Seung Min Kim
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August 7, 2025

Professors Caroline Flammer and Stefano Giglio
Organizers, PhD Student Workshop on Climate Finance
National Bureau of Economic Research

Re: Application for PhD Student Workshop on Climate Finance

Dear Professors Flammer and Giglio,

I am a PhD candidate at Columbia University's School of International and Public Affairs, currently at the dissertation-writing stage, with an expected completion date of May 2028. My current research interests lie at the intersection of environmental economics, political economy, and climate finance, with research projects on the sustainable investment practices of institutional investors (joint with Caroline Flammer and Steve Lydenberg) and on the existence of political bias in the bureaucratic process surrounding federal disaster aid in the U.S. (joint with Hannah Farkas).

I am currently completing a full draft of my paper, *Climate Change and Firm Exposure to Political Risk,* which I would welcome the opportunity to present at the workshop for feedback from leading scholars in the field and brilliant fellow PhD students. The paper lies at the continuum of my interest in climate finance and in political economy, as it explores how investors' assessment of the risk of government expropriation are affected by climate shocks.

Beyond my current project, I look forward to writing my dissertation either as a further development of the above-mentioned paper, or as a separate project that explores the role of finance in climate action and in reducing environmental pollution.

My faculty adviser, **Professor Caroline Flammer**, is familiar with my work and can serve as a reference. I would be honored to participate in the workshop and to receive insightful feedback that would undoubtedly improve the current paper.

Thank you for considering my application.

Sincerely,
Seung Min Kim

Seung Min Kim

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Education

Columbia University, New York, USA — Sep 2023 -

Ph.D., Sustainable development
- Fields: Environmental economics, political economy, climate finance

Yale University, New Haven, USA — Sep 2021 - May 2023

MESc., Environmental economics
- Research Advisor: Robert Mendelsohn

Seoul National University, Seoul, South Korea — Mar 2015 - Aug 2021

B.A., *summa cum laude*, Economics (Minor in Earth Sciences)

Publications

* Lead-authored. † Lightly refereed publications.

5. "Climate Change and Fractional Outcomes: A Long-Run Panel Study of Crop Failure and Pasture Rates"* (with Robert Mendelsohn). *Journal of Environmental Economics and Management* 130:103116.
4. "Air Pollution and Solar Energy: Evidence from Wildfires"* (with Kenneth Gillingham). *Journal of the Association of Environmental and Resource Economists* 12(2):493-526.
3. "Measuring the impacts of air pollution"† (with Robert Mendelsohn). 2023. *Science* 382: 878-879.
2. "Climate change to increase crop failure in US"* (with Robert Mendelsohn). 2023. *Environmental Research Letters* 18 (1): 014014.
1. "A Panel Analysis on the Locality of Paddy Rice Yield's Response to Temperature Conditions: The case of South Korean municipalities"* (with Jeongha Hwang, Jiwan Han, and Kwansoo Kim). 2020. In Korean. *Journal of Climate Change Research* 11:597-607.

Working Papers

"Estimating Spring Frost Risk in Apple Farms from Crop Insurance Data"* (with Kwansoo Kim and Jeongha Hwang). R&R, *Weather and Climate Extremes*.

"Evaluating carbon offset projects using machine learning"* (with Luke Sanford) Draft Link.

"Bureaucracy and Political Bias: Evidence from Floods"* (with Hannah Farkas). Draft Link.

Works in Progress

"Climate change and institutions"*

"Improving state effectiveness in environmental risk mitigation: Large-scale experimental evidence from Bangladesh" (with Prabhat Barnwal, Michael Best, Lex van Geen, and Jack Willis)

"System-level investment" (with Caroline Flammer and Steve Lydenberg)

"Well-water Arsenic Mitigation in Bangladesh: Benefits outweighing risks of sharing private data" (with Lex van Geen, Prabhat Barnwal, Kazi Matin Ahmed, Mahfuz Khan et al.)

Awards & Fellowships

* Known number of awardees in parentheses ( ). All awards competitive.

2024-2028	*Ilju Fellowship	(<10, nation-wide)
	– $120,000 in stipend support & research funding (no strings attached).	
2021-2023	*Kwanjeong Fellowship	(<20, nation-wide)
2023	Dean's Scholarship, Yale School of the Environment	
2021	*Best Undergraduate Thesis Award, SNU	(1, departmental)
2015-2019	*Merit scholarships (5 times), SNU	(<5%, university-wide)
2015	*Top Freshman Award, SNU	(<0.5%, university-wide)
	– For top 10 incoming undergraduates at SNU.	

Research Grants

2025	Weiss Special Window for USAID Research (Student Co-PI, PI: Jack Willis)	$77,000
	– Title: "Nolkup: an app to access low arsenic water in Bangladesh"	
2022	Jubitz Family Research Grant (*via* Yale School of the Environment)	$4,300
2020	SNU Undergraduate Research Grant	$7,300
2020	SNU Creative Research Fellowship	$3,000
2016, 2020	SNU ARE Overseas Undergraduate Research Support Program	$13,700

Academic Presentations

* Full presentations ($\geq$ 30 mins).

2025 *Columbia IPWSD; *Columbia SustDev Colloquium; Northeast Workshop on Energy Policy and Environmental Economics (Yale); *Virtual SusDev Seminar

2024 *Columbia IPWSD; *Columbia Lamont-Doherty; *Columbia SustDev Colloquium; *Seoul National University

2023 *AAEA Annual Meeting; *Columbia SustDev Colloquium; Northeast Workshop on Energy Policy and Environmental Economics (Cornell); *Yale Carbon Offset Workshop; *Yale Environmental Economics Seminar; Yale School of the Environment (Research Day)

-2022 AAEA Annual Meeting; Seoul National University (AERD); Seoul National University (Faculty of Liberal Education); *Yale School of the Environment (Confluence)

Research Assistantships

Columbia	RA for Prof. Caroline Flammer (System-level investment)	2024-
	RA for Profs. Michael Best, Lex van Geen, Jack Willis, and Prabhat Barnwal (Information and environmental risk: Experimental evidence from Bangladesh)	2023-
Yale	RA for Prof. Kenneth Gillingham (Solar manufacturing employment)	2022
	RA for Prof. Robert Mendelsohn (Temperature and mortality)	2023
	RA for Prof. Luke Sanford (Forest carbon offset projects)	2023
SNU	RA for Profs. Kwansoo Kim & Donghwan An (Climate change policy)	2019-2020
	RA for Prof. Kwansoo Kim (Crop insurance policy)	2021

Teaching Experience

2025F Data Analysis for Policy Research (Columbia, graduate 20+, TA)

2025S Financial Economics of Climate and Sustainability (Columbia+, PhD 100+, TA)

2022F Economics of Natural Resources (Yale, undergrad 130+, Head TA)

2021F Economics of Natural Resources (Yale, undergrad 120+, TA)

Core Coursework

* Received highest grade. All PhD-level courses.

Economics	(Columbia) Micro I/II, Macro I, *Econometrics III, *Political Economy I, *Public Economics and Development, *Topics in Micro Development Economics, *Topics in Organizational Economics (Yale) Econometrics *I/*II, *Environmental and energy economics, *Machine Learning and Causal Inference
Finance	(Columbia) Asset Pricing I, Climate Finance, Empirical Corporate Finance, Financial Economics of Climate and Sustainability
Earth Sciences	(Columbia) *Aquatic Chemistry, Atmospheric Radiation (Yale) Climate Dynamics (SNU) *Ecosystem remote sensing, Atmospheric chemistry, Pollutant dynamics

Skills

Statistical analysis	*R*, MATLAB, Python, Stata
Geospatial analysis	Google Earth Engine, QGIS
Other softwares	LaTeX, WRF numerical weather prediction model
Language	Korean (Native), English, French (Fluent)

Climate Change and Firm Exposure to Political Risk*

Seung Min Kim†

August 7, 2025

Abstract

We study the impact of climate shocks on firms' exposure to political risk–risk from government expropriation and political violence. Using a novel panel dataset of country-level Political Risk Insurance (PRI) ratings, we find that hotter and drier weather conditions increase the probability of rating downgrades, which are in turn associated with increases in actual expropriation and decreases in investment and income. The climate effects are stronger for low-income countries and for countries in colder and wetter climates. We find evidence suggesting that democratic institutions can reduce the impact of climate shocks.

*I thank Caroline Flammer, Dylan Hogan, Robert Mendelsohn, Jeffrey Shrader, and participants at Columbia Sustainable Development Colloquium for helpful comments that greatly improved the study. I also thank the Credendo country risk assessment team for providing their proprietary risk rating data and for sharing their insights on the risk rating process.

†Kim: Columbia University, 420 West 118th Street, New York, NY 10027 (email:sk5316@columbia.edu).

1 Introduction

Climate shocks such as droughts and heatwaves affect firms' financial performance by damaging physical assets and reducing worker productivity (Hong et al., 2019; Somanathan et al., 2021). A separate yet related issue is climate-induced *political risk*, in which the economic consequences of extreme weather can lead to armed conflict and violations of property rights. However, quantifying the impact of climate shocks on political risk is challenging, as concrete incidents of institutional degradation (e.g., expropriation) are seldom systematically documented. Further, focusing solely on such realized events only partially identifies the scope of climate-induced political risk for investors, since the *perception* of expropriation risk alone may be enough to discourage investment (Besley and Ghatak, 2010).

This study explores the effect of climate shocks on firm exposure to political risk using a novel global data set of Political Risk Insurance (PRI) ratings. PRIs are financial products devised specifically to hedge multinational investors against the risk of political violence and governmental expropriation, as this risk remains one of the "key obstacles to investment [...] in developing countries (United Nations, 2025)." The providers of PRI policies, who are largely private insurers, assign a "country risk rating" to each host country. Just as how corporate bond ratings reflect the investment market's perception on the risk of credit default, the PRI country ratings reflect the investors' perceived political risk in a given country. The ratings determine the insurance policies' premiums and coverage, and their accuracy is disciplined by actual occurrence of institutional breakdowns (Jensen, 2008). Our panel data set of PRI ratings, spanning 174 countries and 23 years, provide a unique opportunity to assess how climate shocks affect the perceived political risk of investors.

We assess the performance of PRI ratings as metrics of institutional quality by linking the our data with independent data sets of actual PRI claims and country-level macroeconomic outcomes. Using event-study methods (Callaway and Sant'Anna, 2021), we find that the PRI rating downgrades are indeed associated with an increase in PRI claims and expropriation events. Further, the downgrades are associated with statistically significant drops in per capita real income, foreign direct investment, and domestic investment by 4%, 27%, and 14%, respectively. Such results are not only consistent with the prior literature on the importance of property-right institutions (Acemoglu, Johnson and Robinson, 2001), but also imply that investors both inside and outside the host country respond to its institutional degradation.

We then combine the ratings data with a gridded weather data set and estimate a fixed-effects panel model (Deschênes and Greenstone, 2007) to measure the effect of anomalously hot weather and droughts on PRI rating downgrades. The identification strategy hence relies on the quasi-experimental year-to-year variations in weather, holding country characteristics fixed. We follow prior studies (e.g., Carleton et al., 2022) to allow the effect of weather shocks to be a function of the country's average climate and its average income levels, hence accounting for climate adaptation and income effects.

We find that the effects of warmer-than-average weather are larger in countries with *colder* climate, with countries of average temperature above 20°C (Spain and Australia) being less vulnerable to anomalously warm weather. Similarly, the effect of droughts are stronger for countries with a wetter climate. Low-income countries are more vulnerable to both temperature and precipitation shocks. The drought and warm weather's effects are largely nefarious (increasing downgrade probability), and estimates of beneficial effects (decreasing downgrade probability) are seldom statistically significant. On average, a standard deviation increase in temperature leads to a 0.5 percentage point increase in downgrade probability, versus an average downgrade probability of 5%. The results are robust to using actual realizations of expropriation events, or the proxies thereof, as the outcome variable.

The effect of warmer weather being more harmful in colder climates stands in contrast to prior studies in the literature which have identified a "hill-shaped" relationship between economic productivity and temperature (Mendelsohn et al., 1994; Burke et al., 2015). Two possible explanations exist for such results. First, it is possible that colder and wetter countries are poorly adapted to heatwaves and droughts–analogous to the high mortality responses to heatwaves in traditionally cold counties in the U.S. (Heutel et al., 2021). Alternatively, hot weather could indeed lead to economic gains for the cold countries, but their exogenous nature could be what is prompting the government to simply expropriate such windfall benefits. This is similar to the empirical findings on how U.S. food aid (Nunn and Qian, 2014) and unconditional cash transfers (Premand and Rohner, 2024) led to increases in violence against the recipient regions.

Rather than ruling out one hypothesis over another, we note the importance of democratic institutions for both channels, in that they promote investment in public goods (e.g., adaptation measures) and reduce rent-seeking behavior (Besley and Persson, 2009a; Acemoglu et al., 2019). We then take country-level average of indexes of democratic institutions to split the countries into subsamples. The analyses reveal that more democratic countries are significantly less vulnerable to temperature shocks than their less

vulnerable peers, conditional on climate and income. Similarly, countries with stronger anti-corruption institutions are less vulnerable to droughts.

This paper speaks to the broad literature that studies the risk posed by climate change on the firms' financial outcomes (Addoum et al., 2020; Krueger et al., 2020; Pankratz et al., 2023; Sautner et al., 2023). Government expropriation of capital pose real risks to firms considering large-scale investments in developing countries, as evidenced in the vibrancy of the PRI market itself. Our results suggest that the impacts of climate shocks are already observable in the PRI market's signals. The heterogeneous effects of warm weather, in turn, suggest that regions of the world that were traditionally thought to be safer from climate change impacts may not be so in their institutional resilience–hence adding to the urgency of climate action.

This study also contributes to the burgeoning "climate-conflict" literature (Hsiang et al., 2013; Burke et al., 2024), which identify the link between weather shocks and civil conflicts. While a few studies in the literature (Burke and Leigh, 2010; Brückner and Ciccone, 2011) have explored the impact of weather shocks on institutional quality, such studies were focused on non-market indexes of democratic institutions (e.g., Polity V index, Marshall and Gurr, 2020). In contrast, this paper's outcome measures property-right institutions and are direct results of the investment market's shifting evaluations–hence being a more convincing metric of firm exposure to political risk.

More broadly, the theoretical literature on political violence (Besley and Persson, 2009b, 2011) have suggested that the weakening of institutions precedes civil violence, the subject of the climate-conflict literature. The results in this paper imply that this "middle step" between climate shocks and violence does exist. The mechanism results highlight the importance of democratic institutions in preventing this chain reaction, from climate shocks to property-right institution degradation–and ultimately to violent conflicts.

The remainder of the paper is structured as follows. Section 2 discusses the PRI ratings in detail and presents the data that we use, followed by Section 3 on the empirical strategy. Section 4 presents the main empirical results, additional findings, and the potential mechanisms. Section 5 concludes.

2 Background and Data

2.1 Political Risk Insurance and its country-level risk ratings

This study uses country-level risk ratings of PRI policies to assess firms' exposure to climate-induced political risk. PRI products are offered by both governmental and private insurers to private investors aiming to hedge their investments against political risk.[1] Investors covered by PRI policies can file for claims when their assets or the returns thereof are subject to losses from political reasons, such as unilateral expropriation and destruction from violent conflicts. The insurers' country-level risk ratings, the source of this study's outcome variable, plays a crucial role in the setting of premium, coverage, and terms of contract of PRI policies. For example, some insurers stipulate that projects hosted in countries with the worst ratings are not eligible for insurance coverage.

We use PRI ratings from the Belgian governmental export credit agency (ECA), Credendo (formerly *Office National du Ducroire*). On top of being the source of data for prior cross-sectional studies using PRI ratings (Jensen, 2008; Jensen and Johnston, 2011), Credendo's ratings have several other properties that improve their representativeness and their usefulness. First, Credendo publicly discloses its most recent annual country-level ratings on its website. Such public disclosure of ratings, combined with the multinational nature of most purchasers of PRI policies, have meant that a considerable degree of parity has been established in the PRI market–such that premiums of other PRI products show similar variations to those of Credendo (Jensen, 2008).

Further, unlike other ECAs which capture a country's overall political risk with a single rating, Credendo breaks down a country's ratings into the different aspects of political risk. We focus on ratings for expropriation risk, which "encompasses all discriminatory measures taken by a host government which deprive the investor of its investment without any adequate compensation (Credendo, 2024)." To compare our results with the studies in the climate-conflict literature (Burke et al., 2024), we also study rating changes for political violence risk, which include risk of damages from terrorism attacks or violent conflicts.

Every year, Credendo adjusts the countries' risk rating by combining results from its own propriety quantitative risk model, the investors' experiences, and regional experts' assessments. We use all Credendo ratings from 2002 to 2024, and define a dummy variable of "downgrades" from the changes in the country's ratings. Crucially, weather and climate

[1] Governmental insurers mostly consist of export credit agencies (ECAs) aiming to promote investments in developing countries, such as U.S. International Development Finance Corporation (DFC).

characteristics are *not* part of the risk rating adjustment process–suggesting that our core results on the link between climate shocks and PRI ratings are not mere artifacts of the Credendo's assessment methods.

A first inspection into the PRI expropriation rating data reveals that upgrades and downgrades are pervasive, observed in more than half of the countries (113 out of 174) and with an average probability of 5% per country-year. Importantly, Appendix Figure A1 suggests that these shifts are not disproportionately focused on specific climate zones of the world. Most of the countries' records span 23 years (from 2002 onward), with global coverage (174 countries, Appendix Figure A2). Appendix Figure A3 presents the average expropriation risk rating over the sample period, where lower value means lower expropriation risk.

Notably, Appendix Figures A4 and A5 show that certain countries (e.g., non-OECD countries) have experienced multiple downgrades and upgrades, while a few countries (e.g., South Korea *and* North Korea) have not experienced any changes in their ratings.

2.2 Risk rating, claim occurrence, and macroeconomic outcomes

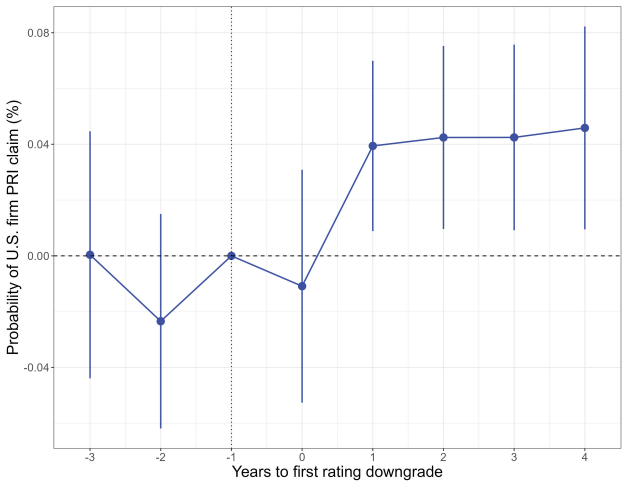
To be a good proxy of the institutional environment that firms face in different countries, the Credendo expropriation risk ratings must be predictive of actual expropriation events. To empirically validate this, we combine the Credendo rating data with a firm-level panel data of expropriation events, from Arel-Bundock et al. (2020). The latter firm-level data set compiles PRI purchases and loss claims from a U.S. governmental PRI program run by the U.S. International Development Finance Corporation, and provides an albeit partial information on the extent of political risk-induced losses.[2] The unit of observation is at the investment project-year level, and each investment project is linked with the Credendo data using the projects' host country and year.

We estimate an event study model (Callaway and Sant'Anna, 2021) using the combined data, with "first expropriation risk rating downgrade" as the treatment variable and an indicator variable of a firm filing for PRI claims as the outcome variable. The coefficient

[2]The following excerpt from a claim filed to OPIC (precursor of the U.S. DFC) on an expropriation event in Russia aptly illustrates the kind of incidents that are covered by DFC's PRI policies:

"On March 1, 2008, Terminal [Russian partner of GFMG] brought its own security service onto the Facility [owned by GFMG] and SGP [Facility's maintaining entity]'s security service resigned. (...) [W]ith the change in security services, Terminal took over all access into the Facility (the "Takeover"). (...) Following the Takeover, GFMG, as 70% owner of SGP, immediately sought intervention from the Russian police, court, and local government authorities, but no action was taken against Terminal during the illegal occupation period... (Overseas Private Investment Corporation, 2011)"

(a) Political risk insurance claims, U.S. investors



(b) Income and investment per capita

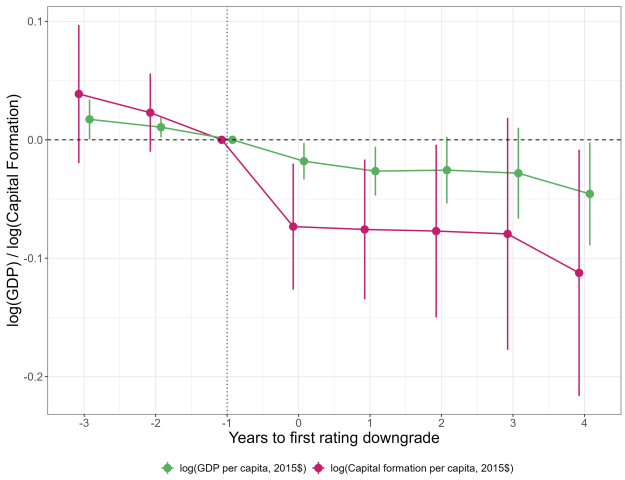


Figure 1. Country-level PRI rating, claim occurrence, and macroeconomic outcomes

Notes: Figure shows Callaway and Sant'Anna (2021) event study coefficients, with the treatment variable being "first Credendo expropriation risk rating downgrade." Credendo is the Belgian governmental export credit agency whose country-level risk ratings we use as primary outcome of interest. Figure 1a uses as outcome the investment project-level dummy of the project filing for a political risk-induced loss (losses from expropriation, war, and other political violence), while Figure 1b has macroeconomic variables of the country experiencing the downgrade. All standard error clustered at country level. Error bars represent 95% confidence intervals. See Appendix Figure A4 for coverage of Credendo ratings and country-level downgrade frequency.

estimates measure the dynamic correlation between a country's downgrade in Credendo expropriation rating and the conditional probability of a U.S. company filing for PRI losses in that country. The model includes project- and year-fixed effects, and uses the "never treated" projects (i.e., projects in countries that have never experienced rating downgrade) used as the control group.

The results, shown in Figure 1a, suggest that Credendo's expropriation risk rating downgrades are indeed followed by persistent increases in the probability of a U.S. firm filing for PRI losses in the country. While a firm files for PRI claims with a probability of 0.22%, the probability increases by 0.05%p following the downgrade. Interestingly, there is little noticeable pre-trend in PRI claims prior to the downgrade. These estimates indirectly suggest that the Credendo rating downgrades occur in anticipation of expropriation events, rather than as a mere responses to an actual expropriation occurrence.

Prior studies suggest that such deterioration of property-right institutions, as evidenced in the increase in expropriation events following the rating downgrade, likely discourages investment and hamper economic growth (Acemoglu et al., 2001; Besley and

Ghatak, 2010). We empirically test this possibility by estimating event study coefficients on a data set combining the Credendo ratings with the countries' real GDP per capita and capital formation per capita, the latter defined as gross investment net of inventory changes. Both data are obtained from World Bank Development Indicators (World Bank Group, 2024).[3] We estimate the coefficients conditional on log of real GDP in year 2000 (prior to the first Credendo risk rating), in light of the differences in income levels of the countries that experience downgrades versus those who do not (Appendix Figure A4).

The event study coefficients in Figure 1b suggest that indeed, countries experience significant drops in income and capital accumulation following expropriation rating downgrade. The GDP and investment per capita drop by 4.1% and 14.0% respectively, while there are no obvious evidence of recession prior to the downgrade. Appendix Figure A6 suggests that the decreases are also observed in log of net FDI inflow (27% drop). Such results suggest that the infringement of property rights, as captured by the downgrades, affect investment incentives of both domestic and foreign investors, suppressing income growth. Further, Appendix Figure A7 implies that the downgrades are not driven by, or are followed with, deterioration of the countries' fiscal health–as measured through the ratio of external debt to currency reserves.

The Figure 1 results are robust to using "not-yet-treated" countries as the control group (Appendix Figures A9 and A10). Figure 1a results also stand when we limit the PRI claims to those related to expropriation (Appendix Figure A10). Lastly, Figure 1b results are robust to not conditioning the coefficients on income levels (Appendix Figure A11), although the coefficients become noisier.

2.3 Additional data

Actual expropriation cases. We obtain records of actual cases of government expropriation from United Nations Trade and Development's (UNCTAD) Investment Dispute Settlement Navigator (UNCTAD, 2023). The data set focuses on investors' international arbitrage attempts following alleged breaches of the investor right from a sovereign state, and includes information on the investor raising the claim, the state concerned, and a brief summary of the matter of contention.

Weather and climate. We collect data on experienced weather from two sources. First,

[3]To be precise, World Bank provides the "share of capital formation in the GDP" data. We multiply this quantity with the inflation-adjusted GDP per capita to obtain domestic investment per capita.

temperature data come from National Oceanic and Atmospheric Administration (NOAA)'s GHCN CAMS gridded temperature data (NOAA, 2024b), which provides monthly temperature at 0.5 degree resolution from 1948 onward. We obtain precipitation data from NOAA's Global Unified Gauge-Based Analysis of Daily Precipitation (NOAA, 2024a), which provide daily precipitation at 0.5 degree scale from 1979.

We aggregate both data to calendar year level, by computing the annual average temperature and the yearlong average of monthly accumulated precipitation. We weight each grid by its population density to remove the effects of sparsely inhabited grids, where the population data come from NASA's Gridded Population of the World v4.11 product (NASA, 2024). We use gridded population density as of year 2010.

In order to make the weather shock terms more comparable, and to account for regional differences in variability of weather, we normalize the annual temperature and precipitation by the individual country's climatological average and standard deviation. The climatological averages are taken over the period 1991-2020.

Macroeconomic variables. On top of the real GDP per capita and capital formation data, we collect from World Bank (World Bank Group, 2024) the data on population, foreign direct investment per capita, ratio of total foreign reserve to external debt (in %), ratio of international trade to GDP (%). The latter two variables are winsorized at 2.5th and 97.5th percentiles.

We also collect information on country-level government annual balance sheet from the International Monetary Fund's (IMF) Investment and Capital Stock Dataset (International Monetary Fund, 2022), which present the value of government-owned and private-owned capital stock and yearly investment in purchasing power parity (PPP) dollars.

Governance data. We obtain data on time-varying levels of governance and other institutions' qualities at the country-year level, from the World Bank's Worldwide Governance Index (World Bank Group, 2025). We also use Polity V index (Marshall and Gurr, 2020), an index of democratic institutions, at the country-year level. Such variables are used in understanding the role of other institutions in moderating the effect of climate shocks on firm exposure to political risk.

3 Empirical strategy

We estimate the effect of climate shocks on firm's exposure to property-right violations through a panel fixed-effects model of PRI ratings and country-level annual weather. Previous studies on the effect of climate on violence have pointed to the possibilities of lagged effects from weather shocks (Burke et al., 2024). We capture such dynamic effects by including lagged values of the weather shocks. We also account for adaptation and state-dependence of the weather effects by allowing them to vary with the climatological average temperature and precipitation (Heutel et al., 2021; Auffhammer, 2022; Nath et al., 2024). Lastly, in light of the global coverage of our observations, we follow previous studies (e.g., Carleton et al., 2022) in interacting the weather variables with the country's average real GDP per capita levels over the sample period, hence allowing responses to weather shocks to vary with income. The preferred reduced-form equation of interest is thus:

$$\begin{aligned} y_{it} = & \sum_{\ell \in \{0,1\}} \beta_{1\ell} T_{i,t-\ell} + \gamma_{1\ell} T_{i,t-\ell} \bar{T}_i + \zeta_{1\ell} T_{i,t-\ell} \bar{Y}_i + \beta_{2\ell} P_{i,t-\ell} + \gamma_{2\ell} P_{i,t-\ell} \bar{P}_i + \zeta_{3\ell} P_{i,t-\ell} \bar{Y}_i \\ & + \alpha_i + \delta_t + \varepsilon_{it} \end{aligned} \tag{1}$$

where y_{it} is a dummy of country i experiencing the PRI rating downgrade in year t, $\bar{T}_i$ and $\bar{P}_i$ the average temperature and precipitation over the years 1991-2020, $\bar{Y}_i$ the log of average real GDP per capita of country i, and $T_{i,t-\ell}$ and $P_{i,t-\ell}$ the temperature and precipitation of year $t-\ell$. α_i and δ_t capture country- and year-fixed characteristics, respectively. The error term ε_{it} is clustered at the country level to account for correlation of errors across time.

Notably, our preferred specification uses *locally* normalized T_{it} and P_{it} values using country-level average and standard deviation of T_{it} and P_{it} for years 1991 to 2020. While such normalization improves their across-country comparisons and allows the comparison of T_{it} coefficients with P_{it} coefficients, we test the robustness of our results to using raw temperature and precipitation, in which case the coefficients would represent the effect of 1°C increase in annual temperature and 1cm increase in monthly precipitation (versus a standard deviation increase in temperature and precipitation in the original definition).

The model (1) identifies the effect of weather shocks on PRI rating downgrade using quasi-experimental variations in intertemporal weather (Deschênes and Greenstone, 2007). Under this model, the cumulative effect of a standard deviation increase in temper-

ature on the probability of PRI rating downgrade, for country i, is:

$$\beta_{10} + \beta_{11} + (\gamma_{10} + \gamma_{11})\bar{T}_i + (\zeta_{10} + \zeta_{11})\bar{Y}_i \tag{2}$$

Our estimand of interest is (2) and its equivalent for precipitation, for different countries i. The coefficients β capture the cumulative effect of weather shocks, while γ and ζ coefficients measure the effect of adaptation and income in moderating climate shocks' effect on PRI rating downgrade probability. Standard errors are computed using the Delta method.

While our main outcome y_{it} is obtained from Credendo's risk rating data, we also test whether similar effects of climate and income are observed for the occurrence of actual investment disputes involving government expropriation. We also gather indirect evidence by assessing whether climate shocks are associated with sudden growths in government-owned capital stock, conditional on the general economy's growth patterns.

Finally, we evaluate potential mechanisms that drive the climate shocks' effects by inspecting the role of democratic institutions and anti-corruption institutions. We take the country-level average of the indexes pertaining to such institutions and divide the sample into two groups using the median of the country-level averages.

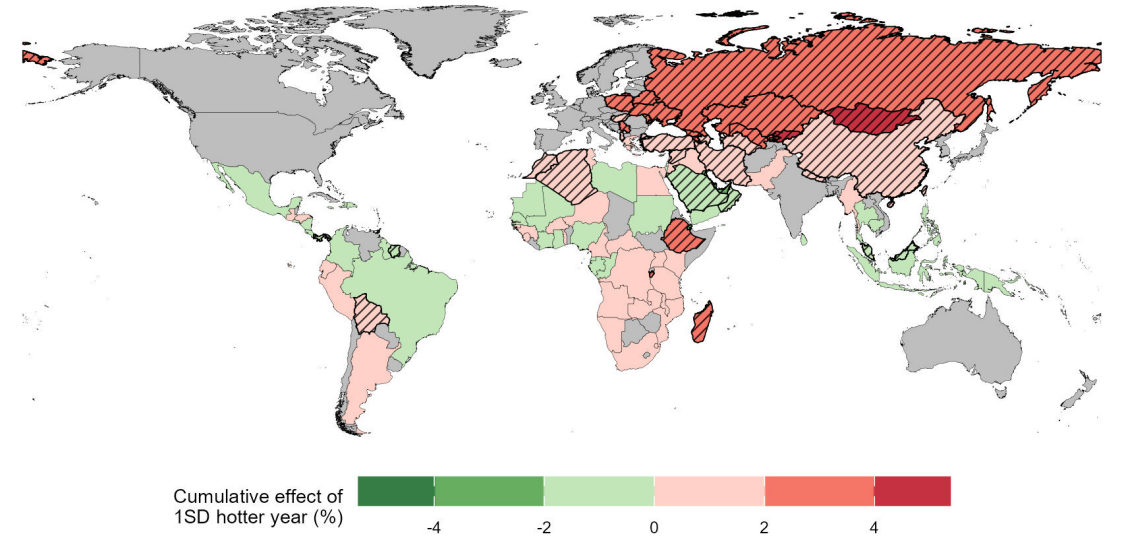
4 Results

4.1 Main results

Figure 2a present the estimates of cumulative effects of temperature, from the panel OLS model (1), with dummy variable of "experienced PRI risk rating downgrade" as the outcome. Positive marginal effects (i.e., *increases* in the risk of rating downgrade) are shown in red, versus green for negative estimates (*decreases* in downgrade probability). Countries with estimates significant at 95% level are shown with hatches. We do not show the marginal estimates for countries that did not experience any downgrades, and hence did not have their variations included in the estimation of the coefficients.

The results suggest that it is the countries that are in colder climates, such as Mongolia (MNG) and Russia (RUS), that are more vulnerable to anomalously hot weather. This is highlighted in Figure 2b, which plot the marginal effects against the country's average temperature. There is, however, a strong heterogeneity in the marginal effects within countries with similar average temperature. Figure 2c suggests that this heterogeneity is

(a) Marginal effect of temperature



(b) Heterogeneity with average temperature

(c) Heterogeneity with income

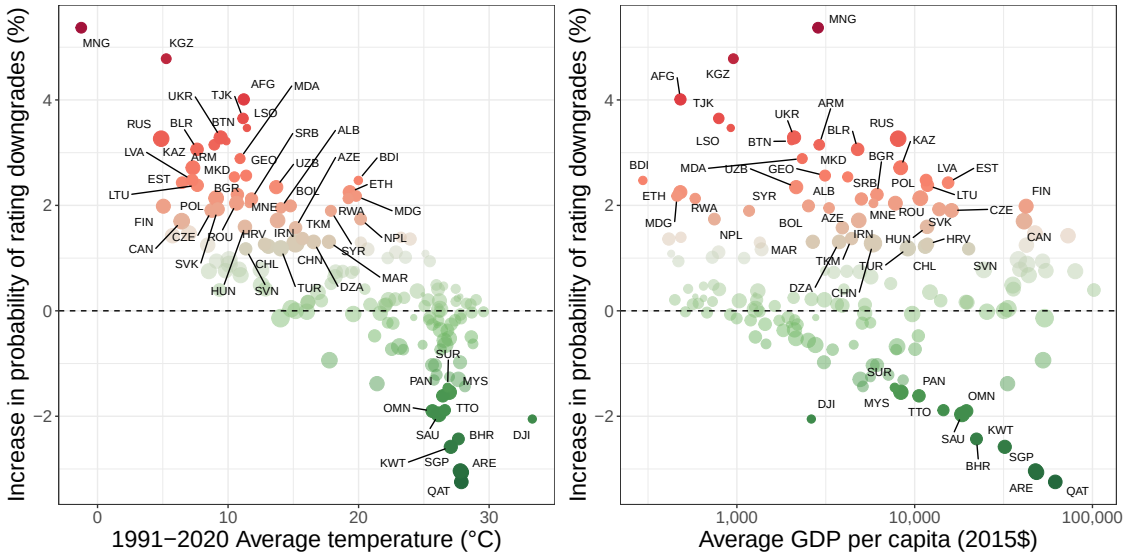


Figure 2. Temperature and political risk

Notes: Figure shows the effect of temperature shocks on country-level political risk insurance rating downgrade (equation (2)). Figure 3a plots the marginal effects, with increases (decreases) in downgrade probability from warmer weather shown in red (green). Countries with statistically significant marginals (at 95% level) shown in hatched fill, while countries that did not experience any downgrades are shown in grey. Figure 2b plots the marginals against the countries' climatological average temperature, while Figure 2b does the same but for average GDP per capita over the sample period (log-scaled). Three-character ISO codes for countries only shown when their marginals are statistically significant. Larger and darker dots mean larger gross GDP and higher significance.

driven by income per capita, where developing countries are more vulnerable to warm anomalies; even relatively hot-climate countries, such as Ethiopia (ETH), still have statistically significant positive effects from warm weather. In general, the statistically significant estimates are largely negative, and are positive only in hot, high-income countries such as Saudi Arabia (SAU). The size of the marginal effects are economically significant, in that the average probability of downgrade for a country-year is 5%.

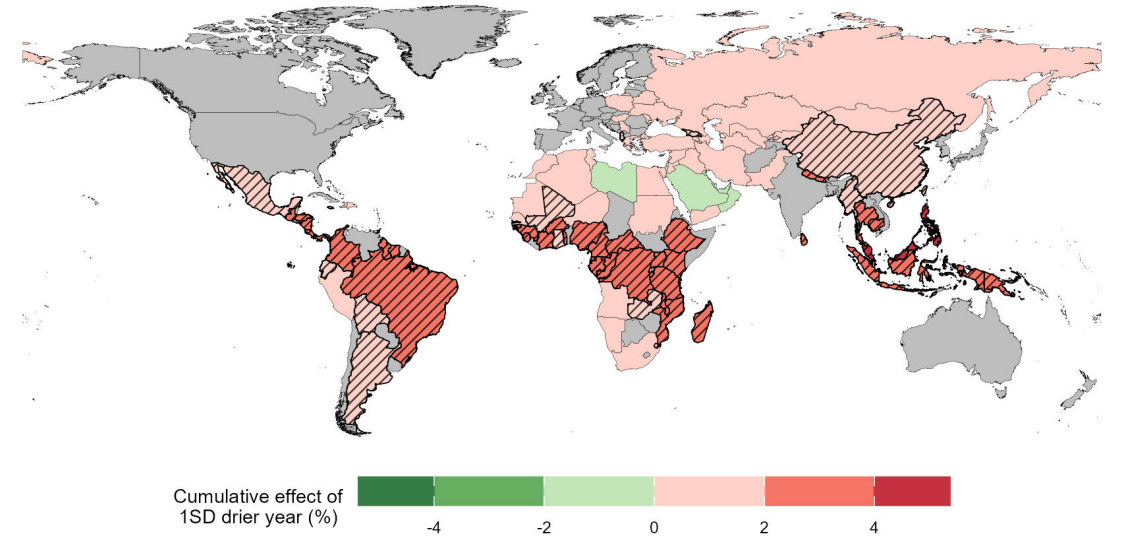
Figure 3 presents the results for precipitation shocks, where we show the results of a one standard deviation *drier* weather (i.e., inverse of the marginal (2)). Contrary to temperature, it is the countries with *wetter* climate that are more vulnerable to droughts (Figure 3b), with exceptionally dry countries (e.g., central Asian countries) showing statistically insignificant effects, versus wet countries such as Philippines (PHL) and Malaysia (MSY) predicting increases in rating downgrade probability from droughts. Further, low-income countries show stronger responses to droughts (Figure 3c), although the income-associated heterogeneity is less salient than in temperature. All statistically significant marginal estimates are *positive* (increasing downgrade risk). The effect of droughts in sub-Saharan Africa are consistent with prior climate-conflict studies that point to the importance of precipitation in violent conflicts and institutional breakdowns in the region (McGuirk and Nunn, 2025; Eberle et al., 2025).

Taken together, the results suggest the importance of adaptation, as droughts and hot weathers are more detrimental to countries that are wetter and colder in climate. Importantly, while the experience of on-site investor corporations and regional experts' evaluations factor into Credendo's rating evaluations, climate shocks *per se* are not part of the input variables–suggesting that the results identified here are not artifacts of Credendo's rating policy. We now present additional results that confirm similar trends in a separate data set and provide important insights on the role of dynamics.

4.2 Additional results

While our main outcome of interest relies on Credendo's country-level ratings, Figure 4 identifies similar patterns in the role of climate shocks in *realized* outcomes. Figure 4a refers to Investor-State Dispute Settlement (IDSDS) cases, where investors engage their host country in an international arbitrage process for an alleged breach of their investment rights. In particular, we focus on the existence of newly initiated cases where the arbitrators mention "expropriation" in their settlement rulings for each country-year. Figure 4a plots the country-level marginals from fitting this outcome in the model (1). While the

(a) Marginal effect of precipitation



(b) Heterogeneity with average precipitation

(c) Heterogeneity with income

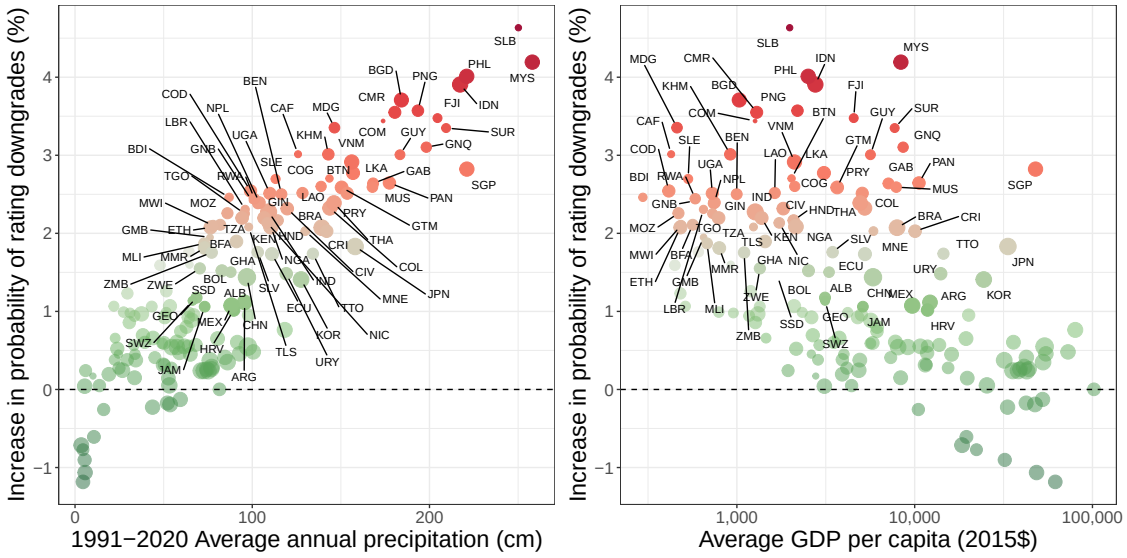


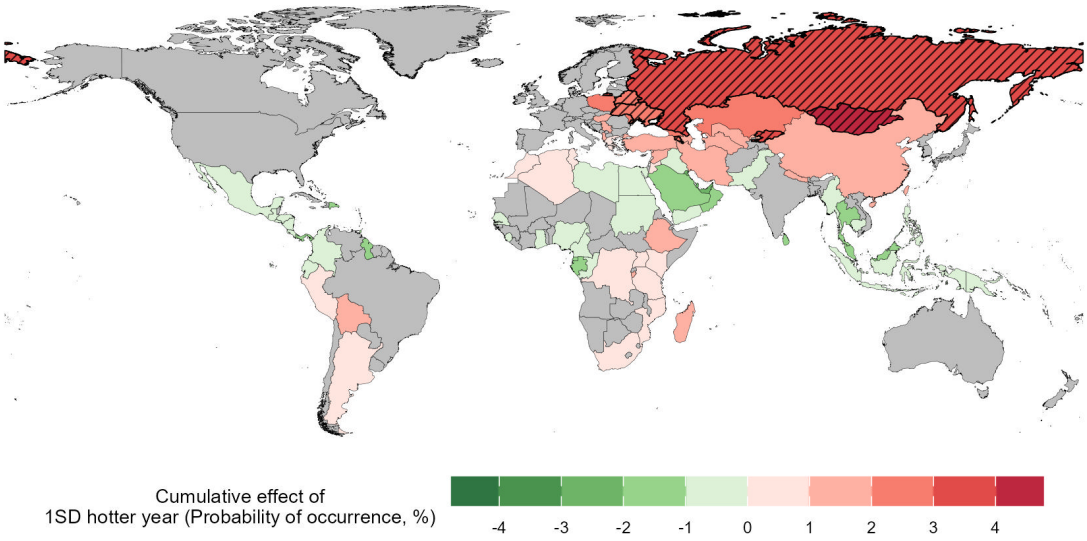
Figure 3. Precipitation and political risk

Notes: Figure shows the effect of drought on the probability of country-level political risk insurance rating downgrade. Visualization of panels (a), (b), and (c) identical to that of Figure 2.

difficulty in pinpointing the exact date of results are less precise the trend of lower average temperature and low income being associated with higher vulnerability to temperature shocks.

A more indirect way to identify the occurrence of expropriation is through sharp increases in government-owned capital stock. Using data from the IMF Investment and

(a) Occurrence of expropriation cases



(b) Growth in government-owned capital

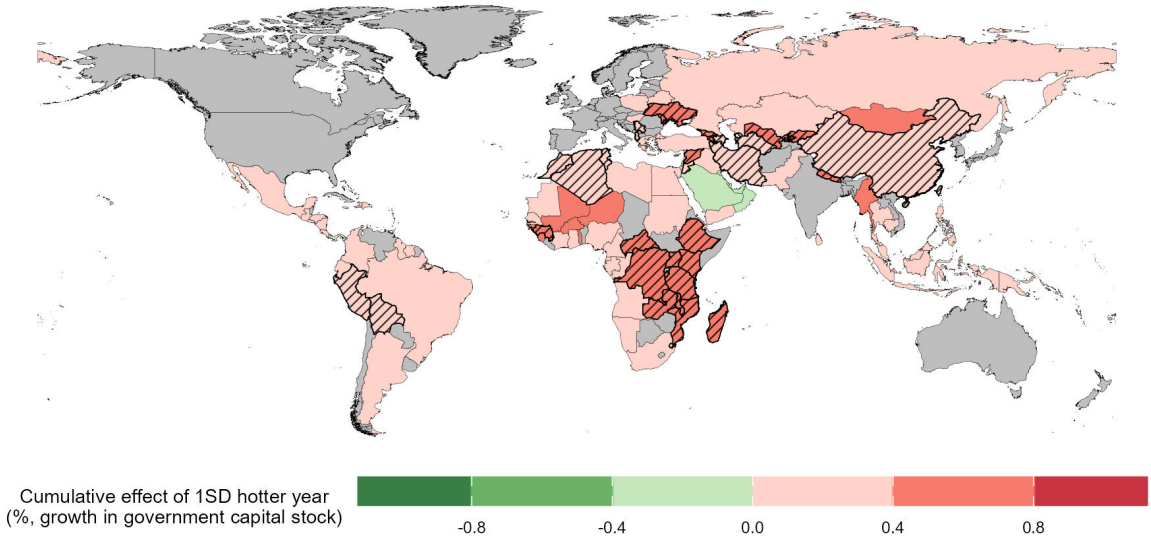


Figure 4. Temperature, realized expropriation cases, and government-owned capital

Notes: Figure shows the effect of temperature on proxies of *realized* expropriation. Figure 4a uses the number of investor-state dispute cases involving government expropriation, and Figure 4b focuses on % growth in government capital, controlling for growth in GDP per capita and in private capital. Countries without investor-state dispute cases shown in grey for Figure 4a.

Capital Stock Dataset, Figure 4b estimates the effect of warm weather on the *growth* of government capital stock. We control for growth rates of GDP per capita and private capital stock, in light of the effect of temperature on economic productivity (Burke et al.,

2015). The results once again suggest that government capital stock follows the pattern in Figure 2a. A separate regression that uses the *share* of government capital stock over total capital stock also finds a similar pattern (Appendix Figure A12). In contrast, the effects of precipitation shocks are less precise and statistically insignificant (Appendix Figures A13 to A12).

To be clear, the impact of climate on expropriation risk, does *not* have to be materialized for it to affect investor incentives and hamper economic growth; a mere increase in the *expected* probability of expropriation suffices (Besley and Ghatak, 2010). Nevertheless, the results in Figure 4 do suggest that the effect of temperature shocks are also observed in macroeconomic outcomes and in investor actions against sovereign states.

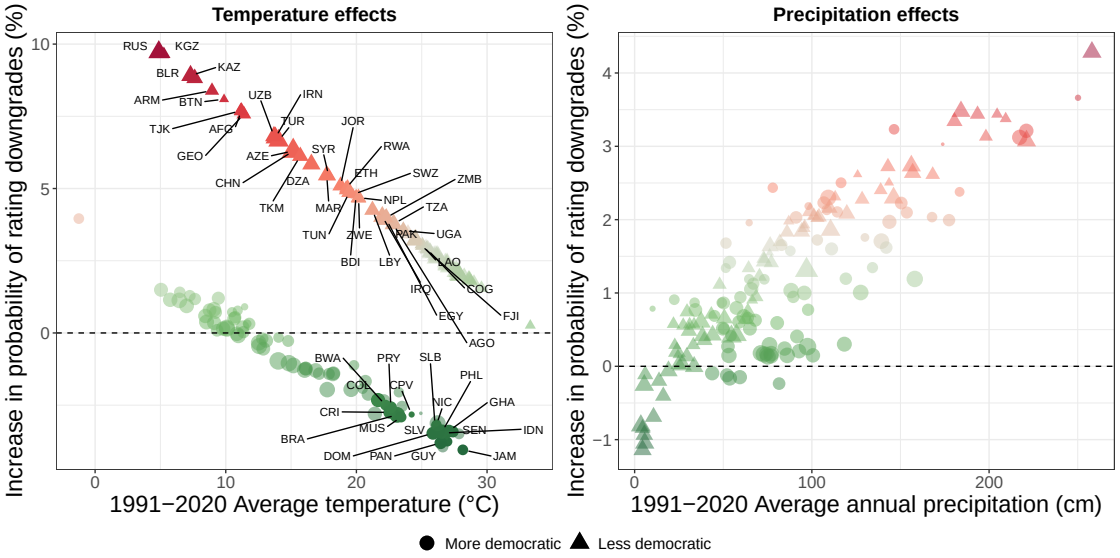
We now return to Credendo risk rating to explore the role of lagged effects in our results. To this end, we estimate a new model after dropping the lagged terms ($\ell = 1$ terms) on the right-hand side of (1). Under "harvesting" effects where weather shocks simply triggers a downgrade that would have occurred anyway, the more parsimonious model would lead to *larger* estimates (Hsiang, 2016). The results, shown in Appendix Figures A15 and A16, are smaller in size–pointing to the absence of strong harvesting effects. The lagged terms are particularly large in size for precipitation marginals, pointing to the importance of lagged effects in drought effects.

Lastly, while we have been focused on Credendo's expropriation risk rating downgrades, we assess whether political violence ratings, which evaluate risk of war and terrorism, are also affected by weather shocks. Appendix Figures A17 and A18 suggest that warm weather and droughts do have adverse effects on risks of political violence, particularly in countries with *drier* climate and low income. Such results are consistent with the climate-conflict literature (Burke et al., 2024).

4.3 Potential mechanisms

Prior studies have suggested that democratic institutions, in particular its effect on equal political rights and on minimizing government rent-seeking behavior, can protect property-right institutions (Besley and Persson, 2011; Acemoglu et al., 2019; Acemoglu, 2025). We hence assess whether democratic institutions and institutions against corruption can drive the heterogeneity in the vulnerability of property-right institutions to climate shocks. For the former, we use country-level average of the Polity V index (Marshall and Gurr, 2020), a widely used index of democratic institutions and policies. For the latter, we refer to the Worldwide Governance Indicator's (WGI) "Control of Corruption" index, which measure

(a) Democratic institutions



(b) Corruption

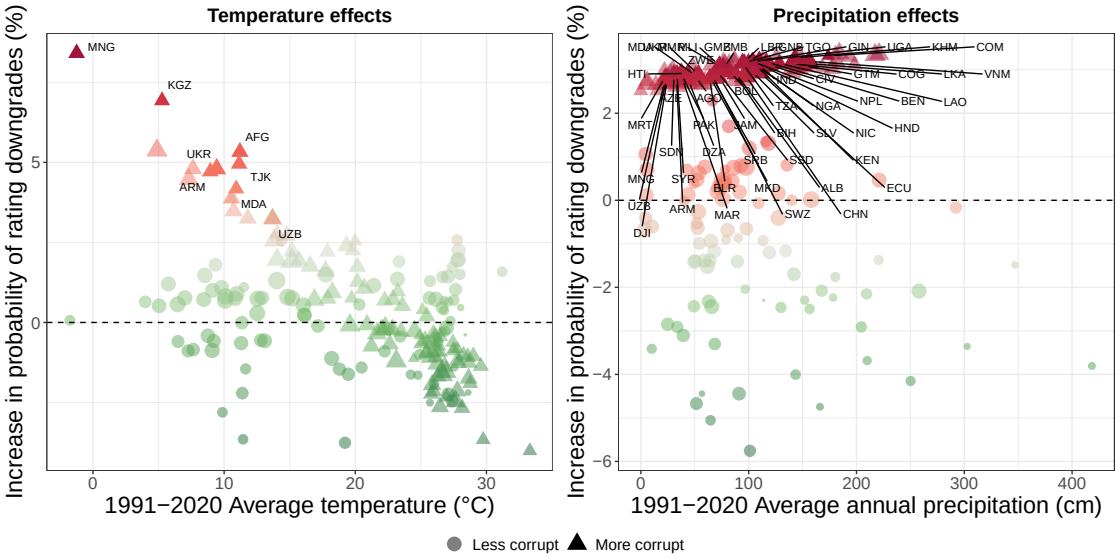


Figure 5. Heterogeneous responses to climate shocks from subsample analyses

Notes: Figure explores potential mechanisms driving the results by dividing the countries in the sample into two groups, using the averages of indexes representing the quality of their democratic institutions and anti-corruption institutions. We use Polity V index for the former, and World Bank's Worldwide Governance Index for the latter. Figures on the panel show the temperature marginals (1SD hotter year), versus precipitation marginals (1SD drier year) for the right panel. ISO codes are shown for countries with statistically significant marginals. Points' shape represent the subsample that they belong to.

the extent to which "public power is exercised for private gain (World Bank Group, 2025)."

We divide the *countries* into two subsamples based on the within-sample average of

these indexes, and assign the observations belonging to each country to the two subsamples. We then estimate the regression (1) for the two subsamples and plot the marginal effect of climate shocks.

Figure 5a presents the results for the subsample regressions using country-average Polity V index. The temperature marginals (left panel) strongly suggest that the less democratic countries, in triangesl, have a significantly larger marginal effect (i.e., more likely to experience downgrades) than their more democratic counterparts with similar climate conditions, in circle. In fact, none of the more democratic countries have a statistically significant positive marginal. The general pattern of colder-climate countries being more prone for downgrades faced with warm weather remains for both subgroups.

In contrast, the right panel of Figure 5a, which shows the precipitation marginals, suggests that the two groups do not differ in their responses to droughts. The marginals are largely just a function of average precipitation levels, with the triangle and circle points largely overlapping.

The two panels of Figure 5b repeat the exercise, but using the WGI "control of corruption" index. The results suggest that while temperature effects' heterogeneity are not strongly driven by temperature, the drought effects are substantially larger and almost exclusively focused on more corrupt countries–to the extent that there is no overlap in the distribution of less- and more-corrupt countries.

Taken together, the results highlight the interaction between democratic institutions, anti-corruption institutions, and property-right institutions as captured by PRI expropriation risk rating. We leave the establishment of causal link between democratic institutions and resilience to climate shocks for future studies.

5 Conclusion

Combining novel global panel data set of PRI risk ratings, gridded weather data set, and other macroeconomic outcomes, we find that countries in colder and wetter climates are particularly likely to have their risk rating downgraded following hotter- and drier-than-average climate conditions. Such results also follow through for actual expropriation cases and in the sudden accumulation of government capital. We identify democratic institutions as a potential driver of the effects that we observe throughout the analysis.

Future studies could potentially aim to link the firm-level expropriation records, as presented in Arel-Bundock et al. (2020), with firm-level balance sheet results. Additional

studies that highlight the flow of exogenous gains from weather shocks to actual government capital would also be very useful.

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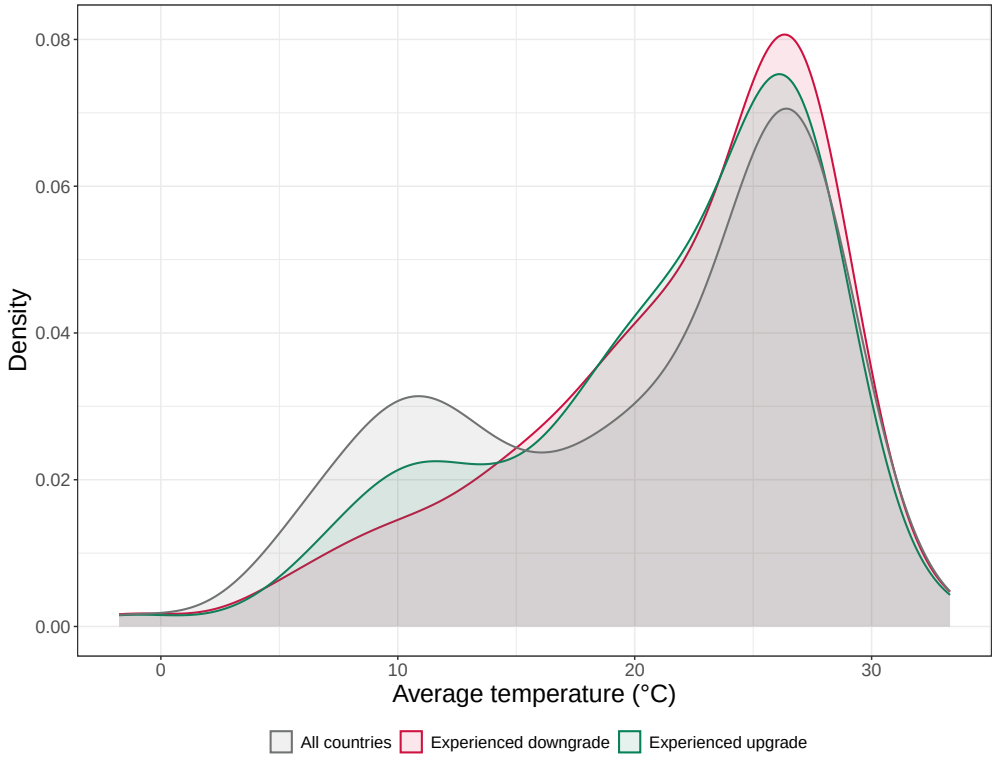
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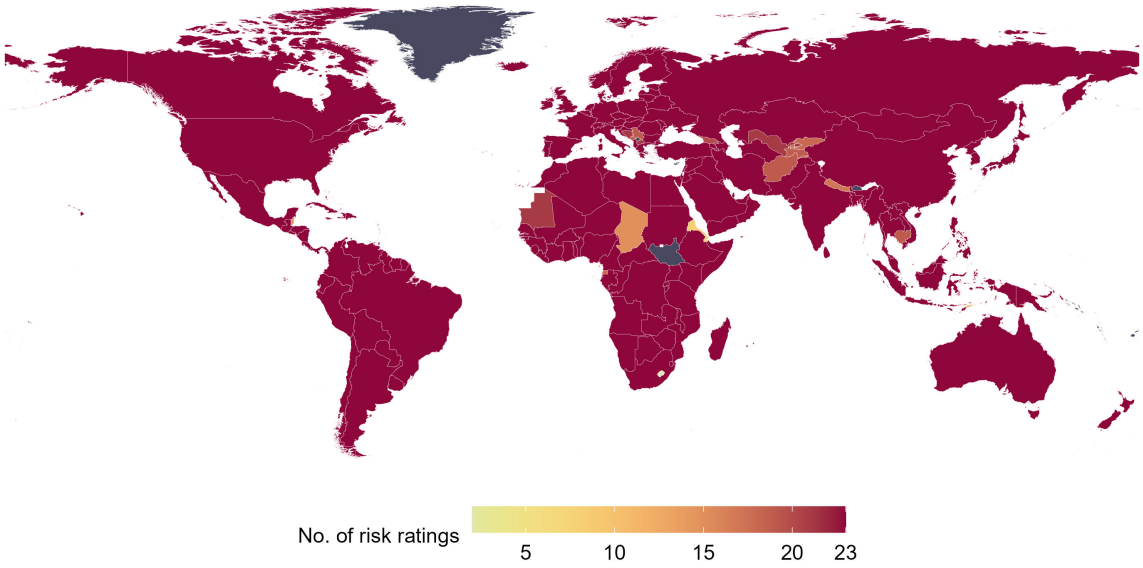
Appendix

A Additional Tables and Figures



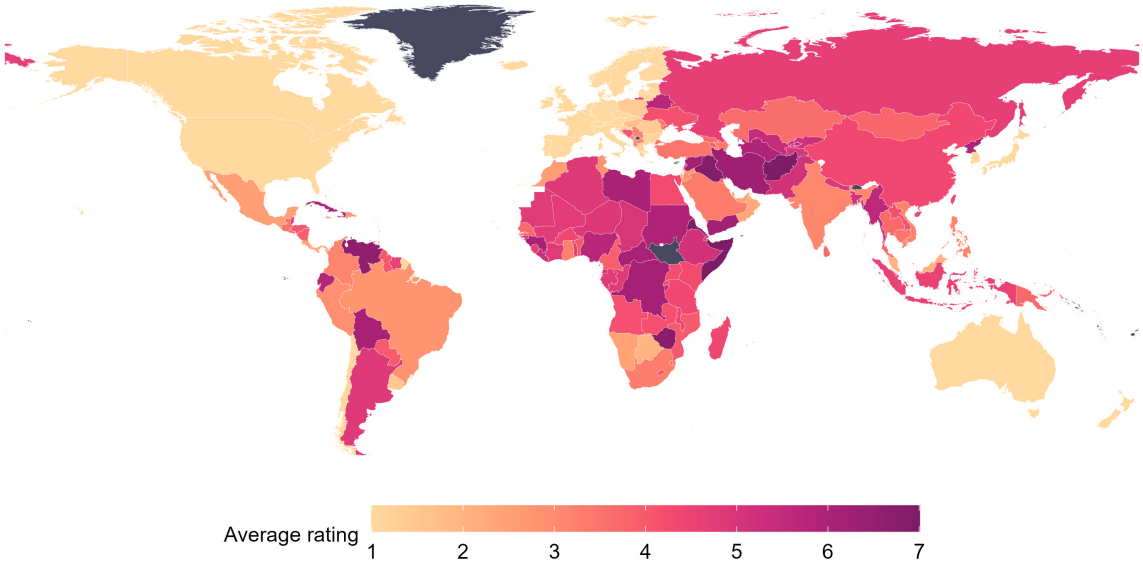
Appendix Figure A1. Distribution of average temperature and experience of rating shifts

Notes: Figure shows the distribution of average temperature for all countries in this study' data set (black), versus those of countries that have experienced upgrades at least once (green) and downgrades at least once (red).



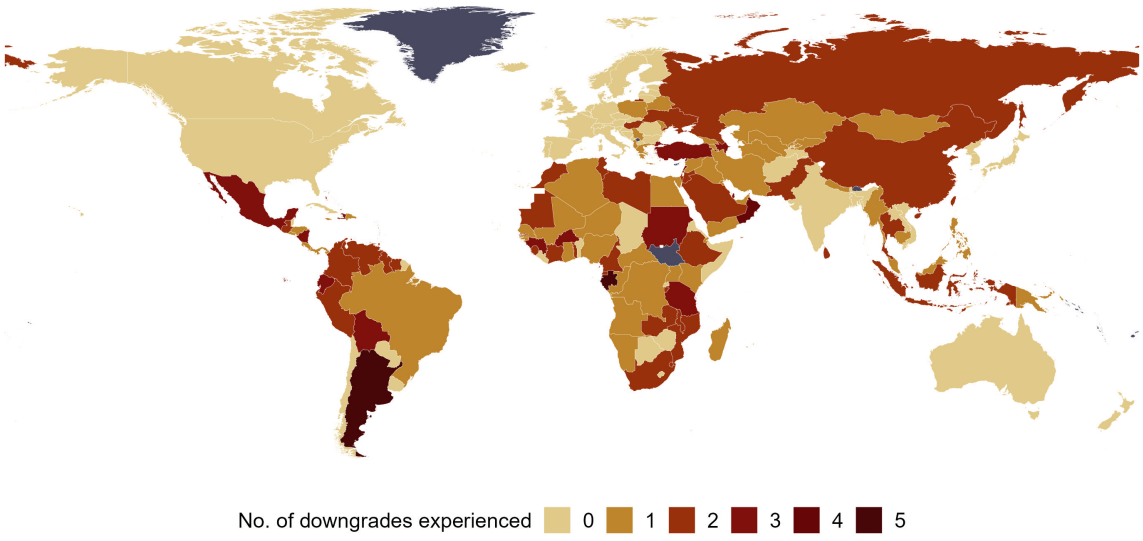
Appendix Figure A2. Number of Credendo expropriation risk ratings for each country

Notes: Figure shows the number of expropriation risk ratings recorded for each country. Countries with missing expropriation risk ratings shown in grey.



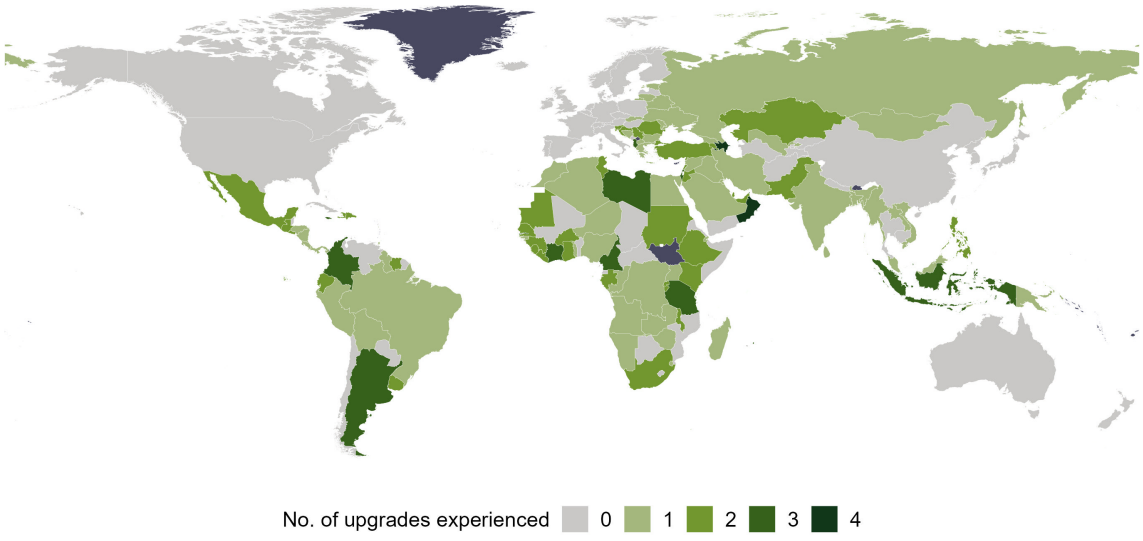
Appendix Figure A3. Average Credendo expropriation risk ratings for each country

Notes: Figure shows the average rating of Credendo expropriation risk in each country, where higher value (on a scale of 1 to 7) represents higher expropriation risk (lower institutional quality).



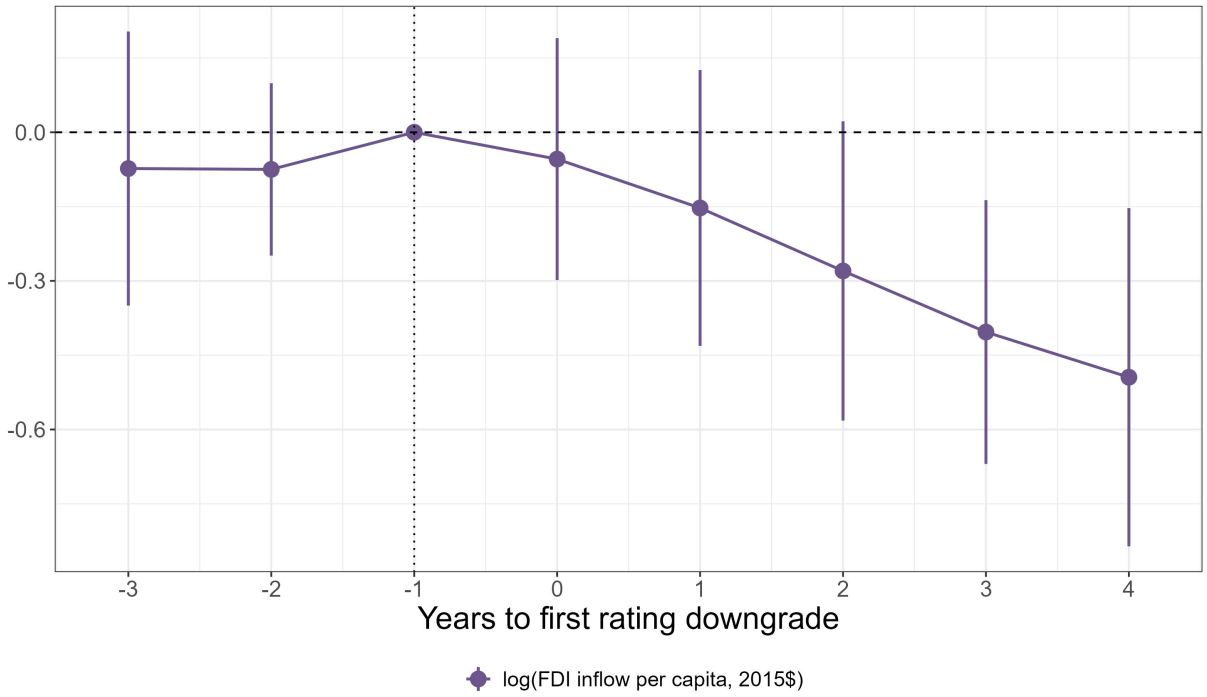
Appendix Figure A4. Frequencies of expropriation risk rating downgrades

Notes: Figure shows the frequency of Credendo expropriation risk rating downgrade experienced by each country. Countries without ratings shown in dark grey.

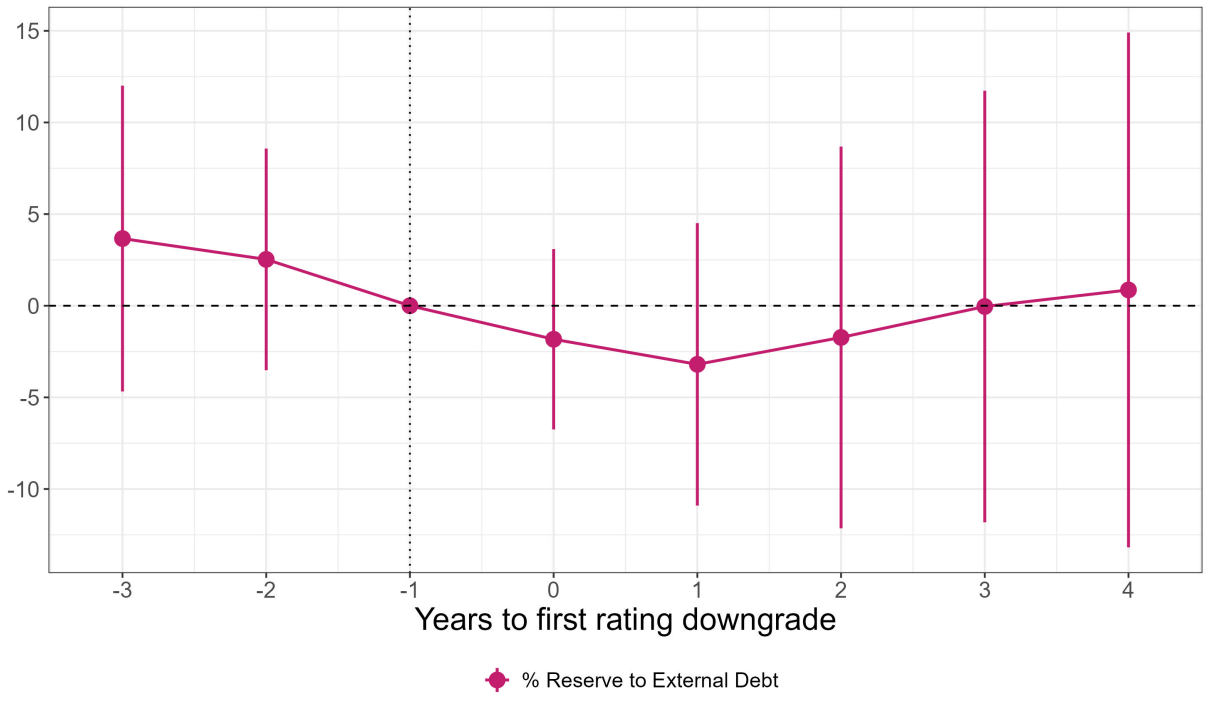


Appendix Figure A5. Frequencies of expropriation risk rating upgrades

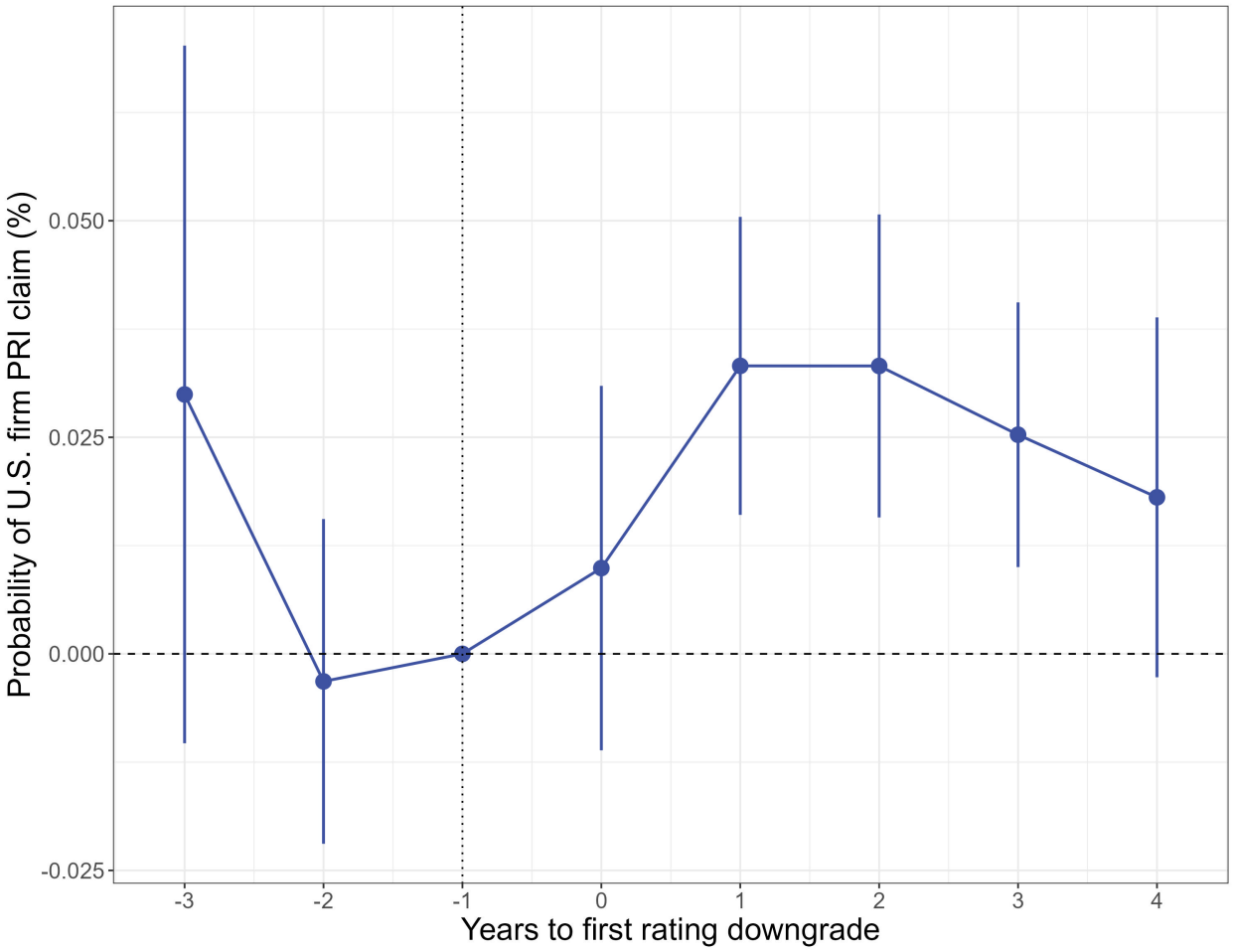
Notes: Figure shows the frequency of Credendo expropriation risk rating upgrade experienced by each country. Countries without ratings shown in dark grey.



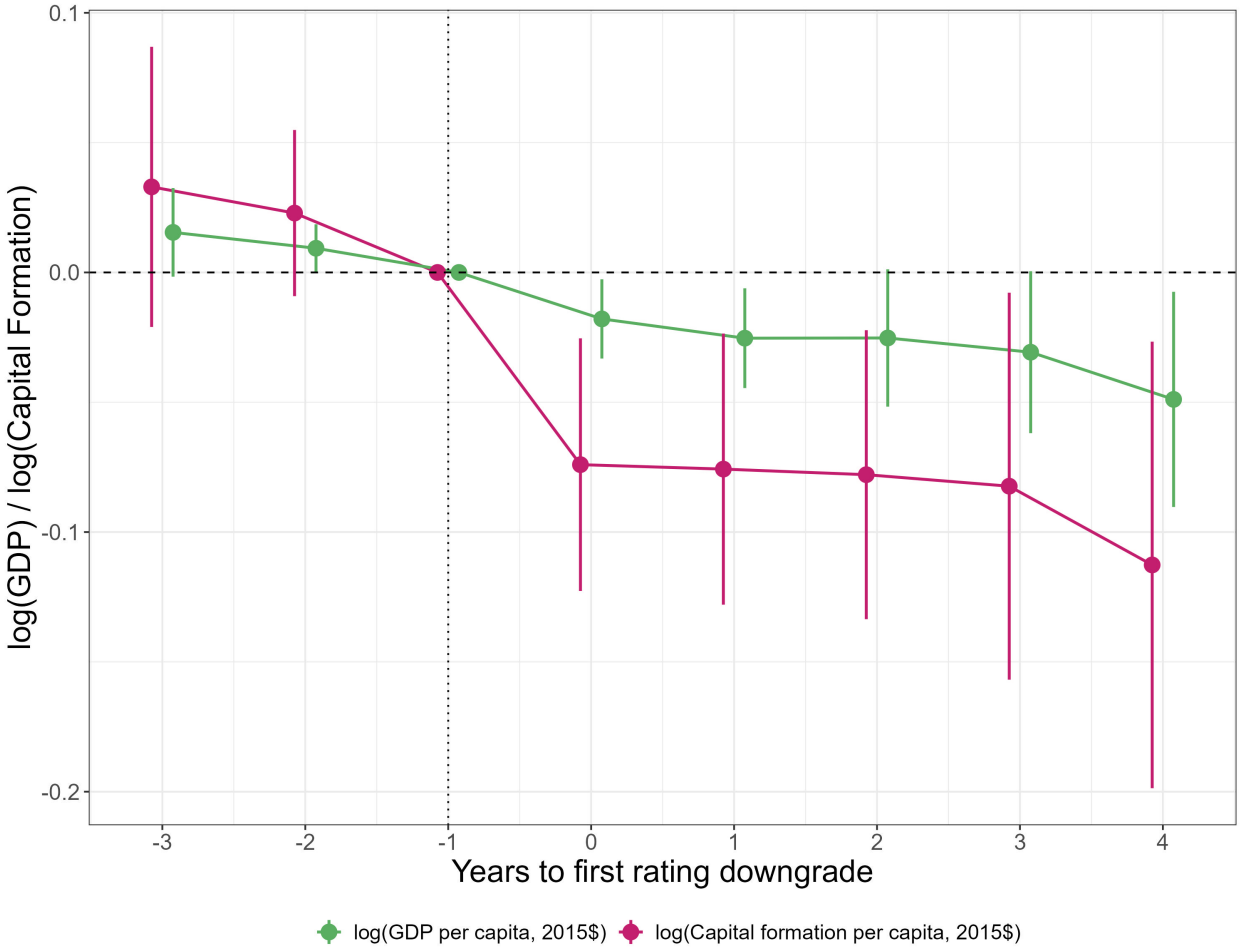
Appendix Figure A6. Credendo expropriation ratings and log of FDI per capita



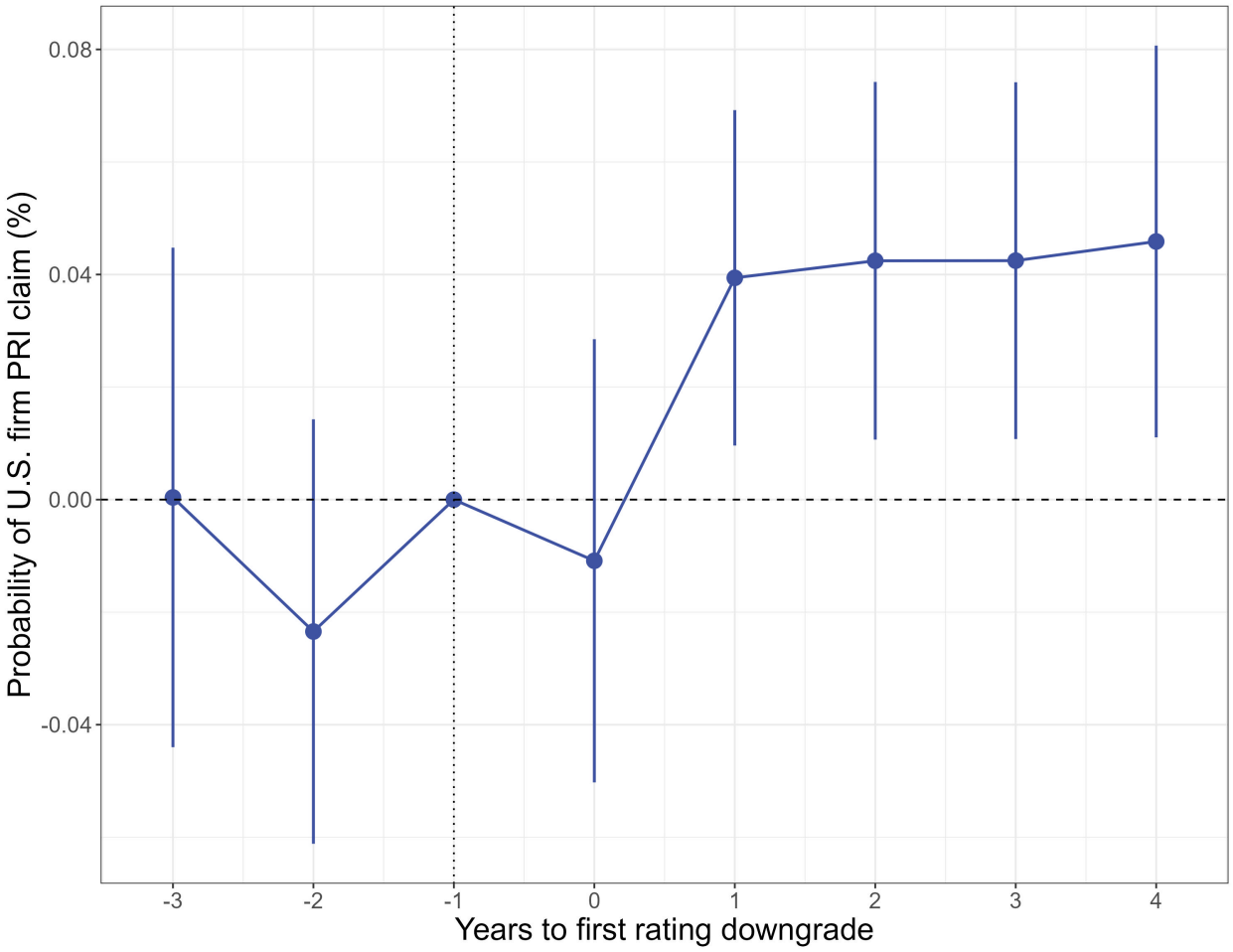
Appendix Figure A7. Credendo expropriation ratings and % of Reserve to External Debt



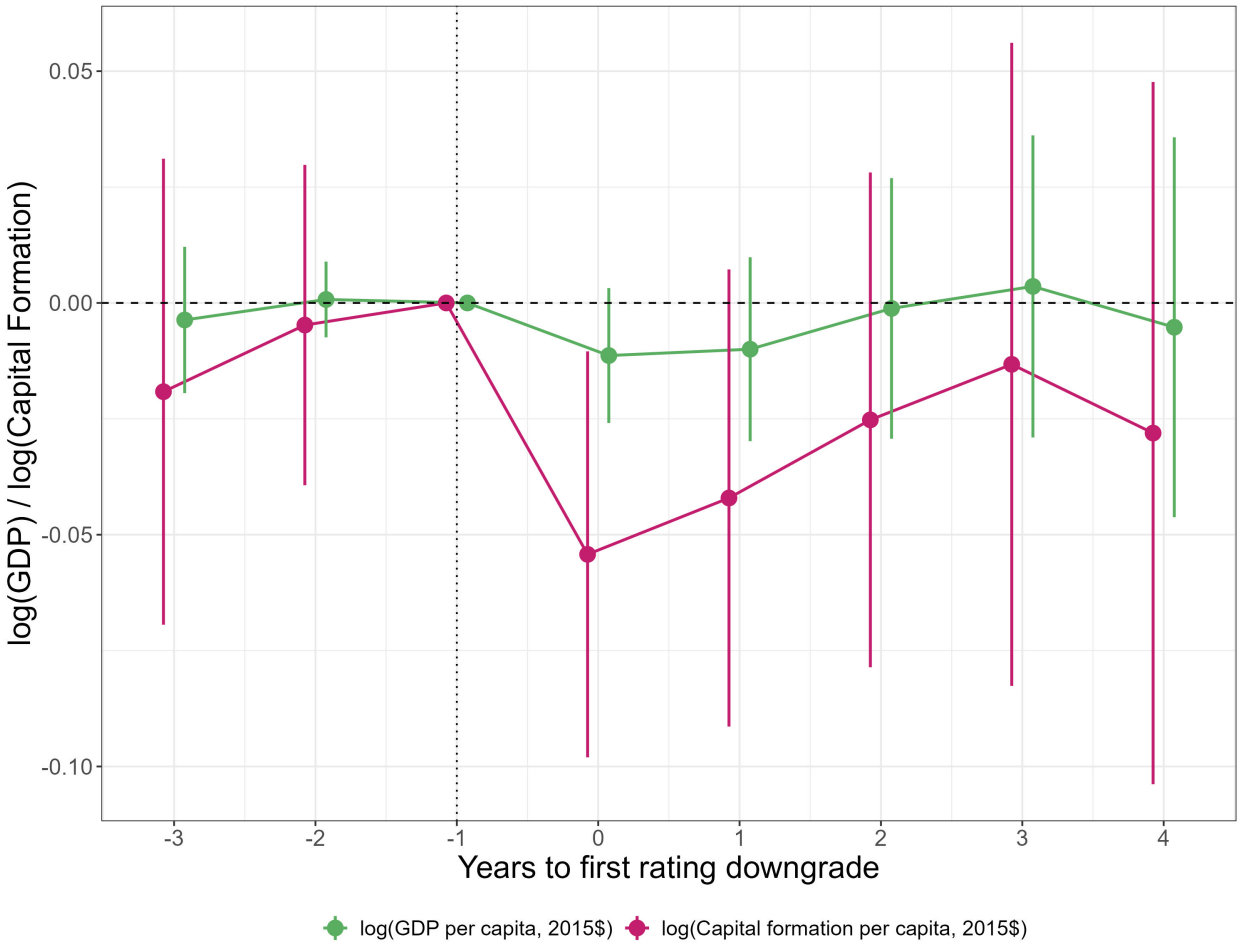
Appendix Figure A8. Downgrades and PRI claims, alternative control group



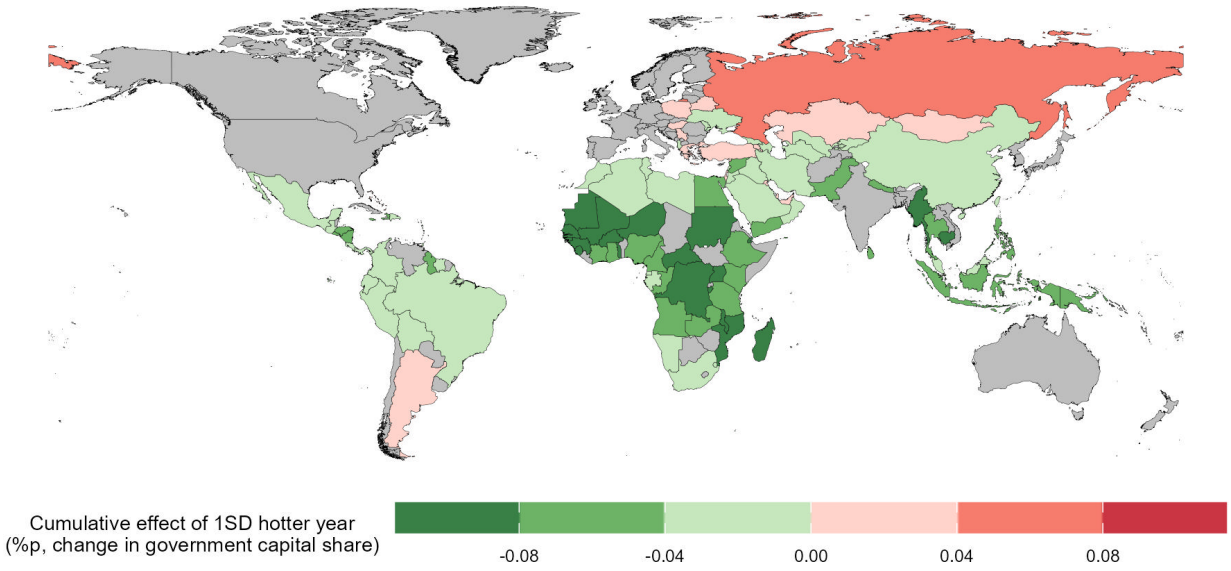
Appendix Figure A9. Downgrades and macroeconomic outcomes, alternative control group



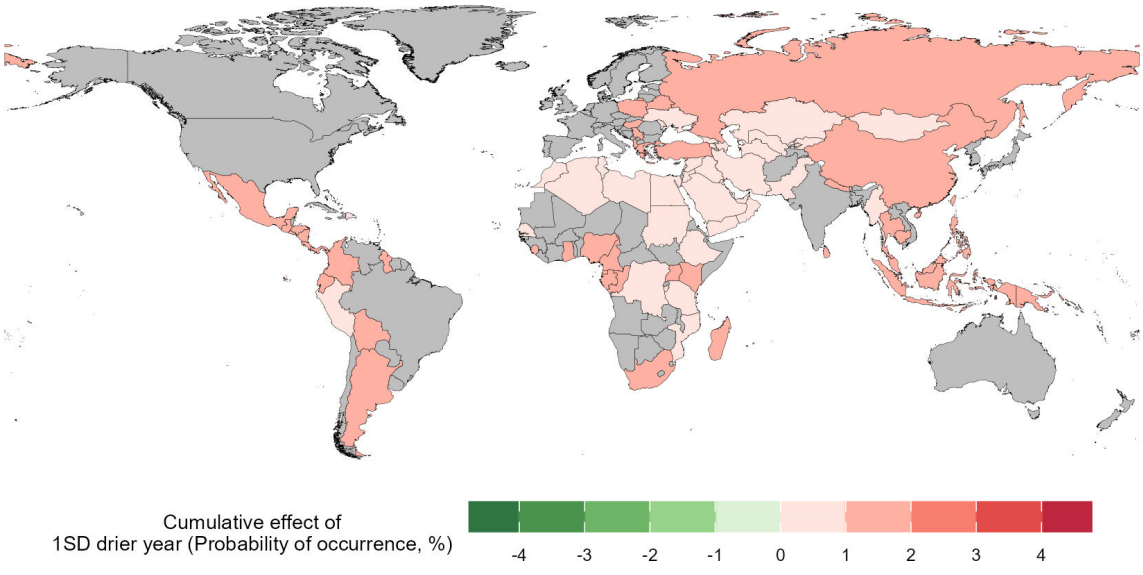
Appendix Figure A10. Downgrades and expropriation-related PRI claims



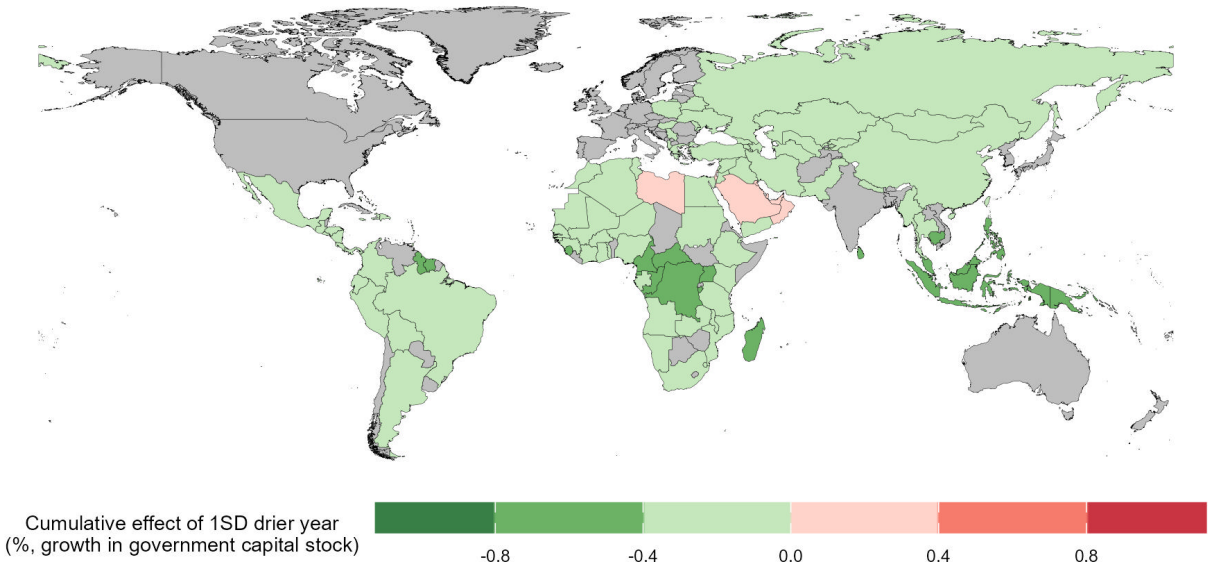
Appendix Figure A11. Downgrades and macroeconomic outcomes, unconditional



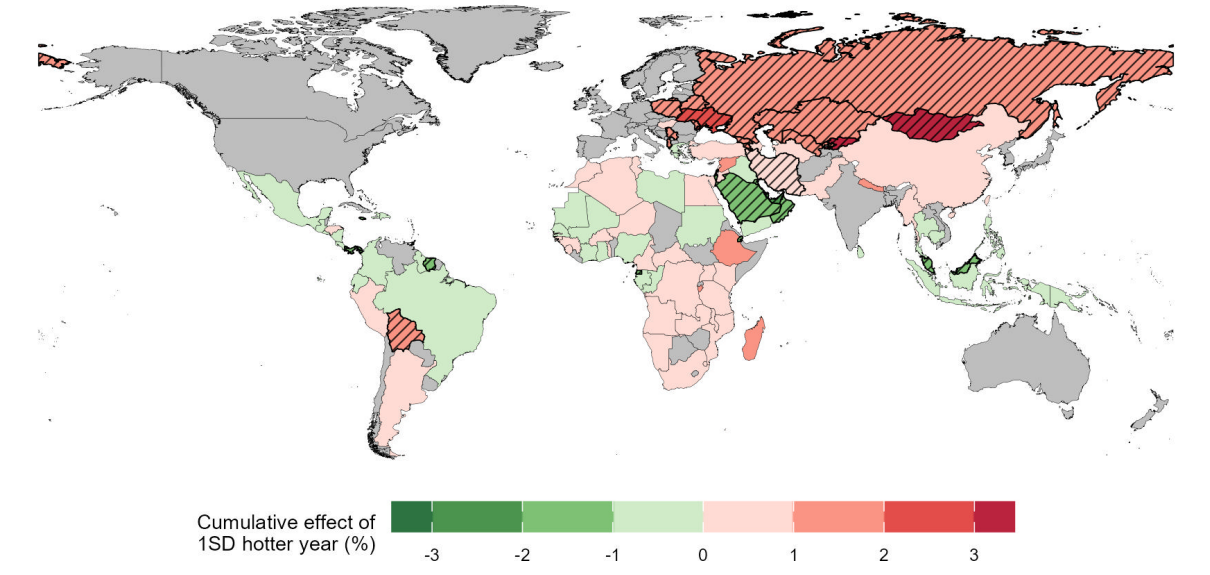
Appendix Figure A12. Temperature shocks and government capital stock share



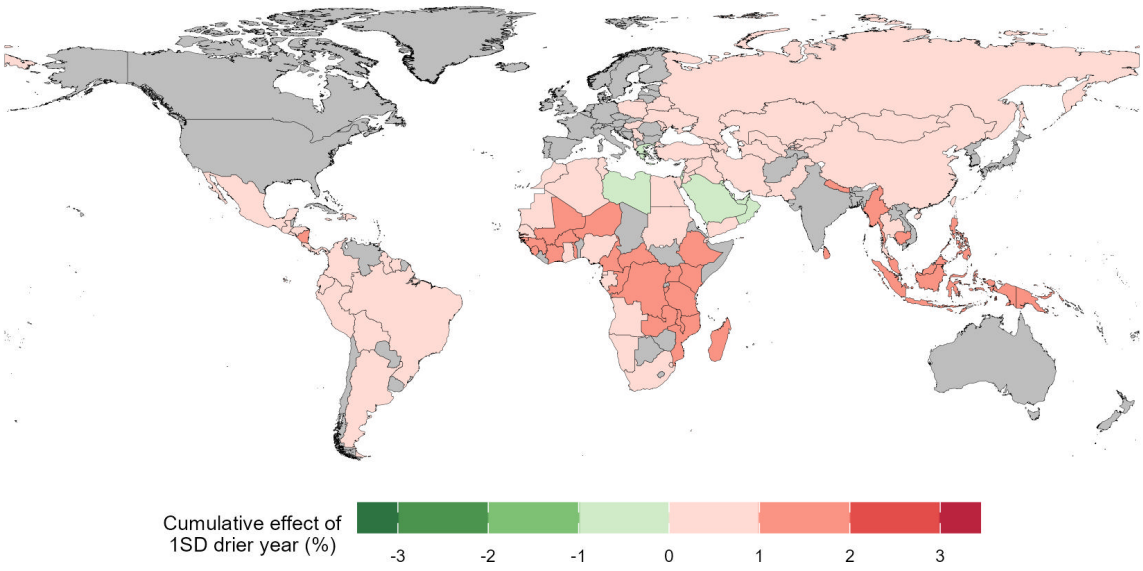
Appendix Figure A13. Precipitation shocks and expropriation cases



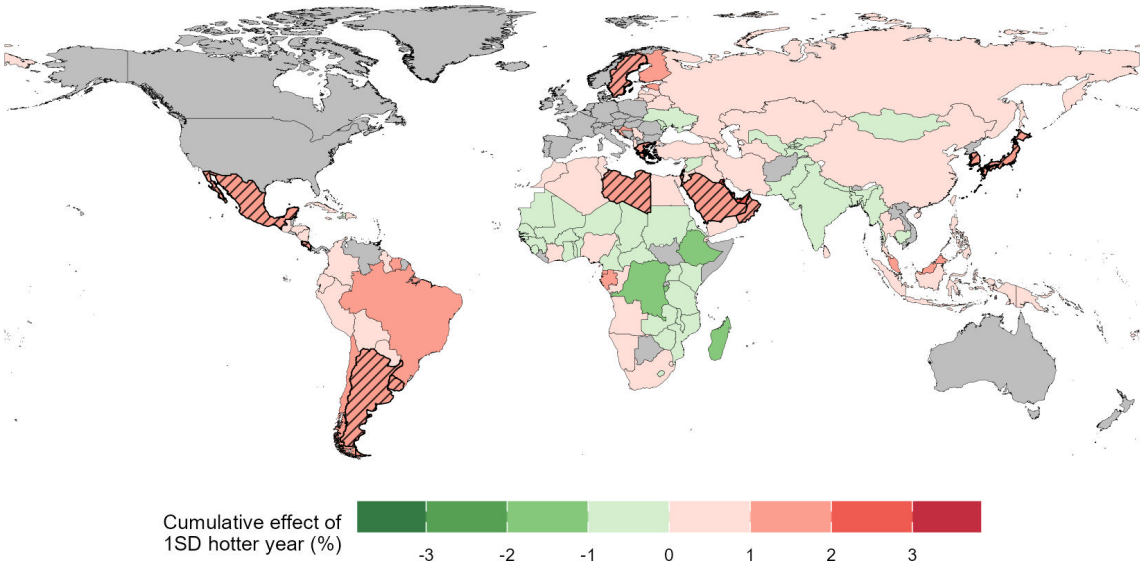
Appendix Figure A14. Precipitation shocks and government capital growth



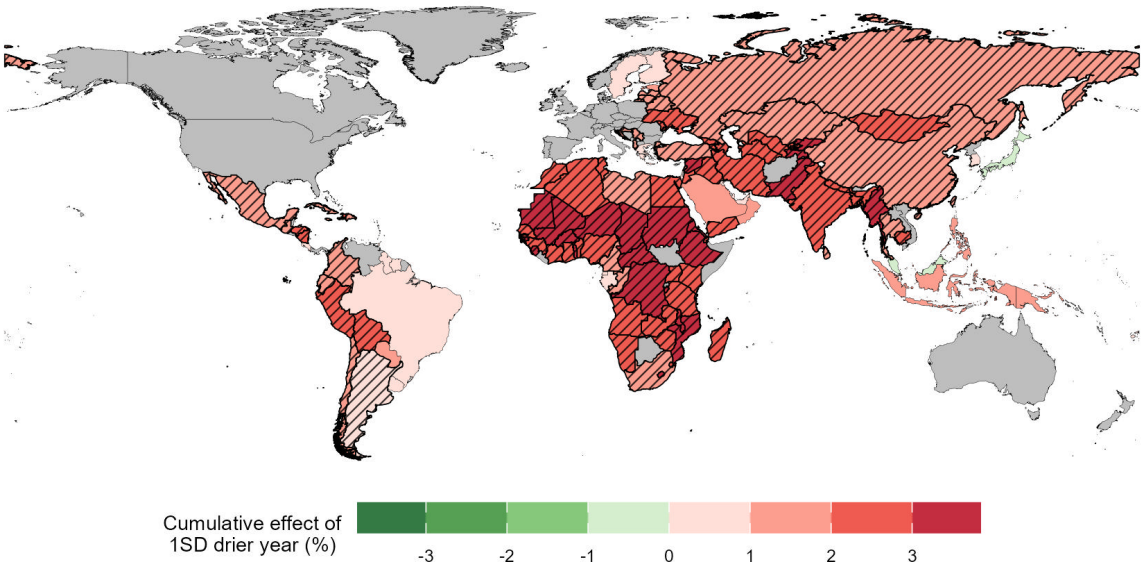
Appendix Figure A15. Temperature and political risk, no lags



Appendix Figure A16. Precipitation and political risk, no lags



Appendix Figure A17. Temperature and political violence rating downgrade



Appendix Figure A18. Precipitation and political violence rating downgrade