REM WORKING PAPER SERIES

Climate Change and Government Borrowing Costs: A Triple Whammy for Emerging Market Economies

Benedict Clements, Sanjeev Gupta, João Jalles, Bernat Adrogue

REM Working Paper 0294-2023

October 2023

REM – Research in Economics and Mathematics
Rua Miguel Lúpi 20,
1249-078 Lisboa,
Portugal

ISSN 2184-108X

REM – Research in Economics and Mathematics

Rua Miguel Lupi, 20
1249-078 LISBOA
Portugal

Telephone: +351 - 213 925 912
E-mail: rem@iseg.ulisboa.pt

https://rem.rc.iseg.ulisboa.pt/

https://twitter.com/ResearchRem

https://www.linkedin.com/company/researchrem/

https://www.facebook.com/researchrem/

Climate Change and Government Borrowing Costs: A Triple Whammy for Emerging Market Economies*

Benedict Clements[1] **Sanjeev Gupta**[2] **João Jalles**[3] **Bernat Adrogue**[4]

October 2023

Abstract

Climate change is a systemic risk to the global economy. While there is a large body of literature documenting the potential economic consequences of climate change, there is relatively little research on the link between vulnerabilities to climate change, the buildup of climate debt by countries with historically large carbon dioxide emissions, and how well financial markets incorporate (or not) these risks to sovereign governments. This paper investigates the impact of both climate debt and climate vulnerabiities/resiliency on sovereign bond yields and spreads in advanced and emerging market economies, using a novel dataset. We find that changes in climate debt are an important determinant of spreads, but only in emerging market economies. Countries with high vulnerabilities and low resilency to climate change also pay higher spreads. This implies a triple whammy of challenges for emerging market economies as they confront the economic damages of climate change, the high fiscal costs of climate adaptation, and high borrowing costs.

JEL Classification Numbers: C23, E21, H5, H63, H74, Q54

Keywords: climate change vulnerability; government bond spreads; sovereign risk; panel data; social cost of carbon

---

* This work was supported by the FCT (*Fundação para a Ciência e a Tecnologia*) [grant numbers UIDB/05069/2020]. The opinions expressed herein are those of the authors and not necessarily those of their employers.

[1] Universidad de las Américas, De Los Colimes esq, Quito 170513, Ecuador. Email: benedict.clements@udla.edu.ec

[2] Center for Global Development. 2055 L St NW, Washington, DC 20036, United States. Email: sgupta@cgdev.org

[3] University of Lisbon-Lisbon School of Economics and Management (ISEG), Rua do Quelhas 6, 1200-781 Lisboa, Portugal. Research in Economics and Mathematics (REM) and Research Unit on Complexity and Economics (UECE), Universidade de Lisboa-ISEG, Rua Miguel Lupi 20, 1249-078 Lisbon, Portugal. Economics for Policy, Universidade Nova de Lisboa-Nova School of Business and Economics, Rua da Holanda 1, 2775-405 Carcavelos, Portugal. IPAG Business School, 184 Boulevard Saint-Germain, 75006 Paris, France. Email: joaojalles@gmail.com

[4] Center for Global Development. 2055 L Street NW, Washington, DC 20036, United States. Email: badrogue@cgdev.org.

I. INTRODUCTION

Climate change already poses a systemic risk to the global economy. With global average surface temperature rising by at least 1.1 degrees Celsius since 1880 (GISTEMP, 2023), the frequency and severity of climate shocks—ranging from heatwaves and droughts to hurricanes and coastal flooding—have intensified across the world. Continued increases in average global temperatures risk catastrophic climate change as well as reduced world GDP per capita (Kahn et al., 2021; Intergovernmental Panel on Climate Change, 2021). The socioeconomic consequences of climate change will be felt across the world, but potential economic vulnerability to weather anomalies depends on the size and composition of economies, the resilience of institutions and physical infrastructure, and the capacity for adaptation and mitigation (Mearns and Norton, 2010).

The contribution of a country to climate change can be traced to its cumulative emissions of carbon dioxide and its effects on global temperatures. The negative economic effect of these emissions can be conceptualized as a "climate debt" that a country owes to the rest of world (Clements et al., 2021). Advanced economies have accumulated the highest levels of climate debt, given their historically high levels of energy consumption. While there is no formal mechanism yet in place for countries to collect this climate debt, there are growing demands by developing countries for compensation for climate damages. For example, at the United Nations Climate Change Conference (COP27), countries agreed to provide "loss and damage" funding for vulnerable countries hit by climate disasters.[5] Thus, countries with high levels of climate debt can be seen as having a contingent liability that may require substantial fiscal outlays over the medium or longer term. An important issue, in this regard, is whether sovereign bond markets reflect these considerations in the risk premium for long-term sovereign debt.

In a similar vein, the extent to which financial markets incorporate the economic consequences of climate change for different countries is important. The growing awareness of climate change and discussions around climate debt can lead investors to perceive climate-related risks as material factors affecting the creditworthiness of governments and corporations (Beattie, 2021). The growing availability of climate-related financial risks assessments from various institutions that emphasize the potential impact of climate debt and related risks on financial stability has also heightened awareness of these issues (NGFS, 2020). If financial markets are efficient, sovereign bond yields should fully reflect these risks, with larger spreads in more vulnerable/less resilient countries, other things being equal. At the same time, this higher premium for climate risk implies that emerging market economies pay twice for climate change—first, through its adverse effects on their economies as reflected by growing global climate debt, and second, through higher costs of borrowing. The higher interest rates that emerging market economies pay on sovereign bonds is likely to curtail the needed borrowing for public investment to mitigate and adapt to climate change. For example, the IMF (2021) has estimated that

[5] The meeting reached agreement on the creation of the fund, but not on how it would be funded and how eligibility for compensation would be determined. https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnerable-countries .

the Asia/Pacific region would need additional investment of over 3 percent of GDP annually for climate-proofing its infrastructure, much of which would have to be undertaken by governments.

Advanced economies (both the US and EU) have implemented policies to subsidize the energy transition of their economies. This has made it more attractive for private capital to flow to advanced economies rather than to emerging market economies. On top of this, if the cost of borrowed funds is higher for emerging market economies because of the risk premium demanded by financial markets, it will lower the scale of public investment for mitigation and adaptation in these countries.

In this paper, we shed light on these issues by investigating the impact of both climate debt and climate vulnerabilities/resiliency on sovereign bond yields in advanced and emerging market economies, using a novel dataset. We find that changes in climate debt are incorporated into bond pricing, but only in emerging market countries. Markets appear to price in the effects of climate vulnerabilities into sovereign bond spreads, and reward (with lower spreads) countries that are resilient to the risks posed by climate change.

The remainder of the paper is organized as follows. In section II, we provide a brief overview of the literature on the determinants of sovereign spreads, as well as research on the economic effects of climate change and how this affects sovereign yields. In section III, we describe the data used in the study. Section IV discusses the econometric methodology and empirical results. Section V summarizes the key findings of the paper and the policy implications of our findings.

II. A Brief Overview of the Literature

Most literature finds that the level and composition of government debt, as well as key macroeconomic factors, have an impact on government bond yields and spreads (Engen and Hubbard, 2004; Ardagna et al., 2007; Laubach, 2009; Kinoshita, 2010; Hischer and Nosbusch, 2010; Gómez-Puig et al., 2014). Institutional factors, including the quality of political, legal and regulatory frameworks, governance (measured e.g. by the World Bank´s government effectiveness indicator), and quality of bureaucracy, also seem to play a role in determining spreads (Attinasi et al., 2009; Afonso, 2010; Poghosyan, 2014; Beirne and Fratzscher, 2013; Afonso and Nunes, 2015; Godl and Kleinert, 2016; de Grauwe et al., 2017; Jalles, 2019).[6] However, there is limited research on how risks associated with climate change are priced in financial markets.

There is a growing literature on the economic effects of climate-related shifts in the physical environment. These efforts primarily rely on integrated assessment models, which link (i) changes in carbon dioxide emissions with average global temperatures; (ii) changes in average temperatures with

[6] For example, as governments debt rises, sovereign bond yields should go up in recognition of the higher risk (default, monetization-driven depreciation, and inflation) carried by investors holding government securities. The successful elimination of fears of a looming Eurozone break-up following the Global Financial Crisis can be partly attributed to improvements in economic fundamentals (Muellbauer, 2014).

adverse climate conditions or events; and (iii) the impact of such conditions on economic activity. Based on these models, it is possible to estimate the "social cost of carbon"—a measure of the adverse economic effects of a ton of carbon dioxide emissions. Estimates of this social cost of carbon (SCC) can then be combined with information on country emissions to estimate a country's climate debt (Robinson et al., 2021; Clements et al., 2021).

Only recently have studies begun assessing the impact of climate change on asset valuations, company profits, probability of sovereign debt default and sovereign credit ratings. Bansal et al. (2016) and IMF (2020) find that the risk of climate change—as proxied by increases in temperatures—has a negative effect on asset valuations, while Bernstein et al. (2019) show that real estate exposed to the sea level rise sells at a discount relative to similar, unexposed properties. Focusing on the US, Painter (2020) finds that counties more likely to be affected by climate change pay more in underwriting fees and initial yields to issue long-term municipal bonds, compared to counties unlikely to be affected by climate change. Similarly, Addoum et al. (2020) combine granular daily data on temperatures across the US with the locations of public companies' establishments and find that extreme temperatures significantly impact earnings in over 40 percent of industries, with bi-directional effects that harm some industries while others benefit. Hong et al. (2019) use data from the Palmer Drought Severity Index (PDSI) to conclude that a poor trend ranking for a country on PDSI predicts relatively poor profit growth for food companies in that country and poor returns on their stocks. Kling et al. (2018) find higher exposure to climate vulnerability, as measured by the Notre Dame Global Adaptation Initiative (ND-GAIN) index,[7] results in a higher cost of borrowing in a group of 48 developing and advanced countries. More recently, Cevik and Jalles (2022a; 2022b, 2023) show that climate change vulnerability and resilience have significant effects on government bond yields, spreads, the probability of sovereign debt default, and sovereign credit ratings, especially in developing countries. Beirne et al. (2021) find that climate vulnerability is associated with higher spreads in developing economies, but it has no effect on spreads in advanced economies. Similarly, Bolton et al. (2022) find limited sensitivity of spreads for advanced economies compared to emerging and developing economies.

What has yet to be tackled in the empirical literature is whether markets incorporate risks for countries that emit large emissions and accumulate high levels of climate debt. Previous research suggests several reasons why markets could be expected to do so. The first is the issue of contingent fiscal liability, since climate debt represents potential future financial obligations for governments and entities associated with historical greenhouse gas emissions. These obligations could take the form of payments for climate adaptation, mitigation measures, or compensation for climate-related damages. As such, they can be seen as contingent fiscal liabilities that may strain public finances (IPCC, 2014). The debate at COP27 on "loss and damage" funding for vulnerable countries hit by climate disasters also suggests that demands for compensation from climate-affected countries will continue, which could lead to a higher risk premium on debt instruments. The second, and related, are legal and regulatory risks, since climate debt discussions have raised the possibility of legal actions against

[7] See section III for further discussion on the ND-GAIN indices.

governments and corporations for their contributions to climate change and failure to take adequate action. Legal and regulatory risks associated with climate litigation can be viewed as financial risks, potentially increasing the cost of capital (Preston and Lehmann, 2018). The third deals with resource reallocation, which is often necessary to address climate change but can impact economic growth and profitability. Climate debt obligations, if enforced, may necessitate diverting resources from other government or corporate priorities (Dietz and Stern, 2015). Markets may perceive this resource reallocation as a factor contributing to increased risk. The fourth has to do with carbon transition risks, as companies and industries heavily reliant on carbon-intensive activities may face increased regulatory and market risks. This transition can affect asset valuations and creditworthiness (Carney, 2015). In this paper, we address this gap in the literature by providing an empirical assessment of how well markets price in this and other climate-related risks for long-term sovereign bonds.

III. DATA OVERVIEW

We use several sources to construct an unbalanced panel dataset of annual observations over the period 1980–2018.[8] Economic and financial statistics are assembled from the IMF's International Financial Statistics (IFS) and World Economic Outlook (WEO) databases, and the World Bank's World Development Indicators (WDI) database. Our dependent variable is the government bond spread defined as the difference between 10-year government bond yields vis-à-vis the U.S. benchmark. This data comes from Haver-Analyticsand covers 44 countries from 1980 until 2018 split between 29 advanced and 15 emerging market economies. Alternatively, the J. P. Morgan Emerging Markets Bond (EMBI) index is also used. The EMBI, commonly known as "riesgo país" in Spanish speaking countries, is a weighted financial benchmark that measures the interest rates paid each day by a selected portfolio of government bonds from 41 emerging market economies.[9] It is measured in basis points, which reflect the difference between the return rates paid by these countries' government bonds and those offered by U.S. Treasury bills. Summary statistics are displayed in Appendix Table A1.

Climate debt data comes from Clements et al. (2021). In that paper, climate debt for each country is estimated based on its historical CO_2 emissions, available from Ritchie and Roser (2017). In order to capture as many countries as possible for both the starting date and projections, the sample for emissions begins in 1959, which allows us to incorporate a large number of countries (totaling 131) and helps capture all of the climate debt that advanced economies emitted since that year. In absolute terms, global CO_2 emissions from 1959 to 2018 amounted to 1,259 gigatons, or about 83 percent of

[8] The list of countries covered includes United States, United Kingdom, Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Norway, Sweden, Switzerland, Canada, Japan, Finland, Greece, Ireland, Malta, Portugal, Spain, Turkey, Australia, New Zealand, South Africa, Brazil, Chile, Cyprus, Israel, India, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore, Thailand, Tanzania, China, Czech Republic, Hungary, Croatia, Slovenia, Poland.

[9] The list of countries covered includes Turkey, South Africa, Argentina, Brazil, Chile, Colombia, Dominican Republic, Ecuador, El Salvador, Mexico, Panama, Peru, Uruguay, Venezuela, RB, Belize, Jamaica, Trinidad and Tobago, Iraq, Lebanon, Sri Lanka, Indonesia, Malaysia, Pakistan, Philippines, Vietnam, Gabon, , Morocco, Nigeria, Tunisia, Belarus, Georgia, Kazakhstan, Bulgaria, China, Ukraine, Czech Republic, Hungary, Lithuania, Croatia, Poland.

historical global emissions. These estimates capture CO_2 emissions from the burning of fossil fuels, cement production, and the flaring of natural gas.

To estimate climate debt for a given country, its historic emissions are multiplied by an estimate of the social cost of carbon (SCC).[10] Estimates of the SCC are based on both (1) an assessment of how much CO_2 emissions contribute to global warming and (2) the adverse economic effects of global warming. Drawing on Clements et al. (2021), a SCC of $100 per ton of CO_2 emissions (in 2005 prices) for 2030 is used, which is within the range produced by several integrated assessment models (IPCC, 2021). Given the nonlinear relationship between global warming and its economic damages, the SCC rises over time. This implies that the timing of a country's emissions matters: more recent emissions are more harmful than those emitted in the past.

Climate debt figures drawing on Clements et al. (2021) for the G-20 countries are shown, for illustrative purposes, in Table 1. The estimates indicate that climate debt is large in relation to GDP and explicit government debt.

[10] For an overview of the debate on the social cost of carbon (SCC), see Pindyck (2013), Tol (2018), Nordhaus (2019), Wang et al. (2019), IPCC (2021), Dennis (2022), and Stern et al. (2021).

Table 1. Cumulative climate and public debt *(Percent of GDP)*, G20[1] countries

	Climate debt, 1959-2018	*General government gross debt 2020*
Argentina	65	103
Australia	53	61
Brazil	37	99
Canada	69	118
China	85	67
France	34	114
Germany	54	69
India	101	90
Indonesia	66	37
Italy	44	156
Japan	52	256
Korea	52	49
Mexico	71	61
Russia	245	19
Saudi Arabia	97	32
South Africa	215	77
Turkey	68	37
United Kingdom	44	104
United States	60	127
G20 average	**80**	**88**
Non-G20 average	91	54
All countries average	88	56

[1] Ratios to GDP are based on 2018 prices. The exception is gross debt to GDP in 2020, which is based on 2020 prices.
Source: Authors and the IMF.

Countries most vulnerable to climate change–in tandem with the continued accumulation of climate debt at the global level—would be expected to suffer the most severe economic consequences. As noted above, these countries face a type of contingent fiscal liability, given that adapting to these climate risks will likely entail fiscal resources but of an uncertain magnitude. Indeed, the newly instituted IMF's Resilience and Sustainability Trust which began lending to low- and middle-income countries in 2022 is requiring through IMF conditionality that borrowing countries incorporate climate change vulnerability in their fiscal risk statement (IMF, 2022).

To measure this, we use, as part of our measure of climate risk, the proxies given by the ND-GAIN vulnerability and resilience indices, which capture a country's overall susceptibility to climate-related disruptions and capacity to deal with the consequences of climate change. The composite indices are based on 45 indicators, of which 36 variables contribute to the vulnerability score and 9 variables constitute the resilience score.[11] These indicators, which have been utilized in a number of studies,

[11] Vulnerability refers to "a country's exposure, sensitivity, and capacity to adapt to the impacts of climate change" and comprise indicators of six life-supporting sectors—food, water, health, ecosystem services, human habitat and infrastructure. The ND-GAIN climate change resilience index, on the other hand, assesses capacity for adaptation and covers three areas—economic, governance and social readiness—with nine indicators. Chen et al. (2015) provides a

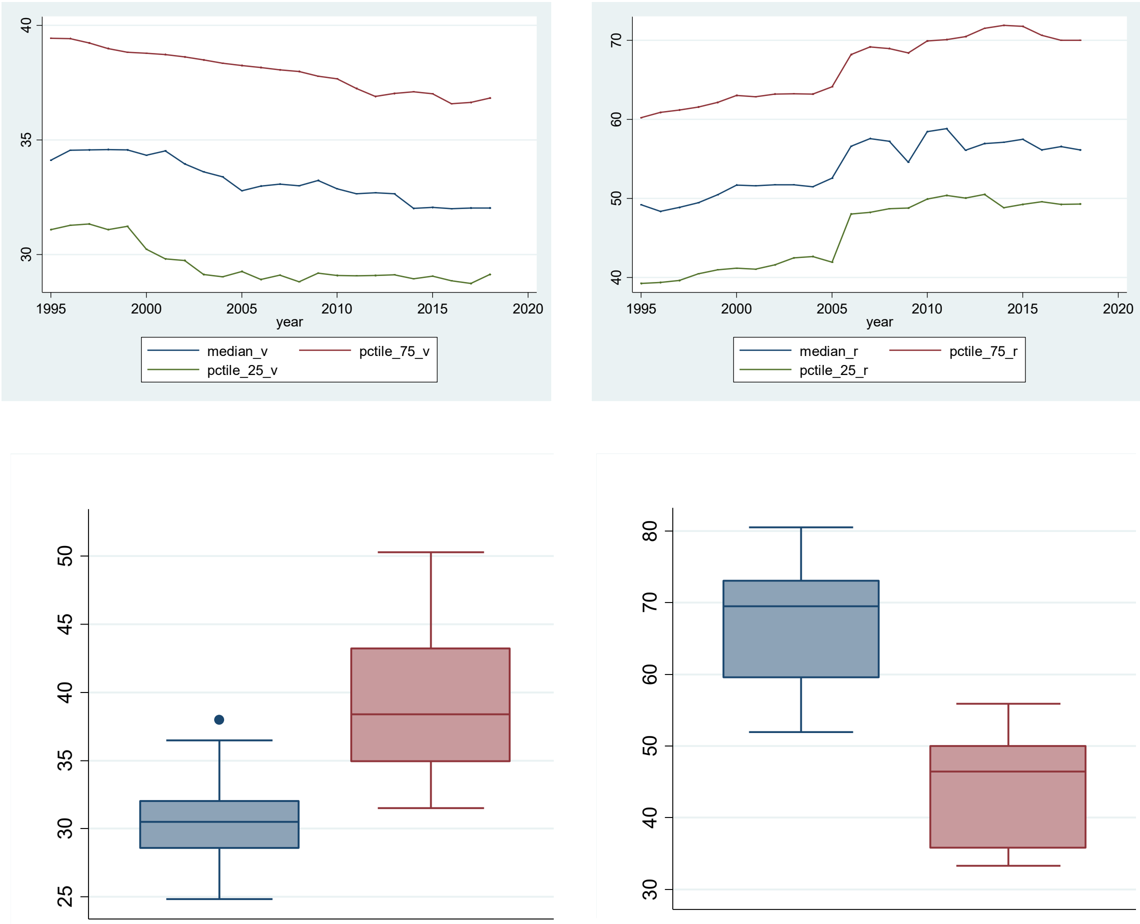
indicate that these vulnerabilities have generally declined over the past decade (Figure 1). However, these indicators present an incomplete picture of climate risks, as the economic costs of climate change, at the global level, have risen. Rising cumulative emissions, for example, can increase the probability of adverse climate events that could potentially affect a number of countries. Thus, an individual country's vulnerability or resilience is only a partial measure of the fiscal risks it faces from climate change. We address this in our study by interacting the global level of climate debt with country measures of vulnerability and resilience. If financial markets are operating efficiently, sovereign yields should recognize not only the degree to which individual countries are vulnerable or resilient to climate change, but the risks associated with rising global climate debt.

Figure 1 shows the time profile between 1995 and 2018 and box-whisker plots for both the climate change vulnerability and resilience indices for the entire sample of countries for which we have spreads data and split between advanced and emerging market economies. The ND-GAIN indices show considerable improvement in climate change vulnerability and resilience in recent years, with significant heterogeneity across our sample of countries. For example, while the mean value of climate change vulnerability is 0.35 over the sample period, it varies between a minimum of 0.24 and a maximum of 0.55. Climate change resilience exhibits even greater variation between a minimum of 0.29 and a maximum of 0.82, with a mean value of 0.55 over the period 1995–2018. The data shows that advanced economies are much less vulnerable to climate change than developing countries. This is also true when we focus on climate change resilience, in which developing economies score significantly worse than advanced economies. It should be noted though that the time-series variation in the ND-GAIN indices reflect the past changes in countries' levels of vulnerability and resilience, not the projected vulnerability and resilience to climate change in the future.

Figure 1. Climate Change Vulnerability and Resilience, 1995-2018

Vulnerability *Resilience*

detailed presentation of the methodology and data sources for the ND-GAIN database, which is available at https://gain.nd.edu/.



Note: Top panel with blue, red and green lines showing the median, top and bottom quartiles of respectively distributions. Bottom panel with box-whiskers: blue=Advanced Economies; red=Emerging Market Economies.
Source: ND-GAIN; authors' calculations.

IV. EMPIRICAL METHODOLOGY AND RESULTS

We empirically investigate the impact of climate debt on sovereign bond spreads vis-à-vis the U.S. benchmark by applying two reduced-form model specifications.. First, we assess whether increases in climate debt to GDP ratios at the country level are perceived by markets as a public bad and contingent fiscal liability that is then reflected in a higher risk premium. This is our testable empirical hypothesis.

We begin by estimating the following equation:

$$y_{it} = \beta_0 + \beta_1 + \beta_2 \Delta climatedebt_{it} + \beta_3 X_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

in which the dependent variable, y_{it}, denotes government bond spreads in country i and time t (in years). $climatedebt_{it}$ is the climate debt variable expressed in percent of GDP for each country and time period and Δ is a first difference operator. $X_{i,t}$ is a set of control variables including the growth rate of real GDP, consumer price inflation, government gross debt as a share of GDP, the government budget balance as a share of GDP, the log of international reserves (in USD), the real effective exchange rate, and measures of institutional quality (from International Country Risk Guide (ICRG) and the Database of Political Institutions). The use of the change in climate debt, rather than its level, reflects the assumption that markets take note of the risks coming from increases in climate debt, but not its level.[12] The η_i and μ_t coefficients denote the time-invariant country-specific effects and the time effects controlling for common shocks that may affect financial conditions across all countries each year, respectively. $\varepsilon_{i,t}$ is an idiosyncratic error term that satisfies the standard assumptions of zero mean and constant variance.

Then, given the fact that global climate debt imposes a negative externality in all countries, we employ a second specification where the global climate debt (in trillions of US$) is interacted with a country-specific measures of climate change vulnerability and/or resilience from the ND-GAIN database. We estimate:

$$y_{it} = \beta_0 + \beta_1 + \beta_2 [ND\_GAIN_{it} \times Globalclimatedebt_t] + \beta_3 X_{i,t} + \varepsilon_{i,t} \quad (2)$$

in which the dependent variable ND_GAIN_{it} denotes either the vulnerability or resilience indices and $\times\, Globalclimatedebt_t$ denotes the global climate debt level in trillions of US$ in logs. All other variables and parameters are as in equation (1).

[12] Using the level of climate debt as an independent variable can be suitable when one wants to understand how the current level of climate debt affects some outcome. Using the change in climate debt as an independent variable, as we do, is appropriate when we are more interested in analyzing the dynamics or trends in this variable and their impact on the proxies of sovereign risk. This approach allows us to capture the effects of climate debt accumulation or reduction over time. Note that adding the level of climate debt, for each country and year, yields a statistically insignificant coefficient (not shown).

Equations (1) and (2) are estimated using Ordinary Least Squares (OLS) with heteroskedasticity and serial correlation robust standard errors.

To begin with, we estimate Equation (1) using country and time fixed effects with alternative vectors of control variables for all the Haver Analytics´ and EMBI´s countries with available data, split into advanced and emerging market economies.These results are presented in Table 2 and suggest a substantial contrast between advanced and emerging market economies. Advanced economies, it appears, do not pay higher spreads when climate debt rises. In contrast, in emerging market economies, specification (7) in Table 2 suggests that an increase in the climate debt by one percent of GDP would result in higher spreads of about 61 basis points. Results for the control variables are broadly consistent with previous research, indicating that countries with higher levels of public debt have higher spreads, while countries with stronger economic growth pay less. Inflation has a statistically significant effect on spreads in both advanced and emerging market economies. The appreciation of the real exchange rate (REER) is found to increase spreads in advanced economies, in line with the findings of previous empirical research looking at this group of countries (see e.g. Afonso et al., 2013).[13] In emerging market economies, appreciation reduces spreads, but only for the set of countries covered in the Haver data. Greater financial openness is associated with lower sovereign spreads in advanced economies, but higher spreads in emerging market economies. In addition, a faster rate of reserve accumulation dampens spreads in emerging market economies.

[13] Afonso et al. (2013) find that the impact of the real exchange rate on spreads in the European Monetary Union is sensitive to the time period under examination.

Table 2. Change in climate debt and sovereign risk, by income group

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Regressors							
Income group (data source)	Advanced (Haver Analytics)			Emerging (Haver Analytics)	Emerging (EMBI)		
Change in climate debt (t-1)	-29.7275	-37.9672	-29.4672	149.4950***	38.9850	61.8060***	61.3716***
	(45.738)	(43.521)	(43.110)	(47.436)	(32.389)	(22.246)	(22.376)
Real GDP growth (t-1)	-18.5750***	-17.7339***	-17.6556***	-3.0688	-7.2258	-9.2402*	-9.1554*
	(6.846)	(6.762)	(6.798)	(10.850)	(5.275)	(5.071)	(5.075)
Inflation rate (t-1)	40.8736***	40.9039***	40.7619***	-0.0160	9.8546*	10.7329***	10.7802***
	(5.007)	(5.140)	(5.109)	(15.215)	(5.069)	(4.111)	(4.105)
Debt-to-GDP ratio (t-1)	1.6738***	1.8683***	1.8532***	5.3548**	8.9037***	9.0471***	8.9696***
	(0.346)	(0.353)	(0.355)	(2.087)	(1.214)	(1.201)	(1.178)
Overall balance (t-1)	-1.6851	-1.2422	-1.3940	5.5923	-1.4688	0.6132	0.6809
	(3.118)	(3.183)	(3.176)	(13.762)	(5.099)	(4.764)	(4.840)
REER (t-1)	0.2144	1.5843**	1.5024**	-6.7706***	0.6358	0.7623	0.7339
	(0.741)	(0.667)	(0.666)	(2.531)	(0.892)	(0.794)	(0.803)
Change in (log) reserves (t-1)	28.0126	32.0505	31.8145	47.9739	-239.3656***	-246.0992***	-246.0926***
	(22.565)	(22.071)	(22.142)	(124.165)	(70.381)	(64.917)	(65.023)
Financial Openness Index	-156.9678***	-136.5274**	-139.9832**	-130.2312	212.1154***	227.9625***	228.9864***
	(60.680)	(56.626)	(56.164)	(227.274)	(70.578)	(65.346)	(65.589)
Checks and Balances (t-1)	2.2750				-16.6003		
	(4.028)				(15.196)		
ICRG Corruption index (t-1)		-0.1706				0.5492	
		(0.304)				(0.795)	
Bureaucratic quality (t-1)			-1.4376	7.3675			-0.2575
			(1.020)	(6.630)			(1.659)
Observations	690	754	754	182	397	447	447
R-squared	0.7634	0.7517	0.7523	0.8682	0.7105	0.7206	0.7204
No. countries	22	26	26	10	23	25	25

Note: dependent variable for advanced economies corresponds to spreads with respect to the US 10-year sovereign bond yield in basis points; for emerging markets we use both the Bloomberg and EMBI sources (with the latter also in basis points). Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. Country and time effects included but omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Next, we explore whether the cumulative level of climate debt (in percent of 2018 GDP) matters—that is, do markets only pay attention to changes in climate debt when its level is already high? We assess this by looking at how the results vary when we split the sample into countries below the average value of the distribution (low climate debt countries) vs. countries above the average value of the distribution (high climate debt countries). The results in Table 3 indicate that financial markets do not penalize positive changes in climate debt when we assess the effects for both advanced and emerging market economies together that have low cumulative climate debt (column 1). However, when we focus on emerging market economies alone (column 3), changes in climate debt are still significant, even for those with low levels of cumulative climate debt. For the sample as a whole and for emerging market economies, countries with an initially high level of climate debt do pay higher spreads when climate debt rises, but much more so in emerging market economies: for these countries, an increase in climate debt to GDP raises spread by 95 basis points, compared with 44 points for the sample as a whole.

Table 3. Sensitivity to the cumulative stock of climate debt: Change in climate debt and sovereign risk

Specification	(1)	(2)	(3)	(4)
Data source	Haver Analytics (all countries)		EMBI (emerging market economies)	
sample split criterion (based on respective data source median value)	Low cumulative stock climate debt	High cumulative stock climate debt	Low cumulative stock climate debt	High cumulative stock climate debt
Change in climate debt (t-1)	61.5263	44.3501***	59.2782***	95.2323**
	(61.012)	(13.701)	(19.807)	(36.896)
Real GDP growth (t-1)	-0.2616	-30.7460***	-7.4402	4.2561
	(5.367)	(10.316)	(4.716)	(9.339)
Inflation rate (t-1)	28.4884***	42.0045***	9.2069**	18.4755**
	(6.010)	(5.849)	(3.926)	(8.793)
Debt-to-GDP ratio (t-1)	1.6854***	1.9291***	8.3761***	12.6997***
	(0.480)	(0.528)	(1.379)	(2.818)
Overall balance (t-1)	-7.0076	0.8357	-2.3438	7.5547
	(4.664)	(3.147)	(5.007)	(9.599)
REER (t-1)	-2.0004	0.3096	0.0418	5.5097**
	(1.486)	(0.709)	(0.946)	(2.751)
Change in (log) reserves (t-1)	4.3677	39.0586	-184.2931***	-443.7907**
	(26.638)	(33.962)	(55.653)	(207.988)
Financial Openness Index	-368.6548***	-75.7093	83.3571	390.5079***
	(90.501)	(91.720)	(88.723)	(139.863)
Bureaucratic quality (t-1)	-2.5211*	2.3471	0.3661	-133.6789
	(1.384)	(1.645)	(1.967)	(106.696)
Observations	475	461	324	145
R-squared	0.8654	0.7725	0.7138	0.7992

Note: dependent variable expressed as spreads with respect to the US 10-year sovereign bond yield in basis points. Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. Country and time effects included but omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

In sum, our results suggest that for advanced economies, markets appear to ignore the impact of climate debt in the pricing of their sovereign bonds. This suggests that these countries are not expected to compensate developing economies for the loss and damage caused by climate change. In contrast, markets do appear to add a risk premium to the sovereign bonds of emerging market economies when climate debt rises. This may reflect that these countries with high emissions will need to undertake the most significant economic transformation to use less carbon-intensive forms of energy.

We now turn to estimate equation (2) by using the ND-GAIN country indices to interact with the level of global climate debt(in 2018 US dollars).[14] As already mentioned earlier, the ND-GAIN indices measure climate vulnerability and adaptation readiness (resilience), based upon compiled indicators.[15] We expect that countries with greater vulnerability to pay higher spreads, and that those spreads should rise if the expected damage to activity (over the longer run) rises as global climate debt rises. Table 4, reveals that for countries with a larger vulnerability to climate change and, hence, for which the global climate debt weighs (negatively) more, markets do appear to add a risk premium. They also reward countries that are more resilient to climate change, where we find the effects are negative and statistically significant. These effects are robust if one focuses only on emerging market economies using the EMBI data (Table 5), with larger coefficients than the sample as a whole on the resilience variable.

[14] In the regressions, we use an inverted measure of resilience (1/resilience). An improvement in resilience reduces the economic and fiscal costs of climate change and is thus expected to reduce spreads. We also undertook Im-Pesaran-Smith panel unit root tests on the log of global climate debt multiplied by our measures of vulnerability and (inverted) resilience. These tests do not reject the null of non-stationary and thus these variables are appropriate for use in our regressions. Results are available upon request.

[15] Due to the collinearity between global climate debt and time effects, the latter are dropped in our econometric estimates of equation (2). Including time effects would underestimate the effects of global climate debt on spreads

Table 4. Global climate debt and sovereign risk (Haver Analytics), the role of climate change vulnerability and resilience, all countries

Specifications Regressors	(1)	(2)	(3)	(4)
Vulnerability*global_clim_debt	115.7288***	72.5692***		
	(11.294)	(13.531)		
Resilience*global_clim_debt			-38.2326***	-18.7167***
			(5.533)	(6.329)
Real GDP growth (t-1)	-13.7518***	-18.6807***	-9.9326*	-17.0887***
	(5.310)	(5.630)	(5.652)	(5.895)
Inflation rate (t-1)	73.4672***	66.2459***	81.9065***	69.8360***
	(5.466)	(5.094)	(6.324)	(5.315)
Debt-to-GDP ratio (t-1)	-0.6984**	-0.3907	0.0105	0.1436
	(0.338)	(0.403)	(0.323)	(0.360)
Overall balance (t-1)	-12.6000***	-9.8068***	-9.1674***	-7.6448**
	(3.055)	(3.133)	(3.360)	(3.376)
REER (t-1)	-2.4072**	-2.9618***	-1.1220	-2.3125**
	(1.025)	(1.016)	(1.020)	(1.034)
Change in (log) reserves (t-1)	27.2355	20.3614	59.9631**	32.2107
	(28.667)	(28.296)	(30.090)	(29.406)
Financial Openness Index		-239.8060***		-307.3910***
		(56.927)		(54.513)
Bureaucratic quality (t-1)		4.1060		3.7324
		(2.653)		(2.886)
Observations	796	751	796	751
R-squared	0.5588	0.5828	0.5367	0.5748

Note: dependent variable expressed as spreads with respect to the US 10-year sovereign bond yield in basis points. Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Table 5. Global climate debt and sovereign risk, the role of climate change vulnerability and resilience, emerging market economies

Specifications	(1)	(2)	(3)	(4)
Data Source for Spreads	Haver Analytics		EMBI	
Regressors				
Vulnerability*global_clim_debt	89.5219***		81.6420***	
	(27.947)		(18.572)	
Resilience*global_clim_debt		-13.2550		-58.7328***
		(15.372)		(8.519)
Real GDP growth (t-1)	-11.4431	-9.8364	-14.7603***	-9.6052**
	(9.596)	(9.917)	(4.409)	(4.336)
Inflation rate (t-1)	49.9963***	53.0515***	23.3259***	24.4318***
	(6.723)	(7.420)	(4.044)	(3.763)
Debt-to-GDP ratio (t-1)	4.3515***	5.5921***	2.8906***	3.7546***
	(1.568)	(1.491)	(0.699)	(0.680)
Overall balance (t-1)	8.3017	16.2625	7.4100	5.3836
	(11.879)	(11.257)	(5.051)	(4.914)
REER (t-1)	-8.1722***	-7.6970**	1.0293	1.6772*
	(2.953)	(2.961)	(1.041)	(0.965)
Change in (log) reserves (t-1)	-36.5769	7.1225	-288.8540***	-305.6312***
	(146.850)	(145.925)	(77.346)	(76.647)
Financial Openness Index	-183.2615*	-254.1648**	-98.2044***	-42.7157
	(104.107)	(100.811)	(36.857)	(37.602)
Bureaucratic quality (t-1)	30.2430***	34.9556***	-2.5323	-2.5563
	(6.587)	(6.709)	(1.702)	(1.878)
Observations	178	178	448	448
R-squared	0.6698	0.6588	0.3992	0.3984

Note: dependent variable corresponds to spreads with respect to the US 10-year sovereign bond yield in basis points or the EMBI index also in basis points. Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Finally, to better understand the transmission channels, we also interact each of the vulnerability and resilience sub-categories for each country with the level of global climate debt and assess their impact on spreads. Results indicate that climate-related vulnerabilities in the categories of ecosystems, food, human habitat, and health have a statistically significant positive impact on spreads (Table 6). Surprisingly, vulnerabilities on infrastructure and water have a statistically significant negative impact on spreads. These results seem to suggest that markets are not pricing these as a risk that will lead to fiscal costs or economic distress. In Table 7 we look at the three areas of climate change resilience related to the capacity of governments to adapt to climate change. The results suggest that markets reward greater resilience related to governance and social readiness, but not economic resilience.

Table 6. Global climate debt and Sovereign Risk (Haver Analytics), the role of climate change vulnerability categories, All countries

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Regressors						
Vulnerability category	Ecosystems	Food	Habitat	Health	Infrastructure	Water
Vulnerability sub-category*global_clim_debt	39.4132***	26.9149***	78.4114***	66.1732***	-19.0274***	-15.3075***
	(8.365)	(6.220)	(9.433)	(8.192)	(3.745)	(5.368)
Real GDP growth (t-1)	-17.0892***	-15.3985***	-14.1766***	-20.1615***	-14.4808***	-13.9600**
	(5.586)	(5.615)	(5.447)	(5.765)	(5.557)	(5.447)
Inflation rate (t-1)	71.0568***	69.0172***	62.8353***	65.5749***	72.4965***	73.2102***
	(5.113)	(5.139)	(4.715)	(4.588)	(5.313)	(5.320)
Debt-to-GDP ratio (t-1)	-0.2149	0.0388	-0.1213	0.1716	0.4380	0.3426
	(0.399)	(0.365)	(0.377)	(0.348)	(0.392)	(0.397)
Overall balance (t-1)	-10.9874***	-9.3025***	-13.4851***	-10.8637***	-10.6435***	-10.3388***
	(2.966)	(3.052)	(3.000)	(2.936)	(2.890)	(2.957)
REER (t-1)	-2.6397**	-2.5948**	-1.6810*	-2.5070***	-2.0894**	-2.1680**
	(1.035)	(1.024)	(0.958)	(0.970)	(1.012)	(1.017)
Change in (log) reserves (t-1)	20.6360	26.2758	2.6548	26.0008	21.9163	27.0339
	(28.543)	(28.808)	(29.072)	(27.476)	(29.664)	(29.443)
Financial Openness Index	-280.5623***	-279.7028***	-251.0409***	-122.8932**	-360.3678***	-382.6014***
	(55.156)	(55.465)	(43.333)	(50.218)	(49.202)	(50.704)
Bureaucratic quality (t-1)	4.4424*	3.5137	4.9109**	3.5168	4.4377*	3.9511
	(2.699)	(2.638)	(2.456)	(2.631)	(2.734)	(2.686)
Observations	919	919	919	919	896	919
R-squared	0.778	0.777	0.785	0.777	0.782	0.780

Note: dependent variable expressed as spreads with respect to the US 10-year sovereign bond yield in basis points. Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

Table 7. Global climate debt and Sovereign Risk (Haver Analytics), the role of climate change resilience categories, All countries

Specifications Regressors	(1)	(2)	(3)
Resilience category	Economic	Governance	Social
Resilience sub-category*global_clim_debt	1.2610	-35.5637***	-14.9218***
	(4.187)	(7.852)	(4.376)
Real GDP growth (t-1)	-15.5684***	-17.8804***	-18.0173***
	(5.642)	(5.894)	(5.965)
Inflation rate (t-1)	71.8107***	70.1673***	69.3482***
	(5.347)	(5.101)	(5.396)
Debt-to-GDP ratio (t-1)	0.1290	-0.3178	0.2168
	(0.384)	(0.315)	(0.366)
Overall balance (t-1)	-9.9732***	-6.8426**	-7.4660**
	(3.097)	(3.479)	(3.259)
REER (t-1)	-2.5257**	-2.5933**	-2.0932**
	(1.034)	(1.016)	(1.014)
Change in (log) reserves (t-1)	24.7235	23.4569	36.6792
	(29.106)	(28.348)	(28.903)
Financial Openness Index	-377.2150***	-185.1180***	-309.6067***
	(50.345)	(65.208)	(50.238)
Bureaucratic quality (t-1)	4.4093	3.7657	4.1296
	(2.784)	(2.918)	(2.845)
Observations	751	751	751
R-squared	0.5694	0.5867	0.5757

Note: dependent variable expressed as spreads with respect to the US 10-year sovereign bond yield in basis points. Heteroskedasticity and serial correlation robust SE in parenthesis. Constant omitted for reasons of parsimony. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively.

V. CONCLUSION AND POLICY IMPLICATIONS

The economic results presented in this paper suggest that financial markets do an imperfect job of incorporating the risks arising from high levels of emissions (proxied by increases in climate debt) and the vulnerabilities/resilience of individual countries to climate change. The impact is uneven across advanced and emerging market economies. Even though advanced economies have created a substantial share of the global climate debt through 2018 (about half), markets appear to ignore this in the pricing of their sovereign bonds. This may indicate that these countries are not expected to compensate market economies for the loss and damage caused by climate change. For emerging market economies, markets do appear to add a risk premium when climate debt rises. This may reflect that these countries with high emissions will need to undertake the most significant economic transformation to use less carbon-intensive forms of energy. Overall, markets add a risk premium on the sovereign debt of countries that are vulnerable to climate change, except, surprisingly, for those vulnerable to high risks to infrastructure and water systems.. Markets reward countries that score well with respect to the resiliency of their governance and social readiness to adapt to climate change.

Our results imply that emerging market economies face a triple whammy of challenges from climate change. First, their economic activity will suffer because of climate change. Second, markets will continue to tack on a risk premium for countries with high emissions and high annual changes in climate debt, while, at the same time, advanced economies face no such penalty. Third, to adapt to the adverse effects of climate change and improve their resiliency, they will need to raise public expenditures at a time when debt levels are already elevated in the wake of the pandemic. Advanced economies, which enjoy more fiscal space, have had a freer hand in providing subsidies and expanding public expenditures to adapt to and mitigate climate change.

Our analysis suggests that sovereign debt markets in advanced economies do not reward those countries that reduce emissions and the accumulation of climate debt. This suggests that other mechanisms that provide clear signals of the need to reduce dirty energy consumption (such as carbon taxes) are needed. In addition, given the fiscal constraints of climate vulnerable emerging market economies—which are aggravated by the risk premium on their debt—additional concessional financing or grants are needed to facilitate adaptation to climate change. In this regard, concessional climate financing from multilateral development banks, including the World Bank, becomes even more critical, given the scale of investment that is needed.

REFERENCES

1. Addoum, J. M., Ng, D. T., Ortiz-Bobea, A. (2020). "Temperature Shocks and Establishment Sales." The **Review of Financial Studies**, 33(3), 1331-1366.
2. Afonso, A. (2010). "Long-Term Government Bond Yields and Economic Forecasts: Evidence for the EU." **Applied Economics Letters**, 17(15), 1437-1441.
3. Afonso, A., Arghyrou, M. Kontonikas, A. (2013). "The Determinants of Sovereign Bond Yield Spreads in the EMU." Technical University of Lisbon Working Paper 36/2012/DE/UECE.
4. Afonso, A., and Nunes, A.S. (2015). "Economic Forecasts and Sovereign Yields." **Economic Modelling**, 44, 319-326
5. Ardagna, S., Caselli, F., Lane, T. (2007). "Fiscal Discipline and the Cost of Public Debt Service: Some Estimates for OECD Countries". **The BE Journal of Macroeconomics**, 7(1).
6. Arghyrou, M. and Tsoukalas, J. (2011), "The Greek Debt Crisis: Likely Causes, Mechanics and Outcomes", **World Economy**, 34(2), 173-191
7. Attinasi, M. G., Checherita-Westphal, C. D., Nickel, C. (2009). "What Explains the Surge in Euro Area Sovereign Spreads During the Financial Crisis of 2007-09?" ECB Working Paper No. 1131, December.
8. Bansal, R., Kiku, D., Ochoa, M. (2016). "What Do Capital Markets Tell Us About Climate Change". 2016 Meeting Papers 542, Society for Economic Dynamics.
9. Beattie, A. (2021). Climate Change: Investors Wake Up to Risks in their Portfolios. Financial Times.
10. Beirne, J., Fratzscher, M. (2013). "The Pricing of Sovereign Risk and Contagion during the European Sovereign Debt Crisis" **Journal of International Money and Finance**, 34, 60-82
11. Bernstein, A., Gustafson, M. T., Lewis, R. (2019). "Disaster on the Horizon: The Price Effect of Sea Level Rise." **Journal of Financial Economics**, 134(2), 253-272.
12. Bulow, J., and K. Rogoff (1989), "A Constant Re-Contracting Model of Sovereign Debt," **Journal of Political Economy**, 97, 155-178.
13. Carney, M. (2015). Breaking the Tragedy of the Horizon – Climate Change and Financial Stability. Speech by Mark Carney, Governor of the Bank of England.
14. Cevik, S., and Jalles, J.T. (2023). "Feeling the Heat: Climate Shocks and Credit Ratings," **Review of Development Finance**, 13(2).
15. Cevik, S., and Jalles, J.T. (2022a). "An Apocalypse Foretold: Climate Shocks and Sovereign Defaults," **Open Economies Review**, 3, 89–108.
16. Cevik, S., and Jalles, J.T. (2022b). "This Changes Everything: Climate Shocks and Sovereign Bonds," **Energy Economics**, 107, 105856.
17. Chen, C., Noble, I., Hellman, J., Coffee, J., Murillo, M., Chawla, N. (2015). "University of Notre Dame Global Adaptation Index" University of Notre Dame
18. Clements, B., Gupta, S. Liu, J. (2021). "Who's Responsible for Climate Change? New Evidence Based on Country-Level Estimates of Climate Debt," Center for Global Development Policy Paper 242, November.
19. De Grauwe, P., Ji, Y., Steinbach, A. (2017). "The EU Debt Crisis: Testing and Revisiting Conventional Legal Doctrine." **International Review of Law and Economics**, 51, 29-37.
20. Dennis, B., (2022). "Climate Change and Financial Policy: A Literature Review". FEDS Working Paper No. 2022-48.

21. Dietz, S., and Stern, N. (2015). Endogenous Growth, Convexity of Damage and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions. **The Economic Journal**, 125(583), 547–620.

22. Engen, E. M., and Hubbard, R. G. (2004). "Federal Government Debt and Interest Rates". **NBER Macroeconomics Annual**, 19, 83-138.

23. GISTEMP Team, (2023). "GISS Surface Temperature Analysis (GISTEMP), version 4". NASA Goddard Institute for Space Studies. Dataset accessed 2023-02-06 at https://data.giss.nasa.gov/gistemp/.

24. Godl, M., Kleinert, J. (2016). "Interest Rate Spreads in the Eurozone: Fundamentals or Sentiments?", **Review of World Economics**, 152(3), 449-475

25. Gómez-Puig, M., Sosvilla-Rivero, S. (2014). "Causality and Contagion in EMU Sovereign Debt Markets. **International Review of Economics and Finance**, 33, 12-27.

26. Hilscher, J., and Nosbusch, Y. (2010). "Determinants of Sovereign Risk: Macroeconomic Fundamentals and the Pricing of Sovereign Debt." **Review of Finance**, 14(2), 235-262.

27. Hong, H., Li, F. W., Xu, J. (2019). "Climate Risks and Market Efficiency". **Journal of Econometrics**, 208(1), 265-281.

28. International Monetary Fund. (2020). "Global Financial Stability Report: Markets in the Time of COVID-19. Chapter 5: Climate Change: Physical Risk and Equity Prices". Washington, DC, April.

29. International Monetary Fund. (2021). "Unlocking Access to Climate Finance for Pacific Island Countries". Washington DC,

30. International Monetary Fund. (2022). "IMF Policy Paper—Proposal to Establish a Resilience and Sustainability Trust". Washington DC, April.

31. Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the IPCC.

32. Intergovernmental Panel on Climate Change Working Group, (2021). "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide"; Interim Estimates under Executive Order 13990. (February), 48.

33. Intergovernmental Panel on Climate Change, (2021)." Climate Change 2021: The Physical Science Basis (New York: United Nations)", available at https://www.ipcc.ch/report/ar6/wg1/#FullReport

34. Jalles, J.T. (2019), "Wagner's Law and Governments' Functions: Granularity Matters", **Journal of Economic Studies**, 46(2), 446-466.

35. Kahn, M., Mohaddes, N., R., Hasheem Pesaran, M., Raissi, M., Yang, J. (2021). "Long-Term Macroeconomic Effects of Climate Change: A Cross-country Analysis." **Energy Economics**, 104, 105624.

36. Kinoshita, N. (2010) "Government Debt and Long-Term Interest Rates". **Journal of Economic Integration**, 25(4), 722-733,

37. Kling, G., Lo, Y. C., Murinde, V., Volz, U. (2018). "Climate Vulnerability and the Cost of Debt."

38. Laubach, T. (2009). "New Evidence on the Interest Rate Effects of Budget Deficits and Debt". **Journal of the European economic Association**, 7(4), 858-885.

39. Mearns, R., Norton, A. (2010). "Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World." New Frontiers of Social Policy. World Bank. https://openknowledge.worldbank.org/handle/10986/2689 License: CC BY 3.0 IGO.

40. Muellbauer, J. (2014). "Economic Fundamentals and Eurozone Sovereign Spreads: Will the Good News Continue?" **Economic Outlook** 38 (2), 26-36.

41. Network for Greening the Financial System (NGFS). (2020). A Comprehensive Approach to Climate Risks.

42. Nordhaus, W., (2019). "Climate Change: The Ultimate Challenge for Economics." **American Economic Review**, 109(6). 1991-2014.

43. Painter, M. (2020). "An Inconvenient cost: The Effects of Climate Change on Municipal Bonds." **Journal of Financial Economics**, 135(2), 468-482.

44. Pindyck, Robert S. (2013). "Climate Change Policy: What Do the Models Tell Us?" **Journal of Economic Literature**, 51(3), 860-72.

45. Poghosyan, T. (2014). "Long-Run and Short-Run Determinants of Sovereign Bond Yields in Advanced Economies" **Economic Systems**, 38(1), 100-114.

46. Preston, F., and Lehmann, S. (2018). Climate Change Litigation: A Survey. **Columbia Journal of Environmental Law**, 43(1), 165–216.

47. Ritchie, H. and Roser, M., (2017). "CO2 and Greenhouse Gas Emissions." https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

48. Robinson, L., Mitchell, I., Tahmasebi, A., (2021) "Valuing Climate Liabilities: Calculating the Cost of Countries' Historical Damage from Carbon Emissions to Inform Future Climate Finance Commitments" CGD Policy Paper 233. Washington, DC: Center for Global Development. https://www.cgdev.org/publication/valuing-climate-liabilities-calculating-cost-countries-historical-damage-carbon

49. Stern, N. J. Stiglitz, C. Taylor, (2021). "The Social Cost of Carbon, Risk, Distribution, Market Failures: An Alternative Approach." NBER working paper w28472.

50. Tol, R., (2018). "The Economic Impacts of Climate Change." **Review of Environmental Economics Policy,** 12, 4–25.

51. Wang, P., Deng, X., Zhou, H. Yu, S., (2019). "Estimates of the Social Cost of Carbon: A Review Based on Meta-Analysis." **Journal of Cleaner Production,** 209, 1494–1507.

APPENDIX

Table A1. Summary Statistics

Variable	Observations	mean	Standard deviation	minimum	maximum
Bond spreads Haver Analytics	1355	172.93	551.35	-840.33	9124.41
EMBI index	899	446.98	508.54	0	5794.24
Change in Climate debt (% 2018 GDP)	1328	1.462	1.27	0.15	9.74
Vulnerability index	963	0.34	0.065	0.24	0.548
Resilience index	963	0.56	0.12	0.28	0.81
Real GDP (log)	1342	7.31	2.61	1.78	16.15
Real GDP growth (%)	1320	3.07	2.98	-10.70	22.45
Inflation rate (%)	1333	3.76	4.28	-1.69	49.99
Debt (% GDP)	1354	57.31	33.78	3.67	233.52
Overall balance (% GDP)	1226	-2.34	4.19	-32.12	18.63
REER	1187	99.96	14.05	57.59	181.35
Reserves (log)	1327	23.65	1.78	17.30	28.98
Terms of trade	909	104.31	22.34	50.19	217.82
Financial Openness Index	1273	0.73	0.32	0	1
Government effectiveness	1222	7.95	1.70	3	12
ICRG corruption index	1222	14.38	16.27	1	55
Regulatory quality	1222	5.16	6.84	1	35