# Do Adaption Investments Reduce Borrower Credit Risk

Seminar

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# Agenda

## 1. Literature Review

- Key theoretical insights
- Connection to climate–sovereign risk literature
- Motivation for studying adaptation investments

## 2. Empirical Strategy

- Empirical design
- Model setup
- Data and variables
- Main specification
- Baseline model
- Robustness checks
- Interaction effects
- Event study
- Limitations
- Empirical Findings
- Policy implications

# What the Paper Finds

- The paper studies how **cyclones** affect a country's **debt, borrowing costs, and economic recovery**.
- The model is calibrated to **Mexico**,an important emerging market with frequent and severe cyclone exposure.
- **After a major cyclone:**
  - Capital, income, and consumption fall sharply.
  - Recovery is **very slow** — roughly **20 years** to return to trend.
  - Debt levels and sovereign spreads **remain elevated for decades**.

Source: Phan & Schwartzman (2024), *European Economic Review*.

# Mechanism: From Theory to Prediction

## The Vicious Cycle (Base Paper Mechanism)

A disaster strikes, destroying capital ($K_t$). This shrinks output ($Y_t$) and spikes the debt ratio ($b_t/Y_t$).

$$\textit{Disaster} \xrightarrow{\text{destroys}} \downarrow K_t \quad \Rightarrow \quad \downarrow Y_t \quad \Rightarrow \quad \uparrow \text{Default Risk} \quad \Rightarrow \quad \uparrow \text{Spreads}$$

# Interpreting the Mechanism: The Debt–Risk Feedback Loop

**Why the recovery does not naturally bounce back:**

- A cyclone reduces capital and GDP, which temporarily weakens the fiscal position.
- The government must borrow more to rebuild.
- Higher debt and lower output increase perceived default risk.
- Investors demand higher spreads, raising the cost of borrowing.
- Higher borrowing costs slow reconstruction, keeping capital low.

**These forces reinforce each other — this is the core feedback loop.**

# Financial Adaptation

**The core idea:** Financial adaptation is like building a financial ”safety net” for a country. It ensures that when a disaster strikes (like a hurricane or flood), the government has immediate access to cash to help people and rebuild.

**How does it help?**

- **Dampens the Risk:** Acts as a **shock absorber** for the economy, reducing the immediate blow to GDP.
- **Breaks the Vicious Cycle:** Prevents the government from spiraling into debt just to pay for recovery.
- **Smoothes Consumption:** Allows the government to maintain public spending (schools, hospitals) without severe cuts.

# Financial Adaptation: The Proposed Solutions

The paper evaluates two financial tools that might help countries recover faster after disasters:

**Disaster Insurance**

- Government pays a premium during normal years.
- When a disaster occurs, the insurer pays out **cash**.
- Helps smooth consumption and finance rebuilding.

**Catastrophe (CAT) Bonds**

- A special type of bond where the government **does not have to repay** investors if a major disaster occurs.
- In normal years: the government pays interest like a regular bond.
- After a big disaster: **payments are reduced or cancelled**, giving the government financial breathing room.

## Climate Change Has a Large, Long-Run Macroeconomic Cost

- Stronger cyclones (+10%) increase expected long-run welfare losses by **0.95% of permanent consumption**.

## Disasters Create Persistent Financial Stress

- After a shock, default risk rises sharply and remains elevated for many years.
- Spreads stay high because the country enters a “high-risk, low-capital” trap.
- Recovery of capital and output takes **around 20 years**.

## Limits of Financial Adaptation

- Disaster insurance offsets only **about 20%** of the climate-induced welfare loss.
- CAT bonds have **almost no long-run impact** because extra borrowing in good states offsets the benefits.
- Overall: financial tools soften but do not eliminate macro-financial vulnerability.

## Why Go Beyond the Theory?

- Theory predicts climate disasters raise sovereign default risk and that financial adaptation softens – but does not eliminate – these pressures.
- But the theory is entirely model-based: it tells us mechanisms, not whether financial markets actually price real-world adaptation

## Why study Real-World Adaptation Spending?

- Government increasingly invest in climate adaptation, yet it is unclear whether credit markets view these actions as improving resilience.
- If adaptation lowers expected losses from future disasters, then sovereign credit markets should reflect this through lower CDS spreads.
- This raises the empirical question: *Do adaptation investments reduce sovereign credit risk in practice?*

## Our Empirical Contribution

- We provide the first cross-country emperical test of whether adaptation spending lowers CDS spreads.
- We examine whether this effect differs across low-risk and high-risk countries.

# Our Core Idea: The Adaptation Lever

**Our Hypothesis (The Adaptation Lever)**

**Adaptation investment** protects capital stock ($K_t^{\text{protected}}$).

$$\uparrow \text{Adaptation} \quad \Rightarrow \quad \text{Stable } K_t \quad \Rightarrow \quad \text{Reduce shock} \quad \Rightarrow \quad \downarrow \text{5Y CDS}$$

# Empirical Design (Conceptual Framework)

**Approach:**

- Panel data for 44 countries (2009–2023)
- Compare CDS spreads across different adaptation investment levels
- Control for climate vulnerability, readiness, disaster exposure, macro fundamentals

**Key Idea:** If adaptation builds resilience, countries investing more in adaptation should exhibit lower CDS spreads.

# Model Construction

**Conceptual Relationship:** Adaptation ↑ → Resilience ↑ → Sovereign risk ↓

**Model Setup:**

- Panel OLS with country fixed effects and year fixed effects
- Standard errors clustered at the country level
- All continuous regressors standardized

# Data Sources & Variable Construction

## 1. Financial (Dependent Variable)

**Refinitiv / LSEG**

- Daily Sovereign 5-Year CDS Spreads.
- *Variable:* $\ln(\textit{Avg CDS})$

## 2. Macroeconomic Controls

**World Bank WDI**

- Debt-to-GDP, Inflation, GDP Growth, Reserves
- *Variables: Controls* $X_{it}$

## 3. Climate Adaptation (Independent)

**IMF COFOG & OECD**

- Public environmental protection spending (COFOG 5.4).
- *Variable: Adaptation Investment*

**ND-GAIN Index**

- Vulnerability & Readiness scores.
- *Variable: Readiness*

**EM-DAT Database**

- Disaster frequency & intensity.
- *Variable: Event Windows* $(t_0, t_2)$

# Data Overview

**Dependent Variables:**

- log(Average CDS)
- log(Median CDS) (Robustness)

**Main Explanatory Variables:**

- Adaptation investment as % of GDP
- ND-GAIN Vulnerability index
- ND-GAIN Readiness index
- EM-DAT climate disasters

**Controls:**

- Debt-to-GDP
- GDP growth
- Inflation
- Foreign reserves

**Sample Composition:**

- The panel consists mainly of **advanced and upper-middle-income economies** (e.g., AUS, AUT, FRA, JPN, SWE), with limited representation of highly climate-vulnerable low-income countries.
- We selected this sample because **CDS spread data and adaptation investment** are only consistently available for these countries.
- The final country list results from **overlapping datasets** to retain only those with complete observations for both CDS spreads and adaptation investment.

# Key Variable: Sovereign CDS Spread

**Definition**

- A credit default swap (CDS) spread is the **price of insurance against a country (or company) failing to repay its debt.**.
- Higher spreads mean investors perceive the country as **riskier**.

**Key components**

- Market-implied probability of default
- Risk premium demanded by investors
- Global financial conditions (risk-on/risk-off)
- Domestic fundamentals: fiscal balance, growth, inflation, institutions

# Key Variable: Adaptation Investment (COFOG 5.4)

**Definition**

- Government spending on environmental protection and climate adaptation, expressed as a share of GDP.
- Higher adaptation investment may enhance climate resilience and reduce sovereign risk over time.

**Key components**

- Waste management and wastewater treatment
- Pollution abatement
- Environmental protection n.e.c.
- R&D for environmental protection

# Key Variable: ND-GAIN Vulnerability

**Definition**

- Measures a country's exposure and sensitivity to climate-related risks.
- Higher values mean greater vulnerability and are expected to raise sovereign credit risk (higher CDS spreads).

**Key components**

- Food security
- Water security
- Health systems
- Ecosystem services
- Human habitat
- Infrastructure vulnerability

# Key Variable: ND-GAIN Readiness

**Definition**

- Measures a country's institutional, economic, and social capacity to implement climate adaptation.
- Higher readiness implies stronger adaptive capacity and may lower CDS spreads.

**Key components**

- Economic readiness (investment climate, macro stability)
- Governance readiness (institutions, regulatory effectiveness)
- Social readiness (education, communication, social capacity)

# Key Variable: DisasterCount (EM-DAT)

**Definition**

- Annual count of climate-related disasters recorded for each country.
- More frequent disasters increase physical and fiscal stress, raising perceived sovereign risk.

**Key components**

- Storms (cyclones, hurricanes)
- Floods (coastal, riverine, flash)
- Droughts
- Wildfires
- Extreme temperature events

# Macro Control Variables (WDI & WGI)

## 1. Debt-to-GDP

- Measures how large a country's government debt is compare to the size of its economy
- Higher debt burdens increase default probability and CDS spreads.

## 2. GDP Growth

- Signals economic performance and repayment capacity.
- Higher growth generally lowers sovereign credit risk.

## 3. Inflation

- Indicator of macroeconomic stability.
- High inflation increases uncertainty, risk premia, and default risk.

## 4. Foreign Reserves

- Provide external liquidity buffers during crises.
- Higher reserves reduce external vulnerability and CDS spreads.

# Final Empirical Specification

## Baseline Model

$$\log(CDS_{it}) = \alpha_i + \lambda_t + \beta_1 \text{Adapt}_{i,t-2} + \beta_2 \text{Vul}_{it} + \beta_3 \text{Ready}_{it} + \gamma' X_{it} + \varepsilon_{it}$$

## Expected Signs

- $\beta_1 < 0$: adaptation lowers CDS spreads
- $\beta_2 > 0$: vulnerability increases sovereign risk
- $\beta_3 < 0$: readiness improves resilience

## Estimation

- Two-way fixed effects (country + year)
- Clustered standard errors at the country level

# Distribution of Adaptation Investment Data

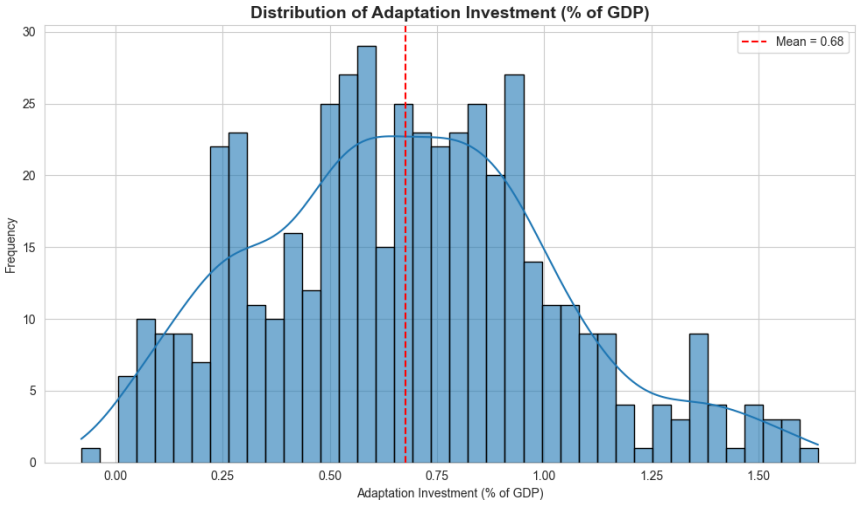


Figure: Distribution of Adaptation Investment (% of GDP) across the sample.

# Average Sovereign CDS Spread across Sample

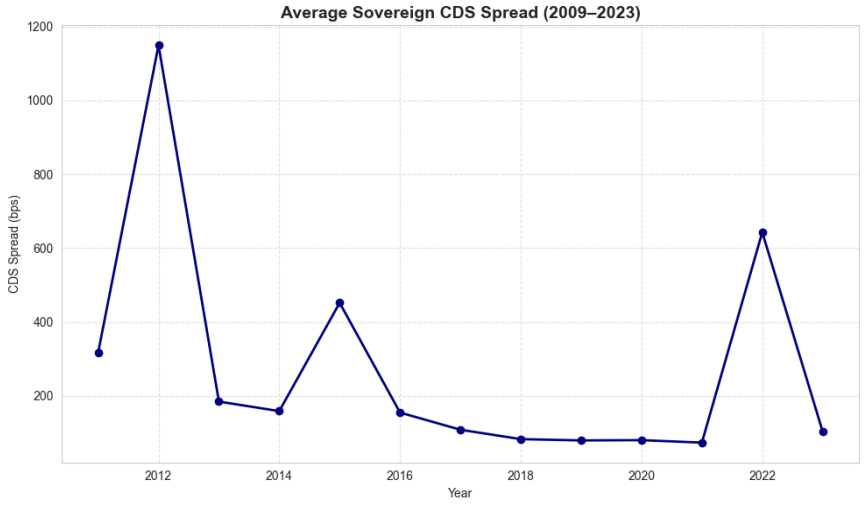


Figure: Average Sovereign CDS Spread across Sample.

# Relationship between Readiness and Vulnerability

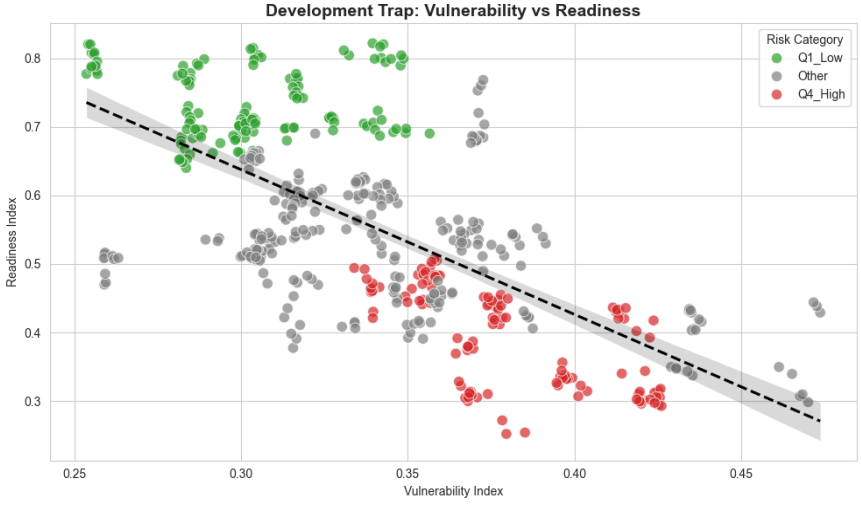


Figure: Relationship between z_Readiness and z_Vulnerability

# Baseline Model: Panel OLS Estimates (All Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Number of observations: **488** Entities: **44** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 4.3252 | 0.0107 | 405.28 | 0.0000 | 4.3042 | 4.3462 |
| z_AdaptInv_lag2 | -0.0773 | 0.1251 | -0.6175 | 0.5372 | -0.3232 | 0.1687 |
| z_Vulnerability | 0.2273 | 0.2379 | 0.9556 | 0.3398 | -0.2403 | 0.6949 |
| z_Readiness | -0.1169 | 0.2310 | -0.5063 | 0.6129 | -0.5710 | 0.3371 |
| **z_ln_DebtGDP** | **0.6095** | 0.1389 | 4.3879 | **0.0000** | 0.3365 | 0.8825 |
| **z_GDPgrowth** | **-0.2862** | 0.0649 | -4.4092 | **0.0000** | -0.4138 | -0.1586 |
| **z_Inflation** | **0.1182** | 0.0198 | 5.9806 | **0.0000** | 0.0794 | 0.1570 |
| z_Reserves | -0.0140 | 0.0120 | -1.1692 | 0.2430 | -0.0377 | 0.0096 |

Table: Baseline Panel OLS Estimates for log(Average CDS), All Countries.

$R^2$(Overall): 0.2061 **F-stat: 33.763** ($p < 0.01$) Poolability: 36.368 ($p < 0.01$)
$R^2$(Within): 0.0623

# Interpretation: Baseline Model (All Countries)

**Adaptation Investment (lag 2)**

- Negative but insignificant ($p = 0.537$).
- No evidence that adaptation spending lowers CDS spreads across all countries.

**Debt-to-GDP**

- Strongly positive and highly significant ($p = 0.000$).
- Higher indebtedness is a key driver of sovereign credit risk.

**GDP Growth**

- Strongly negative and significant ($p = 0.000$).
- Higher growth reduces sovereign default risk.

**Inflation**

- Positive and significant ($p = 0.000$).
- Macro instability increases perceived default probability.

**Summary**

- Macro fundamentals (debt, growth, inflation) dominate CDS pricing.
- Adaptation and climate vulnerability measures show weak pricing effects in the full sample.

# Baseline Model: Q1 (Low-Risk Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Number of observations: **132** Entities: **11** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 3.1789 | 0.5179 | 6.1376 | 0.0000 | 2.1516 | 4.2062 |
| **z_AdaptInv_lag2** | **0.2990** | 0.1440 | 2.0769 | **0.0403** | 0.0134 | 0.5846 |
| z_Vulnerability | 0.3259 | 0.4923 | 0.6621 | 0.5094 | -0.6504 | 1.3023 |
| z_Readiness | 0.1635 | 0.2557 | 0.6394 | 0.5240 | -0.3437 | 0.6707 |
| **z_ln_DebtGDP** | **0.5504** | 0.1788 | 3.0785 | **0.0027** | 0.1958 | 0.9050 |
| **z_GDPgrowth** | **-0.1180** | 0.0501 | -2.3544 | **0.0205** | -0.2175 | -0.0186 |
| **z_Inflation** | **0.2777** | 0.0989 | 2.8072 | **0.0060** | 0.0815 | 0.4738 |
| z_Reserves | -0.0985 | 0.0794 | -1.2397 | 0.2179 | -0.2560 | 0.0591 |

Table: Baseline Panel OLS Estimates for log(Average CDS), Q1 (Low-Risk Countries).

$R^2$(Within): -0.0072 **F-stat: 10.253** ($p < 0.01$) Poolability: 61.848 ($p < 0.01$)

# Interpretation: Baseline Model (Q1 Low-Risk Countries)

**Adaptation Investment (lag 2)**

- Positive and significant ($p = 0.040$).
- In low-risk countries, higher adaptation spending is associated with **higher** CDS spreads.
- Likely reflects **fiscal cost effects**: adaptation spending may crowd out fiscal space.

**Debt-to-GDP**

- Positive and highly significant ($p = 0.0027$).
- Debt remains a key determinant of sovereign risk, even in safer countries.

**GDP Growth**

- Negative and significant ($p = 0.020$).
- Growth reduces perceived sovereign risk in low-vulnerability countries.

**Inflation**

- Positive and significant ($p = 0.006$).
- Inflation concerns translate directly into higher credit risk.

**Summary**

- In low-risk countries, adaptation spending may signal **higher fiscal burden**, not resilience.

# Baseline Model: Q4 (High-Risk Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Number of observations: **116** Entities: **12** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 4.4534 | 1.1607 | 3.8367 | 0.0002 | 2.1456 | 6.7613 |
| **z_AdaptInv_lag2** | **-0.6352** | 0.2164 | -2.9349 | **0.0043** | -1.0656 | -0.2049 |
| z_Vulnerability | 0.1654 | 1.0014 | 0.1652 | 0.8692 | -1.8256 | 2.1565 |
| z_Readiness | -0.4089 | 0.3048 | -1.3419 | 0.1832 | -1.0149 | 0.1970 |
| **z_ln_DebtGDP** | **0.7611** | 0.3155 | 2.4122 | **0.0180** | 0.1338 | 1.3885 |
| **z_GDPgrowth** | **-0.3898** | 0.0540 | -7.2195 | **0.0000** | -0.4972 | -0.2825 |
| **z_Inflation** | **0.0806** | 0.0273 | 2.9523 | **0.0041** | 0.0263 | 0.1348 |
| z_Reserves | -0.1470 | 0.3094 | -0.4750 | 0.6360 | -0.7621 | 0.4682 |

Table: Baseline Panel OLS Estimates for log(Average CDS), Q4 (High-Risk Countries).

$R^2$(Overall): 0.2488 **F-stat: 186.67** ($p < 0.01$) Poolability: 10.741 ($p < 0.01$)
$R^2$(Within): 0.3785

# Interpretation: Baseline Model (Q4 High-Risk Countries)

**Adaptation Investment (lag 2)**

- Strongly negative and significant ($p = 0.004$).
- In high-risk countries, adaptation investment **reduces** CDS spreads.
- Markets reward adaptation where climate exposure is high.

**Debt-to-GDP**

- Positive and significant ($p = 0.018$).
- High debt increases sovereign vulnerability in climate-risk-intensive countries.

**GDP Growth**

- Strongly negative and highly significant ($p = 0.000$).
- Growth sharply reduces sovereign credit risk.

**Inflation**

- Positive and significant ($p = 0.004$).
- Inflation remains a consistent risk amplifier.

**Summary**

- Unlike Q1, adaptation in high-risk countries provides a **resilience premium**—reducing sovereign credit risk.
- Markets differentiate between “safe” and “exposed” countries when pricing adaptation.

# Relationship between Adaptation Investment lag 2 and Annual average CDS Spread

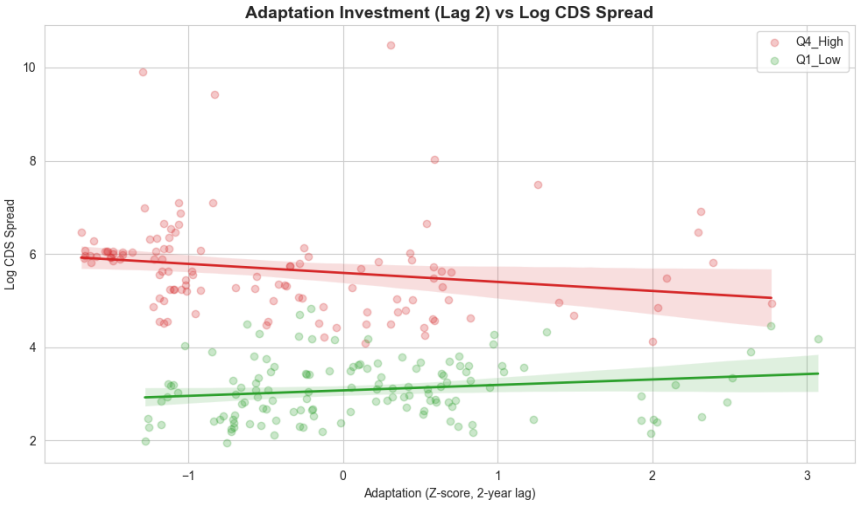


Figure: Relationship between Adaptation Investment Lag 2 and Log of Annual CDS Spread

# Resilience Premium: Effect of Adaptation Investment on CDS spread

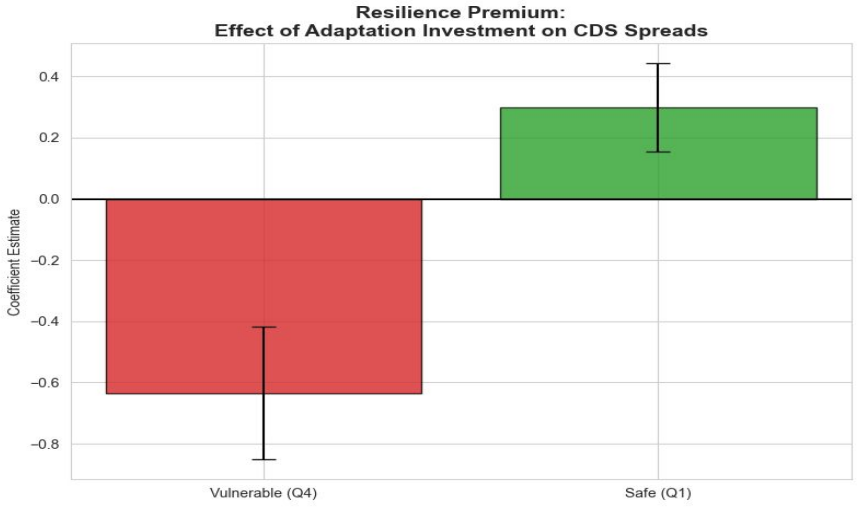


Figure: Effect of Adaptation Investment on CDS spread

# Robustness Check: Median CDS (Q1 Low-Risk Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Observations: **132** Entities: **11** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 3.2784 | 0.5336 | 6.1435 | 0.0000 | 2.2200 | 4.3369 |
| **z_AdaptInv_lag2** | **0.3443** | 0.1423 | 2.4201 | **0.0173** | 0.0621 | 0.6264 |
| z_Vulnerability | 0.3387 | 0.5205 | 0.6507 | 0.5167 | -0.6937 | 1.3711 |
| z_Readiness | 0.0777 | 0.2416 | 0.3216 | 0.7484 | -0.4015 | 0.5569 |
| **z_ln_DebtGDP** | **0.5515** | 0.1919 | 2.8747 | **0.0049** | 0.1710 | 0.9321 |
| **z_GDPgrowth** | **-0.1349** | 0.0519 | -2.5988 | **0.0107** | -0.2378 | -0.0319 |
| **z_Inflation** | **0.3084** | 0.1133 | 2.7223 | **0.0076** | 0.0837 | 0.5331 |
| z_Reserves | -0.0688 | 0.0637 | -1.0802 | 0.2826 | -0.1952 | 0.0576 |

Table: Robustness: log(Median CDS), Q1 Low-Risk Countries.

$R^2$(Overall): -0.2520 **F-stat: 6.8579** ($p < 0.01$) Poolability: 52.387 ($p < 0.01$)
$R^2$(Within): -0.0228

# Interpretation: Q1 Low-Risk Countries (Median CDS)

**Adaptation Investment (lag 2)**

- Positive and significant ($p = 0.017$).
- Markets interpret adaptation spending as a **fiscal burden**, not a resilience signal.

**Debt-to-GDP**

- Positive and significant ($p = 0.005$).
- High debt is the strongest driver of sovereign risk in low-risk countries.

**GDP Growth**

- Negative and significant ($p = 0.011$).
- Higher growth reduces CDS spreads even where baseline spreads are small.

**Inflation**

- Positive and significant ($p = 0.0076$).
- Inflation is heavily priced in low-risk sovereign markets.

**Summary**

- Adaptation **raises** risk in Q1 (consistent with Average CDS results).
- Macro fundamentals dominate sovereign risk pricing.

# Robustness Check: Median CDS (Q4 High-Risk Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Observations: **116** Entities: **12** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 4.3723 | 1.1060 | 3.9532 | 0.0002 | 2.1733 | 6.5713 |
| **z_AdaptInv_lag2** | **-0.6461** | 0.2195 | -2.9429 | **0.0042** | -1.0826 | -0.2096 |
| z_Vulnerability | 0.2261 | 0.9609 | 0.2353 | 0.8146 | -1.6844 | 2.1365 |
| z_Readiness | -0.4011 | 0.2842 | -1.4112 | 0.1618 | -0.9663 | 0.1640 |
| **z_ln_DebtGDP** | **0.7891** | 0.2984 | 2.6446 | **0.0097** | 0.1958 | 1.3825 |
| **z_GDPgrowth** | **-0.4073** | 0.0543 | -7.4967 | **0.0000** | -0.5153 | -0.2992 |
| **z_Inflation** | **0.0857** | 0.0271 | 3.1655 | **0.0021** | 0.0319 | 0.1395 |
| z_Reserves | -0.2102 | 0.3056 | -0.6876 | 0.4936 | -0.8179 | 0.3975 |

Table: Robustness: log(Median CDS), Q4 High-Risk Countries.

$R^2$(Overall): 0.2373 **F-stat: 266.63** ($p < 0.01$) Poolability: 10.947 ($p < 0.01$)
$R^2$(Within): 0.4026

# Interpretation: Q4 High-Risk Countries (Median CDS)

**Adaptation Investment (lag 2)**

- Strongly negative and significant ($p = 0.004$).
- Clear evidence of a **resilience premium**—adaptation lowers CDS spreads.

**Debt-to-GDP**

- Positive and significant ($p = 0.0097$).
- Debt concerns are magnified in climate-exposed sovereigns.

**GDP Growth**

- Strongly negative and significant ($p = 0.000$).
- Growth is the strongest stabilizer of sovereign risk in high-risk economies.

**Inflation**

- Positive and significant ($p = 0.0021$).
- Inflation shocks materially increase sovereign risk.

**Summary**

- Adaptation **reduces** CDS spreads (opposite of Q1).
- Markets reward resilience where climate risk is structurally high.

# Interaction Model: Adaptation × Vulnerability (All Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Observations: **488** Entities: **44** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 4.3363 | 0.0253 | 171.28 | 0.0000 | 4.2866 | 4.3861 |
| z_AdaptInv_lag2 | -0.0747 | 0.1231 | -0.6067 | 0.5443 | -0.3168 | 0.1673 |
| z_Vulnerability | 0.2416 | 0.2453 | 0.9851 | 0.3251 | -0.2405 | 0.7237 |
| z_Readiness | -0.1167 | 0.2316 | -0.5039 | 0.6146 | -0.5720 | 0.3386 |
| **Int_AdaptLag2_Vuln** | 0.0338 | 0.0596 | 0.5665 | 0.5713 | -0.0834 | 0.1510 |
| **z_ln_DebtGDP** | **0.6127** | 0.1397 | 4.3844 | **0.0000** | 0.3380 | 0.8873 |
| **z_GDPgrowth** | **-0.2854** | 0.0646 | -4.4179 | **0.0000** | -0.4124 | -0.1584 |
| **z_Inflation** | **0.1182** | 0.0195 | 6.0569 | **0.0000** | 0.0799 | 0.1566 |
| z_Reserves | -0.0142 | 0.0120 | -1.1775 | 0.2397 | -0.0378 | 0.0095 |

Table: Interaction Model: Adaptation × Vulnerability.

$R^2$(Overall): 0.1997 **F-stat: 37.353** ($p < 0.01$) Poolability: 36.008 ($p < 0.01$)
$R^2$(Within): 0.0607

# Interpretation: Adaptation × Vulnerability

**Interaction Term: Adaptation × Vulnerability**

- Coefficient is small and insignificant ($p = 0.571$).
- No evidence that adaptation affects CDS **differently** for more vulnerable countries.
- Markets do **not** price adaptation effectiveness based on vulnerability alone.

**Main Effects**

- Adaptation (lag 2): insignificant — no direct effect on average CDS in full sample.
- Vulnerability: insignificant — vulnerability by itself is not strongly priced.

**Macro Controls**

- Debt-to-GDP, inflation, and growth remain **highly significant**, consistent with prior models.
- Macro stability still dominates market pricing of sovereign risk.

**Summary**

- Adaptation does **not** generate a differential effect for vulnerable countries.
- Markets may believe adaptation is insufficient or too slow to offset vulnerability risks.

# Interaction Model: Adaptation × Readiness (All Countries)

Estimated via Panel OLS (Fixed Effects) with clustered SEs.
Observations: **488** Entities: **44** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| const | 4.2351 | 0.0278 | 152.09 | 0.0000 | 4.1803 | 4.2898 |
| z_AdaptInv_lag2 | -0.0697 | 0.1090 | -0.6394 | 0.5229 | -0.2840 | 0.1446 |
| z_Vulnerability | 0.3368 | 0.2393 | 1.4078 | 0.1599 | -0.1334 | 0.8071 |
| z_Readiness | -0.0620 | 0.2113 | -0.2937 | 0.7692 | -0.4773 | 0.3532 |
| **Int_AdaptLag2_Readiness** | **0.2562** | 0.0779 | 3.2871 | **0.0011** | 0.1030 | 0.4094 |
| **z_ln_DebtGDP** | **0.6203** | 0.1287 | 4.8203 | **0.0000** | 0.3673 | 0.8732 |
| **z_GDPgrowth** | **-0.2898** | 0.0656 | -4.4193 | **0.0000** | -0.4188 | -0.1609 |
| **z_Inflation** | **0.1286** | 0.0201 | 6.3996 | **0.0000** | 0.0891 | 0.1681 |
| z_Reserves | -0.0168 | 0.0110 | -1.5306 | 0.1266 | -0.0385 | 0.0048 |

Table: Interaction Model: Adaptation × Readiness.

$R^2$(Overall): 0.1898 **F-stat: 47.189** ($p < 0.01$) Poolability: 38.259 ($p < 0.01$)
$R^2$(Within): 0.1071

# Interpretation: Adaptation × Readiness

**Interaction Term: Adaptation × Readiness**

- Positive and highly significant ($p = 0.001$).
- Adaptation is **more effective** in countries with strong readiness.
- Markets reward adaptation if institutions and governance can implement it efficiently.

**Economic Meaning**

- Adaptation spending in high-readiness countries produces a **risk-reducing effect**.
- Institutional strength enhances the credibility and impact of adaptation efforts.

**Macro Controls**

- Debt, inflation, and growth remain significant — macro stability continues to matter.

**Summary**

- Vulnerability alone does NOT moderate adaptation effectiveness.
- But **readiness strongly amplifies** the beneficial effects of adaptation.
- Markets believe that "good institutions make adaptation work."

# Event Study (Q4 High-Risk Countries): DisasterCount $\geq 3$

Estimated via Panel OLS (EventID FE + Time FE) with clustered SEs.
Observations: **187** Entities (EventID): **32** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| t-3 | -0.0941 | 0.0831 | -1.1328 | 0.2594 | -0.2584 | 0.0702 |
| t-2 | 0.0399 | 0.0764 | 0.5222 | 0.6024 | -0.1113 | 0.1911 |
| t0 | -0.0990 | 0.0654 | -1.5139 | 0.1325 | -0.2283 | 0.0304 |
| t1 | -0.0655 | 0.0407 | -1.6122 | 0.1093 | -0.1460 | 0.0149 |
| t2 | -0.0266 | 0.0858 | -0.3100 | 0.7571 | -0.1964 | 0.1432 |
| z_Vulnerability | 1.0349 | 1.3585 | 0.7618 | 0.4475 | -1.6525 | 3.7224 |
| z_Readiness | -0.6025 | 0.3907 | -1.5422 | 0.1254 | -1.3753 | 0.1704 |
| **z_AdaptInv_lag2** | **-0.5296** | 0.1013 | -5.2276 | **0.0000** | -0.7300 | -0.3292 |
| z_ln_DebtGDP | 0.5299 | 0.3121 | 1.6983 | 0.0918 | -0.0874 | 1.1473 |
| **z_GDPgrowth** | **-0.2806** | 0.0945 | -2.9697 | **0.0035** | -0.4675 | -0.0937 |
| **z_Inflation** | **0.1665** | 0.0266 | 6.2527 | **0.0000** | 0.1138 | 0.2191 |
| z_Reserves | -0.1883 | 0.1869 | -1.0072 | 0.3157 | -0.5580 | 0.1815 |

Table: Event Study (Q4 High-Risk): Impact of Climate Disasters on log(Average CDS).

$R^2$(Overall): 0.5871 **F-stat:** $3.16 \times 10^{15}$ ($p < 0.01$) Poolability: 11.234 ($p < 0.01$)
$R^2$(Within): 0.4493

# Event Study: CDS Reaction to major Disaster (High-Risk Countries)

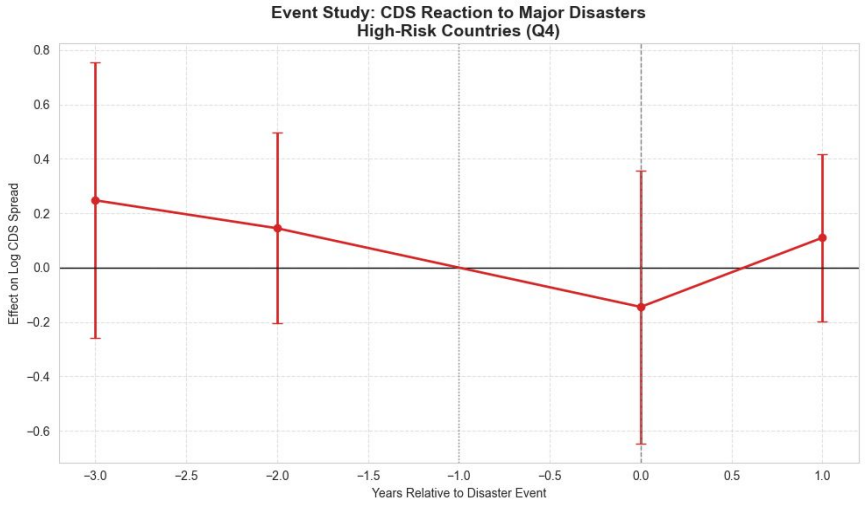


Figure: CDS Reaction to major Disaster Event for High Risk Countries

# Interpretation: Event Study (Q4 High-Risk Countries)

**Main Disaster Effects**

- No significant anticipation effects (t–3, t–2).
- Event-year effect (t0): negative but insignificant.
- Post-event effects (t1, t2): also insignificant.

**Interpretation**

- High-risk (Q4) countries do **not** experience CDS spikes from climate disasters with DisasterCount $\geq 3$.
- Markets may already price high structural climate and macro risk into spreads.

**Key Significant Variables**

- **Adaptation (lag 2):** strongly negative and significant — adaptation lowers CDS in high-risk states.
- **GDP growth:** significantly reduces CDS.
- **Inflation:** strongly increases CDS.

**Climate Fundamentals**

- Vulnerability and readiness are insignificant during disaster windows.

**Summary**

- Disasters do not destabilize CDS in Q4 countries.

# Event Study (Q1 Low-Risk Countries): DisasterCount $\geq 3$

Estimated via Panel OLS (EventID FE + Time FE) with clustered SEs.
Observations: **196** Entities (EventID): **33** Time periods: **13**

| Variable | Coef | StdErr | t | P | Lower CI | Upper CI |
|---|---|---|---|---|---|---|
| t-3 | 0.0009 | 0.0295 | 0.0316 | 0.9749 | -0.0574 | 0.0592 |
| t-2 | 0.0040 | 0.0186 | 0.2137 | 0.8311 | -0.0327 | 0.0407 |
| t0 | -0.0053 | 0.0085 | -0.6243 | 0.5334 | -0.0222 | 0.0115 |
| t1 | -0.0107 | 0.0112 | -0.9561 | 0.3407 | -0.0329 | 0.0114 |
| t2 | -0.0552 | 0.0330 | -1.6750 | 0.0962 | -0.1204 | 0.0100 |
| z_Vulnerability | 0.6063 | 0.3196 | 1.8968 | 0.0599 | -0.0257 | 1.2383 |
| z_Readiness | 0.1090 | 0.1253 | 0.8696 | 0.3860 | -0.1388 | 0.3568 |
| **z_AdaptInv_lag2** | **0.4094** | 0.0784 | 5.2229 | **0.0000** | 0.2544 | 0.5644 |
| z_ln_DebtGDP | 0.2183 | 0.2009 | 1.0869 | 0.2790 | -0.1788 | 0.6155 |
| **z_GDPgrowth** | **-0.1216** | 0.0588 | -2.0692 | **0.0404** | -0.2378 | -0.0054 |
| z_Inflation | 0.2020 | 0.1598 | 1.2643 | 0.2082 | -0.1139 | 0.5180 |
| **z_Reserves** | **-0.1500** | 0.0727 | -2.0625 | **0.0410** | -0.2938 | -0.0062 |

Table: Event Study (Q1 Low-Risk): Impact of Climate Disasters on log(Average CDS).

$R^2$(Overall): -0.1582 **F-stat:** $4.71 \times 10^{15}$ ($p < 0.01$) Poolability: 33.583 ($p < 0.01$)
$R^2$(Within): 0.2094

# Interpretation: Event Study (Q1 Low-Risk Countries)

**Main Disaster Effects**

- Pre-event periods (t–3, t–2) show no CDS movement → this supports parallel trends.
- Event-year effect (t0): small and insignificant.
- t2 shows a mild negative effect ($p \approx 0.096$), but it is not statistically strong.

**Key Significant Variables**

- **Adaptation (lag 2):** strongly positive — adaptation increases CDS in Q1 countries.
- **GDP growth:** reduces CDS.
- **Reserves:** negative and significant — liquidity buffers lower risk.

**Interpretation**

- In low-risk countries, disasters do not significantly impact CDS spreads.
- Markets may view these states as having a strong disaster response capacity.
- A positive adaptation coefficient suggests:
  - adaptation spending may be countercyclical (higher spending → bad times),
  - or markets interpret increases as fiscal pressure, not resilience.

**Summary**

- Disasters do not raise CDS in Q1 countries.
- Adaptation is priced **negatively in Q4 but positively in Q1**, showing strong heterogeneity.

# Limitations

## Data & Sample Constraints

- The sample includes mostly **advanced and upper–middle–income economies**; highly vulnerable low-income countries are underrepresented.
- The availability of CDS data creates **selection bias**, excluding many climate-exposed sovereigns.
- The adaptation proxy (COFOG 5.4) is an **imprecise measure** of true climate adaptation spending.

## Identification & Measurement Challenges

- Adaptation spending may be **endogenous** (reactive to worsening conditions), raising concerns about reverse-causality.
- Vulnerability and readiness indices are **slow-moving**, limiting within-country variation for FE estimation.
- Very low within $R^2$ in Q1 models suggests important **omitted factors** in CDS dynamics.

## Modeling Limitations

- DisasterCount $\geq 3$ aggregates heterogeneous shocks, limiting causal interpretation in event studies.
- Global financial conditions (e.g., VIX, U.S. rates) not explicitly modeled beyond year FE.
- Mechanisms behind heterogeneous effects (Q1 vs. Q4) remain **unobserved in regressions**.

# Empirical Findings

**1. Adaptation Spending**

- Overall: No clear effect on CDS spreads.
- High-risk countries (Q4): Adaptation reduces sovereign risk.
- Low-risk countries (Q1): Adaptation raises CDS spreads — likely due to fiscal pressure or reactive spending.

**2. Climate Vulnerability & Readiness**

- Vulnerability: No significant effect.
- Readiness: Not important on its own, but essential when combined with adaptation.
- Adaptation $\times$ Readiness: Positive and significant — adaptation works better when institutions are strong.

**3. Macro Fundamentals**

- Higher GDP growth $\rightarrow$ lower CDS spreads.
- Higher inflation & debt $\rightarrow$ higher CDS spreads.
- Markets still prioritize macro stability over climate variables.

**4. Event Study (DisasterCount $\geq$ 3)**

- No big CDS spikes after climate disasters.
- Adaptation lowers risk in Q4 but increases risk in Q1.
- Reserves help stabilize low-risk countries.

# Policy Implications

- Adaptation is more effective when governments are capable, transparent, and well-organized.
- Countries most exposed to climate risk need both climate resilience and financial resilience.
- Low-risk countries should invest wisely so that climate spending doesn’t increase debt or weaken public finances.
- Improving macro fundamentals remains the most reliable way to reduce sovereign risk.

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# Appendix: Data Sample (44 Countries)

**Sample Period:** 2009–2023 **Total Entities:** 44

| | | | |
|---|---|---|---|
| Australia (AUS) | Austria (AUT) | Belgium (BEL) | Bulgaria (BGR) |
| Brazil (BRA) | Canada (CAN) | China (CHN) | Costa Rica (CRI) |
| Cyprus (CYP) | Czech Rep. (CZE) | Germany (DEU) | Denmark (DNK) |
| Egypt (EGY) | Spain (ESP) | Estonia (EST) | Finland (FIN) |
| France (FRA) | United Kingdom (GBR) | Greece (GRC) | Croatia (HRV) |
| Hungary (HUN) | Indonesia (IDN) | Ireland (IRL) | Iceland (ISL) |
| Israel (ISR) | Italy (ITA) | Japan (JPN) | Kazakhstan (KAZ) |
| Lithuania (LTU) | Latvia (LVA) | Netherlands (NLD) | Norway (NOR) |
| New Zealand (NZL) | Poland (POL) | Portugal (PRT) | Romania (ROU) |
| El Salvador (SLV) | Serbia (SRB) | Slovakia (SVK) | Slovenia (SVN) |
| Sweden (SWE) | Thailand (THA) | Ukraine (UKR) | South Africa (ZAF) |

# Data Sources & Overview

**Data Sources :**

- **IMF COFOG (Climate Adaptation Investment)**
  Government expenditure data, including COFOG 5.4 (Environmental Protection and Adaptation).
  https://data.imf.org/en/Data-Explorer
- **Refinitiv / LSEG (Sovereign CDS Data)**
  Daily sovereign credit default swap (CDS) spreads for 5-year.
  https://developers.lseg.com/
- **ND-GAIN Index (Vulnerability and Readiness)**
  Measures climate vulnerability and readiness across countries.
  https://gain.nd.edu/our-work/country-index/rankings/
- **World Bank WDI (Macro Controls)**
  Provides macroeconomic variables: debt-to-GDP, GDP growth, inflation, reserves, governance.
  https://databank.worldbank.org/home
- **EM-DAT Disaster Database**
  Annual counts of climate-related disasters (storms, floods, droughts, etc.).
  https://public.emdat.be/
- **OECD (Adaptation Framework Reference)**
  OECD Climate Adaptation Investment Framework (2024). https://www.oecd.org