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The climate-sovereign debt doom loop: what does the literature suggest?

Stavros A Zenios[1,2,3]

The current literature documents significant effects of climate change on the cost of sovereign debt and debt levels. These effects are due to a complex nexus of climate change systemic effects on the economy, characterized by deep uncertainty, fat tails, feedback loops, and uncertain fiscal costs of climate policies. Investors believe that climate risks have begun to materialize but are underpriced. I give an overview of the multichannels and review the evidence on fiscal costs from climate change, climate premia for sovereign debt, and climate risk assessments of sovereign bond portfolios. Recent advances integrate forward-looking climate scenarios in debt sustainability analysis and credit ratings. The findings suggest several mechanisms may activate a doom loop between climate change and sovereign debt.

Addresses
[1] Durham University, UK
[2] University of Cyprus and the Cyprus Academy of Sciences, Letters, and Arts, Nicosia, Cyprus
[3] Bruegel, Brussels, Belgium

Corresponding author: Zenios, Stavros A (stavros.zenios@durham.ac.uk)

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Introduction

The view that climate change is an ‘existential threat’ is shared by prominent economists [11], with the risks to sovereign debt attracting recent attention. A word count of the annual reports of the International Monetary Fund and the European Central Bank until 2018 found a couple of innocuous references such as “other risks are unlikely to manifest themselves on a significant scale over the next few years (e.g. climate change).” The year 2019 saw a surge to 140 and 105 words, respectively.

I review the literature on the climate-sovereign debt nexus. I synthesize evidence from publications in economics, finance, climate sciences, management science, *Nature* and *Science*, and institutions with internal review processes. To enhance confidence in the evidence, I follow [30] and provide, when possible, ranges of climate effect estimates.

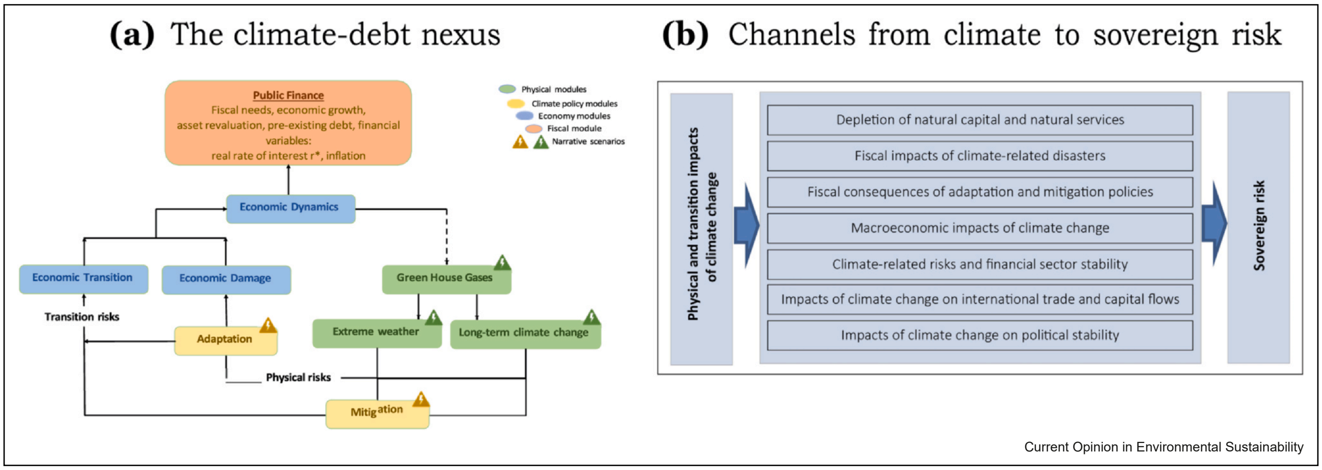
Sovereign debt dynamics — macroeconomic determinants, feedback to the real economy, and fiscal–monetary interactions — are complex and uncertain, see the debt sustainability methodologies of the International Monetary Fund (IMF), European Central Bank (ECB), European Commission, or European Stability Mechanism [12,63]. The study of climate risks to debt is exacerbated by the systemic effects of climate change on the economy [48], deep uncertainty [6], fat tails [61], feedback loops [2], and uncertainty about fiscal costs [13].

Literature on climate effects on sovereign debt explores debt financing of climate policies and channels through which climate change impacts fiscal costs [34,60], and [15] asks whether climate sustainability and debt sustainability can be reconciled. These works identify the channels from climate change to the economy, fiscal and financial variables, and eventually to debt. They include the impact on natural capital, natural disasters, adaptation and mitigation expenditure, financial crises associated with stranded assets and corporate distress, capital flow volatility, and political instability. Liability risk also emerged recently [16], with California’s PG&E declared as “the first climate-change bankruptcy” by the *Wall Street Journal* in January 2019, but “probably not the last”.

Figure 1 illustrates the links between climate change and sovereign debt. The rest of the paper fills in the details. *Climate effects on debt* reviews the impact of various channels on sovereign debt, *Forward-looking climate change risks in debt analysis* addresses the integration of climate in debt risk assessment, and *The climate-debt doom loop* discusses how this literature suggests a potential climate-debt doom loop. *Perspectives* concludes.

A doom loop does not imply we are doomed to fail in dealing with the complex problems climate change imposes on global economies. Instead, it tells us we need multi-pronged policies to deal effectively with the challenge

Figure 1



Climate change and sovereign debt.
Source: (a) from Ref. [62], (b) from Ref. [59].

[11,15]. Carbon pricing remains the economists' first-best, but it is not a silver bullet. Ref. [57] estimates the *Leviathan tax* as the carbon tax that could replace the revenue of all other taxes combined and argues that reaching stringent climate targets is fiscally impossible unless transition targets are eased.

Instead, multipronged policies should fairly distribute costs between the winners and losers of the climate policies. Fairness also considers the future generations that will be called upon to pay the debts for fighting climate change but stand to benefit if the efforts succeed or will pay the price if the efforts fail. These considerations necessitate a study of the complex interactions between climate, sovereign debt, and various mitigation and adaptation policies. In this paper, I survey this literature. This is a first step in understanding if policies that avoid triggering a potential doom loop are possible. We do not have an answer to this question, but this paper advances our understanding.

Climate effects on debt

Following the seminal work on *integrated assessment models* (IAM) in Ref. [48], a vast body of literature explores the effects of climate on the macroeconomy. For the study of debt, we are interested in the effects on economic growth as the denominator of the debt-to-Gross-Domestic-Product (GDP) dynamics [24,28,31,36]. We are also interested in the debt stock numerator that accounts for mitigation and adaptation costs and contingent liabilities for rescue and social support [3,22,24,37,47]. These are the direct effects of climate on debt. Indirect effects include the fiscal burden of climate-induced financial instability [21,42] and forced migration and climate conflicts [32], with global political risk effects on asset prices [26]. The potentially adverse effects of climate change on debt are complex.

Investors believe that climate risks to asset prices are already materializing, especially in the form of changing climate regulations [41]. Regulatory risk is considered the top climate risk over the next five years and physical risk over the next 30 [56]. Deep uncertainty, nonlinearities, risk endogeneity, and inadequate disclosures cast doubts on the efficient pricing of these risks by the markets [15,16]. The prevailing opinion is that climate risks are underpriced [52], although investors think mispricing is small [16], with possibly overpriced green assets.

Does climate change increase debt?

Deficits cause debt, and debt-to-GDP ratio — a key metric of debt sustainability — increases with insufficient economic growth. Loosely speaking, if the economy's growth rate is lower than the interest rate on debt, the debt burden on the sovereign will keep increasing [12]. Regarding climate change effects, there is a complex interaction between revenues and expenditures, as different types of expenditure might have markedly different effects on long-term debt sustainability. For instance, green investments may spur growth, and adaptation costs may reduce losses and damages so that increased spending (numerator) can grow the economy (denominator) with potentially neutral effects on debt. On the other hand, physical risks facing low-income countries can reduce growth and increase the need for deficit spending. Existing literature sheds some light on these complex interactions.

Limiting global warming to 1.5 C is projected to require annual investments in energy systems of about 2.5% of global GDP until 2035 [35]. Assuming this is shared between households, nonfinancial corporations, and sovereigns implies additional fiscal spending of 0.8% p.a. of global GDP. The European Union's climate goals require additional green investments estimated at 2% p.a. of GDP [22], with governments expected to finance 0.5–1%. The Porter Hypothesis [51] suggests such investments can trigger innovation and spur growth. For instance, European Union member states that use the European Green Deal to stimulate innovation will adapt to climate change. In contrast, those who fail to stimulate innovation will become laggards, aggravating existing imbalances and accelerating capital flight toward innovators. Empirical support for a pervasive manifestation of the Porter Hypothesis is lacking. On the contrary, governments are currently struggling to reduce historically high debts in the aftermath of the great financial crisis and the pandemic, and climate investments of the magnitude discussed above can be a challenge [24].

We also need to consider potential adaptation costs. Estimates for developing countries range from USD 0.14 tn by 2030 to 0.5 tn by 2050, p.a. [3]. For sub-Saharan Africa, the range is 2–3%, for Middle East and Central Asia, 0.1–3.3%, and an astronomical 500% for some island countries. This reference points out that estimating adaptation benefits is difficult and highly uncertain, but there is a growing consensus that benefits are large but are reduced as adaptation costs increase. However, the studies reviewed in Ref. [3] focus on the (positive) net effect on economic growth, and studies on the effects of sovereign debt are virtually nonexistent. While preventive (*ex ante*) rather than reactive (*ex post*) adaptation may be beneficial to economic growth, the net effect on debt-to-GDP ratios can be positive [17] or virtually neutral [62]. Such findings raise questions on the optimal level of adaptation and cast doubts on how much public investment for adaptation is possible.

Governments also finance losses and damages, contingent on whether losses are replaced and if damages are insurable or require government assistance. For examples of sovereign-contingent liabilities from Australia, Japan, and New Zealand, see [62], Annex B.

Low-income countries are disproportionately impacted [47]. Over half of them are assessed by the IMF–World Bank as at risk of or already in debt distress, and half of the most climate-vulnerable nations are in this category. Adverse climate effects on the ability of Caribbean countries to use debt are documented in Ref. [45]. The temperature change of MENA countries is projected to increase debt by 18% during 2080–2099 under high emissions and about one-third of this under low emissions [28]. Climate-vulnerable countries are less prepared and bear little responsibility for climate change, and [59] suggests debt relief based on a country's climate risk exposure to allow for recovery from disasters and investment in adaptation.

Is there a climate premium for sovereign debt?

Is there evidence of a climate premium for physical or transition risks for sovereigns? We examine first the pricing of physical risks. A higher cost of debt for 20 vulnerable countries is documented in Ref. [38], which finds that with every 10 dollars spent on debt servicing, they pay one more for climate vulnerability. More recent estimates on a larger sample of 40 countries [10] find a climate premium of 275 bp for a high-risk group, 155 bp for the South-East Asian Nations (ASEAN), 113 bp for other emerging markets, and insignificant for advanced economies, with resilience less impactful than vulnerability. The spread sensitivity to climate for 98 countries is estimated by Ref. [18], that a 1% increase in vulnerability is associated with an average spread increase of 60 bp, whereas a 1% resilience improvement is associated with a 15-bp decrease.

The potential effects of transition on sovereign bond yields are discussed in Ref. [54]. Ref. [46] discussed the pricing of credit risk conditioned on forward-looking climate scenarios from [9] and Ref. [8] assessed the impact of a sudden introduction of carbon pricing aligned with the Paris Agreement. Using two IAMs, they estimate climate spreads on bond yields and document more significant shocks for countries with larger fossil-based energy contributions to GDP. Countries with growing shares of renewable energy experience lower bond yields. Yield increases can be significant (e.g. up to 245 bp for Australia and 175 bp for Poland).

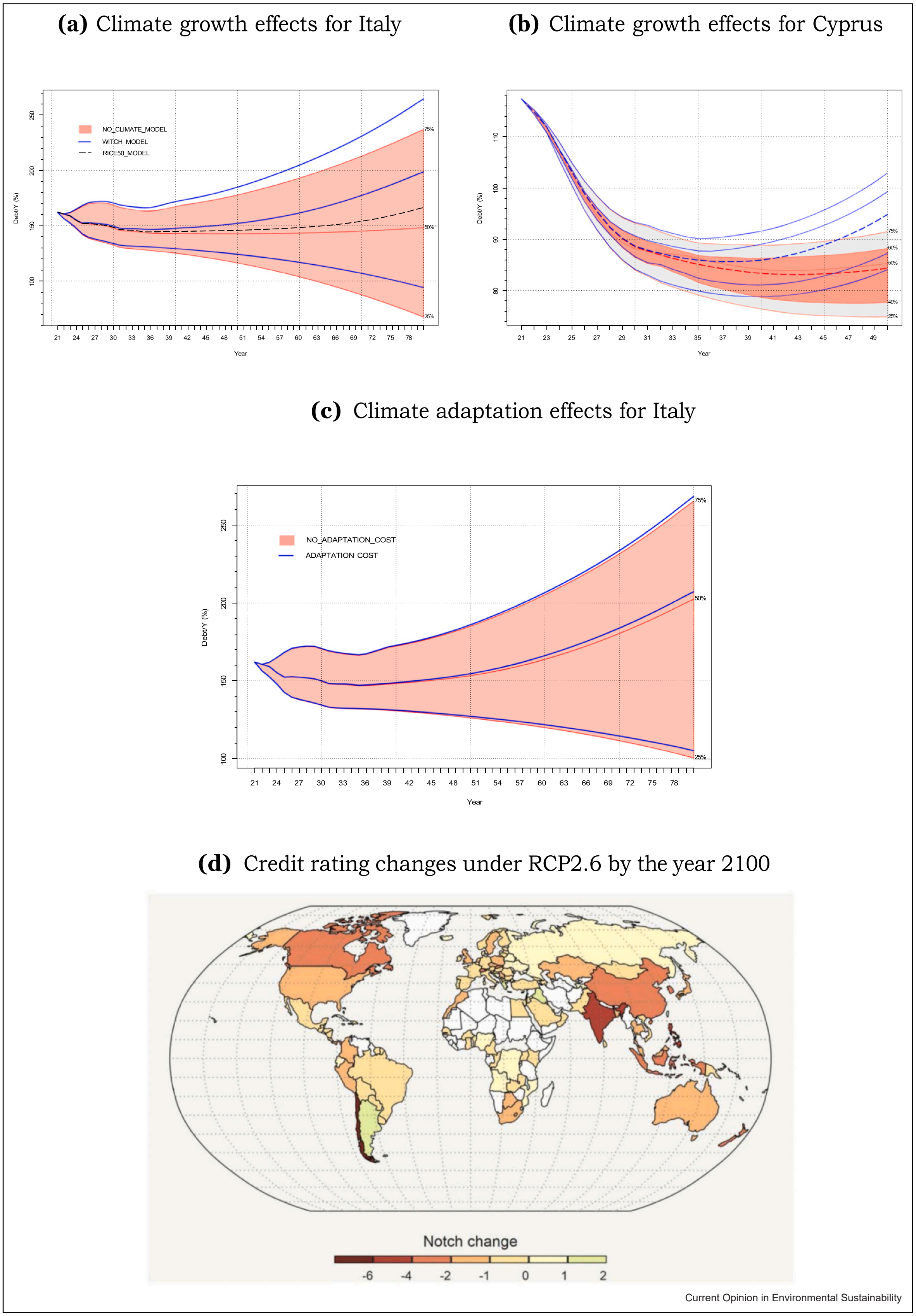
An analysis of 10-K reports filed with the Securities and Exchange Commission differentiates transition from physical risk using natural language processing and finds that spreads respond differently to climate disclosures about the transition or physical risk [40]. Disclosure of transition risk increases spreads because of investors' risk perception; disclosure of physical risks reduces spreads due to lower information asymmetry.

Portfolio climate risk assessment

Going beyond the pricing of climate effects on individual assets, we have also seen the development of climate-related risk metrics for portfolios, such as climate spread [9] and climate value at risk [25]. Climate spreads of the sovereign bond portfolios of European insurers can suffer estimated losses of up to 5% for several transition scenarios, with expected losses below 3% under adverse economic conditions and less than 1% under a mild economic scenario [7]. Similar results for the Austrian National Bank are reported in Ref. [8].

The conclusion from the literature in this section is that there is no consensus on the magnitude of the effects of climate on debt. Still, there is consistency in the

Figure 2



(a) Climate growth effects for Italy
(b) Climate growth effects for Cyprus
NO_CLIMATE_MODEL
WITCH_MODEL
RICE50_MODEL
Debt/Y (%)
Year
(c) Climate adaptation effects for Italy
NO_ADAPTATION_COST
ADAPTATION COST
Debt/Y (%)
Year
(d) Credit rating changes under RCP2.6 by the year 2100
Notch change
-6
-4
-2
-1
0
1
2
Current Opinion in Environmental Sustainability

Climate risk effects on sovereign debt dynamics and credit ratings.
Source: (a) and (c) from Ref. [62], (b) from Ref. [20], (d) from Ref. [39].

estimated direction of travel. Specifically, there is a risk of increasing debt due to both numerator and denominator effects with increasing debt servicing costs.

Forward-looking climate change risks in debt analysis

More recent works employ IAMs for forward-looking debt analysis. Using IAMs within stochastic debt sustainability analysis [12,63] to simulate climate change effects on debt dynamics is suggested in Ref. [62]. It shows how the RCP–SSP (*representative concentration pathways–shared socioeconomic pathways*) scenario matrix architecture [19] and tail risk measures can lead to informative, albeit not precise, analysis under deep uncertainty. An illustrative example for Italy is in Figure 2 (panel A), and this approach was used for the public audit of Cyprus' debt in Ref. [20] (panel B). Integrating two different IAMs (WITCH and RICE50) into debt sustainability analysis [63], these figures display fan charts and the median, 0.25, and 0.75 quantiles of the debt-to-GDP ratios for the two countries. The (coral-shaded) fan chart is obtained without climate effects, and the quantiles and the dashed-line median are obtained with the two IAMs. Likewise, linking IAMs with general equilibrium adaptation models can be used to analyze growth-debt trade-offs [3], and panel C shows an example with neutral effects. However, more work is needed to reach conclusions with confidence.

Using IAMs to project sovereign credit ratings under different RCPs is developed in Ref. [39]. It uses machine learning to link climate-adjusted GDP estimates to sovereign ratings. After training the network on S&P ratings, it uses two IAMs to project climate-adjusted macroeconomic input data and estimate ratings under different climate scenarios. Fifty-five sovereigns face downgrades under a 2 C temperature increase and 80 under 4.2 C, see Figure 2 (panel D). Most G20 and EU countries would be downrated marginally within the Paris Agreement targets, with significant downratings under 4.2 C.

The debt trajectories of Ref. [62] imply the lower ratings of [39]. Both papers find climate effects starting from 2030. The consistency of these results obtained using different methodologies and IAMs leads to higher confidence in their validity.

The climate-debt doom loop

"Climate change may not be correctly priced—and as the costs eventually become clearer, the potential for rapid adjustments could have destabilizing effects on markets."
— Michael Bloomberg.

Climate risks increase the cost of debt, making debt servicing more difficult. At the same time, climate-related damages reduce fiscal space, making it difficult to secure debt financing for mitigation or adaptation policies to reduce climate risks. A *doom loop* emerges, with low-income countries particularly vulnerable. The potential of a climate loop is raised in Refs. [5,10,14,62].

Several mechanisms can trigger this loop. First, we have the pressure on public finance and debt costs. For instance, Ref. [39] finds an increasing cost of debt servicing even in a 2 C scenario, which can be material for countries with tight fiscal space; their findings align with the literature reviewed in sections 2.1–2.2. The increase in debt servicing costs materializes as growth faces adverse climate effects, pushing the debt-to-GDP trajectories toward potentially nonsustainable territory. Such trajectories are illustrated in Figure 2 (panels A–B), obtained from Ref. [62].

Second, the mispricing of climate risks can be destabilizing, as suggested by Michael Bloomberg. For instance, underpricing of flood risks can lead to a housing market crash, depending on policies such as a reduction in post-disaster recovery funding or a stop in mortgage securitization [29]. In contrast, flood risk disclosure can lead to abrupt repricing and a crash or efficient pricing with a soft landing. Bloomberg's assertion finds justification in the theory of neglected risk [27], which has been documented empirically for eurozone sovereign debt [43].

Third, we have the impact of financial stability on public finance [4], with the destabilizing effects of climate change on the financial system discussed in Refs. [14,16,23,46]. The climate channel from financial stability to public finance is through the well-documented 'deadly embrace' between banks and the real economy whereby adverse effects on the banking system reduce credit to the economy and affect public finance, with deteriorating public finance adversely affecting the banking system. This channel can be amplified even for firms not directly affected by climate change, through network externalities as studied for banking networks by [53] or through cascade from the financial system to the real economy [55]. A theoretical model of the doom loop through the banking system is given in Ref. [21].

Tail risk — arising from a climate attention channel [33] or in models of default under climate uncertainty [1] — can also be destabilizing, given the feedback from debt to premia [2].

Perspectives

The literature documents empirically climate change impacts on sovereign debt through multiple channels and develops a better understanding of these channels through models. The climate-debt nexus is complex and plagued by deep uncertainty, nonlinearities that create fat tails, and feedback loops with risk endogeneity. It deserves concerted multidisciplinary efforts [24]. Linking IAMs with debt sustainability analysis and advanced credit rating models for comprehensive, forward-looking assessments looks promising. However, IAMs have both proponents [49] and critics [50]; they are useful 'with caveats' [58]. It is best to work with *ensembles* of IAMs to understand the potential disagreements among models and reach confidence for a range of possible outcomes instead of searching for elusive precision.

The literature is consistent in its findings on the timing (not too distant) and direction (primarily negative) of climate effects. Quantitative discrepancies highlight that findings are sample-specific, with researchers only gradually accounting for climate effects in sample selection and controls. The literature is still emerging. Although several papers robustly establish and rigorously model specific channels, a synthesis is not on the horizon.

Further insights are obtained from the literature on municipal and corporate bonds; I summarize without references due to space limitations: climate premia increase with maturity, climate premia are affected by investor beliefs or attention, climate spreads are driven by lower credit quality and are stronger for longer-term bonds, and after the Paris Agreement, liability risk is becoming significant. Climate premia are not only due to the physical impact of climate change or transition targets but also to uncertainty about the impacts or targets. Whether these stylized facts hold for sovereigns deserves further research.

Countries issuing green bonds enjoy a premium against the adverse climate effects on debt [44]. However, debt financing with green bonds provides very modest discounts and cannot offset the climate change risks. Financial instruments alone cannot hedge a global systemic risk.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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