

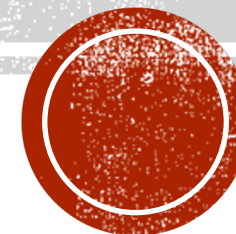
CLIMATE RISKS FOR SOVEREIGN DEBT

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University of Cyprus

National Academy of Sciences, Letters, and Arts

Bruegel





OUTLINE

Introduction

Climate risk exposure of European sovereigns

- **EU vulnerabilities and readiness**
- **Climate-debt vicious circle**

Pricing of climate risk in sovereign debt markets

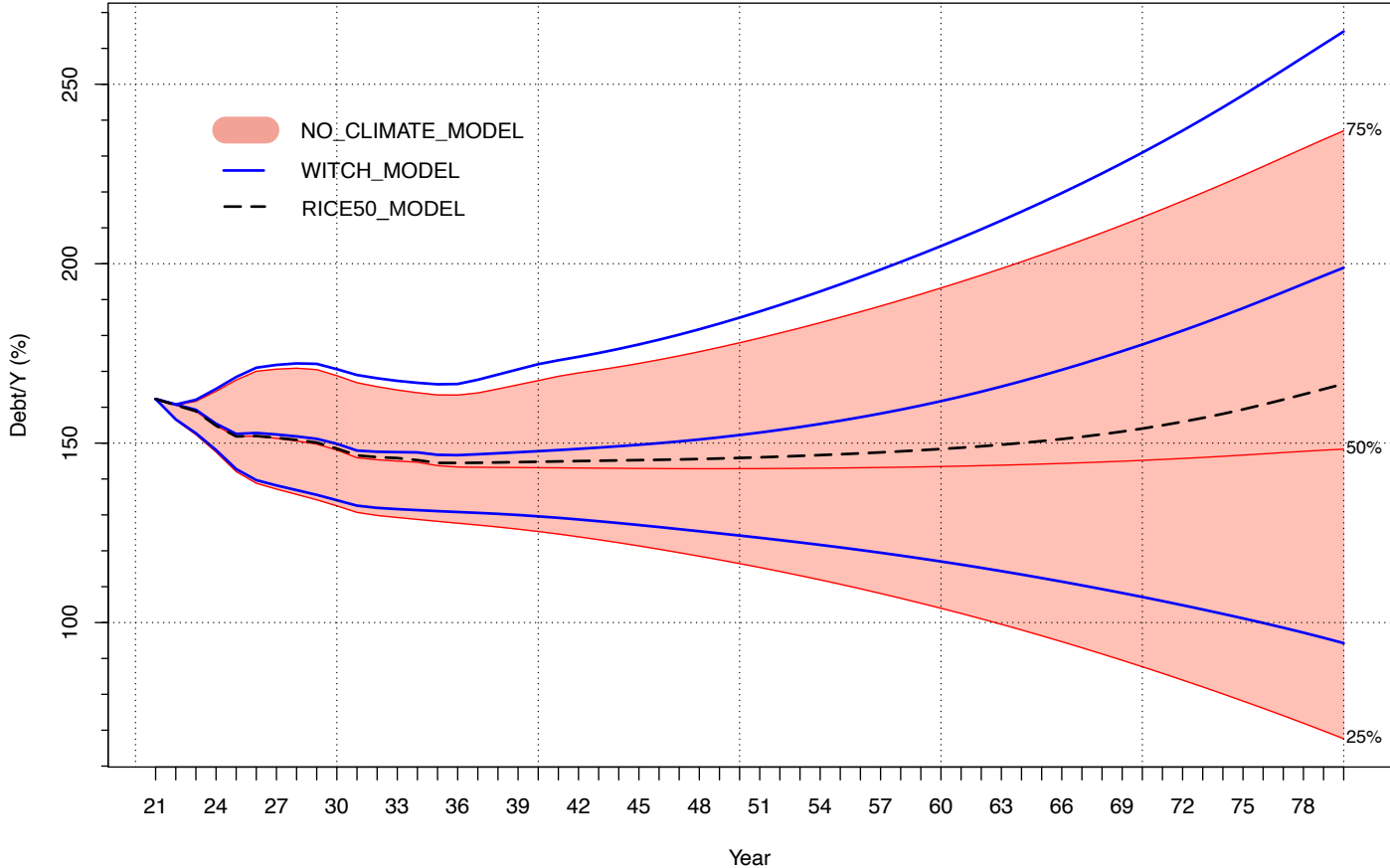
- Evidence
- **Do unto the climate as you would have the climate do unto you**

Debt Sustainability Analysis with climate risks

- **How to deal with the deep uncertainty**
- **Narrative scenario matrix architecture**

Climate-proof sovereign debt

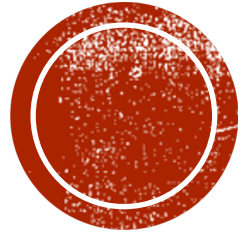
ITALY POST COVID-19 WITH CLIMATE RISK



A problem of **DEEP** uncertainty

- Uncertainty (pink)
- Ambiguity (blue)
- Misspecification (black)





CLIMATE RISK EXPOSURE OF EUROPEAN SOVEREIGNS



A NEW CLIMATE DIVIDE



Notre Dame Global Adaptation Initiative

- **Vulnerability**, predisposition to be negatively impacted by climate hazards.
- **Readiness**, ability to leverage investments for adaptation. It reflects a country's investment climate, institutional stability, and social conditions.
- Losses of 12bn p.a., projected to 170bn (1.3% GDP).



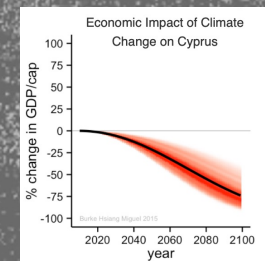
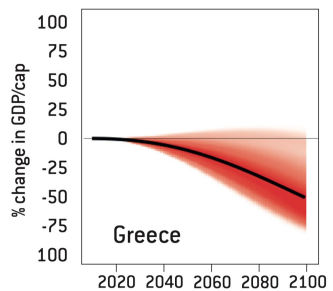
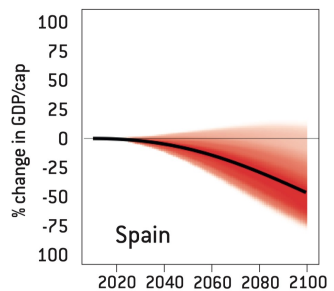
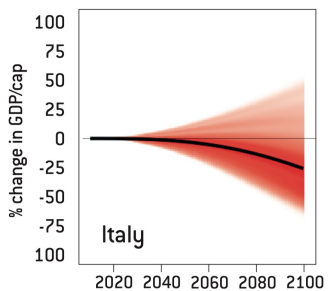
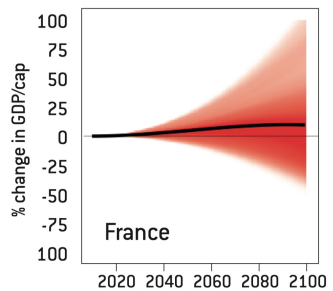
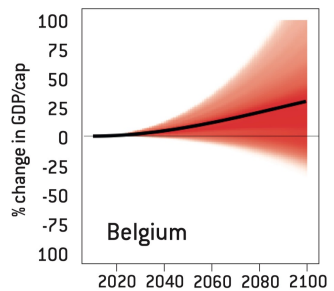
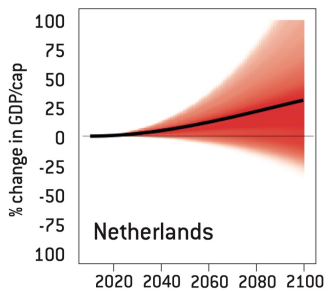
GDP/PER CAPITA UNDER REPRESENTATIVE CONCENTRATION PATHWAY RCP8.6

Burke, Hsiang, and Miguel, *Nature*, 2015.

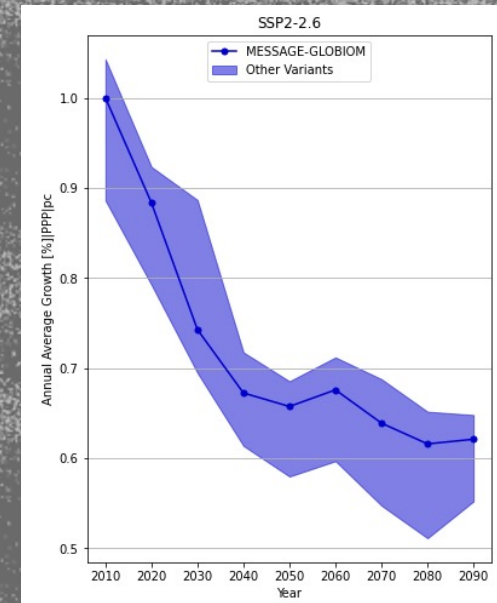
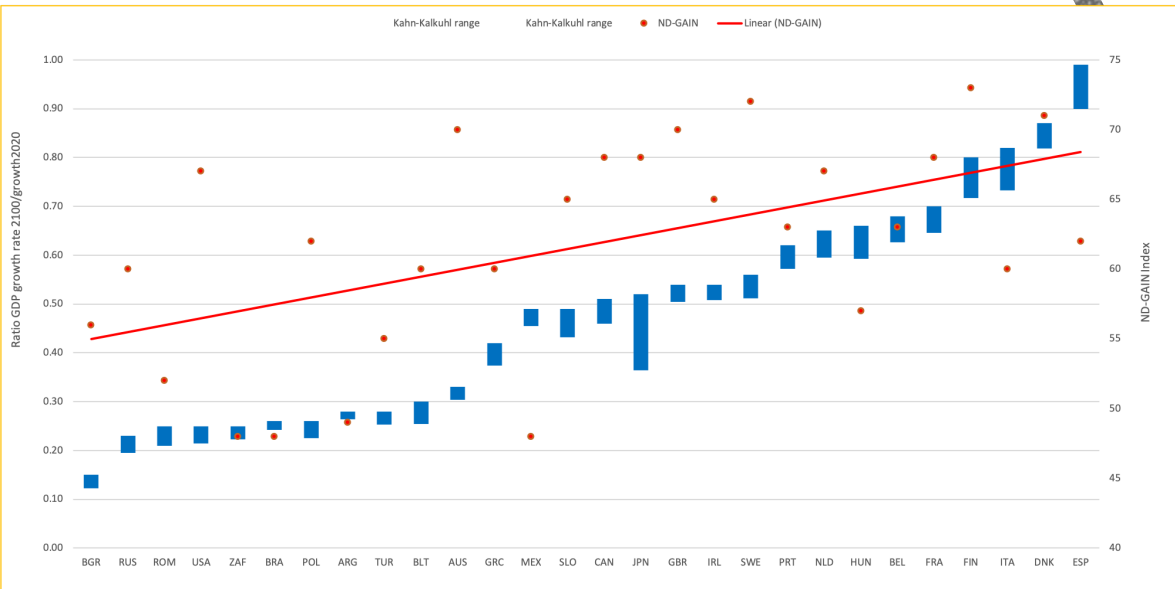
<https://web.stanford.edu/~mburke/climate/map.php>



A NEW CLIMATE DIVIDE



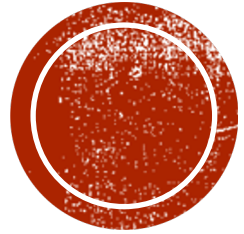
CLIMATE DIVIDE OF EUROPEAN SOVEREIGNS



OECD from IIASA scenarios

Source:
Author based on RICE50+ under RCP2.6-SSP2





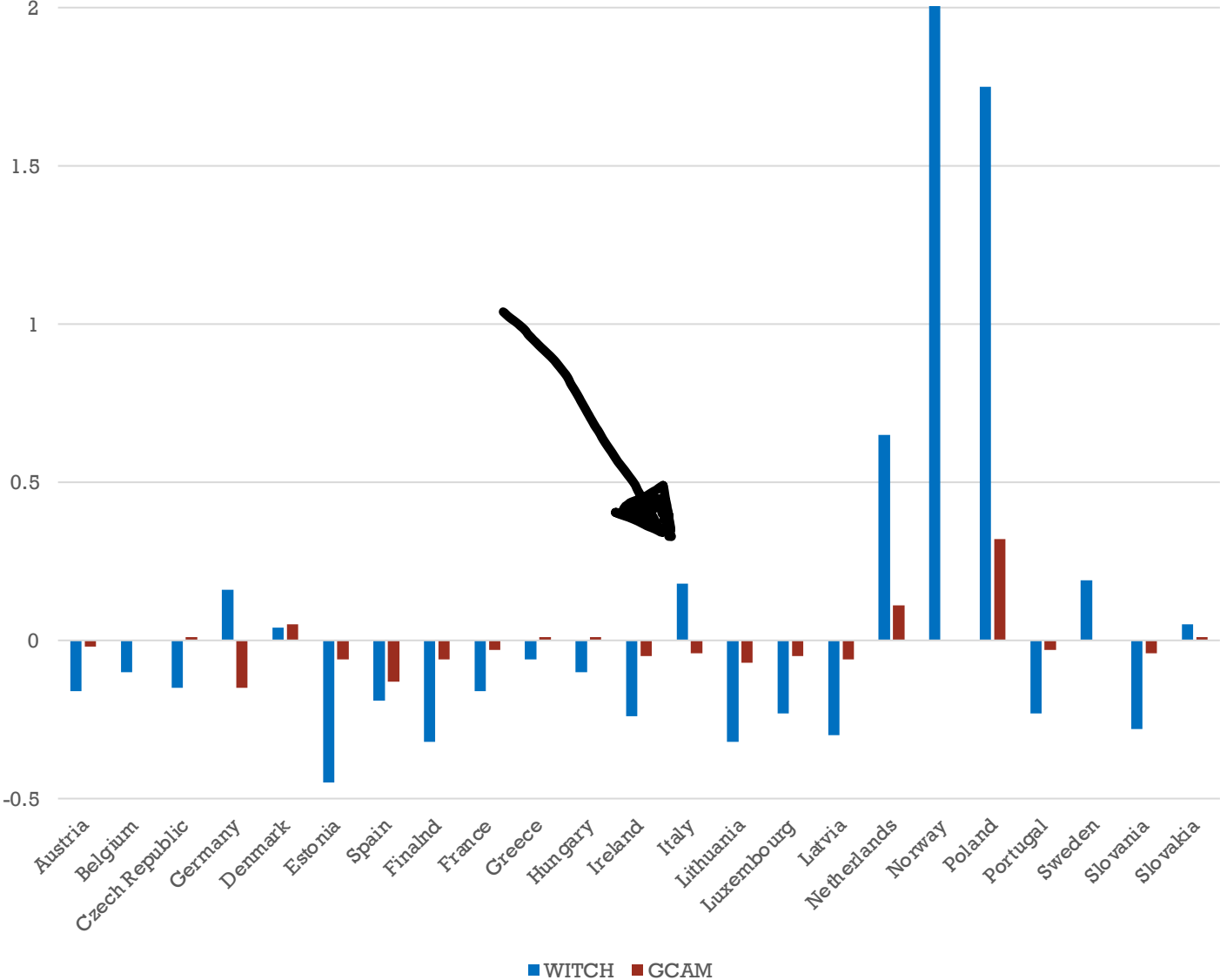
PRICING CLIMATE RISK IN SOVEREIGN DEBT MARKETS



CHANGE IN BOND YIELDS

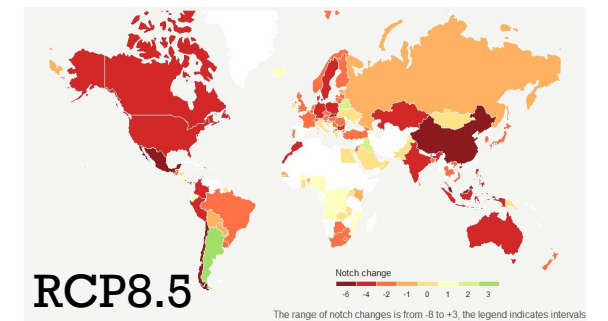
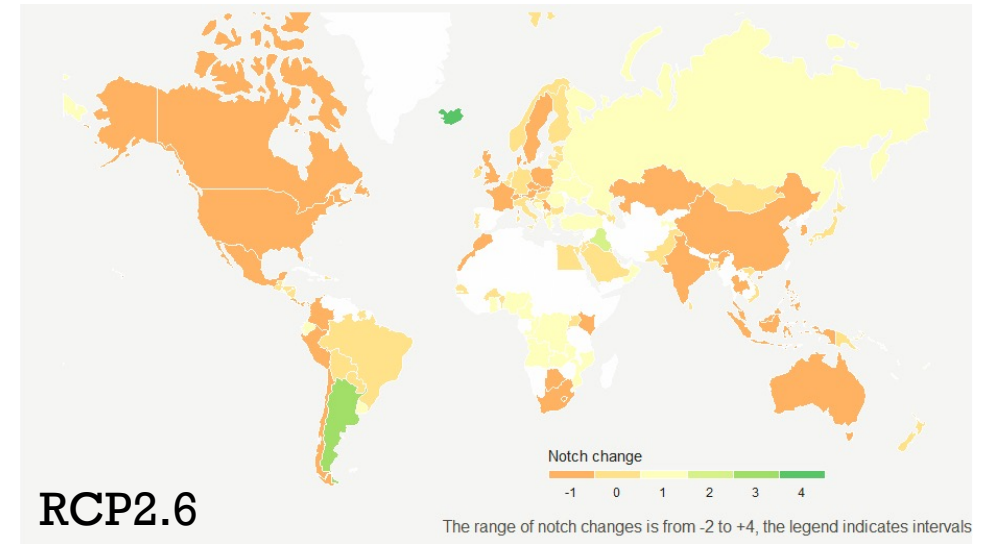
Battiston-Monasterollo (2020), using IAM for energy transition

Kahn et al. (2021), *Energy Economics*.



CREDIT RATINGS

- Downgrades are at the top of ratings scale
- RCP2.6 → 55 down ratings by 0.66 notches
- RCP8.5 → 80 down ratings by 2.48 notches
- Temperature increase and variability
- Downgrades start from 2030
- Increase of borrowing costs:
 - France 1,35-2 bn per year
 - Germany 0.23-0.35 bn per year





PRICING THE EFFECT OF CLIMATE RISK
ON AN ISSUER?



PRICING THE EFFECT OF AN
ISSUER ON THE CLIMATE?

**DO UNTO THE
CLIMATE AS YOU
WOULD HAVE
THE CLIMATE
DO UNTO YOU**



THE CLIMATE- DEBT VICIOUS LOOP

- Adverse effects:
 - GDP growth
 - Damages (chronic and acute)
 - Transition risks
 - Stranded assets
 - Bail-outs.
- Mitigation and adaptation policy costs
- Each climate effect may seem small and inconsequential
- Aggregate effects can become a first order problem
- Aggregate effects raise concerns with adverse effects on ratings (borrowing costs)



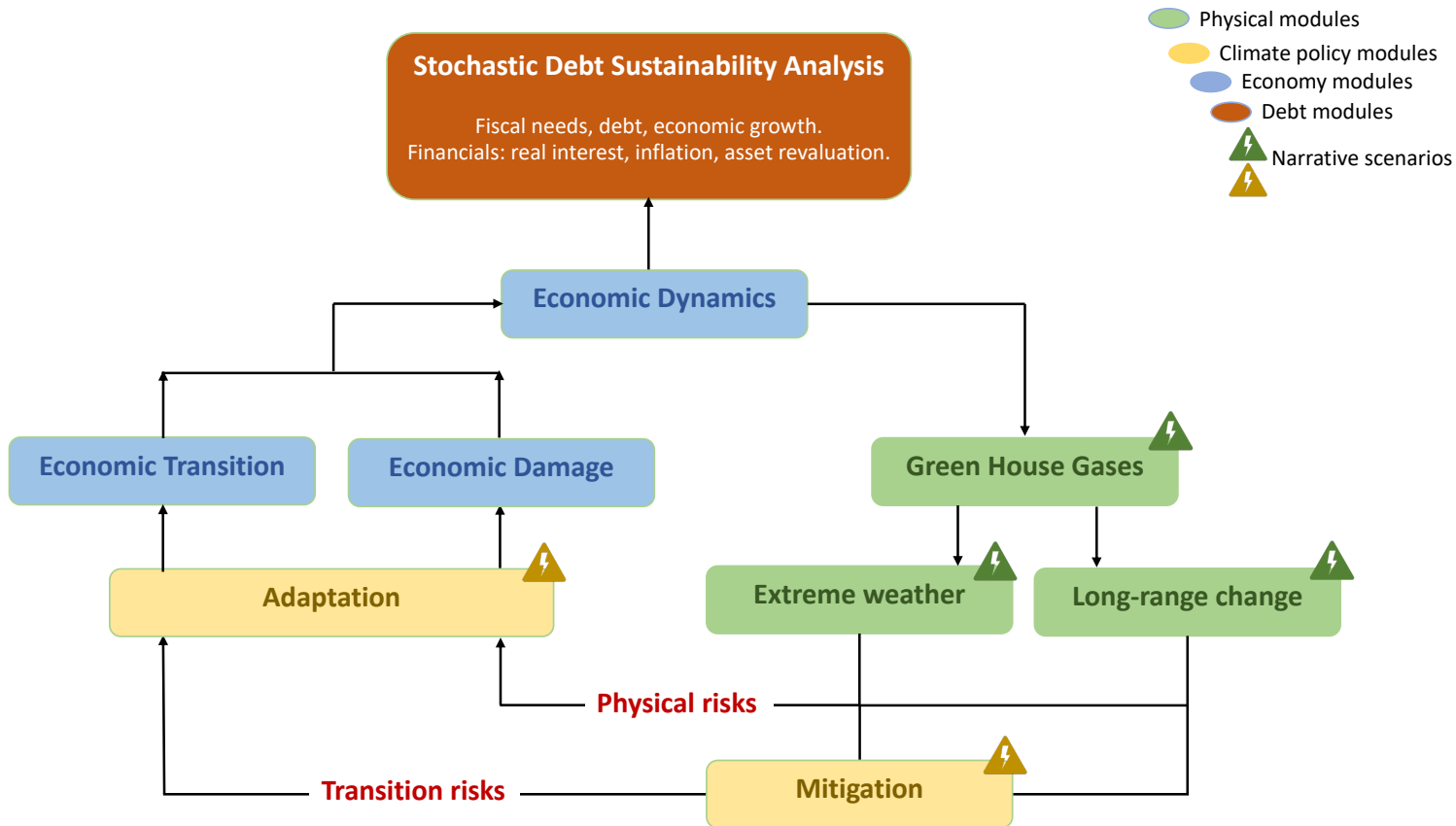
CAN WE MODEL CLIMATE RISKS TO SOVEREIGN DEBT?

“even if the true scientists should all recognize the limitations of what they can do, so long as the public expects more there will always be some who will pretend, and perhaps honestly believe, that they can do more to meet popular demands than is really in their power.”

-Friedrich von Hayek, Nobel Prize Lecture



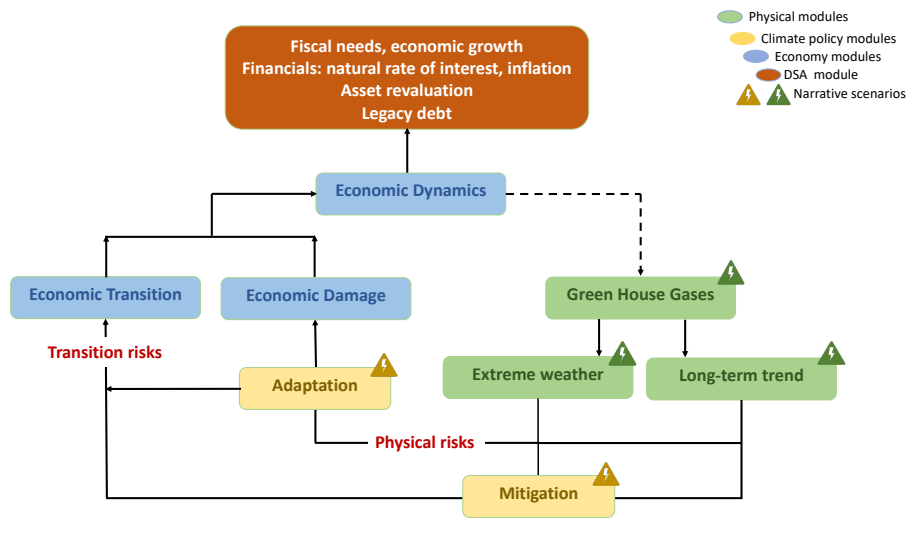
TRANSMISSION TO FISCAL RISKS



- Narrative scenarios
- Integrated Assessment Models
- Implications for fiscal stability
- NGFS- implications for financial stability



STOCHASTIC DEBT SUSTAINABILITY ANALYSIS



- **Deep uncertainty**
 - Risk
 - **Ambiguity**
 - **Miscpecification**
- **Fat-tails**
- **Acute and chronic effects**
- **The tragedy of the horizon (Carney)**





DICE-2016R2 and RICE-2010

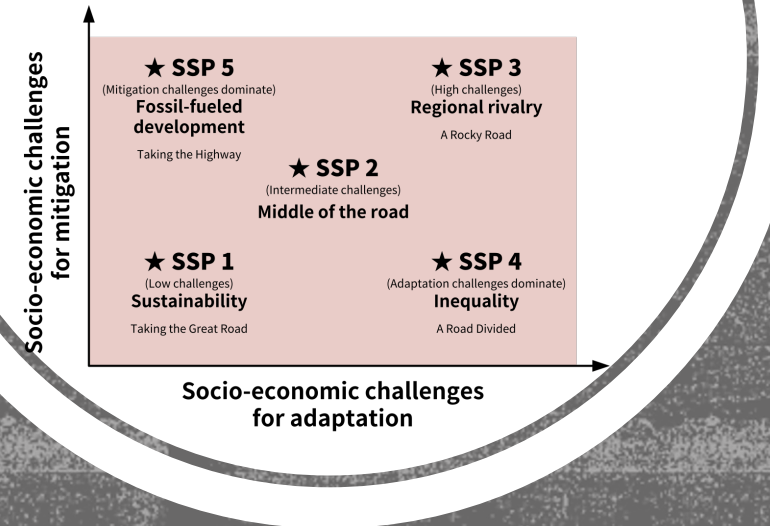
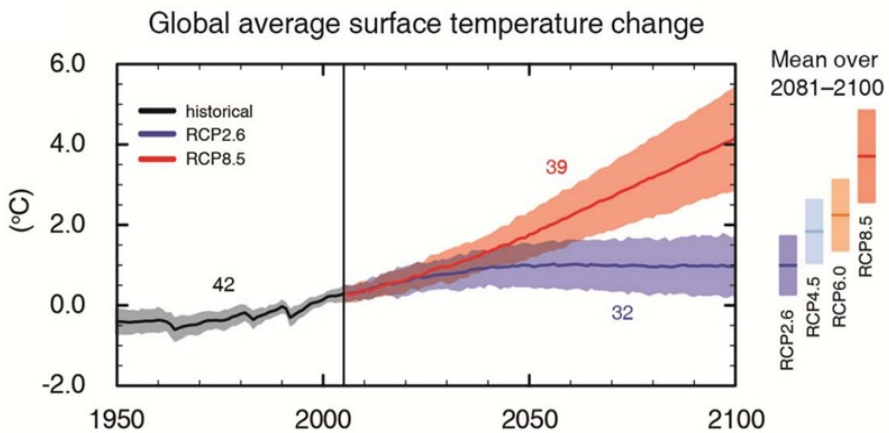


Burke et al., *Nature*, 2015
Hsiang et al., *Science*, 2017
Kahn et al., *IMF Working Paper*, 2019

IAM FOR DSA

- **Forward looking scenarios**
 - GDP growth
 - Fiscal: mitigation, adaptation, damages
 - Financial: r^* , inflation \rightarrow ECB
 - Asset revaluation
 - Contingent liabilities
- **Narrative scenarios**
- **Acute and chronic: extreme weather & gradual changes**
- **Ensemble of climate integrated assessment models**



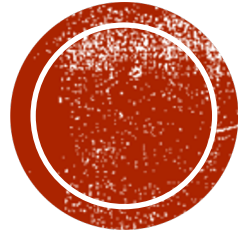


NARRATIVE SCENARIOS

- SSP- Shared Socio-economic Pathways
- RCP- Representative Concentration Paths

Climatic Change (2014), special issue.





CLIMATE RISK FRAMEWORK FOR DEBT SUSTAINABILITY

$$D_t = (1 + i_{t-1})D_{t-1} - B_{t-1} \text{ (stock)}$$

$$F_t = i_{t-1}D_{t-1} + A_t - B_{t-1} \text{ (flow)}$$

Y_t (debt-to-GDP)

$\Rightarrow D_t/Y_t$ and F_t/Y_t

	SSP1	SSP4	SSP2	SSP3	SSP5
RCP8.5					
RCP6.0					
RCP4.5				4	4
RCP2.6	6	6	6		3
RCP1.9	6	3	6		2

Number of IAM that converge, Rogelj, Emmerling et al. (2018), *Nature*.

SCENARIO MATRIX ARCHITECTURE
VAN VUUREN ET AL. (2014), *CLIMATIC CHANGE*



DSA WITH CLIMATE RISK



Operations Research

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

Risk Management for Sustainable Sovereign Debt Financing

Stavros A. Zenios, Andrea Consiglio, Marialena Athanasopoulou, Edmund Moshhammer, Angel Gavilan, Aitor Erce

- Italy post COVID-19
- Work with Andrea Consiglio and Johannes Emmerling



TECHNICAL VERSION

Sovereign debt risk management

The economic problem

- Sovereign issues debt X to finance its debt
- Uncertain correlated financial, economic, fiscal variables
- Debt sustainability controls
- Feedback loop

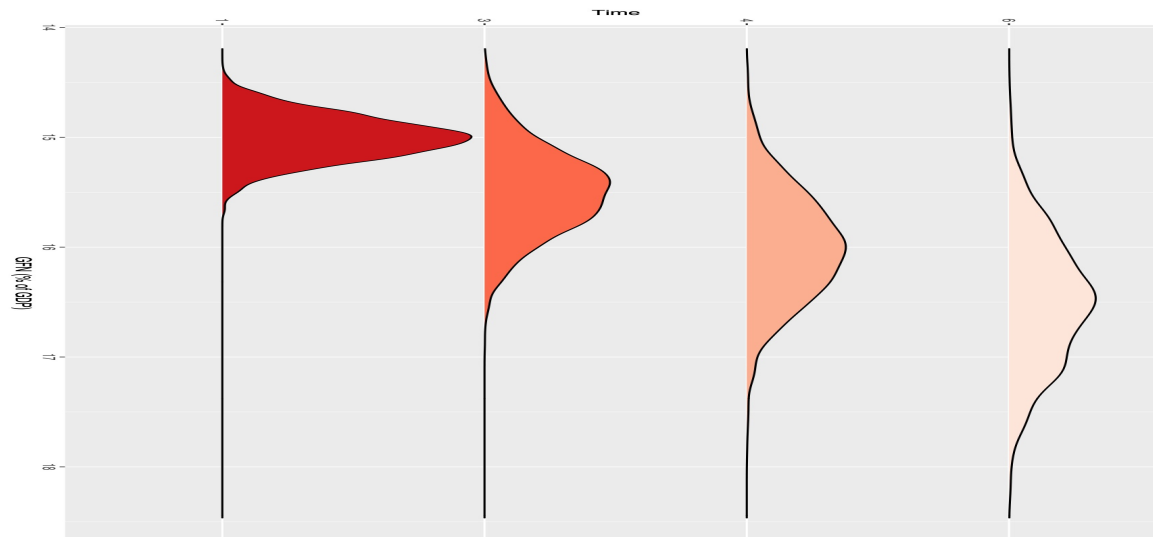
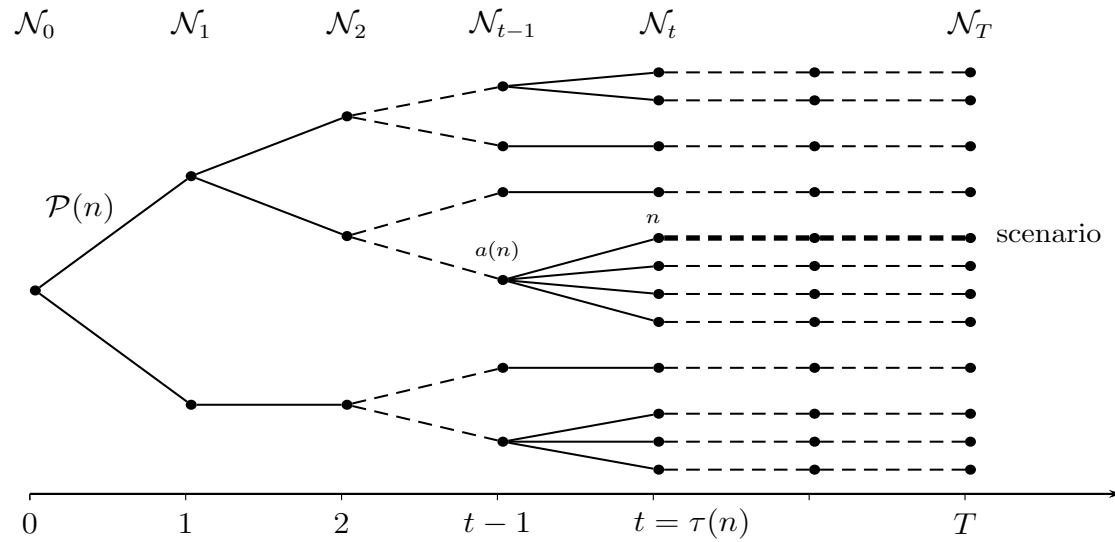
$$X \rightarrow D \rightarrow r \rightarrow X$$

- Tension between debt stock and flow



Q1. Optimize debt financing

- Discrete state-space, discrete time-space scenario tree

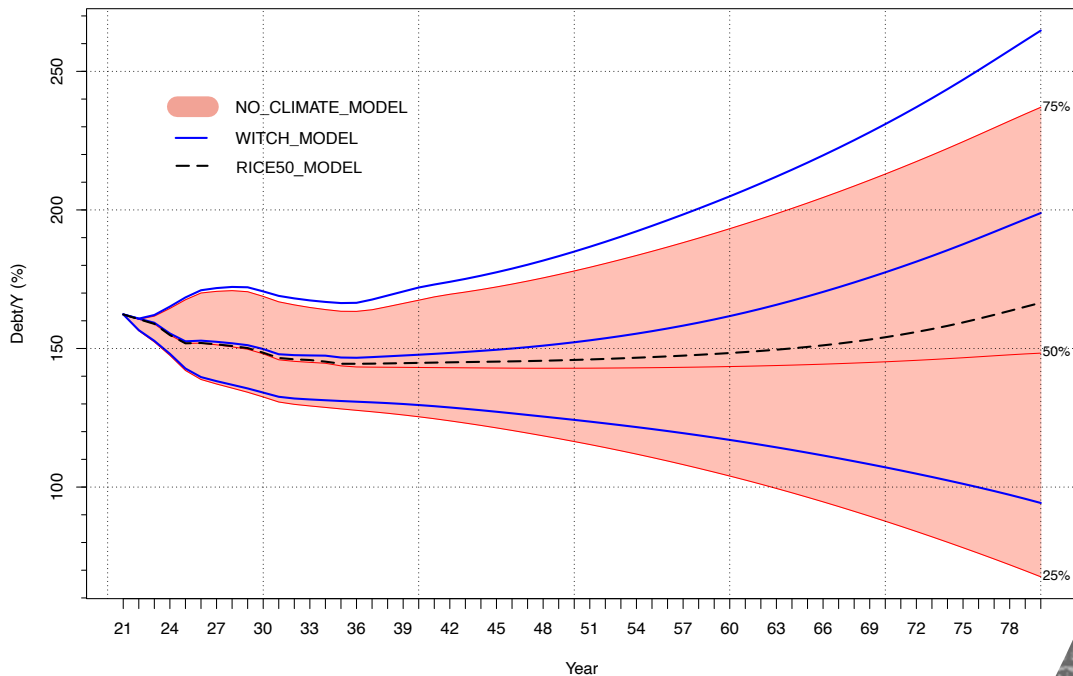


Q1+Q2. Optimize debt financing with sustainability controls

$$\begin{aligned} &\text{Minimize}_x && \sum_{n \in \mathcal{N}} p^n NIP_t^n \\ &\text{s.t.} && \\ &&& \Psi(gfn) \leq \omega \\ &&& \frac{\partial d^n}{\partial t} \leq \delta \end{aligned}$$



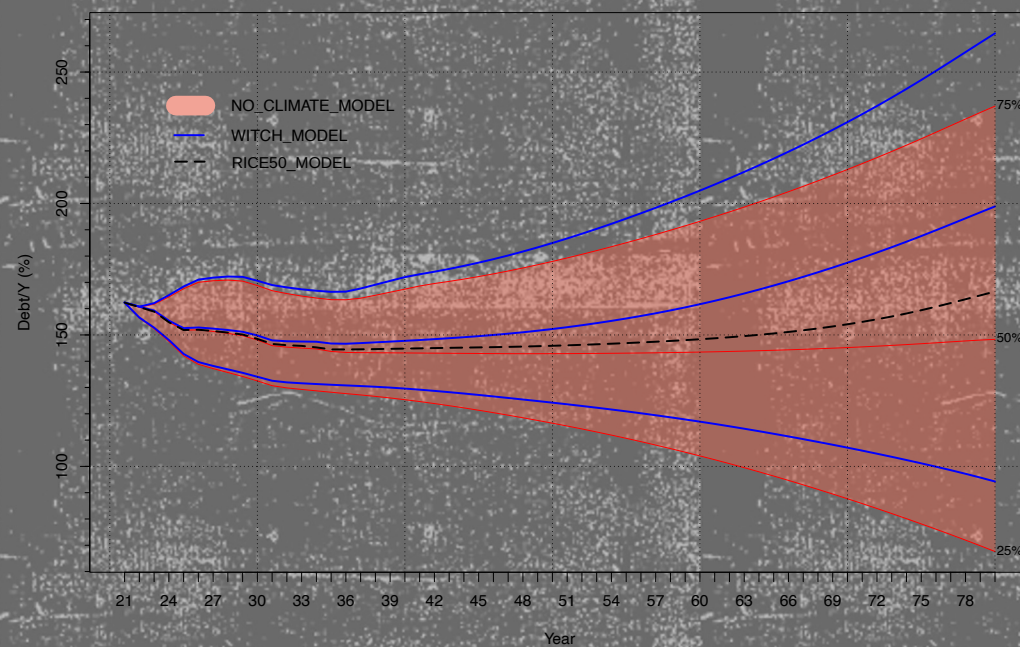
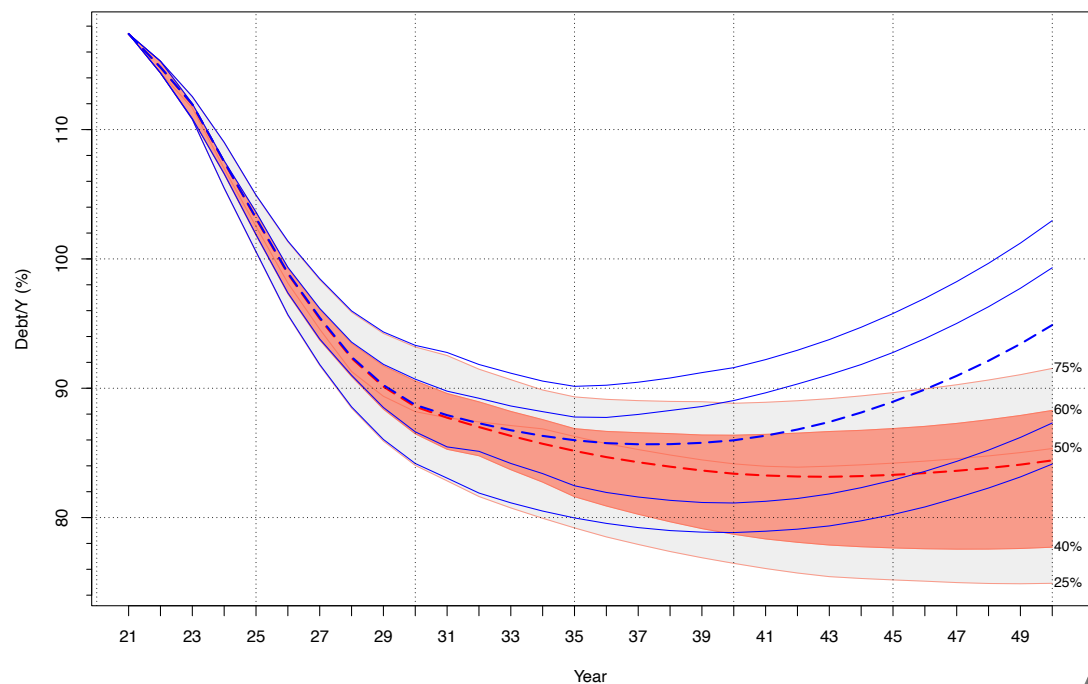
ITALY POST COVID-19 WITH CLIMATE RISK: GDP EFFECT



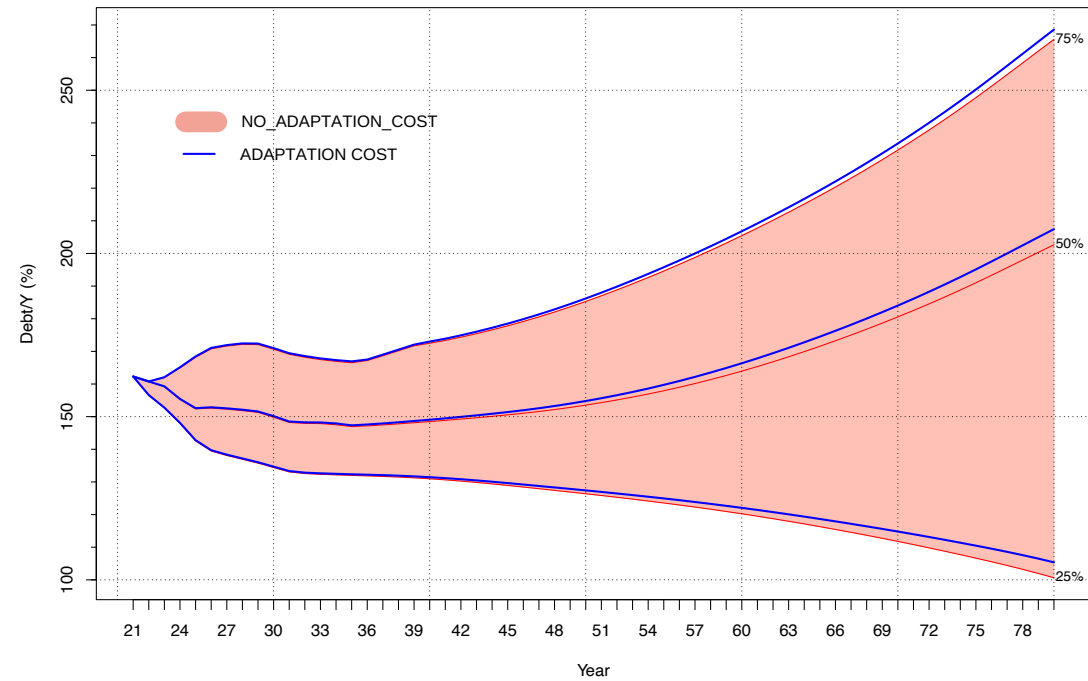
- Pink – risk
- Blue- ambiguity
- Black- misspecification



CYPRUS POST COVID-19 WITH CLIMATE RISK: GDP EFFECT



ITALY POST COVID-19 WITH CLIMATE RISK: ADAPTATION EFFECT



FINALIST G20-BANK OF ITALY FINTECH COMPETITION



CLIMATE-PROOF SOVEREIGN DEBT

- **EU institutions coordination scenario-based systematic assessment**
 - Scenario matrix architecture
 - EU-wide integrated assessment model for climate risk
 - Mandated DSA with climate risks
- **Fiscal authorities** mainstream climate risk analysis in public finance
 - Budgetary plans account for climate risks
 - Risk-sharing instruments (Sovereign CoCo, GDP-linked bonds, CAT bonds, participation funds)
 - Off balance sheet items
- **Disclosure** of climate exposure of public debt

