Natural Disasters, Climate Change, and Sovereign Risk

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Motivation

Erce et al. (2020): identify, review, and analyze domestic sovereign defaults since the 1980s

- Wide range of shocks may tip countries with fiscal vulnerabilities in a sovereign debt crisis:
  - Domestic shocks (i.e. banking crises, political uncertainty)
  - International shocks (i.e fluctuations of commodity prices or risk-free rate)
  - Disasters (i.e. pandemics, wars, natural disasters)

Motivation II

- The literature has analyzed some of these triggers:
  - Business cycle fluctuations (Arellano, 2008)
  - Price of commodities (Reinhart et al., 2016)
  - Financial crises (Baltenau et al., 2018)
  - Political uncertainty (Cuadra et al., 2008)
- Yet, studies on disasters have been lagging behind
  - Wars (Horn et al., 2020)
  - Pandemics (Arellano et al., 2020)
  - Natural disasters

Motivation III

Natural disasters appear especially salient:

- They have played an important role in recent default episodes (Moldova 1993, Ecuador 1997, Suriname 1998, Grenada 2004, Antigua y Barbuda 2004-2009,...)
- Their frequency and intensity is expected to increase amid climate change
- Evidence that vulnerabilities to climate change affects sovereign borrowing costs (Cevik et al. 2020)
- Recent emphasis on natural disaster risk in macroeconomic risk management

Motivation IV

Caribbean countries are especially vulnerable to extreme weather:

- They are regularly hit by major hurricanes
- They are small: natural disasters have a nation-wide impact

Some Caribbean countries have began to issue bonds with disaster clauses:

- Debt moratorium if the economy is struck by natural disasters
- Official lenders have endorsed disaster clauses

Grenada

Research Questions

- How do natural disasters affect sovereign risk?
- How will climate change affect governments' borrowing terms in the future?
- Can disaster clauses help?

I answer these questions through the lens of a sovereign default model that I calibrate to a sample of 7 countries:

- Antigua y Barbuda, Belize, Dominican Republic, Dominica, Grenada, Honduras, and Jamaica

Results

- Natural disasters reduce governments' ability to borrow
- Climate change will further reduce market access
- Disaster clauses improve governments' access to financial markets, but may lead to overborrowing
    - Debt limits may be needed in conjunction with disaster clauses

Model

Model Highlights

Endogenous sovereign default model á la Eaton-Gersovitz (1981) that I modify to:

- Allow for long-term debt (Hatchondo et al., 2009)
- Account for natural disasters
  - Exogenous disaster risk - Hurricane risk

Government Problem

Government is benevolent and takes the borrowing and default decisions in three steps:

1. Chooses the borrowing policy b' that maximizes households' lifetime utility in the non-default scenario
2. Computes households' value function in the default scenario
3. Takes the default decision comparing households' value functions in the default and non-default scenarios

Government Problem: Key Features

- Government bonds are perpetuities with decay parameter ψ

$$q\left(y,h,b\right)=\frac{1}{\left(1+r^{rf}\right)}E\left[\left(1-d'\right)+\left(1-\psi\right)\left(1-d'\right)q'\right].$$

- Income process is subject to disaster risk:

$$\log(y')=\rho\log(y)-\xi h+\epsilon^{y}$$

- $h=\begin{cases}p_h & \mathcal{N}\left(\mu_h,\sigma_h\right)\\ 1-p_h & 0\end{cases}$
- ξ is an indicator that is equal to one when $h\neq 0$

Model

Calibration

Model is calibrated to reproduce 7 Caribbean economies at the annual frequency. 3 sets of parameters:

1. Parameters that differ across countries:
   - Income process parameters: GDP data from 1980 to 2019
   - Disaster risk parameters: frequency and intensity of major hurricanes (Cat. III and above)
2. Parameters that are the same in every country: Risk aversion, re-entry probability, and the risk-free rate
3. Parameters that are jointly calibrated to match spreads and debt-to-GDP ratios:
   - Discount factor and output costs of defaults

Calibration

Panel A: Common Parameters

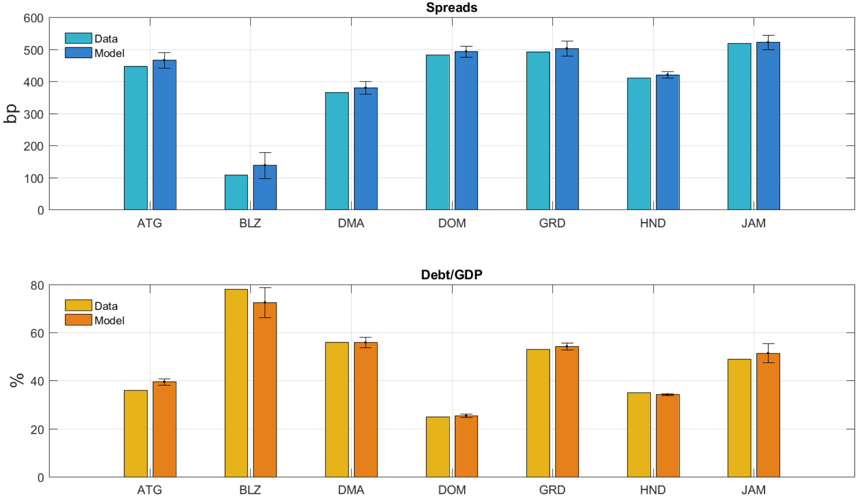
Moment		Value	Source/Target Statistic
Relative risk aversion	γ	2	Standard
Readmission probability	λ	0.33	Dias et al. 2009
Rik free rate	r^{rf}	0.0451	US T-Bill

Panel B: Country-Specific Parameters

Moment		ATG	BLZ	DMA	DOM	GRD	HND	JAM	Source/Target
Duration	ψ	0.0824	0.0442	0.0467	0.1731	0.0612	0.1639	0.0564	Maturity
Hurr. frequency	p_h	0.103	0.077	0.026	0.051	0.051	0.051	0.103	NOAA
y autocorr.	ρ_y	0.92	0.99	0.94	0.88	0.91	0.83	0.96	GDP/GNI WB
y std	σ_y	0.046	0.036	0.027	0.046	0.052	0.026	0.026	GDP/GNI WB
mean Hurr. loss	μ_h	0.049	0.021	0.098	0.040	0.070	0.052	0.023	GDP/GNI WB
std Hurr. loss	σ_h	0.029	0.028	0.028	0.034	0.052	0.027	0.02	GDP/GNI WB
Disc. factor	β	0.90	0.9425	0.905	0.88	0.90	0.805	0.88	Debt/GDP
Output cost	δ	0.80	0.6	0.79	0.84	0.77	0.85	0.82	Mean spread

Quantitative Analysis

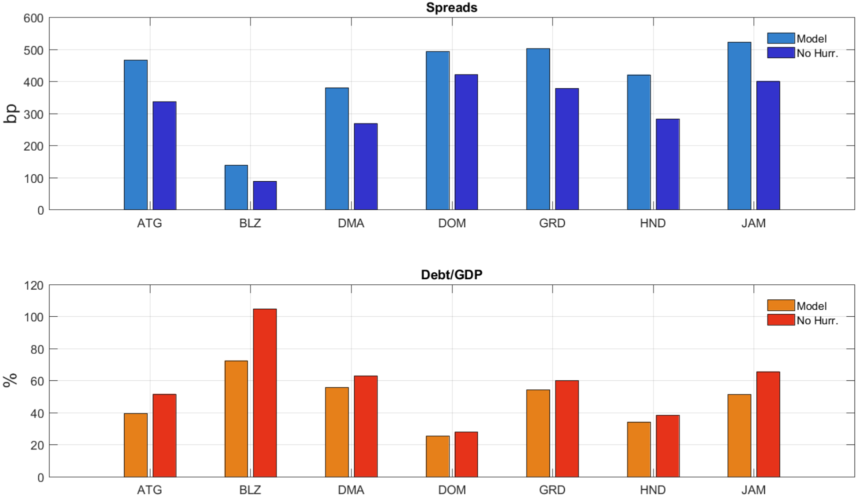
Moment Matching Exercise



Counterfactual Exercises

- Eliminate hurricane risk
- Climate change

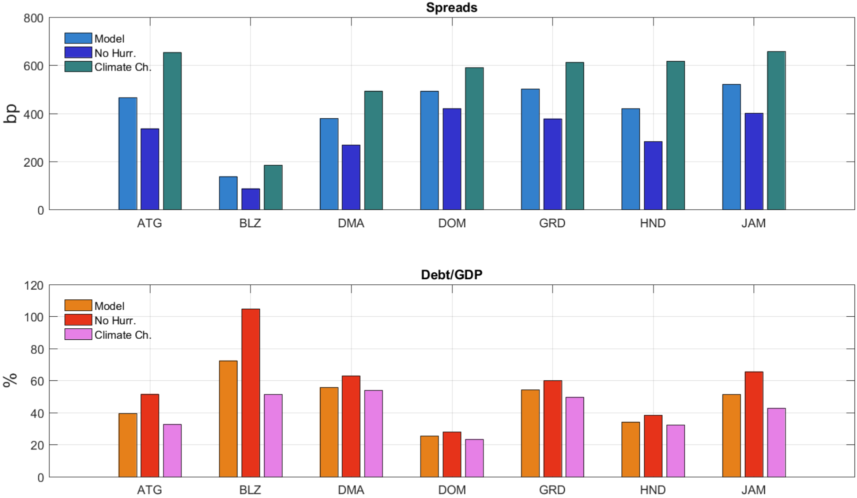
No Hurricane Risk - Lower Spreads, Higher Debt



Climate Change

- Increasing frequency of major hurricanes:
  - 29.2% increase in the North Atlantic (Bhatia et al., 2018)
- Increasing intensity of major hurricanes:
  - Heavier rain, stronger wind, lower forward speed
  - Saffir-Simpson scale might need to be extended
  - Economic costs of hurricanes will increase 20% – 77% due to intensity of winds (Acevedo, 2016)
- Modal scenario:
  - Frequency of hurricanes increases 29.2%
  - Economic costs increases 48.5%

Climate Change - Higher Spreads, Lower Debt



Summarizing

- Hurricane risk restricts governments' access to financial markets
- Spreads increase
- Debt-to-GDP ratios decline
- Climate change will weigh on governments' market access

Disaster Clauses

Modeling Disaster Clauses

- Disaster clauses allow for a one-period debt moratorium, when hurricanes hit
- Governments choose whether to activate the clause
- No output cost of activating the hurricane clause

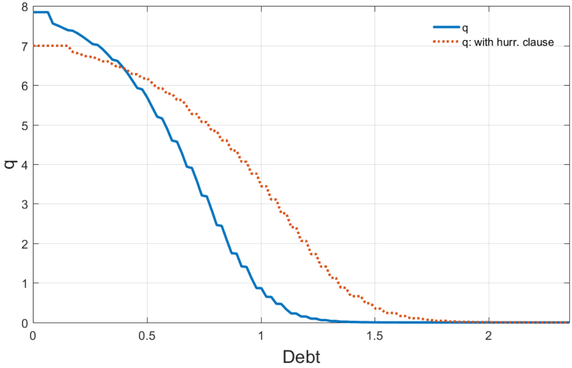
Disaster Clause: Price Function

$$q\left(y', h', b'\right) = \frac{1}{\left(1+r^{rf}\right)} E\left[\left(1-d' - rel'\right) + (1-\psi)\left(1-d'-rel'\right)q' \right.$$
$$\left. + \frac{rel'}{\left(1+r^{rf}\right)} E\left[\left(1-d''-rel''\right) + (1-\psi)\left(1-d''-rel''\right)q'' | y'\right] | y\right]$$

Price of government bonds also depends on:

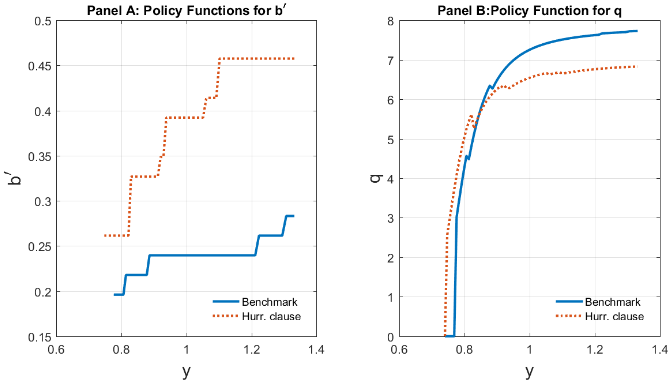
- The risk that the hurricane clause is activated
- Expected value of coupon payments after the government resumes payments

Hurricane Clause: Price Function



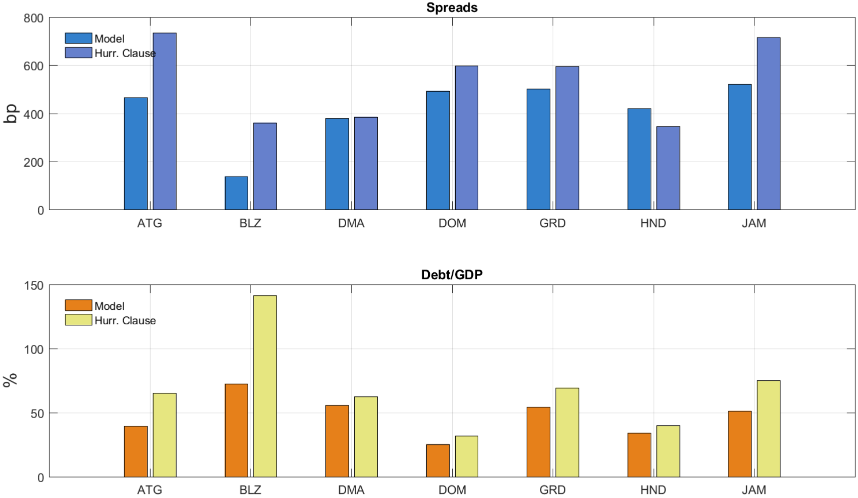
- Borrowing terms are generally better with disaster clauses: $q_{hc} \geq q$
- The risk of delayed repayment explains why $q_{hc} \leq q$ when default risk is zero

Hurricane Clause: Policy Functions

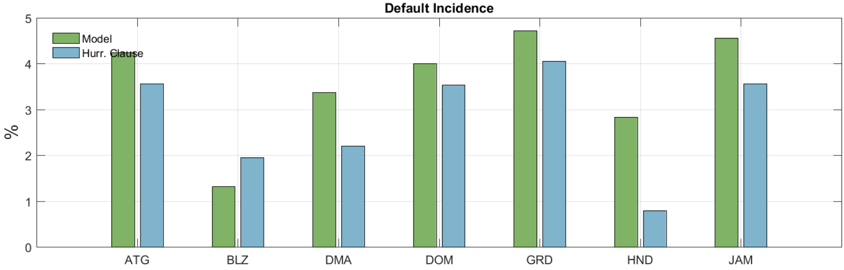


- Sizable increase of government debt
- In equilibrium, the price of government debt declines

Hurricane Clause - Higher Spreads, Higher Debt

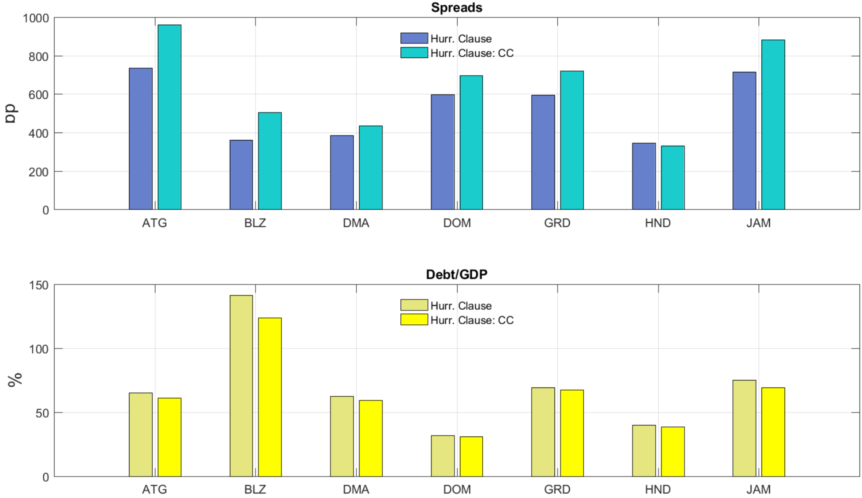


Hurricane Clause- Same Default Risk



- Default risk is little changed
- Rise in spreads is due to risk of delayed repayment
- Total borrowing costs are little affected by delay risk:
  - Price of government debt declines
  - Debt servicing costs decline

Climate Change - Higher Spreads, Same Debt



Decomposing the Impact of Climate Change

1. Increasing intensity of hurricanes:
    - Spreads increase due to increase in default risk
    - Debt levels decline

2. Increasing frequency of hurricanes:
    - Spreads increase due to delay in repayment risk
    - Debt levels unaffected as total borrowing costs are little changed

On net, higher spreads and only slightly lower levels of debt

Hurricane Clause: Welfare analysis

- Δ_{WC}: Consumption equivalent welfare change that makes an agent in the economy without disaster clauses indifferent between that economy and the one with the disaster clause
- Agents are worse off with hurricane clauses: overborrowing depresses consumption

Welfare Analysis

Moment	ATG	BLZ	DMA	DOM	GRD	HND	JAM
Δ_{WC}	-2.76%	-7.09%	-0.96%	-1.22%	-1.60%	-1.57%	-1.41%

Hurricane Clauses and Debt Limits: Welfare analysis

- Consider the case for a policy introducing both disaster clauses and debt limits
- Debt levels cannot be higher than in the baseline scenario
- Repeat welfare analysis: welfare increases

Welfare Analysis - Disaster Clause and Debt Limits

Moment	ATG	BLZ	DMA	DOM	GRD	HND	JAM
Δ_{WC}^{DL}	2.02%	3.63%	0.26%	1.34%	1.06%	1.19%	1.87%

Conclusions

- Natural disasters reduce governments' ability to borrow
- Climate change will further reduce market access
- Disaster clauses improve governments' access to financial markets, but lead to overborrowing
- Rich research agenda
  - Climate adaption policies
  - Official credit, international aids, private insurances

Motivation V

The case of Grenada is quintessential:

- Grenada began cumulating large deficits in the early 2000s
- September 2004, hurricane Ivan hits Grenada:
  - Damages worth 148% of GDP
  - The entire crop of nutmeg was wiped out
  - Tourism infrastructures were damaged
- In October 2004, debt restructuring
- In 2013, bonds featuring a disaster clause were issued

Back

Step I: Non-default Scenario

$$W^{nd}(y,h,b) = \max_{c,b'} \; u(c) + \beta \mathbb{E} W\left(y', h', b'\right)$$

$$\text{s.t. } \; c = y + q\left(b' - (1-\psi)b\right) - b$$

$$q(y,h,b) = \frac{1}{(1+r^{rf})} E\left[\left(1-d'\right) + (1-\psi)\left(1-d'\right) q'\right].$$

Government bonds are perpetuities with decay parameter ψ.

Step II: Default Scenario

$$W^d(y,h,0) = u(c) + \beta\mathbb{E}\left[(1-\lambda)W^d(y',h',0) + \lambda W(y',h',0)\right]$$

$$\text{s.t. } c = \delta(y)$$

Where $\delta(y)$ is an output cost of default

$$\delta(y) = \begin{cases} y & \text{if } y \leq \delta \\ \delta & \text{if } y > \delta \end{cases}.$$

Step III: Default Decision

Government compares value functions in the default scenario and in the non-default scenario:

$$W = \max_{d} \left\{ (1 - d)\, W^{nd} + dW^{d} \right\}$$

- d: default decision
- W^{d}: value function in the default scenario
- W^{nd}: value function in the non-default scenario

International Lenders

- Have access to government bonds and risk-free bonds
- Price government bonds by arbitrage:

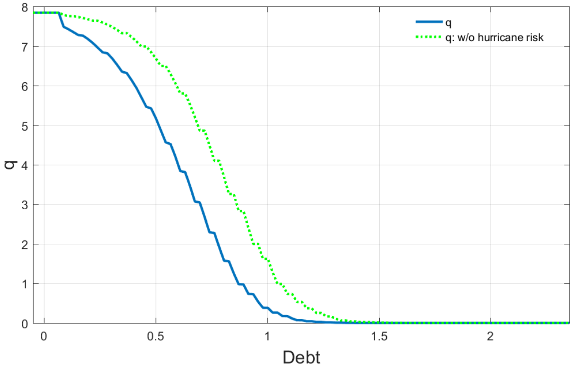
$$q\left(y,h,b\right)=\frac{1}{\left(1+r^{rf}\right)}E\left[\left(1-d'\right)+\left(1-\psi\right)\left(1-d'\right)q'\right]$$

Back

Eliminating Hurricane Risk -Intuition

Elimination of hurricane risk reduces output fluctuations:

- The price function shifts out



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