PEK
POLİTİK EKONOMİK KURAM

Research Article

Greenhouse Gas Emissions, Energy Use, and Sovereign Risk: ARDL–ECM Evidence from Turkey's CDS Spreads (2005–2023)

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Abstract: This study investigates the impact of environmental factors on Turkey's sovereign credit default swap (CDS) spreads over the period 2005–2023. Using annual data on greenhouse gas (GHG) emissions per capita, energy use per capita, and five-year CDS spreads, we apply the Autoregressive Distributed Lag (ARDL) bounds testing approach and its associated Error Correction Model (ECM) to capture both short-run and long-run dynamics. Unit root tests reveal mixed integration orders, justifying the ARDL framework. The empirical results show that higher GHG emissions significantly increase CDS spreads in both the short and long run. Energy use per capita exhibits a more nuanced role: while contemporaneous increases reduce CDS spreads by signaling stronger economic capacity, lagged effects reveal partial reversal. The ECM results confirm a rapid adjustment toward long-run equilibrium, with over half of deviations corrected within one year. Overall, the findings underscore that Türkiye's environmental performance is a determinant of its sovereign borrowing costs. From a policy perspective, reducing emissions and transitioning to cleaner energy sources are not only environmentally essential but also financially prudent, as they can mitigate sovereign risk premiums in international credit markets.

Keywords: CDS Premiums, Sovereign Risk, Greenhouse Gas Emissions, Türkiye
Jel Codes: K32, H81

Sera Gazı Emisyonları, Enerji Kullanımı ve Ülke Riski: Türkiye'nin CDS Primlerinden ARDL–ECM Bulguları (2005–2023)

Öz: Bu çalışma, çevresel faktörlerin Türkiye'nin CDS primleri üzerindeki etkisini 2005–2023 dönemi için incelemektedir. Kişi başına sera gazı emisyonları, kişi başına enerji kullanımı ve beş yıllık CDS primlerine ilişkin yıllık veriler kullanılarak, hem kısa hem de uzun dönem dinamiklerini yakalamak amacıyla Otoregresif Dağıtılmış Gecikme (ARDL) sınır testi yaklaşımı ve buna bağlı Hata Düzeltme Modeli (ECM) uygulanmıştır. Birim kök testleri değişkenlerin farklı bütünleşme derecelerine sahip olduğunu göstermiş, bu da ARDL çerçevesini uygun kılmıştır. Ampirik sonuçlar, artan sera gazı emisyonlarının hem kısa hem de uzun dönemde CDS primlerini anlamlı şekilde yükselttiğini ortaya koymaktadır. Kişi başına enerji kullanımı ise daha karmaşık bir rol üstlenmektedir: eşanlı artışlar daha güçlü ekonomik kapasiteyi yansıtarak CDS primlerini düşürürken, gecikmeli etkilerde kısmi bir tersine dönüş gözlemlenmektedir. ECM sonuçları, uzun dönem dengesine hızlı bir uyum olduğunu teyit etmektedir; sapmaların yarısından fazlası bir yıl içinde düzelmektedir. Genel olarak bulgular, Türkiye'nin çevresel performansının egemen borçlanma maliyetlerinin bir belirleyicisi olduğunu vurgulamaktadır. Politika açısından bakıldığında, sera gazı emisyonlarının azaltılması ve daha temiz enerji kaynaklarına geçiş, yalnızca çevresel açıdan değil, aynı zamanda uluslararası kredi piyasalarında egemen risk primlerini azaltarak finansal açıdan da rasyonel bir tercih olacaktır.

Anahtar Kelimeler: CDS Primi, Ülke Riski, Sera Gazı Emsiyonları, Türkiye
Jel Kodları: K32, H81

Cite: Küçükefe, Bige & Kaya Kanlı, N. (2026). Greenhouse Gas Emissions, Energy Use, and Sovereign Risk: ARDL–ECM Evidence from Turkey's CDS Spreads (2005–2023), *Politik Ekonomik Kuram*, *10*(1), 182-193. https://doi.org/10.30586/pek.1792565

Submitted: 28.09.2025
Accepted: 22.01.2026

1. Introduction

The link between environmental performance and financial stability has received increasing attention in recent literature, particularly within the framework of environmental, social and governance (ESG) factors and sovereign risk. This study investigates how green growth policies influence sovereign credit risk by focusing on their impact on CDS spreads. Environmentally conscious strategies—such as enhancing energy efficiency, expanding renewable energy investments, and reducing greenhouse gas emissions—strengthen long-term economic sustainability and debt repayment capacity, thereby lowering sovereign default risk. Using sovereign CDS spreads as a forward-looking market indicator, we empirically assess whether countries with stronger green growth performance enjoy lower borrowing costs in international capital markets. Our findings provide evidence that green growth serves as a risk-mitigating factor, contributing not only to sustainable development but also to improved financial credibility. This study contributes to the literature by bridging environmental policy and sovereign credit risk, highlighting the dual role of green growth in fostering both ecological and financial resilience.

In recent decades, global financial governance institutions such as the IMF, World Bank, and OECD have increasingly recognized that climate and environmental performance are fundamental drivers of macroeconomic resilience. Poor environmental management can reduce potential output, heighten fiscal vulnerability, and expose economies to climate-related shocks that erode investor confidence. Conversely, progress in decarbonization and energy transition enhances a country's long-term debt sustainability and improves access to international capital markets. These mechanisms illustrate that environmental sustainability has become a priced factor in sovereign risk models, reflecting its central role in both market expectations and policy credibility (Beirne et al., 2021; Kling et al., 2021).

CDS is a derivative contract that provides insurance against the credit risk of corporate or government bond issuers. The buyer pays premiums, and the seller compensates the buyer if a credit event (e.g., bankruptcy, default, restructuring) occurs. A sovereign CDS is a derivative contract that allows market participants to hedge or speculate on the credit risk of a government's debt securities. In these contracts, the protection buyer pays a periodic premium to the protection seller, who in return agrees to provide compensation if a credit event occurs, such as failure to pay, restructuring, or moratorium on sovereign debt (ISDA, 2023). Sovereign CDS spreads serve as a widely used market-based measure of sovereign risk, reflecting investors' expectations about a country's probability of default as well as its fiscal, macroeconomic, and political fundamentals (Longstaff et al., 2011; Pan & Singleton, 2008). Compared to bond yields, CDS markets are often more liquid and react more quickly to new information, which makes them important forward-looking indicators of creditworthiness. Sovereign CDSs remain essential analytical tools for assessing sovereign credit risk, monitoring contagion across countries, and studying the interaction between financial markets and sovereign debt sustainability.

Moreover, sovereign credit risk has begun to reflect these structural transformations in global capital allocation. The rapid expansion of sustainable finance instruments—such as green bonds, sustainability-linked loans, and ESG investment funds—has created a feedback mechanism in which a country's environmental credibility directly influences its borrowing costs. Nations with credible transition policies often experience a measurable "greenium," or yield discount, in both bond and CDS markets, highlighting the growing financial rewards of environmental responsibility. This dynamic also implies that countries with delayed or inconsistent climate strategies may face higher sovereign spreads, as investors increasingly price transition and physical climate risks into valuation models (UNEP FI, 2022; IMF, 2023).

In recent years, researchers have begun linking climate vulnerability and greenhouse gas exposure to sovereign creditworthiness. The Environmental Risk Integration in

Sovereign Credit (E-RISC) project by the UNEP FI (United Nations Environment Programme Finance Initiative) emphasizes how natural resource availability, climate resilience, and environmental degradation can affect countries' fiscal health and default probability. This project broadened sovereign credit risk analysis by incorporating natural resource availability and environmental pressures alongside traditional economic and fiscal indicators. These risks manifest through several channels: physical risk (e.g., flood damage, agricultural shocks), transition risk (e.g., costs of decarbonization), and liability risk (e.g., climate litigation or stranded assets). These risks are also directly relevant for CDS spreads, which act as market-based measures of sovereign risk. In the short term, commodity price volatility and supply disruptions raise CDS premiums, while medium- and long-term challenges such as environmental degradation and rising emissions further amplify risk perceptions.

This emerging body of evidence illustrates that environmental risks are now considered systemic in nature. As the United Nations Environment Programme Finance Initiative (UNEP FI, 2022) and the Network for Greening the Financial System (NGFS, 2022) emphasize, climate risk is financial risk. The integration of these dimensions into sovereign risk models aligns with the broader paradigm shift toward sustainable macroeconomic management. Consequently, the financial system's sensitivity to climate metrics underscores how sustainability indicators are no longer peripheral but intrinsic to sovereign credit analysis and investor decision-making processes.

As presented in Figure 1, Turkey's sovereign CDS spreads exhibit a strong sensitivity to episodes of economic crises, geopolitical tensions, and shifts in global financial conditions. The peaks in 2001 and 2022 highlight periods of heightened sovereign risk perception. More recently, during the 2023–2024 period, a pronounced decline has been recorded, with CDS levels stabilizing at approximately 300 basis points, indicating an improvement in market confidence regarding Turkey's credit risk profile.

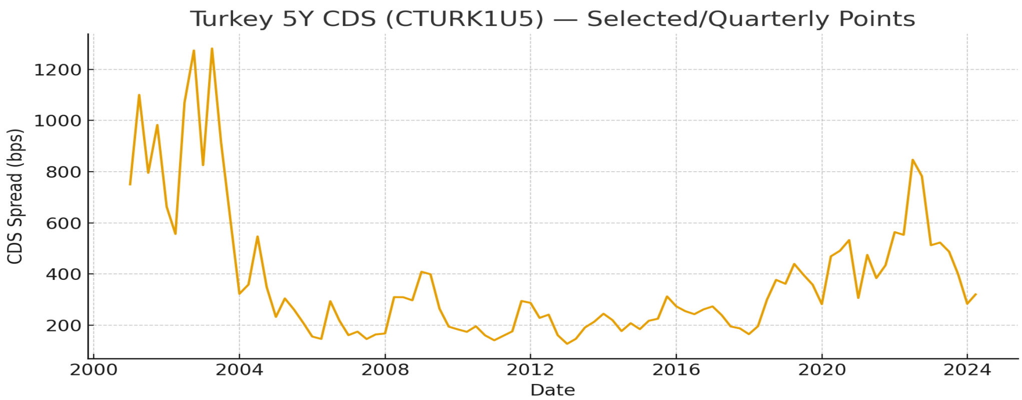

Figure 1. Turkey's Credit Default Swap (CDS) Spreads

In Turkey's case, these fluctuations reflect not only macroeconomic and political factors but also growing investor attention to environmental policy coherence. The country's ongoing energy transition efforts, its exposure to European Union decarbonization policies (notably the Carbon Border Adjustment Mechanism), and its national commitments under the Paris Agreement increasingly shape how global markets perceive sovereign risk. As such, Turkey offers a relevant setting to observe how environmental and financial dimensions converge within an emerging-market context.

While prior research has largely focused on cross-country evidence or firm-level analyses linking emission risk to credit spreads, there remains a notable gap in country-specific studies that integrate sovereign credit risk with environmental sustainability metrics. This study contributes to the literature in three ways. First, it provides novel empirical evidence from Turkey, a major emerging market economy highly exposed to both environmental and financial vulnerabilities, thereby expanding the geographic scope of sovereign risk research. Second, by employing environmental indicators, it bridges macro-level sustainability performance with financial market outcomes, offering a comprehensive framework that extends beyond firm-level or global panel datasets. Third, the econometric strategy allows for the identification of both short-run dynamics and long-run equilibrium relationships between environmental performance and sovereign CDS spreads. Collectively, these contributions highlight how environmental sustainability is not only an ecological or developmental concern but also a critical determinant of sovereign credit worthiness in emerging markets.

In summary, Turkey's case represents a microcosm of a global transition: as investors reassess how sustainability shapes fiscal capacity and creditworthiness, sovereigns are increasingly judged not only by economic growth metrics but also by their environmental stewardship. Recognizing this linkage is crucial for understanding modern sovereign risk dynamics and for designing policy strategies that align financial stability with long-term ecological resilience (IMF, 2023; UNEP FI, 2022).

2. Literature Review: Emissions and Financial Risk

An emerging stream of research explores how environmental risks, emissions, and climate exposure influence CDS. These studies provide early evidence that climate-related vulnerabilities are increasingly priced into sovereign risk assessments. The literature on sovereign credit risk has traditionally focused on macroeconomic fundamentals, global risk aversion, and market liquidity. Foundational contributions such as Pan and Singleton (2008) and Longstaff, Pan, Pedersen, and Singleton (2011) decompose sovereign CDS spreads into default, recovery, and liquidity components, highlighting the importance of both country-specific and global risk factors. Pan and Singleton (2008), who develop a dynamic term structure model of sovereign CDS spreads, highlighting the role of both global and country-specific risk factors. While their work is not specifically centered on environmental risks, it provides the empirical tools later used in green sovereign risk pricing. Longstaff et al. (2011) extend this analysis and decompose sovereign CDS spreads into components such as default, liquidity, and global risk aversion—frameworks which can be enriched with environmental variables. Although these studies do not explicitly incorporate environmental risks, they provide the methodological groundwork for later extensions integrating climate and sustainability variables into sovereign risk pricing.

In the last decade, this foundation has evolved significantly as climate finance and sustainability economics have converged with traditional risk modeling. Researchers have begun integrating environmental indicators—such as carbon intensity, climate vulnerability indices, and renewable energy penetration—into empirical models of sovereign and corporate credit spreads. The shift marks a conceptual reorientation: environmental sustainability is now viewed not only as a moral imperative but as a quantifiable macro-financial variable that affects sovereign risk through productivity, fiscal sustainability, and investor sentiment (Battiston et al., 2017; Kling et al., 2021).

More recent empirical research directly investigates the link between environmental performance, climate vulnerability, and sovereign CDS spreads. For instance, Naifar (2023) examines how climate change readiness and climate change vulnerability affect sovereign credit default swap (SCDS) spread with a large panel of emerging markets between 2010 and 2020. Empirical evidence indicates that climate change readiness exerts a mitigating effect on sovereign credit risk, as reflected in lower CDS spreads across the distribution. Conversely, greater climate vulnerability is associated with elevated CDS spreads, underscoring the market's perception of heightened default risk for less resilient countries. Notably, the risk-reducing impact of readiness is most pronounced in the upper

quantiles of the CDS distribution, suggesting that preparedness yields the greatest benefits for sovereigns already characterized by higher baseline credit risk. Similarly, de Boyrie and Pavlova (2020) incorporate the Environmental Performance Index (EPI) and ESG disclosure variables to examine how a country's environmental performance affects its sovereign credit risk through the analysis of CDS spreads across a broad panel of countries. Employing a dynamic panel GMM model, their results reveal a negative relationship: stronger environmental performance is consistently associated with lower credit risk. This effect remains robust across different CDS maturities, with no significant variation by instrument tenor.

Additional cross-country studies corroborate these findings. Kling et al. (2021) demonstrate that climate vulnerability significantly raises sovereign risk premia, especially in low- and middle-income countries. Similarly, Beirne et al. (2021) find that countries more exposed to climate shocks pay an observable penalty in borrowing costs, highlighting the growing influence of environmental risks on debt sustainability. Moreover, the IMF (2023) and BIS (2025) emphasize that climate-related fiscal shocks—stemming from disaster recovery, energy import dependence, or carbon tax reforms—can alter sovereign yield curves by increasing uncertainty about long-term solvency. Collectively, these studies confirm that environmental performance has become a systemic component of market-based sovereign risk assessment.

Further evidence is provided by Cevik and Jalles (2022) show that climate change vulnerability raises sovereign borrowing costs, while readiness (resilience) lowers them, using data from 98 countries (1995–2017). The effects are especially strong in developing economies, indicating that climate risks are already priced into sovereign debt markets. Likewise, Gratcheva et al., (2022) explores how environmental, social, and governance (ESG) dimensions are integrated into sovereign credit assessments. This report finds that environmental and social factors are only marginally reflected in sovereign credit ratings, mostly through qualitative adjustments. While ESG scores align closely with ratings in high-income countries, they add significant information for low-income economies. The report argues for greater transparency, more systematic inclusion of ESG pillars, and closer engagement by sovereign debt managers with investors on sustainability performance. Similarly, Semet, Roncalli, and Stagnol (2021) show that environmental and governance indicators are most relevant for explaining sovereign bond yields, while social factors become equally important in middle-income countries. By contrast, governance and social dimensions are more influential in predicting credit ratings, whereas environmental aspects remain underweighted, suggesting that rating agencies still underestimate climate-related risks.

A related strand of literature explores the "greenium" phenomenon in sovereign debt markets—the yield differential between conventional and green bonds issued by the same sovereign. Empirical findings indicate that countries with credible environmental policies and transparent use-of-proceeds frameworks enjoy lower borrowing costs (Flammer, 2021; Zerbib, 2019). This pattern suggests that investors reward consistency and clarity in sustainability commitments, implying that ESG credibility has become an asset in sovereign financing. Conversely, governments with weak disclosure or conflicting policy signals may face a reputational penalty, reflected in higher CDS spreads or downgraded rating outlooks.

Institutional reports reinforce these findings. MSCI (2017) documents a negative correlation between sovereign ESG scores and CDS spreads, even after controlling for credit ratings, while the Bank for International Settlements (2025) shows that per capita CO_2 emissions and extreme weather events raise sovereign bond yields, implying higher long-term sovereign risk. Zenios (2022) does not analyze CDS spreads directly but provides a conceptual and methodological framework that links climate risks to sovereign creditworthiness through debt sustainability. By integrating Integrated Assessment Models (IAMs) into Debt Sustainability Analysis (DSA) and applying the framework to Italy, the study demonstrates how climate-induced growth losses can destabilize public debt trajectories from the 2030s onward, creating potential "doom loops" in sovereign finance. Although CDS markets are not explicitly modeled, the findings imply that environmental shocks which undermine debt sustainability will ultimately be priced in by investors, thereby exerting upward pressure on sovereign bond yields and CDS spreads.

Recent evidence from the European Central Bank (2023) and Moody's (2022) also supports this interpretation: sovereigns with robust climate adaptation policies tend to face smaller risk premia, while those dependent on carbon-intensive exports or fossil fuel subsidies are more vulnerable to investor re-pricing. The NGFS (2022) further highlights that climate scenario stress tests are increasingly embedded in central banks' and supervisors' assessments of financial stability. Such institutional integration underscores the mainstreaming of environmental risk in sovereign analysis—a trend particularly relevant for emerging markets like Turkey, where climate exposure intersects with fiscal and external fragilities.

Firm-level evidence consistently shows that carbon emissions and environmental risks are increasingly priced into corporate credit markets. Studies using accounting- and market-based measures highlight this link: higher emissions raise the likelihood of financial distress (Nguyen & Phan, 2020) and widen CDS spreads (Zhang & Zhao, 2022; Zhang, Liu & Wang, 2023), while greater transparency and carbon disclosure lower borrowing costs (Jung et al., 2018). Empirical evidence from China confirms that exposure to air pollution elevates firms' debt costs by increasing environmental violation risks (Wang et al., 2022), and recent EU evidence shows that lowering CO_2 intensity reduces the cost of debt across multiple measures (Kozak, 2021). Bolton and Kacperczyk (2021) examine how corporate carbon emissions affect stock returns using data from about 3,400 U.S. firms between 2005 and 2017. The study finds that investors price carbon risk: firms with higher emissions offer higher expected returns as compensation. However, institutional investors' exclusionary strategies are mostly limited to a few high-emission sectors and do not capture the wider impact of carbon risk across industries.

This firm-level evidence matters for sovereign analysis because it provides microeconomic confirmation that environmental risks are measurable, priced, and transmissible across balance sheets. When aggregated, firm-level vulnerabilities can escalate into macro-level sovereign exposures, particularly in economies with state-owned enterprises or concentrated banking sectors. Thus, firm and sovereign ESG risks are intertwined, forming an integrated system of environmental-financial feedback loops that policymakers must address collectively (OECD, 2023; IMF, 2023).

Importantly, policy interventions also shape credit conditions. Yao et al. (2021)'s research on China's Green Credit Policy demonstrates that stricter lending rules for polluting industries reduce firm performance by heightening financing constraints and curbing investment, with effects most pronounced in state-owned and large enterprises. These finding complements market-based studies, showing that regulation amplifies the financial penalties faced by high-emission firms.

Taken together, the literature indicates that both market mechanisms (through CDS spreads and borrowing costs) and policy-driven tools (such as green credit regulations) increasingly penalize environmentally inefficient firms, while firms that reduce emissions or improve transparency benefit from lower financing costs.

In summary, the evolution of this literature reveals a clear trajectory: environmental performance has become an integral determinant of sovereign and corporate financing conditions. For policymakers, this implies that climate resilience, transparent environmental reporting, and credible transition strategies are no longer optional—they are preconditions for maintaining affordable access to global capital markets.

3. Data and Methodology

This study investigates the relationship between Turkey's sovereign CDS spreads and environmental factors over the period 2005–2023 using annual data. The dependent variable is the 5-year CDS spread for Turkey, which reflects the market's perception of sovereign credit risk. Yearly values of CDS are calculated by taking the average of monthly values. GHG emissions per capita (tons of CO_2 equivalent per person) and Energy use per capita (kilograms of oil equivalent per person) are used as explanatory variables. These variables capture two distinct dimensions of environmental and economic performance. While GHG emissions serve as a proxy for environmental degradation and exposure to climate transition risks, energy use per capita is often associated with industrial capacity, economic activity, and the ability to generate resources for debt repayment. The data source of GHG emissions is Emissions Database for Global Atmospheric Research. Energy use per capita is gathered from World Development Indicators database. The source of the CDS spreads is the Bloomberg database.

The methodological approach involves three steps. First, we conduct unit root tests to determine the order of integration of each variable. The results show that GHG emissions are stationary in levels I(0), while CDS and energy use are integrated of order one I(1). Given this mixed order of integration, the ARDL bounds testing approach (Pesaran, Shin, and Smith, 2001) is particularly suitable. Second, we estimate the $ARDL(p, q_1, q_2)$ model of the form:

$$CDS_t = \alpha_0 + \sum_{i=1}^{p} \phi_i CDS_{t-i} + \sum_{j=0}^{q_1} \beta_j GHG_{t-j} + \sum_{k=0}^{q_2} \gamma_k Energy_{t-k} + \varepsilon_t$$

where:

CDS_t is Turkey's CDS spread in year t,

GHG_t is per capita greenhouse gas emissions,

$Energy_t$ is per capita energy use,

ϕ_i are the autoregressive coefficients,

β_j and γ_k capture the short-run distributed lag effects of the environmental factors,

ε_t is a white-noise disturbance term.

The ARDL framework allows the estimation of both short-run dynamics (through lagged differences of the regressors) and long-run relationships (through the levels of the variables).

The long-run multipliers of the explanatory variables are obtained as:

$$\theta_{GHG} = \frac{\sum_{j=0}^{q_1} \beta_j}{1 - \sum_{i=1}^{p} \phi_i}, \quad \theta_{Energy} = \frac{\sum_{k=0}^{q_2} \gamma_k}{1 - \sum_{i=1}^{p} \phi_i}$$

where θ_{GHG} and θ_{Energy} measure the equilibrium impact of a permanent unit increase in per capita emissions and energy use, respectively, on CDS spreads.

To capture both the short-run and long-run dynamics, the ARDL model can be re-parameterized into an Error Correction Model (ECM) form:

$$\Delta CDS_t = \alpha_0 + \lambda EC_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta CDS_{t-i} + \sum_{j=0}^{q_1-1} \varphi_j \Delta GHG_{t-j} + \sum_{k=0}^{q_2-1} \psi_k Energy_{t-k} + \varepsilon_t$$

where:

Δ denotes the first difference operator,

$$EC_{t-1} = CDS_{t-1} - \theta_{GHG} GHG_{t-1} - \theta_{Energy} Energy_{t-1}$$

is the error correction term representing deviations from the long-run equilibrium, λ is the speed of adjustment coefficient; it is expected to be negative and significant, confirming cointegration and indicating the proportion of disequilibrium corrected each year,

δ_i, φ_j, ψ_k capture the short-run dynamic effects.

The appropriate lag lengths (p, q_1, q_2) are selected based on information criteria (AIC, BIC, HQIC) from an exhaustive grid search. Once the optimal ARDL model is identified, the long-run coefficients and ECM representation are estimated. Diagnostic tests are performed to ensure robustness.

This methodological framework allows the study to separate the short-run shocks in environmental indicators from the long-run equilibrium relationship between environmental performance and Turkey's sovereign credit risk.

4. Results

This study starts with investigating the stationarity of the series by using ADF test.

Table 1. Stationarity Test Results

Variable	Test	Level/ Difference	Statistic	p-value	Lags	Conclusion
CDS	ADF	Level	-1.768	0.397	8	Non-stationary
CDS	KPSS	Level	0.493	0.043	2	Non-stationary
CDS	ADF	1st Diff.	-4.675	0.000	0	Stationary (I(1))
CDS	KPSS	1st Diff.	0.107	0.100	2	Stationary (I(1))
GHG	ADF	Level	-191.232	0.000	8	Stationary (I(0))
GHG	KPSS	Level	0.760	0.010	2	Borderline
Energy	ADF	Level	-0.863	0.800	5	Non-stationary
Energy	KPSS	Level	0.726	0.011	2	Non-stationary
Energy	ADF	1st Diff.	-1.711	0.425	7	Borderline (weak)
Energy	KPSS	1st Diff.	0.106	0.100	0	Stationary (I(1))

Stationarity tests confirm that CDS and energy use are I(1), while GHG emissions are I(0). This motivates the use of ARDL bounds testing. The optimal ARDL(1,2,2) model was selected based on AIC.

Table 2. ARDL(1,2,2) Estimation Results (dependent variable CDS)[1]

Variable	Coefficient	Std. Error	z-Statistic	p-Value	Sign.
constant	-2295.9057	745.7903	-3.0785	0.0117	**
CDS.L1	0.4620	0.1905	2.4255	0.0357	**
GHG.L0	399.5623	239.5942	1.6677	0.1263	
GHG.L1	564.8002	226.3271	2.4955	0.0317	**
GHG.L2	533.9849	248.5092	2.1488	0.0572	*
Energy.L0	-1.2670	0.6170	-2.0534	0.0671	*
Energy.L1	-0.4996	0.7226	-0.6914	0.5051	
Energy.L2	-2.2796	0.8234	-2.7684	0.0198	**

Note: *, **, and *** represent respectively the rejection of the null of normality at 1%, 5%, and 10% significance levels.

The ARDL(1,2,2) results indicate that CDS spreads exhibit significant autoregressive behavior, with the coefficient on CDS.L1 being positive and statistically significant (0.46, $p < 0.05$). This suggests persistence in CDS movements. Greenhouse gas emissions per capita have positive and significant lagged effects (notably at lags 1 and 2), indicating that higher emissions are associated with higher CDS spreads in the short term, reflecting environmental risk premiums in sovereign credit markets. Energy use per capita shows a negative and significant effect at lag 2 (-2.28, $p < 0.05$), implying that increased energy consumption contributes to a reduction in CDS spreads after two periods, potentially signaling that economic growth and energy demand mitigate perceived credit risk. Overall, the results highlight that environmental indicators exert both short-run and lagged influences on sovereign risk, consistent with the hypothesis that sustainability factors affect financial stability.

The following table shows the results of the Error Correction Model.

[1] Model fit: N = 17, $R^2 = 0.879$, Adj. $R^2 = 0.785$, AIC = 205.3, BIC = 213.3

Table 3. Error Correction Model (ECM) Results[2]

Variable	Coefficient	Std. Error	t-Statistic	p-Value	Sign.
constant	0.000000	17.375295	0.000000	1.000000	
EC	-0.537984	0.134212	-4.008464	0.002056	***
Δ GHG	399.562275	178.006546	2.244649	0.046322	**
Δ GHG.L1	-533.984924	204.158770	-2.615538	0.024019	**
Δ Energy	-1.267037	0.472321	-2.682575	0.021310	**
Δ Energy.L1	2.279575	0.619988	3.676805	0.003646	***

The coefficient on the error-correction term is −0.538 ($p < 0.01$), indicating a rapid adjustment toward the long-run equilibrium: roughly 54% of any disequilibrium in CDS from the previous period is corrected within one period. In the short run, changes in GHG per capita raise CDS spreads contemporaneously (ΔGHG: +399.6, $p < 0.05$), while the lagged change exerts a negative correction (ΔGHG.L1: −534.0, $p < 0.05$), suggesting short-lived upward pressure followed by partial reversal. Energy use affects CDS with mixed timing: contemporaneous increases reduce CDS (ΔEnergy: −1.27, $p < 0.05$), whereas the lagged change elevates CDS (Δenergy.L1: +2.28, $p < 0.01$), consistent with a near-term risk-mitigating effect of economic activity that can revert or overshoot subsequently. Together, the significant error correction term and differenced terms indicate both a stable long-run relation between CDS and environmental indicators and economically meaningful short-run dynamics.

5. Conclusion

This study provides new empirical evidence on the environmental determinants of sovereign risk for Turkey. The findings suggest that environmental performance matters for financial markets: higher GHG emissions increase Turkey's CDS spreads both in the short and long run, reflecting higher perceived risk.

Our results align with a growing international literature that identifies environmental indicators as core components of sovereign risk pricing. Empirical analyses from emerging and advanced economies alike demonstrate that climate vulnerability, carbon intensity, and energy dependence are systematically associated with higher sovereign risk premia (Beirne et al., 2021; Kling et al., 2021). In this regard, Turkey's experience mirrors that of several other middle-income countries where the transition toward low-carbon growth remains incomplete, and fiscal exposure to energy imports and environmental shocks continues to influence market sentiment.

These results imply that Turkey's environmental performance is not merely a peripheral concern but a determinant of sovereign risk perceptions. Rising GHG emissions translate into higher borrowing costs through elevated CDS premia, reflecting the market's anticipation of transition risks (e.g., carbon taxation, regulatory tightening) and potential physical risks. At the same time, higher energy consumption may provide temporary relief by signaling growth, but long-term reliance on carbon-intensive energy sources may undermine credibility with investors focused on sustainability.

This duality highlights the need for a balanced policy mix. On one hand, energy intensity supports industrial and economic growth in the short term; on the other, it magnifies transition risks if not accompanied by credible decarbonization strategies. A gradual but consistent shift toward renewable energy, energy efficiency investments, and transparent climate reporting would likely narrow CDS spreads by reinforcing fiscal resilience and investor confidence. Similar mechanisms are observed in other emerging markets, such as Chile and Indonesia, where credible climate policies have been linked to improved sovereign credit outlooks (IMF, 2023; OECD, 2023).

Compared with the international literature, our results are broadly consistent. Studies such as Naifar (2023) and Diarra (2022) show that sovereigns with higher climate

[2] Model fit: N = 17, R^2 = 0.783, Adj. R^2 = 0.684, AIC = 189.8, BIC = 194.8, F-statistic = 7.935 (p = 0.0022), Durbin–Watson = 1.596.

vulnerability face wider CDS spreads, and our findings confirm this mechanism in the Turkish context using time-series econometrics. Similarly, Zhang et al. (2022) and Blasberg et al. (2024) demonstrate that emissions are priced into corporate CDS, and we extend this evidence to sovereign risk.

Furthermore, the analysis underscores the interconnectedness between sovereign and corporate balance sheets in transmitting environmental risk. As domestic firms adjust to environmental regulation, their financial health affects sovereign fiscal outcomes through taxation, employment, and contingent liabilities. Thus, the sovereign risk premium indirectly captures the aggregate environmental risk embedded in the national economy. Recognizing this macro-financial transmission channel provides a richer framework for understanding how environmental performance translates into sovereign credit conditions.

This study underscores the economic costs of environmental inaction: failing to reduce GHG emissions not only exacerbates long-term climate risks but also imposes immediate financial penalties by widening CDS premia and raising sovereign borrowing costs. For policymakers, the implication is clear efforts to curb emissions and transition toward sustainable energy sources are not only environmentally desirable but also financially prudent.

In policy terms, three key lessons emerge. First, integrating environmental targets into fiscal and debt management frameworks can directly support market confidence and reduce risk premiums. Second, strengthening data transparency—through regular publication of emission metrics, energy-use statistics, and green investment plans—can reduce informational uncertainty in sovereign pricing. Third, international cooperation, especially with European markets and multilateral institutions, can provide access to blended finance and climate funds that support Turkey's transition while mitigating short-term adjustment costs (UNEP FI, 2022; NGFS, 2022).

From a broader theoretical perspective, this study also reinforces the argument that environmental sustainability is a priced macroeconomic fundamental, not merely an auxiliary ESG dimension. The Turkish case demonstrates how domestic environmental policy credibility and macro-financial stability interact. Improving energy efficiency, scaling renewable capacity, and aligning fiscal incentives with sustainability goals could simultaneously enhance creditworthiness and reduce fiscal vulnerabilities. These findings open avenues for future research using panel or structural models to test the dynamic feedback between environmental policy shocks and sovereign risk in emerging markets.

Ultimately, the results provide both a cautionary and an optimistic message: environmental neglect carries tangible financial costs, but decisive and credible green transition policies can generate measurable economic rewards. As sovereign risk pricing becomes increasingly intertwined with sustainability metrics, countries that lead in emissions reduction and transparency will likely enjoy lower borrowing costs and stronger fiscal resilience. For Turkey, aligning environmental policy with its economic strategy is thus not only a climate imperative but a financial necessity.

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Conflict of Interest: None.
Funding: None.
Ethical Approval: None.
Author Contributions: Bige KÜÇÜKEFE (50%), Nilüfer KAYA KANLI (50%)

Çıkar Çatışması: Yoktur.
Finansal Destek: Yoktur.
Etik Onay: Yoktur.
Yazar Katkısı: Bige KÜÇÜKEFE (%50), Nilüfer KAYA KANLI (%50)