_index			−2.358	
			(2.064)	
L.co2_per_capita * L.gov_index			−0.043***	
			(0.014)	
Macro Controls	Yes	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3335	3335	3190	3335
r2_a	0.979	0.979	0.981	

Notes: FE estimates. co2_per_capita is interacted with gov_index. Macro controls and FE included. Robust/Driscoll-Kraay SE in parentheses.
*** $p < 0.01$,.
** $p < 0.05$,
* $p < 0.1$.

$$\frac{\partial Rating}{\partial CO2} = 0.064 - 0.051 \times Governance$$

This expression highlights the conditional treatment effect of carbon intensity on sovereign creditworthiness. The results imply that the 'treatment' (higher CO_2 emissions) only exerts a statistically significant negative impact when filtered through a governance level above approximately 1.25. Below this threshold, the treatment effect is negligible, suggesting that carbon exposure is not priced uniformly across the sample. Instead, the transition risk associated with this treatment becomes increasingly detrimental as institutional quality rises, reflecting a higher credibility of climate policy implementation

Fig. 1 provides a visual representation of this conditional relationship by plotting the marginal effect of carbon emissions on sovereign ratings over the observed range of the governance index. The figure shows a clear downward-sloping pattern: at low levels of governance, the marginal effect of emissions is statistically indistinguishable from zero, whereas at higher levels of governance it becomes negative and statistically significant. This evidence supports Hypothesis 2 and suggests that credit rating agencies price carbon exposure primarily where state capacity makes climate policy credible. In such settings, higher emissions imply greater exposure to transition-related adjustment costs associated with future regulation, carbon pricing, and structural economic change.

Finally, Columns 3 and 4 of Table 1 demonstrate the methodological rigor of these findings. Column 3 employs a lagged specification (one-year lag) to mitigate concerns regarding contemporaneous associations and reverse causality, with the interaction term remaining significant (-0.043, $p < 0.01$). Column 4 utilizes Driscoll-Kraay standard errors to ensure that the results are robust to potential cross-sectional dependence and common shocks affecting sovereign bond markets simultaneously

4.2. Decomposing the governance channels

To assess whether this result is driven by a specific institutional dimension, Table 2 replaces the composite governance index with its main pillars: control of corruption, rule of law, government effectiveness, and political stability. All specifications in Table 2 are estimated using the baseline two-way fixed-effects model, with standard errors clustered at the country level. The results are highly consistent across specifications. This pattern is not unexpected, as these dimensions capture closely related aspects of institutional quality and display substantial conceptual overlap. In all four columns, the interaction term between carbon emissions and the relevant governance pillar remains negative and statistically significant, with coefficients ranging from -0.045 to -0.046 (all $p < 0.01$).

These findings indicate that the conditional pricing of carbon exposure does not depend on a single institutional attribute. Instead, it reflects a broader governance environment in which policy commitments are more likely to be translated into effective and credible implementation. Taken together, the results suggest that sovereign transition risk is priced not simply as a function of environmental exposure, but through its interaction with institutional capacity.

5. Robustness checks

To assess the stability of the main findings, we conduct a series of robustness tests based on alternative specifications and variable definitions.

First, we address potential concerns related to timing and reverse causality by replacing the main explanatory variables with their

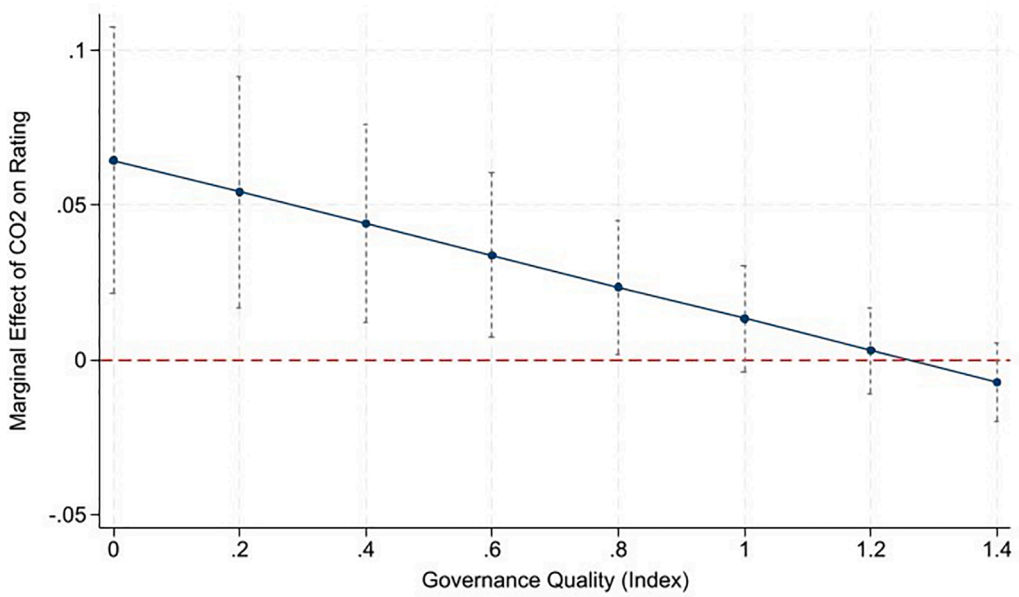

Fig. 1. Marginal effect of CO2 emissions on sovereign ratings across governance levels. Error bars represent 95% confidence intervals.

Table 2
Decomposing the moderating role of governance.

	(1) Corruption	(2) Rule of Law	(3) Gov Effect.	(4) Pol. Stability
co2_per_capita	0.051***	0.053***	0.053***	0.048***
	(0.018)	(0.019)	(0.019)	(0.018)
control_corruption	−1.823			
	(1.751)			
co2_per_capita * control_corruption	−0.045***			
	(0.013)			
rule_of_law		−1.825		
		(1.752)		
co2_per_capita * rule_of_law		−0.045***		
		(0.013)		
gov_effectiveness			−1.822	
			(1.752)	
co2_per_capita * gov_effectiveness			−0.045***	
			(0.013)	
political_stability				−1.903
				(1.822)
co2_per_capita * political_stability				−0.046***
				(0.014)
Macro Controls	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3335	3335	3335	3335
r2_a	0.979	0.979	0.979	0.979

Notes: FE estimates using individual governance pillars. Macro controls and FE included. Robust SE in parentheses.
*** $p < 0.01$,
** $p < 0.05$,
* $p < 0.1$.

one-year lagged values. As reported in Table 1, Column 3, the interaction between lagged carbon emissions and lagged governance remains negative and statistically significant (−0.043, $p < 0.01$). This result indicates that the baseline relationship is not driven solely by contemporaneous associations and is consistent with the interpretation that carbon exposure affects sovereign ratings conditional on institutional quality.

Second, we re-estimate the baseline interaction model using Driscoll-Kraay standard errors in order to account for cross-sectional dependence and common shocks affecting multiple countries simultaneously. As shown in Table 1, Column 4, the interaction coefficient remains negative and statistically significant, with a magnitude very close to that of the main specification. This suggests that the results are robust to alternative inference procedures that account for global shocks and cross-country dependence.

Finally, we test the robustness of the findings using alternative measures of both the dependent and the key explanatory variable. Table 3, Column 1, replaces S&P sovereign ratings with Moody's ratings. The interaction term remains negative and statistically significant (−0.038, $p < 0.01$), indicating that the main result does not depend on the choice of rating agency. Table 3, Column 2, replaces CO2 emissions with methane emissions as an alternative proxy for environmental exposure. Also in this case, the interaction between emissions and governance remains negative and statistically significant (−0.296, $p < 0.01$). Taken together, these results confirm that the conditional effect of environmental exposure on sovereign creditworthiness is robust across estimation methods, rating measures, and alternative greenhouse gas indicators.

6. Conclusion

This paper investigates whether the integration of climate transition risk into sovereign credit ratings is a uniform global phenomenon or whether it depends on institutional capacity. Using a global panel of 145 countries over the period 2002–2024, we show that carbon intensity does not affect sovereign ratings uniformly across countries. Rather, its adverse effect emerges primarily in countries with stronger governance. In settings characterized by weak institutional quality, where the enforcement of stringent environmental regulation is less credible, climate transition risk does not appear to be significantly priced in sovereign credit

Table 3
Additional robustness checks (Alternative rating & proxy).

	(1) Moody's	(2) Methane Proxy
co2_per_capita	0.044**	
	(0.018)	
gov_index	2.612	−1.905
	(1.911)	(2.163)
co2_per_capita * gov_index	−0.038***	
	(0.013)	
Methane		0.381***
		(0.088)
methane * gov_index		−0.296***
		(0.070)
Macro Controls	Yes	Yes
Country FE	Yes	Yes
Year FE	Yes	Yes
Observations	3335	3335
r2_a	0.962	0.979

Notes: Robustness checks using Moody's ratings (1) and methane (2). Macro controls and FE included. Robust SE in parentheses.
*** $p < 0.01$,.
** $p < 0.05$,
* $p < 0.1$.
Standard errors in parentheses.

assessments.

These findings qualify the prevailing assumption in climate finance that environmental exposures are linearly and universally penalized across debt markets (Giglio et al., 2021). Instead, our evidence suggests that credit rating agencies (CRAs) assess climate-related liabilities conditionally, through the lens of institutional capacity. Because transition risk is fundamentally policy-induced, it becomes financially relevant only when governments are able to implement credible and binding decarbonization strategies. In this respect, our results are consistent with recent macro-financial research emphasizing that climate risk cannot be fully understood without accounting for institutional and structural frictions (Mallucci, 2022).

The paper contributes to the literature in two main ways. First, it adds to research on climate finance and sovereign risk by showing that the pricing of environmental exposure is conditional rather than uniform. Second, it contributes to the literature on sovereign rating determinants by demonstrating that carbon intensity matters for sovereign creditworthiness through its interaction with governance, rather than as a standalone risk factor.

These results also have implications for policymakers and investors. For countries with stronger institutions, carbon-intensive development paths may become increasingly relevant for sovereign risk assessment because they imply greater exposure to transition-related adjustment costs. For countries with weaker institutions, the current absence of a significant climate-related rating penalty should not be interpreted as evidence that environmental exposure is irrelevant, but rather that it is not yet translated into credible policy risk. More broadly, the findings suggest that the financial relevance of climate transition risk depends not only on emissions, but also on state capacity.

Future research could extend this framework by examining whether specific climate-policy interventions, such as the introduction of carbon taxes or binding emission targets, trigger discrete rating responses depending on institutional quality.

Finally, while our analysis focuses on how credit rating agencies price carbon exposure, extending this framework to market-based measures of sovereign risk, such as Credit Default Swap (CDS) spreads, would provide a valuable complementary perspective. However, CDS data are typically not available for the full cross-section of countries in our sample, particularly for lower-income and less financially integrated sovereigns. We therefore leave the exploration of how transition risk is priced in these high-frequency, market-based instruments as an important avenue for future research.

Author statement

Nicola Del Sarto: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Writing – original draft, Writing – review & editing, Visualization.

The author has read and approved the final version of the manuscript and agrees to be accountable for all aspects of the work.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.frl.2026.110235.

Data availability

The authors do not have permission to share data.

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