Aumento della temperatura, carbon tax ed impatti economici regionali e nazionali

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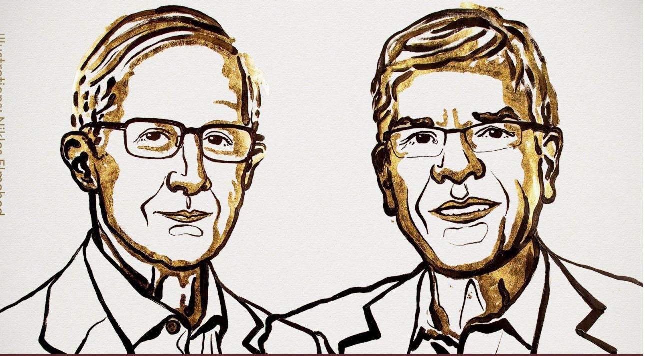
Keywords

- Economia
- Fonti Fossili
- Anidride Carbonica, Diossido di Carbonio, CO_2
- Incremento della temperatura
- Cambiamento climatico
- Valutazione danno economico
- Misure, politiche e strumenti

THE SVERIGES RIKSBANK PRIZE IN ECONOMIC SCIENCES IN MEMORY OF ALFRED NOBEL 2018



Illustrations: Niklas Elmehed

William D. Nordhaus

"for integrating climate change into long-run macroeconomic analysis"

Paul M. Romer

"for integrating technological innovations into long-run macroeconomic analysis"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

Modelli di valutazione integrata (IAMs) di Clima ed Economia

Principali caratteristiche: modulo climatico integrato con modulo di crescita economica, esternalità negativa cambiamento climatico, crescita economica, carbon tax, adattamento, mitigazione

- → DICE - Dynamic Integrated Climate-Economy model [Nordhaus, 1992]: modulo climatico e modulo economico globali.
- → RICE - Regional Integrated Climate-Economy model [Nordhaus and Yang, 1996]: modulo climatico globale, modulo economico regionale.

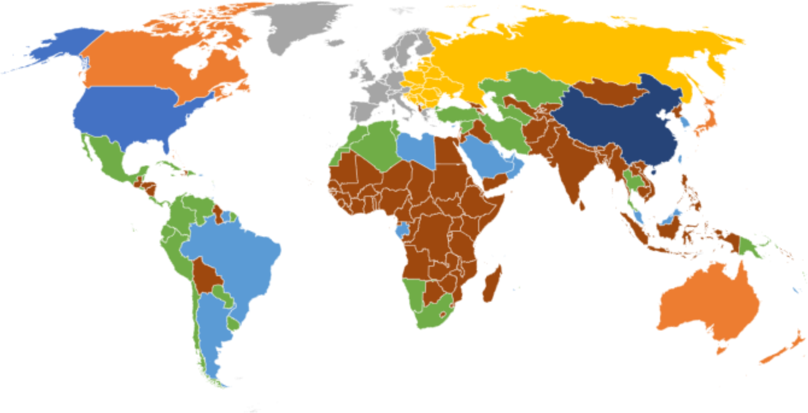


Figure 1: *RICE-96*

Il ruolo dell'IPCC - Intergovermental Panel on Climate Change

Intergovernmental body of the UN dedicated to providing the world with objective, scientific information on:

- the Physical Science Basis (WGI)
- Impacts, Adaptation and Vulnerability (WGII)
- Mitigation (WGIII)

of Climate Change.

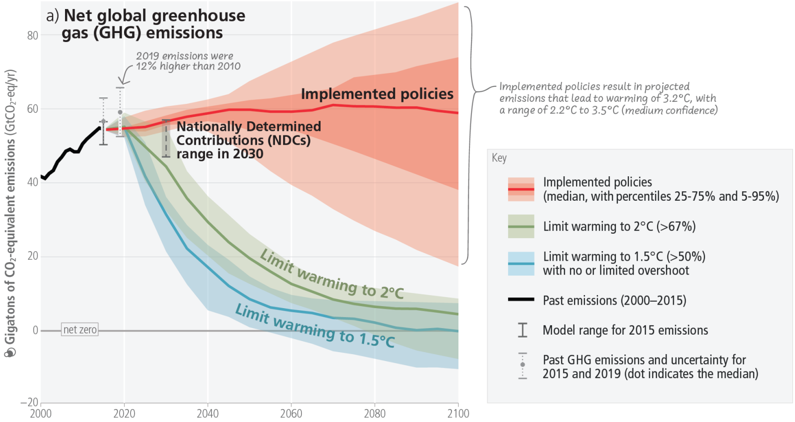
→ The IPCC informs the United Nation Framework Convention on Climate Change (UNFCCC).

→ UNFCCC aim: "stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"

Latest publication: 6th Assessment Reports and several Special Reports (i.e. SR1.5)

Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions

Net zero CO_2 and net zero GHG emissions can be achieved through strong reductions across all sectors



AIII

Annex III: Scenarios and Modelling Methods

IPCC AR6 WGIII direct link to the document

Let us look at pages 1843 - 1845.

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1987

Robert M. Solow

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Robert M. Solow
Facts

Photo from the Nobel Foundation archive.

Robert M. Solow
The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1987

Born: 23 August 1924, Brooklyn, NY, USA

Died: 21 December 2023, Lexington, MA, USA

Affiliation at the time of the award: Massachusetts Institute of Technology (MIT), Cambridge, MA, USA

Prize motivation: “for his contributions to the theory of economic growth”

Prize share: 1/1

Work

Robert Solow was awarded the Economic Sciences Prize for his important contributions to theories of economic growth. In the 1950s, he developed a mathematical model illustrating how various factors can contribute to sustained national economic growth. From the 1960s on, Solow's studies helped persuade governments to channel funds into technological research and development to spur economic growth.

Institute Professor Emeritus Robert Solow, pathbreaking economist, dies at age 99

Nobel-winning scholar changed his field, taught generations of students, and helped make MIT a global leader in economics research.

Watch Video

Peter Dizikes | MIT News

December 22, 2023

RICE-MED: a Regional Integrated assessment modeling of Climate and the Economy for the Mediterranean Basin

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Scan for the working paper

Sixth Assessment Report IPCC 2022 - Cross-Chapter Paper 4

CCP4

Mediterranean Region

> ***Currently incomplete knowledge of climate impacts and risks in the southern and eastern part of the basin hinders the implementation of adaptation measures****, creating a need for implementable plans with enhanced and cooperative research and monitoring capacities between the north, south and southeast countries (high agreement). - (Source: CCP4.4 - IPCC AR6 - 2022).*

→ The ***Mediterranean climate***: these territories - beyond the Mediterranean area - share same temperature paths, wet winters, hot, or warm dry, summers; dried periods and this trend is expected to persist in the long run.[Seager et al., 2019]

The RICE-MED model. An overview.

- a ***Climate and Economy model*** based on the Regional Climate and Economy model ***RICE-99*** by Nordhaus and Boyer [2000],
- All ***world economies*** relies on ***energy produced with fossil fuels*** and there is no international trade.
- ***spatial granularity*** of RICE-99 (world divided in 9 regions) is increased focusing on the ***Mediterranean countries***.
- Original calibration: base year 1995 $\rightarrow$ ***Updated to 2015***.
- RICE- 99 ***Initialization*** process formalized ***analytically***.
- ***New figures*** on the ***social cost of carbon*** in BAU, Social Optimimum and Temperature Limit scenarios.
- ***Golosov et al. [2014] damage function***, with direct link with CO2 concentration.
- ***RICE-MED-U***: ***uncertainty*** associated to climate-induced catastrophic event ***[Castelnuovo et al., 2003]***.

Literature: Mediterranean Basin

- **JRC-PESETA [Ciscar et al., 2009, 2011]**: EU disaggregated in 5 regions
  Climate data scenarios $\rightarrow$ physical models $\rightarrow$ CGE model (GEM-E3) $\rightarrow$ consumer welfare and GDP
- **Galeotti and Roson [2011]**: use ENVISAGE model (World Bank), a recursive dynamic multi-sector multi-region CGE model with emissions and climate module, where the World is divided in 20 regions, of which several countries in the Mediterranean at national level
- **Aaheim et al. [2012]**: GRACE - Global Responses to Anthropogenic Changes in the Environment- model (CGE model) is used to study the impact of adaptation on the EU
- **Paroussos et al. [2013]**: four alternative macroeconomic scenarios for the Southern and Eastern Mediterranean using the GEM-E3 CGE model
- **Bosello and Standardi [2018]**: regional version of the ICES model, a recursive dynamic multiregional CGE model to assess impacts of climate change + mitigation and adaptation policies for the European Mediterranean countries

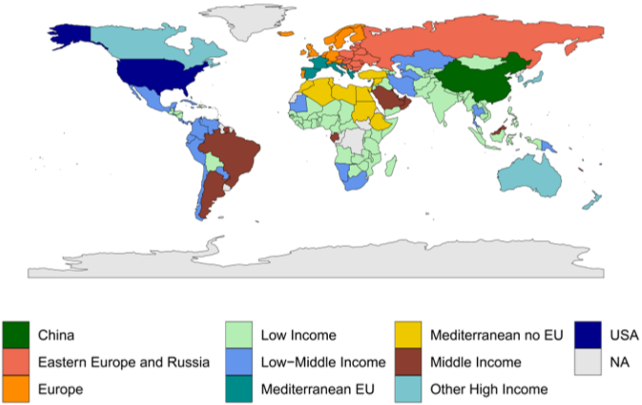
Literature: IAMs - Rice type models

1: RICE-96 Nordhaus and Yang [1996] - 10 regions - no energy as an input
2: Bosello and Moretto [1999] - Uncertainty in different IAMs
3: **Nordhaus and Boyer [2000] - 8 regions energy as an input**
4: Buonanno et al. [2001] - ETC RICE, RICE-96 + end. tech, change
5: Castelnuovo et al. [2003] - ETC-U-RICE= ETC-RICE + uncertainty Bosello and Moretto [1999]
6: **Galeotti and Carraro [2004] - RICE-99 + end.tech. change**
7: Castelnuovo et al. [2005] - RICE-96 + learning doing/research
8: **Bosetti et al. [2006a] - Policies based on Galeotti and Carraro [2004]**
9: **Bosetti et al. [2006b] - carbon and energy intensity based on Galeotti and Carraro [2004]**
10: **Bosetti et al. [2006c] - The WITCH model, energy as an input**
11: **Von Below and Persson [2008] - RICE-99 update calibration (not as in the original)**
12: Nordhaus [2009] - Sea level rise
13: Bosello [2010] - ETC-RICE + R&D + mitigation/adaptation
14: Nordhaus [2010] - 12 regions - adaptation + mitigation
15: **De Bruin [2014] - AD-RICE-99, focus on adaptation**
16: Nordhaus and Yang [2021] - 16,12,6 regions - RICE-2020, based on RICE-2010
17: Gazzotti [2022] - RICE-50+: 57 regions (EU at country level)

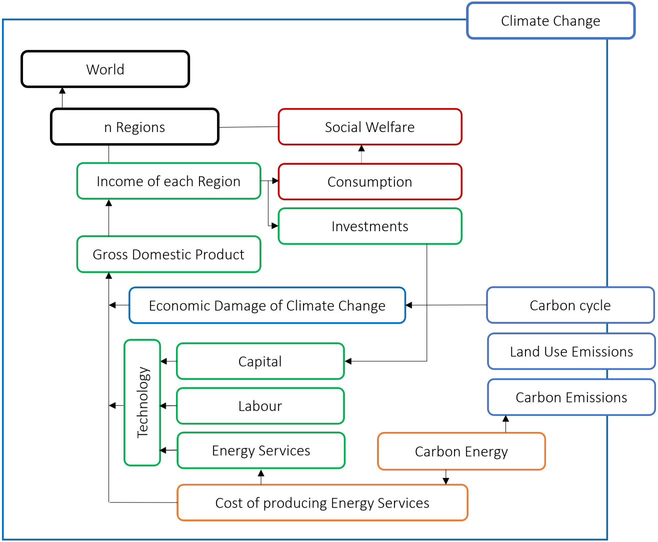
The RICE-MED model. An overview.

A regional model in which *Mediterranean nations* are considered at country level, allowing the identification of the economic damage of climate change at a finer spatial level, while other countries in the world are grouped in macro-regions.

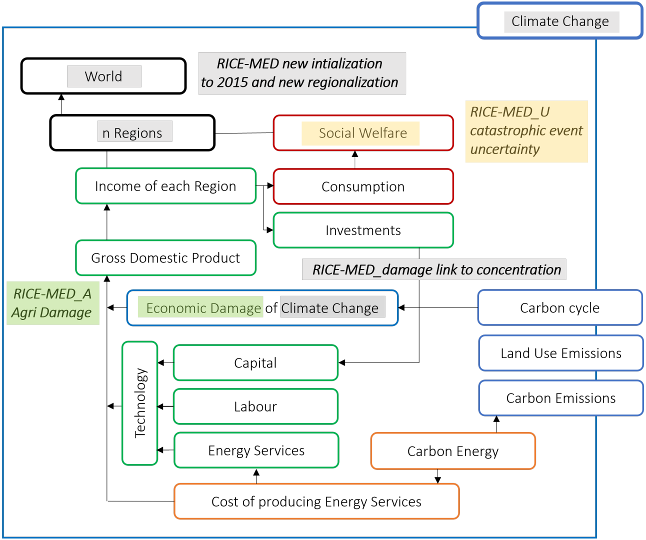
A regional model in which Mediterranean nations are considered at country level, allowing the identification of the economic damage of climate change at a finer spatial level, while other countries in the world are grouped in *macro-regions*.



The RICE-MED model. An overview.



The RICE-MED model. Novelties: RICE-MED, RICE-MED-U and RICE-MED-Agri.



The economy

In a ***one-sector closed economy*** *j*, the GDP $Y_j(t)$ is allocated between the *aggregate consumption* $C_j(n,t)$ and the *investments* $I_j(t)$

$$Y_j(t) = C_j(t) + I_j(t) \quad : \quad \textit{butget constraint}, \tag{1}$$

while the **capital stock** accumulates as:

$$K_j(t) = K_j(t-1)(1-\delta_K)^{10} + 10 I_j(t-1). \tag{2}$$

The **technological progress** is exogenous andevolving as:

$$A_j(t+1) = A_j(t)\, e^{g_j^A(t)}, \tag{3}$$

assuming to slow gradually over the next three centuries until eventually stopping. The **time step (Δt) is 10 years**. In the climate change literature: "is the average time it takes for a small increase in atmospheric CO2 concentration to have an effect on temperature after several years" [Pindyck, 2022].

The optimization problem of the $j - th$ region

A representative agent (the ***society***, she) is characterized by the ***utility*** function $U[c_j(t), L_j(t)]$, subject to existing resources and capital constraints.
The objective of the optimization is thus the ***social welfare*** function W_j.

$$\max_{c_j(t)} \quad W_j = \sum_t U\left[c_j(t), L_j(t)\right] R(t), \quad \text{with} \tag{4}$$

$$U[c_j(t), L_j(t)] = L_j(t) \frac{c_j(t)^{1-\alpha} - 1}{(1-\alpha)}, \tag{5}$$

- $R(t)$: the social preferences discount factor
- $c_j(t) = \frac{C(t)}{L(t)}$: the ***per-capita consumption*** and ***the decision variable***.
- α: the willingness to reduce the welfare of high-consumption generations to improve the one of low-consumption generations

Population $L_j(t)$ evolves overtime according the exogenous path:

$$L_j(t+1) = L_j(t) \left(\frac{L(T)}{L(t)}\right)^{g_j^L(t)}. \tag{6}$$

$\rightarrow$ assumptions: population equals labour; full employment.

The RICE-MED model: analytical framework.

The ***GDP of the economy*** $Y_j(t)$ is obtained as follows:

$$Y_j(t) = \left[A_j(t)\,K_j(t)^{\gamma}\,L_j(t)^{1-\beta_j-\gamma}\,ES_j(t)^{\beta_j}\right] - c_j^E(t)\,ES_j(t), \tag{7}$$

$$\text{where} \quad ES_j(t) = \zeta_j(t)E_j(t) \quad : \quad \textit{energy production function}, \tag{8}$$

the fossil fuels' (or carbon-energy) sector is included in the model as follows:

overall cost of producing energy services: $c_j^E(t)\,ES_j(t)$

regional unitary cost of energy: $c_j^E(t) = q(t) + Markup_j^E$

global wholesale price of energy: $q(t) = \xi_1 + \xi_2\left(\frac{CumC(t)}{CumC*}\right)^{\xi_3}$

regional markup on energy costs: ${Markup_j}^E$

The ***regional output net of environmental damage*** $Q_j(t)$ is defined as:

$$Q_j(t) = \Omega_j(t)\,Y_j(t) = Y_j(t) - D_j(M_{AT}(t))\,Y_j(t) \tag{9}$$

$$\textit{with} \quad \Omega_j(t) = 1 - D_j(M_{AT}(t)) = exp\left(-\theta_j\left(M_{AT}(t) - \bar{M}_{AT}\right)\right). \tag{10}$$

following Golosov et al. [2014]

Considering the global wholesale price of energy $q(t) = \xi_1 + \xi_2 \left(\frac{CumC(t)}{CumC^*}\right)^{\xi_3}$

- $\xi_i = \{113, 700, 4\}$ with $i = 1, 2, 3$: parameters
- $CumC^*$: inflection point beyond which the marginal cost of carbon-energy begins to rise sharply
- $CumC(t)$: cumulative consumption, or world use, of carbon energy at the end of period t expressed in terms of industrial emissions, with dynamics:

$$CumC(t) = CumC(t-1) + 10E(t) \tag{11}$$

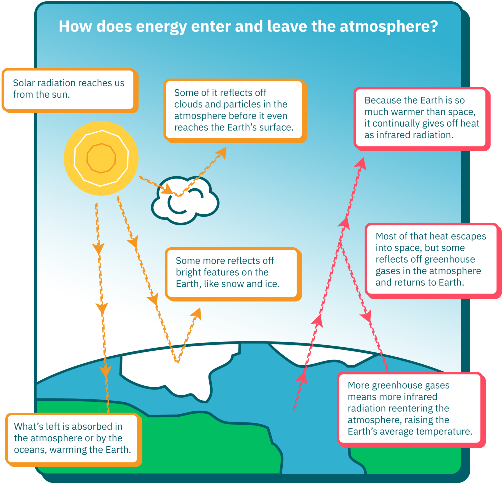
thus a function of:

- $CumC(t-1)$ the cumulative consumption at the previous time period
- $E(t)$ the world use of carbon energy (and industrial emissions) at time t, which yields from:

$$E(t) = \sum_j E_j(t) \tag{12}$$

The model also accounts for *land use emissions* $LU_j(t)$, which are exogenous. Thus the global emissions $ET(t)$ are:

$$ET(t) = \sum_j E_j(t) + LU_j(t) \tag{13}$$



Source: MIT Climate Portal/Radiative Forcings

The climate module of RICE-MED is the same of RICE-99 [Nordhaus and Boyer, 2000].

- Carbon-cycle equations:
  → link between GHGs emissions from the economic activity and and reservoirs' stocks
- Radiative forcing equation:
  → link between the accumulation of GHGs and climate change.
- Climate change equation (e.g.,temperature)
  → link between radiative forcing and tempearature equations.
- Climate-damage relationship:
  → It represents the impacts from climate change on the economic sectors (**applied to the the production function**).

The climate module: carbon cycle equations

We assume that there are three reservoirs for carbon:

- *the atmosphere* (AT), with $M_{AT}(t)$ being the related carbon stock at time t

$$M_{AT}(t) = 10ET(t-1) + \phi_{AT,AT}M_{AT}(t-1) + \phi_{UP,AT}M_{UP}(t-1) \quad (14)$$

- a quickly mixing reservoir in the *upper oceans and the biosphere* (UP), with $M_{UP}(t)$ carbon stock at time t

$$M_{UP}(t) = \phi_{UP,UP}M_{UP}(t-1) + \phi_{AT,UP}M_{AT}(t-1) + \phi_{LO,UP}M_{LO}(t-1) \quad (15)$$

- *the deep oceans* (LO) with $M_{LO}(t)$ as the mass of carbon at time t.

$$M_{LO}(t) = \phi_{LO,LO}M_{LO}(t-1) + \phi_{UP,LO}M_{UP}(t-1) \quad (16)$$

with:

→ $ET(t-1)$ as the global CO2 emissions including those from land use changes a time $t-1$,

→ $\phi_{i,j}$, the transfer rates from the reservoir j (per period), where $i, j = AT, UP, LO$

The climate module: radiative forcings

Radiative forcing is what happens when the amount of energy that enters the Earth's atmosphere is different from the amount of energy that leaves it.
If more radiation is entering Earth than leaving—as is happening today—then the atmosphere will warm up. (MI climate portal)

$$F(t) = \eta \left\{ log \left[\frac{M_{AT}(t)}{M_{AT}(1750)} \right] \frac{1}{log(2)} \right\} + \mathcal{O}(t) \tag{17}$$

where

- $F(t)$ is the change in the total radiative forcings of GHGs since 1750 from anthropogenic source such as CO2.
- η: forcings of equilibrium CO2 doubling (Wm-2)
- M_{AT} is the carbon in the atmosphere, which depends on M_{UP}, the the mass of carbon in the upper reservoir (UP). The latter is in turn affected by the mass of carbon in the lower oceans M_{LO} (Carbon cycle).
- $M_{AT}(1750)$ is the preindustrial level of atmospheric concentration of CO2.
- $\mathcal{O}(t)$ is the forcing of other GHGs (CFCs, CH4, N20 and ozone) and aerosols (exogenous).

The link between radiative forcing and temperature change is provided by:

Temperature increase equation,

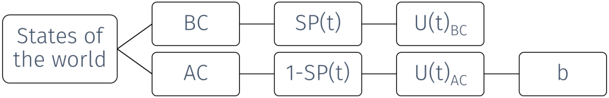
$$T(t) = T(t-1) + \sigma_1 \{F(t) - \lambda T(t-1) - \sigma_2 [T(t-1) - T_{LO}(t-1)]\} \tag{18}$$

where

- $T(t)$ is the increase in the globally and seasonally averaged temperature in the atmosphere and at the upper level of the ocean since 1900.
- $F(t)$ is the radiative forcing
- σ_i are the transfer coefficients reflecting the rates of flow and the thermal capacities of the different sinks.
- T_{LO} is the increase in temperature in the deep oceans
- λ is a feedback parameter

The society is not able to identify the global temperature level at which the catastrophic event may occur, but is aware of that.

It assign two different levels of utility, one before the event (BC) and the other after (AC), duly weighted for a survival probability $SP(t)$ (in BC) and a catastrophe probability $(1 - SP(t))$, in AC. In BC a utility loss defined by the share b is introduced.



The RICE-MED welfare maximization problem is revised as follows:

$$\max_{c_j(t)} \quad W_j = \sum_t U\left[c_j(t), L_j(t)\right] R(t) \tag{19}$$

$$\text{with} \quad U\left[c_j(t), L_j(t), SP(t)\right] = SP(t)\, U\left[c_j(t), L_j(t)\right]_{BC} + [1 - SP(t)]\, U\left[c_j(t), L_j(t)\right]_{AC} \tag{20}$$

$$\text{and} \quad U\left[c_j(t), L_j(t)\right]_{AC} = (1 - b)\, U\left[c_j(t), L_j(t)\right]_{BC}, \tag{21}$$

The survivor probability is a function of the endogenous temperature variation:

$$SP(t) = \exp\left[-HR(t)\right] \tag{22}$$

through the $HR(t)$ is the hazard rate function $HR(t)$:

$$HR(t) = \begin{cases} HR(t-1) + \left[\varphi_0 + \varphi_1 T\dot{(t)}\right] \eta \left[\max\left(0; T(t) - T_0\right)\right]^{\eta - 1} & \text{if} \quad T\dot{(t)}>0, \\ 0 & \text{otherwise} \end{cases} \tag{23}$$

$$\text{and} \quad T\dot{(t)} = \frac{\Delta T(t)}{T(t-1)}, \quad \text{with} \quad \frac{\partial HR(t)}{\partial T(t)} > 0. \tag{24}$$

Policy insights.

- The ***effect of increasing societal awareness of the impact of a potential climate-related disaster*** is found in all model results: ***better performance in temperature increase at the end of the century.***
- This demonstrates the importance of ***society correctly recognising and valuing*** a survivor probability determined by the temperature change and the potential loss of utility associated with the disaster.

- *BAU - Business as Usual*. It assumes no change in climate-related policies. This scenario represents the cost implications of unmitigated climate damage.
- **OPT - Social Optimum**. The social welfare function is maximized under the economic (regional) and climate (global) constraints, identifying the optimal pathways of consumption, production and emissions reduction in each point in time. Such paths allow the identification of the optimal carbon tax to achieve such benchmarks.
- **TL - Temperature Limit**: The OPT scenario runs under an additional constraint that limits the temperature increase below 2°C.

→ *Time horizon*: 2015-2305 (time step: 10 years).

→ *Time range of results*: 2015-2105

Outcomes of the RICE-MED model

Model initialization: in equations and updated 2015

For each country** i**, with** $i \in j - th$ **region,

- $\rightarrow$ $A_i(0)$, the total factor productivity $A_i(0)$,
- $\rightarrow$ $K_i(0)$, the capital stock,
- $\rightarrow$ $\beta_i(0)$, the elasticity of output respect to the energy input,
- $\rightarrow$ $Markup_i^E(0)$, the markup on the wholesale price of energy,

are calibrated so that at the base year the GDP, industrial emissions $E_i(t)$ and the interest rate ***match respective historical observations.***

Model initialization: in equations and updated 2015

Emissions of country i $E_i^d(0)$ are a function of:

→ $X_{s,i}(0)$, the consumption of the ***the carbon energy inputs, or energy source,*** s***, namely coal, oil, gas, for their different purposes***, and

→ γ_s, the emissions per unit of consumption for the energy source s, .

$$E_i^d(0) = \sum_s X_{s,i}(0)\gamma_s = \sum_s \omega_{s,i}(0)\left[\frac{P_{s,i}(0)}{P_{s,i}(0) + \tau_j(0)\gamma_s}\right]^{\eta_s}\gamma_s \tag{25}$$

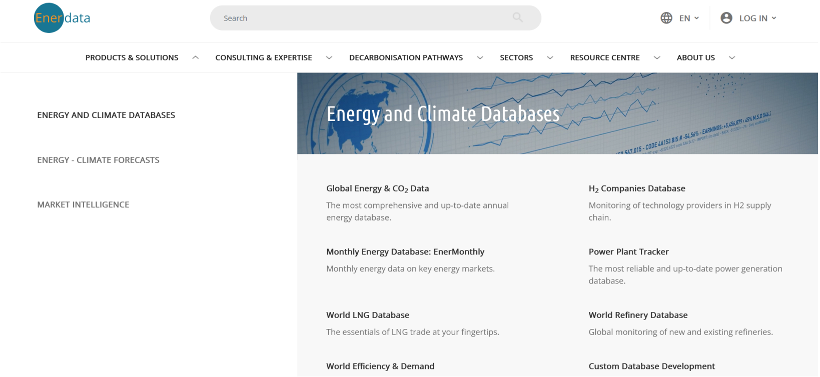
- $\omega_{s,i}(0)$ is the consumption of energy source s in the first period,
- $P_{s,i}(0)$ is its the price at the same time
- η_s is the price elasticity of demand for carbon energy source s.

Model initialization [Nordhaus and Boyer, 2000]: analytical resolution.

The unknown values of $A_i(0)$, $K_i(0)$, $\beta_i(0)$ and $Markup_i^E$ yields from the resolution of this **system of equations**, representing all the assumptions previously mentioned.

$$\begin{cases} Q_i(0) = A_i(0)K_i(0)^{\gamma}L_i(0)^{1-\beta_i-\gamma}E_i(0)^{\beta_i} - c_i^E(0)E_i(0); \\ \\ E_i(0) = \frac{1}{\zeta_i(0)}\left\{\left[c_i^E(0) + \frac{h(0)}{\zeta_i(0)} + \frac{\tau_j(0)}{\zeta_i(0)}\right]\frac{1}{\beta_i(0)A_i(0)K_i(0)^{\gamma}L_i(0)^{1-\beta_i-\gamma}}\right\}^{\frac{1}{\beta_i-1}}; \\ \\ (1+r_i)^{10} = \frac{\partial Q_i(0)}{\partial K_i(0)} + \frac{\partial K_i(1)}{\partial K_i(0)}; \\ \\ \underbrace{E_i(0,\tau=0) - E_i(0,\tau=50)}_{Change \quad in \quad emissions} = \underbrace{E_i^d(0,\tau=0) - E_i^d(0,\tau=50)}_{Disaggregated \quad Energy \quad Model}. \end{cases} \tag{26}$$

Model initialization



Model initialization

Initial conditions: outcomes.

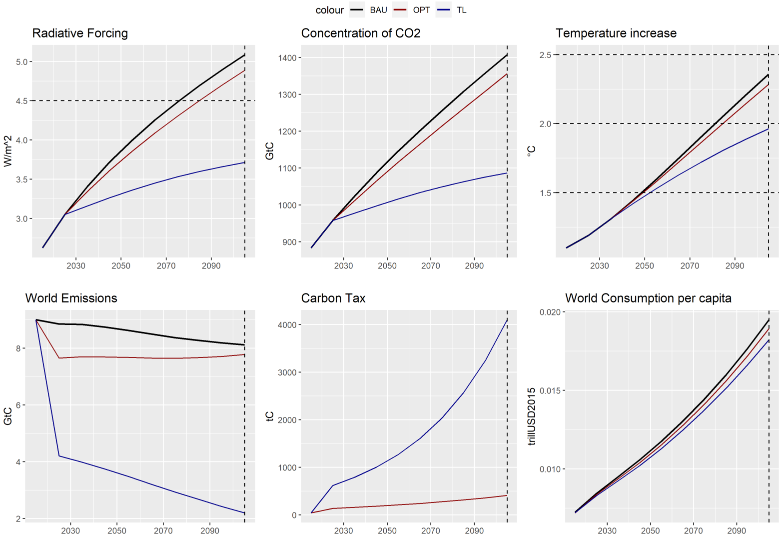
Italy				
Input	*Value*	*Source*	*Output*	*Value*
$L_i(0)$	61(mln)	World Bank	$A_i(0)$	0.084
$Q_i(0)$	1.642 (trillUSD2015)	World Bank	$K_i(0)$	2.18 (trillUSD2015)
$E_i(0)$	0.09 (GtC)	ENERDATA	$\beta_i(0)$	0.047
			$Markup_i^E(0)$	807.304 (thousandsUSD2015/tC)

Base Year is 2015.

From countries to regional aggregation:

- $K_j(0)$ yields from the aggregation of country specific values $K_i(0)$.
- $A_j(0)$, $\beta_j(0)$ and $Markup_j^E(0)$ yield from average values defined on the basis of countries specific ones.

Global results: scenarios overview



RICE-MED: Temperature increase and carbon tax

Variables / Scenario	2015	2025	2035	2055	2105	Average
Temperature increase (°C from 1900)						
Business as Usual	1.10	1.19	1.31	1.60	2.36	
Optimal	1.10	1.19	1.31	1.58	2.29	
Temperature limit ≤ 2.0	1.10	1.19	1.31	1.53	1.96	
Carbon Tax (USD/tC)						
Optimal	38.94	133.87	157.29	209.45	406.42	231.32
Temperature limit ≤ 2.0	39.76	617.36	788.72	1268.63	4104.60	1728.41

Global results: the effect of introducing uncertainty

RICE-MED-U: the survivor probability and catastrophic event probability

Variable / Scenario	2015	2025	2035	2055	2105
RMU0.30-BAU	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.990 (0.010)	0.938 (0.062)
RMU0.50-BAU	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.942 (0.058)
RMU0.70-BAU	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.942 (0.054)
RMU0.30-OPT	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.942 (0.058)
RMU0.50-OPT	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.946 (0.054)
RMU0.70-OPT	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.949 (0.051)
RMU0.30-TL $\leq$2.0	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.955 (0.045)
RMU0.50-TL $\leq$2.0	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.956 (0.044)
RMU0.70-TL $\leq$2.0	0.999 (0.001)	0.998 (0.002)	0.997 (0.003)	0.991 (0.009)	0.956 (0.044)

Text in blue brackets refers to the probability of a catastrophic event.
RMU*b*-Scenario: where *b* is the share sizing the utility loss. The higher is *b* the wider is the utility loss.

Global results: the effect of introducing uncertainty

- As the ***temperature*** continues to ***rise*** over time, the ***probability of facing a disaster highers*** too;
- such proportion is ***mitigated by the scenarios stringency*** and the in the ***size of the utility loss (i.e*** b ***highers)*** associated to the consequences of the disaster.
- ***As we get closer to the end of the century, changes across scenarios become apparent: the more environmentally binding the policy scenario becomes, the smaller the positive variation in the disaster probability overtime***.

Global results: the effect of uncertainty introduction

RICE-MED vs RICE-MED-U

Variables / Scenario	2015	2025	2035	2055	2105	
Temperature increase (°C from 1900)						
RM-Optimal	1.10	1.19	1.31	1.58	2.29	
RMU0.30-Optimal	1.10	1.19	1.31	1.56	2.18	
RMU0.50-Optimal	1.10	1.19	1.31	1.55	2.12	
RMU0.70-Optimal	1.10	1.19	1.31	1.55	2.12	
RM-Temperature limit ≤2.0	1.10	1.19	1.31	1.53	1.96	
RMU0.30-Temperature limit ≤2.0	1.10	1.19	1.31	1.53	1.95	
RMU0.50-Temperature limit ≤2.0	1.10	1.19	1.31	1.52	1.94	
RMU0.70-Temperature limit ≤2.0	1.10	1.19	1.31	1.52	1.94	
Carbon Tax (USD/tC)						*Average*
RM-Optimal	38.94	133.87	157.29	209.45	406.42	231.32
RMU0.30-Optimal	39.02	263.98	299.85	369.79	558.07	371.31
RMU0.50-Optimal	39.30	373.37	423.50	521.68	783.04	521.45
RMU0.70-Optimal	39.40	486.09	551.38	680.90	1031.71	681.66
RM-Temperature limit ≤2.0	39.76	617.36	788.72	1268.63	4104.60	1728.41
RMU0.30-Temperature limit ≤2.0	39.76	714.03	885,57	1348.86	3961.38	1752.02
RMU0.50-Temperature limit ≤2.0	39.76	782.20	788.72	1268.63	3890.40	1778.67
RMU0.70-Temperature limit ≤2.0	39.76	853.29	1028.28	1479.04	3838.53	1814.11

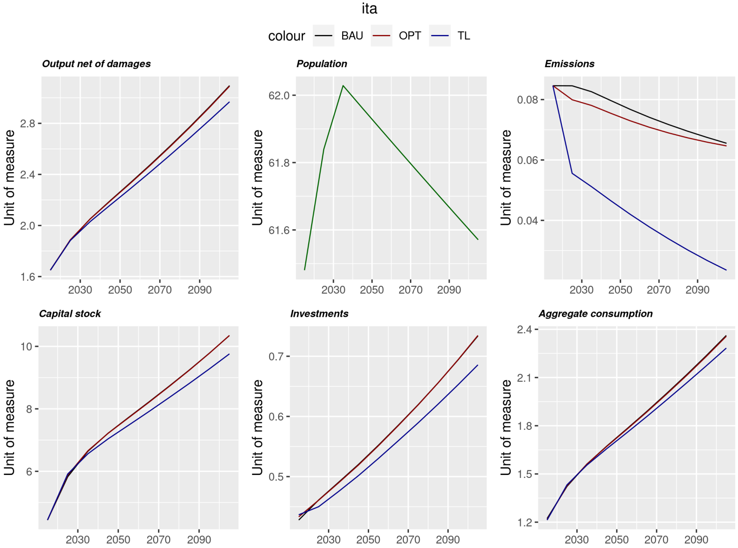
Social Rate of Time Preference (SRTP) is 1.5%. RM: RICE-MED. RMUb: RICE-MED-U model with $b = \{0.3, 0.50\}$.

Regional results

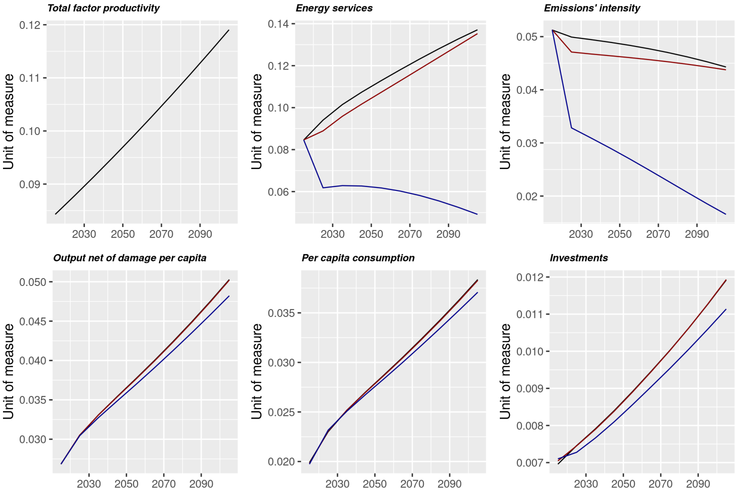
Outline

1. Model outcomes at regional level
2. Regional economic damage

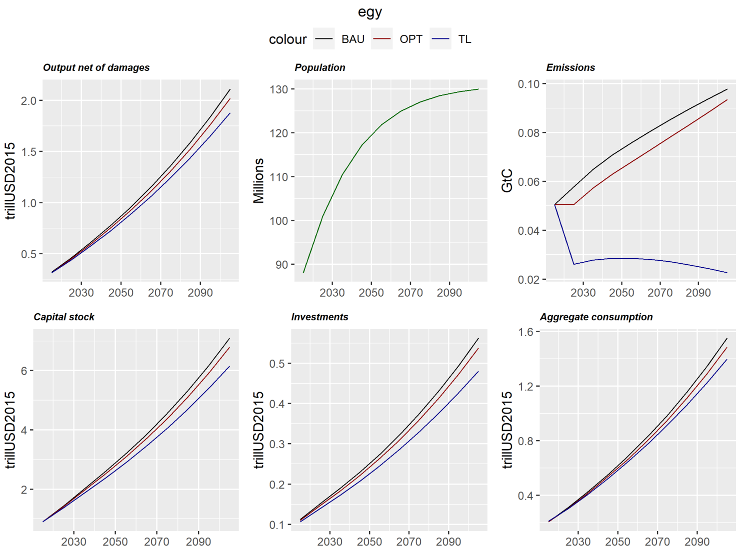
Regional results



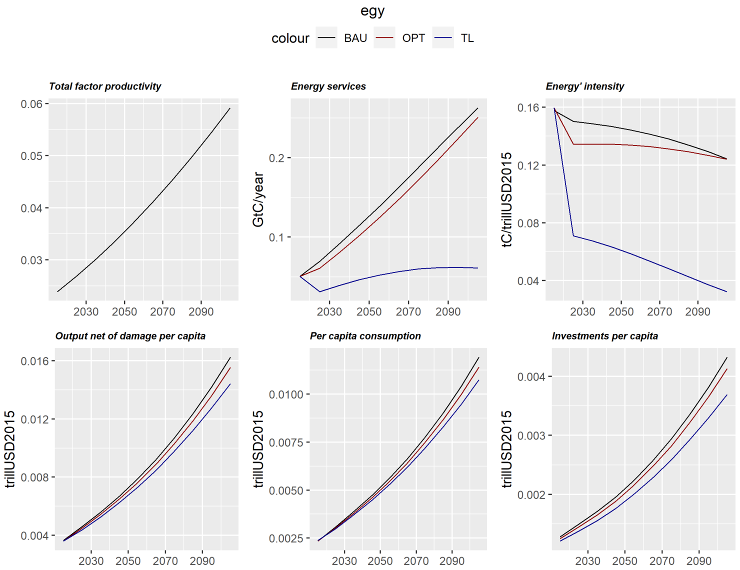
Regional results



Regional results



Regional results



Average changes in GDP reductions between scenarios for MED countries

	Average loss across scenarios		*Group average loss*		*Group variance*	
	BAUvsOPT	*BAUvsTL*	*BAUvsOPT*	*BAUvsTL*	*BAUvsOPT*	*BAUvsTL*
ALB	0.13%	0.29%	0.09%	0.33%	0.07%	0.08%
HRV	0.01%	0.27%				
MNE	0.16%	0.45%				
GRC	0.05%	0.32%				
CYP	0.23%	0.40%	0.19%	0.55%	0.17%	0.58%
ISR	0.10%	0.19%				
LBN	0.08%	0.24%				
SYR	0.46%	1.58%				
TUR	0.06%	0.32%				
DZA	0.25%	1.08%	0.27%	0.90%	0.06%	0.63%
EGY	0.24%	0.75%				
ETH	0.35%	0.31%				
LBY	0.24%	2.21%				
MAR	0.27%	0.46%				
SDN	0.35%	0.61%				
TUN	0.19%	0.86%				
FRA	-0.01%	0.06%	0.07%	0.15%	0.13%	0.062%
ITA	0.01%	0.17%				
MLT	0.27%	0.21%				
ESP	0.03%	0.17%				

Average reduction across scenarios by type of variable in regions

	Energy services		Emissions intensity		Investments	
	BAUvsOPT	*BAUvsTL*	*BAUvsOPT*	*BAUvsTL*	*BAUvsOPT*	*BAUvsTL*
USA	0.31%	4.80%	0.22%	3.42%	0.07%	0.43%
CHINA	0.45%	6.19%	0.25%	3.47%	0.04%	0.36%
EE	0.40%	6.40%	0.34%	3.85%	-0.01%	0.34%
EUROPE	0.35%	4.94%	0.30%	3.84%	0.06%	0.33%
LI	1.00%	8.11%	0.31%	4.06%	0.26%	0.50%
LMI	0.74%	6.86%	0.29%	3.92%	0.15%	.45%
MI	0.85%	6.73%	0.40%	4.21%	0.14%	0.39%
OHI	0.79%	5.42%	0.43%	4.22%	0.20%	0.28%

Average reduction in Energy Services between scenarios for MED countries

	Average Δ ↓ across scenarios		Group average loss		Group variance	
	BAUvsOPT	BAUvsTL	BAUvsOPT	BAUvsTL	BAUvsOPT	BAUvsTL
ALB	0.59%	6.61%	0.43%	5.29%	0.26%	1.50%
HRV	0.18%	4.18%				
MNE	0.71%	6.56%				
GRC	0.24%	3.80%				
CYP	0.95%	6.98%	0.87%	7.02%	0.29%	1.56%
ISR	0.52%	6.08%				
LBN	0.68%	5.48%				
SYR	1.26%	9.57%				
TUR	0.96%	6.98%				
DZA	0.56%	6.57%	0.95%	7.53%	0.56%	1.17%
EGY	0.69%	7.55%				
ETH	1.10%	8.66%				
LBY	0.97%	8.43%				
MAR	2.09%	8.28%				
SDN	0.83%	7.84%				
TUN	0.40%	5.40%				
FRA	0.44%	5.35%	0.47%	4.86%	0.28%	0.79%
ITA	0.21%	3.77%				
MLT	0.86%	5.53%				
ESP	0.37%	4.79%				

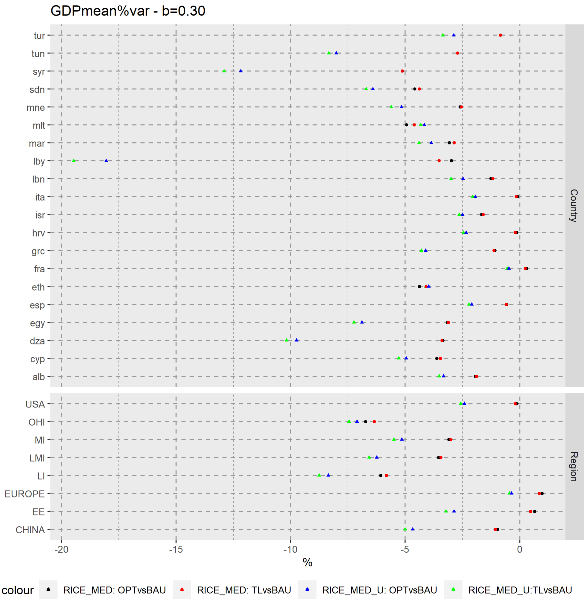
Regional results: regional economic damage induced by climate change

	Scenario	2015	2025	2035	2055	2105
Europe	Optimal	0.35	0.94	0.82	0.89	1.38
(Δ% to Baseline)	Temp Limit	0.35	0.94	0.12	-0.51	-1.41
LMI	Optimal	-1.31	-2.39	-2.19	-3.60	-4.86
(Δ% to Baseline)	Temp Limit	-1.31	-4.40	-5.48	-6.71	-9.54
Egypt	Optimal	-1.14	-2.14	-2.62	-3.23	-4.28
(Δ% to Baseline)	Temp Limit	-1.14	-4.67	-5.80	-7.21	-11.08
Sudan	Optimal	-1.74	-3.08	-3.70	-4.61	-6.37
(Δ% to Baseline)	Temp Limit	-1.74	-4.58	-5.63	-6.83	-9.51
Tunisia	Optimal	-0.93	- 1.80	-2.26	-2.80	-3.64
(Δ% to Baseline)	Temp Limit	-0.93	-4.87	-6.22	-8.00	-13.89

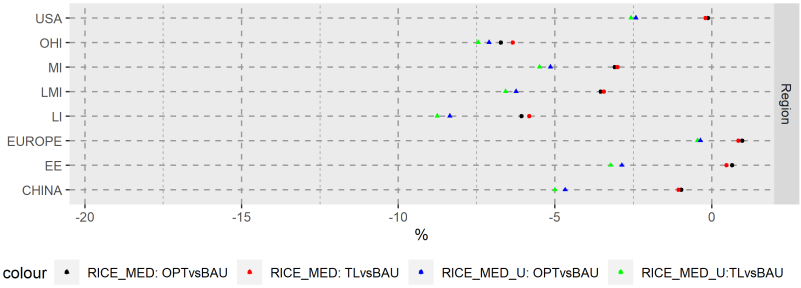
Overtime difference in Output w.r.t. Business As Usual (%)

Conclusions

Results visualization for policy is another challenge



Results visualization for policy is another challenge



RICE-MED, an integrated assessment model for the Mediterranean basin: assessing the climate-economy-agriculture nexus

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The paper in brief.

- Updated calibration of the RICE-99 of Nordhaus and Boyer [2000] to year 2015.
- Analytical formalization of the model initialization process.
- New regionalization, with Mediterranean nations at country level.
- New damage function [Golosov et al., 2014].
- RICE-MED-U: Uncertainty [Castelnuovo et al., 2003].
- RICE-MED-AGRI: economic damages linked to climate change to the agricultural sector.

Scan here to read the working paper.

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Thank you for your time!

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