Adaptation to climate change

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Climate Economics for Engineers

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Outline

Preamble

M Politique

POLITIQUE | Gouvernement Philippe | La République en marche | Les Républicains | Parti socialiste

La canicule de l'été 2018 a fait dix fois moins de morts qu'en 2003

Agnès Buzyn a annoncé vendredi que la vague de chaleur de l'été 2018 avait provoqué environ 1 500 morts de plus qu'une année normale.

LE MONDE | 21.09.2018 à 08h52

La canicule de l'été 2018 a provoqué environ 1 500 morts de plus qu'une année normale, soit dix fois moins qu'en 2003, a annoncé vendredi 21 septembre la ministre de la santé, Agnès Buzyn, sur CNews.

« *Il y a eu un excès de mortalité qui était évidemment attendu chez les personnes très âgées, probablement moins de 1 500 morts de plus que ce qui est attendu normalement dans ces mois-là* », a déclaré la ministre. Ce chiffre représente « *dix fois moins que la canicule de 2003* », qui avait fait entre 15 000 et 20 000 morts, mais aussi « *moins que les autres épisodes caniculaires* » des dernières années, a-t-elle noté. En 2015, environ 3 000 décès supplémentaires avaient été enregistrés selon les autorités sanitaires, mais seulement 700 en 2016, et moins de 400 en 2017. En 2006, année de canicule particulièrement sévère, une surmortalité d'environ 2 000 décès avait été constatée.

Prévention et mobilisation ont porté leurs fruits

Introduction

In the fifth IPCC report [2014] dedicated to *Economics of Adaptation* it is written that

i The previous AR4 report provided a limited assessment of the costs and benefits of adaptation

ii Based on narrow and fragmented sectoral and regional literature

iii Substantial advances have been made in the economics of climate change adaptation after AR4

iv **But** the major challenge is the low quality and limited nature of data

v Also there are simply missing non-market data on such items as the value of ecosystem services

The need for research on adaptation

- Research on economic aspects of climate change were mainly focused on mitigation cost
- As climate negotiations are unsuccessful, the 2° temperature increase seems more and more unreachable
- Climate change will occur and there is a need to make adaptation against global warming
- Needs of research on adaptation

Definition of adaptation

Climate change adaptation:

Adapting to climate change refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive, private and public, and autonomous and planned adaptation (IPCC, 2001).

Endogenous adaptation *versus* exogenous adaptation

- Endogenous adaptation
  - Also called *autonomous*, *private*, *market driven*, *automatic* or *spontaneous*
  - Adaptation that occurs independently to any initiative coming from the Government
  - Response to price changes, change production process, change activity, change consumption,...
- Exogenous adaptation
  - Also called *planned*, *policy driven*, *public*
  - public goods (infrastructure, natural resources, R&D), regulatory measures (norms, legislation), policies measures (taxes, subsidies, ...)

Adaptation as a public good

- A public good is a good that is non-rival and non-excludable:
  - Non-rivalry: the consumption of the good by one individual does not reduce availability of the good for consumption by others
  - Non-excludability: that no one can be effectively excluded from using the good

	Rival	Non-Rival
Excludable	Milk Land	Research and Developement Cinema
Non-Excludable	Wildlife Fish stock	Moonlight Non Commercial Knowledge Radio signal Atmosphere Lighthouse

Public adaptation and private adaptation

Table 1: Domains of adaptation

		Beneficiaries: Private	Beneficiaries: Public
Providers	Private	relocating home against flooding	plant gardens with grass instead pave (limit flooding risk)
	Public	subsidies on house insulation against heatwaves	research fund on climate change

Anticipatory *versus* reactive adaptation

	Anticipatory	Reactive
Natural System		Changes in length of growing season Changes in ecosystem composition Wetland migration
Private	Purchase of insurance Construction of house on stilts Redesign of oil rigs	Change in farm practices Change in insurance premiums Purchase of air-conditioning
Public	Early-warning system New building codes, design standards Incentives for relocation	Compensatory payments, subsidies Enforcement of building codes Beach nourishment

Source:Klein, Richard J.T., et al. (2008) "Adaptation: Needs, Financing and Institutions", The Climate Group, Breaking the Climate Deadlock: Briefing Papers.

Climate change impacts and adaptation

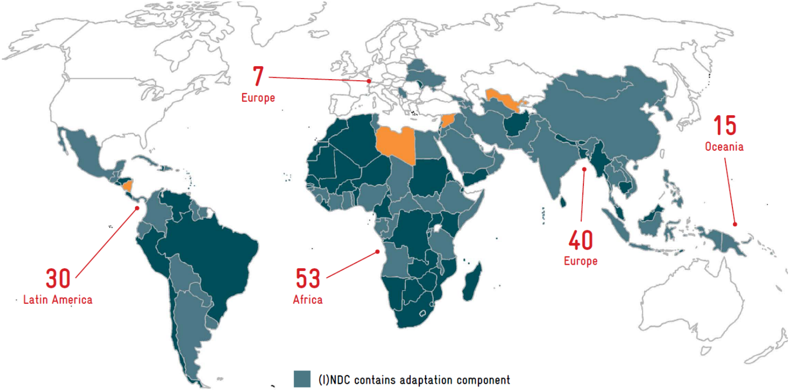
Sector	Adaptation
Agriculture	Change crop species
	Alter timing
	Irrigation
	Plan breeding
Water	Water efficiency
	Divert/store more water
Ecosystems, Biodiversity	Move species
Forestry	Plan news trees
	Change management
Sea level rise	Sea walls
Energy	New cooling capacity
	Changes in insultaion
Health	Prepare for extreme weather

COPs and adaptation

- COP13 - Bali- 2007: Call to enhance adaptation as planned in Bali Action Plan
- COP15 -Copenhagen- 2009: Stressed the need to establish a comprehensive adaptation programme including international support
- COP19 -Warsaw- 2013: Enhanced action and international cooperation on adaptation urgently required to enable and support the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries
- COP20 -Peru- 2014: Decided that a revision of initial guidelines for formulating national adaptation plans is not necessary at that time and identified a need to enhance reporting on the process to formulate and implement national adaptation plans

Source: Godwell Nhamo and Senia Nhamo (2016), "Paris (COP21) Agreement: Loss and damage, adaptation and climate finance issues" *International Journal of African Renaissance Studies - Multi-, Inter- and Transdisciplinarity*

COP21, INDCs and National Adaptation Plan (NAP)



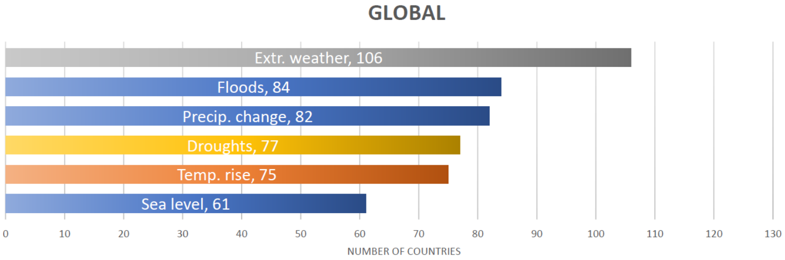
- (I)NDC contains adaptation component
- (I)NDC contains adaptation component & refers to the NAP process
- (I)NDC does not contain adaptation component
- no (I)NDC submitted

SIDS: 38, LDCs: 48, Others: 59

Figure 1:
Distribution of countries that included an adaptation component and referred to the NAP process in their (I)NDC (16)

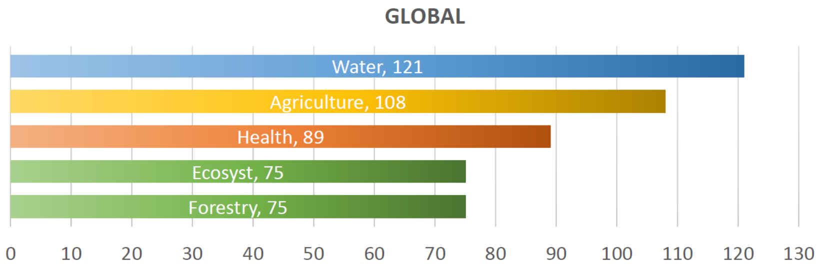
Source: "The role of NAP Process in translating NDC Adaptation Goals into Action", (2017), GIZ

Climate hazards identified in INDCs



Source: M. Goldberg (2016), "Adaptation components of INDCs", UNFCCC

Adaptation priority sectors in INDCs

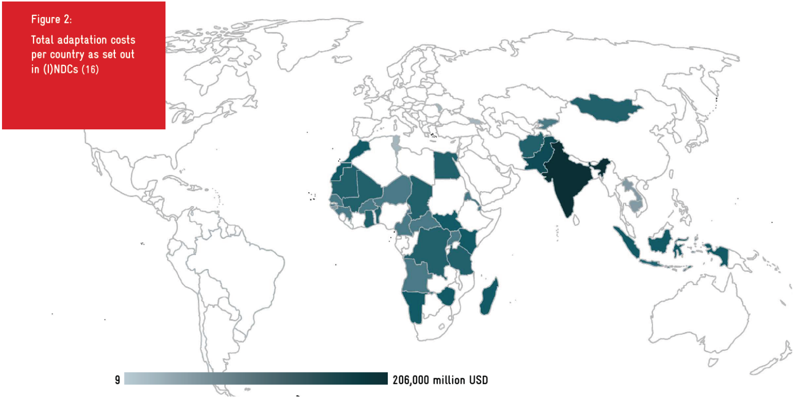


Source: M. Goldberg (2016), "Adaptation components of INDCs", UNFCCC

Adaptation goals:

- 73% are qualitative
- 15% provide quantitative goals
- 12% haven't clear goals

Adaptation costs in INDCs



- 34% of INDCs that include adaptation component provide adaptation cost
- Total adaptation cost in NDCs 140'527 billion US $ (World GDP = 80 700 billions US $)

Source: "The role of NAP Process in translating NDC Adaptation Goals into Action", (2017), GIZ

Interactions between adaptation and mitigation

- Economic modeling was mainly focussed on GHG mitigation
- Usually economic model which integrate damage cost of climate change suppose implicit adaptation
- In the last years researchers and policy makers have devoted greater attention to adaptation ($\leftarrow$ failure of climate negotiation)
- Adaptation could be considered as a control or a policy variable
- What are the interactions between adaptation and mitigation ?
- Mitigation and adaptation are policy substitutes

The DICE model

- DICE model: The **D**ynamic **I**ntegrated **C**limate-**E**conomy model
- developed by William Nordhaus
- Integrates the economics, carbon cycle, climate science, and impacts in a highly aggregated model
- Policy optimization model
- RICE model, regional version of DICE
- see `https://sites.google.com/site/williamdnordhaus/dice-rice`

The DICE model

Objective function:

$$max \sum_t U[c_t, L_t](1+\rho)^t \tag{1}$$

c_t consumption per capita L_t population

the output is given by a Cobb-Douglas function:
$Q_t = \Omega_t A_t K_t^{\gamma} L_t^{1-\gamma}$

where K_t is the stock of capital, and Ω_t a parameter taking into account damage of climate change, adaptation and mitigation cost

$Q_t = I_t + c_t \cdot L_t$
$I_t = K_t - (1-\lambda) K_{t-1}$

The DICE model (*continued*)

Emissions of GHG:
$E_t = (1 - \mu_t)\sigma_t Q_t$ where μ is the level of GHG abatement

Cost of abatement:
$TC_t / Q_t = \alpha_1 \mu_t^{\alpha_2}$

Concentration relative to preindustrial level:
$M_t = h(E_t, M_{t-1})$

Temperature change relative to 1990:
$TE_t = t(M_t)$

Adaptation cost in DICE

Bruin et *alii* (2009) modify the net damages equation (D_t) by distinguish residual damages (RD_t) and adaptation cost (PC_t) with level of adaptation (P_t)

$$\frac{D_t}{Q_t} = \frac{RD_t(GD_t, P_t)}{Q_t} + \frac{PC_t(P_t)}{Q_t} \tag{2}$$

where $GD_t/Q_t = (\alpha_3 TE_t + \alpha_4 TE_t^{\alpha_5})$ with TE temperature change compared to 1990 temperature

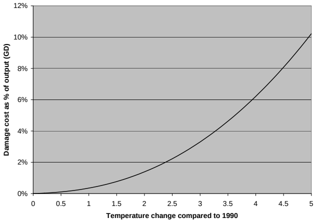


Figure 1: Gross damage cost function

Adaptation cost in DICE (*continued*)

$$RD_t = GD_t \cdot (1 - P_t) \text{ where } 0 \leq P_t \leq 1$$
$$PC_t / Q_t = \alpha_6 P_t^{\alpha_7}$$

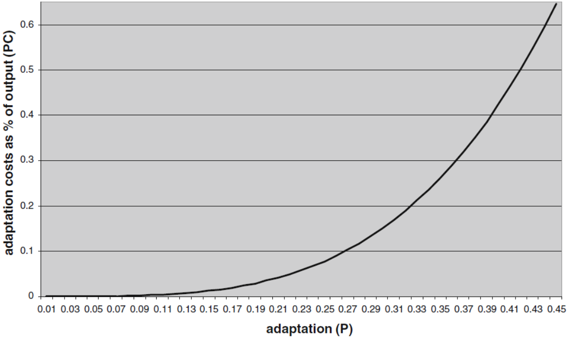


Figure 2: Adaptation cost function

The DICE model (*continued*)

The model is solved on the period 1990-2200 with four scenarios:

1. No control scenario (without adaptation and mitigation)
2. With optimal control (with adaptation and mitigation)
3. With only adaptation
4. With only mitigation

Utility of the different scenarios

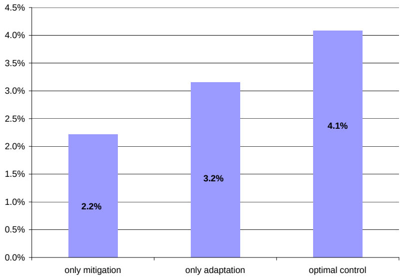


Figure 3: Percentage differences in utility of the different scenarios compared to the *no control* scenario

- The *optimal* scenario leads to the highest welfare level
- The *only adaptation* scenario is better than the *only mitigation* scenario, this result confirms the importance of adaptation

Climate change cost

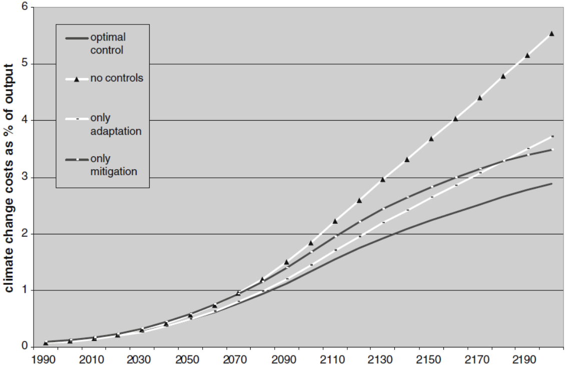


Figure 4: Climate change costs of different policy scenarios

- The *only adaptation* scenario damages are smaller in the beginning periods compared to *only mitigation* scenario
- The assumption used in this model suppose that money spend in adaptation gives immediate benefit

Components of cost

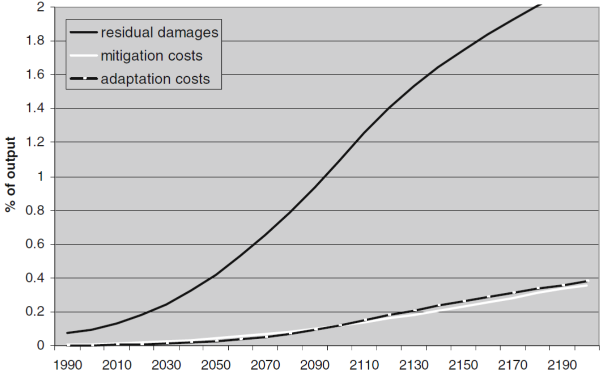


Figure 5: Composition of climate change cost in the optimal scenario

- A large part of costs consist of residual damages
- Adaptation cost and mitigation represent a low fraction

Conclusion of the AD-DICE model

- Adaptation and mitigation can substantially reduce the impacts of climate change
- Applying only adaptation is more beneficial than applying only mitigation
- But more research is needed on adaptation
  - the adaptation function ignores irreversibility (shutdown of the thermohaline circulation)
  - the adaptation function is aggregated
  - the model does not distinguish regions

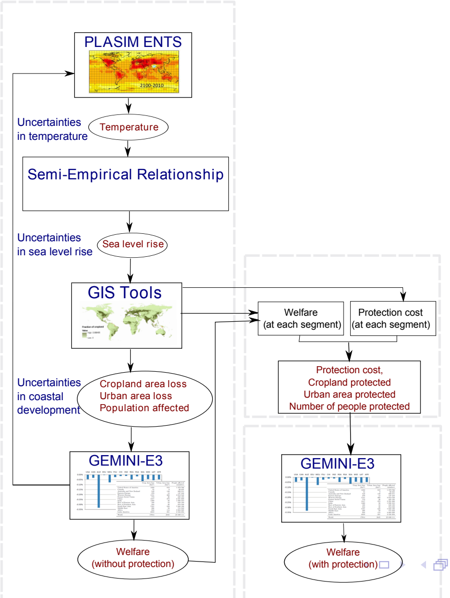
Limits of adaptation representation in DICE

- DICE is a very aggregated (or stylized) view of the climate change problem
- There is a strong disaggregated character of adaptation depending on sector on region ($\rightarrow$ local or regional analysis are needed)
- Adaptation involves mostly bottom-up actions: the benefits of adaptation accrue mostly to the person, mitigation benefits are enjoyed globally
- In respect to adaptation there is a lack of studies, research, information
- Climate change is not only related to global temperature change (other dimensions are to be taken into account: precipitation, extreme events...)

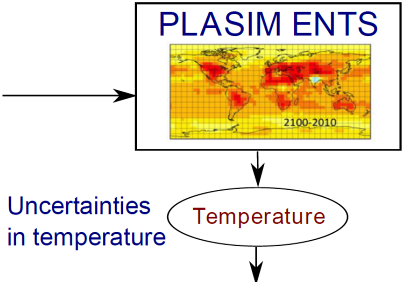
Sea Level Rise: Economic impact with/without adaptation

- Based on a paper published in Environmental and Resource Economics in 2016
- Work done within the FP7 European Project ERMITAGE
- ERMITAGE: Enhancing Robustness and Model Integration for The Assessment of Global Environmental Change
- Contributions of the paper
    1. Examine and analyse physical and economic consequences of SLR
    2. Develop a new modelling framework that combines several modeling tools (economic model, climate model, GIS tool)
    3. Assess the impacts of adaptation
    4. Rank uncertainties coming from different fields

Methodological Framework

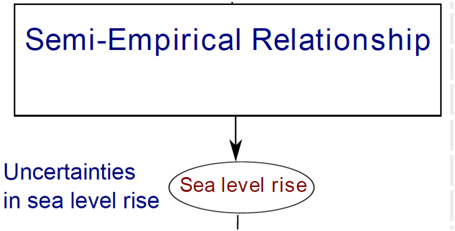


The Climate model



- We use an emulator of a climate model: PLASIM-ENTS
- Based on GHG emissions computed from the GEMINI-E3 model, the climate model computes global warming
- But the climate model allows us to compute also uncertainties related to the temperature increase

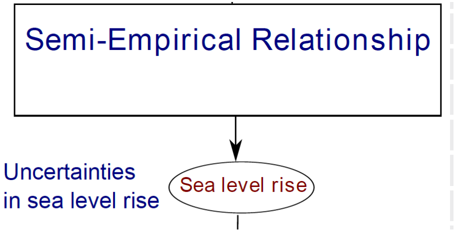
Sea-Level Rise: Semi-empirical Relationship



$$\frac{dS}{dt} = a(T(t) - T_0) + b\frac{dT}{dt} \qquad (3)$$

with $a = 5.6$ mm/year/°C, $b = -66$ mm/°C and $T_0 = -0.43$°C.
T is the global mean temperature (computed by PLASIM-ENTS emulators in our analysis) and T_0 is the previous equilibrium temperature value.

Sea-Level Rise: Semi-empirical Relationship



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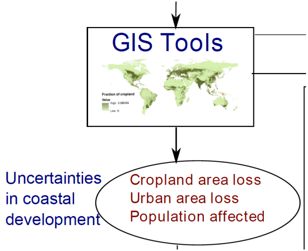
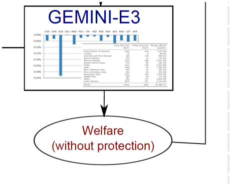
Coastal impacts



We use three maps:

1. The model GTOPO30 which is a global digital elevation model with a horizontal grid spacing of approximately 1 km
2. A Land-use database developed within the Representative Concentration Pathways (RCP) that provides land area for agriculture
3. The Global Rural-Urban Mapping Project which consists of human population estimates by approximately 1 km grid cell

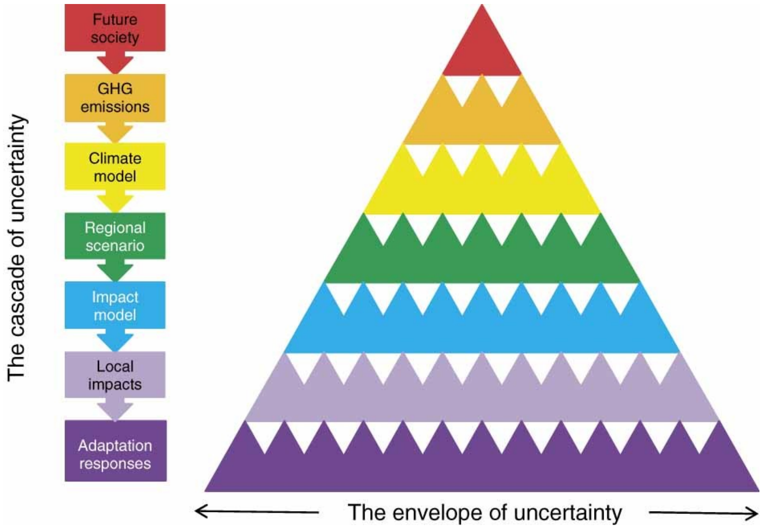
Economic Impacts without adaptation



The GEMINI-E3 model (CGE) is used to compute the economic impact with the following assumptions

- Loss of agricultural land → land endowment is decreased
- Loss of urban areas → capital endowment is decreased
- People living in coastal affected → labor endowment is decreased + cost of resettlement
- The permanent displacement of a person including the related cost of rebuilding houses and infrastructure is three times the GDP per capita of the affected country

Cascading uncertainties

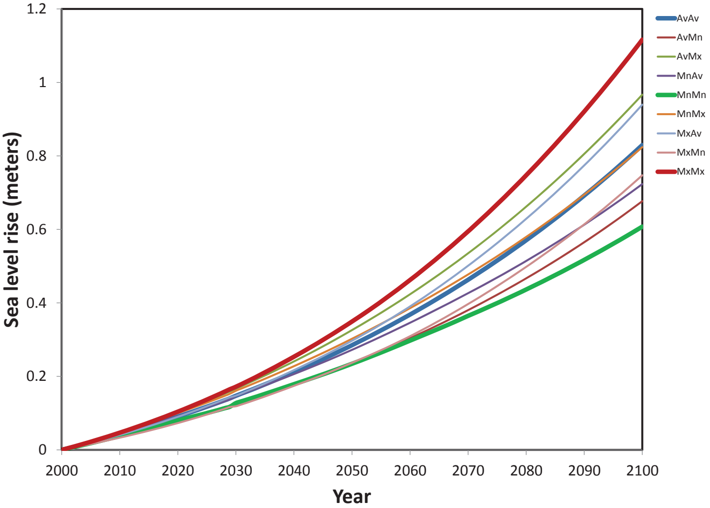


Cascading uncertainties

Uncertainties considered in this study

- Warming uncertainties
- SLR uncertainties
- Coastal evolution in terms of population density, urban areas and cropland areas
- Protection cost

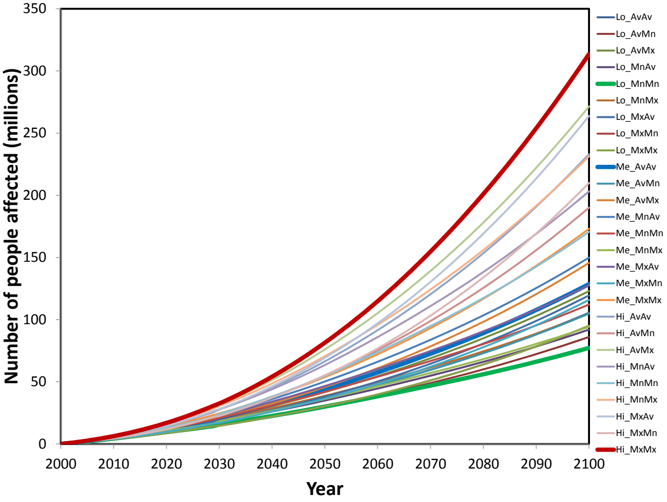
Sea level rise



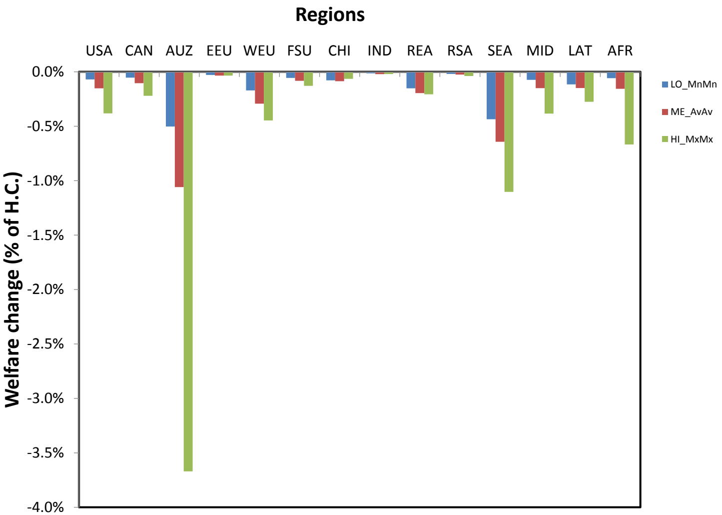
Economic impacts

- Loss of agricultural land → decrease in production → price increase. Cost [31,48] Billions US $ in 2100
- Loss of urban area → decrease in capital → decrease in production → Price increase. Cost [593,2975]
- People affected → decrease in labor supply and additional cost of inhabitants resettlement financed by the government. Cost [227,813]

People affected

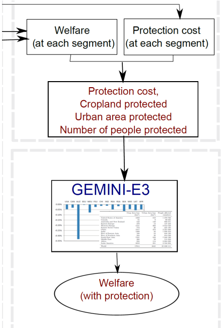


Welfare change related to people affected



Economic Impacts with adaptation

The previous analysis already includes adaptation components



The cost of building dikes is taken from the Global Vulnerability Assessment (GVA) report where it is estimated to equal 11.5 million 2007 US$ per km.

Economic Impacts without/with adaptation

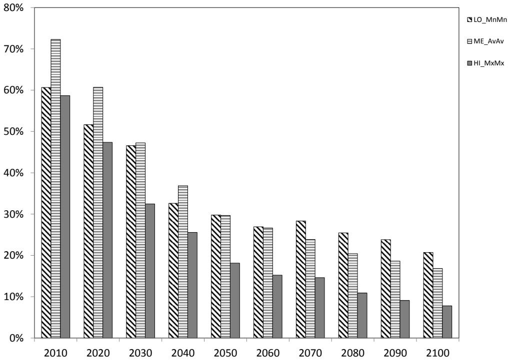


Figure 6: Global welfare change (with protection) as percentage of global welfare change (without protection) for medium protection cost

Main insights

- That economic impacts due to loss in cropland without protection are low
- In contrast, economic impacts of SLR due to loss of capital and number of people affected are quite significant
- Overall, we find that the economic impact of SLR could be significant for the coastal regions
- South East Asia, Australia and New Zealand potentially the most affected regions
- With protection, welfare change is still negative but much less than that without protection
- SLR impacts could be ameliorated by proper management of coastal developments (resettlement of coastal population and building infrastructure away from threatened coastline) in the coming decades

Conclusion

- Most of the studies of climate change impact make simple assumption about adaptation
- During a long time, adaptation was not present at the political agenda
- There are differences between adaptation and mitigation
  - Mitigation is usually resolve at the national or international level
  - Adaptation is primarily a matter of local actors, individual households, firms
  - Adaptation analysis require interdisciplinary approach

Sources and bibliography

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