Joint modelling of adaptation and mitigation costs

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Joint modelling of adaptation and mitigation costs

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Introduction

- Existing Integrated Assessment Models almost always *implicitly* assume optimal adaptation
- Lack of detailed information on regional adaptation costs prevents bottom-up approach
- Our top-down approach: extract a possible adaptation cost curve from existing damage functions
  → provide insight into interactions between mitigation and adaptation

Starting point: DICE model by W. Nordhaus

Joint modelling of adaptation and mitigation costs
• Ramsey growth model and climate module
• Production delivers utility (through consumption) but causes emissions
• Emissions of CO2 $\rightarrow$ concentrations $\rightarrow$ radiative forcing (other GHG exogenous) $\rightarrow$ temperature change $\rightarrow$ damages
• Mitigation can decrease emissions at a cost and delivers benefits in the form of avoided damages

Joint modelling of adaptation and mitigation costs
Explicitating adaptation

DICE
- Damage function implicitly incl. optimal protection
- Damages as percentage of GDP are a function of temperature increase (exponential)

AD-DICE
- *Gross damages* as percentage of GDP are function of temperature increase (exponential)
- *Residual damages* are function of gross damages and “protection effort” (linear)
- *Adaptation (protection) costs* are function of protection effort (exponential to achieve positive first and second derivatives)
- Adaptation costs can also enhance negative damages
We calibrate the gross damage and protection cost functions in AD-DICE such that in every period the sum of residual damages and adaptation costs equal damages in the DICE model using the optimal scenario.

Calibration point is at a doubling of pre-industrial CO$_2$ concentrations in DICE this occurs near the end of the 21$^{\text{st}}$ century with a corresponding 2.4°C temperature change.
Calibration restrictions (global)

At all points:
- Adaptation is optimal: marginal reduced residual damages of adapting equal marginal adaptation costs

At calibration point:
- Protection costs are between 7 and 25% of total damages (Tol et al 1999)
- Adaptation is between 0.3 and 0.8 (various studies)
- Protection costs are between 0.1 an 0.5% of output (Tol et al 1999)

→ most calibration constraints are not binding

Joint modelling of adaptation and mitigation costs
Calibration fit: damages

Joint modelling of adaptation and mitigation costs
Regional implementation: constructing regional AD-RICE from original RICE model using the same framework at a regional scale.

For some regions in some periods, climate change is beneficial (negative damages): adaptation then enhances climate benefits.

Calibration problem for regions with long term near-zero climate benefits.

As RICE is based on older information than DICE and information base for adaptation cost curve is weaker, we use AD-DICE where possible, AD-RICE where necessary.

Joint modelling of adaptation and mitigation costs.
Calibration fit: emissions (optimal)

Joint modelling of adaptation and mitigation costs
Policy scenarios

• Reference scenarios:
  – no controls, optimal control
  – no mitigation, no adaptation

• Mitigation scenarios:
  – climatic constraints
  – OECD carbon taxes

• Adaptation scenarios:
  – limits on adaptation
  – limits on adaptation costs

Joint modelling of adaptation and mitigation costs
## Results: climate costs

<table>
<thead>
<tr>
<th></th>
<th>R1: No controls</th>
<th>R2: Optimal control</th>
<th>R3: No mitigation</th>
<th>R4: No adaptation</th>
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<tbody>
<tr>
<td><strong>Period 2055-2064</strong></td>
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</table>

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Results: Climate costs (opt.control)

Joint modelling of adaptation and mitigation costs
Results: adaptation vs. mitigation

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Results: Temperature change

- M1: 404 ppm limit
- M2: 404 ppm limit after 2150
- M3: 560 ppm limit
- M4: 2 degrees temperature change limit
- M5: 3 degrees temperature change limit

R3: No Mitigation
R2: Optimal Controls

Joint modelling of adaptation and mitigation costs
Results: utility (I)

Joint modelling of adaptation and mitigation costs
Results: utility (II)

Joint modelling of adaptation and mitigation costs
Sensitivity Analysis

- Sensitivity of AD-DICE replicating DICE
  - AD-DICE replicates the mitigation results of DICE also for scenarios the adaptation costs are not calibrated to
  - robust with respect to climate sensitivity, discount rate, ...

- Sensitivity of AD-DICE model simulations
  - changing discount rate brings optimal concentrations closer to results of other models, but does not affect qualitative conclusions on adaptation vs. mitigation
  - changing damages: similar effects

- Sensitivity of regional results
  - integration of AD-RICE adaptation cost curves into FAIR model allows for extensive sensitivity analysis of regional model (results not yet finalised)

Joint modelling of adaptation and mitigation costs
Calculations with FAIR model (I)

Joint modelling of adaptation and mitigation costs
Calculations with FAIR model (II)

Regional adaptation costs as % of GDP

- E&W Afr
- South Asia
- SE Asia
- OECD Eur
- Middle East
- South Am
- World
- USA
- Japan
- East Asia

Joint modelling of adaptation and mitigation costs
Conclusions (I)

- As existing IAMS assume optimal adaptation, making adaptation costs explicit does not influence the optimal results
  - but mitigation results are also robust for other scenarios than the ones our models are calibrated to
  - impact of (suboptimal) adaptation on mitigation is small
    → no grounds to reject mitigation results from existing IAMS
- Adaptation is as important as mitigation
  - adaptation costs this century of same order of magnitude as mitigation costs
  - adaptation can also provide short-term compensation to suboptimal mitigation
  - optimal adaptation levels roughly constant over time: not only a short-term option
Conclusions (II)

• Incentives to mitigate in near future are low as adaptation is more beneficial
  – myopic government will overinvest in adaptation, underinvest in mitigation
  – in later periods mitigation is essential to keep climate change costs (gross damages) manageable

• The availability of adaptation makes mitigation more beneficial in the near future but much less thereafter
  • No adaptation implies overinvestment in short term mitigation

• More empirical information is needed to confront this top-down approach with bottom-up estimates of adaptation costs

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Protection cost curves
Explicitating adaptation (I)

DICE damage function implicitly incl. optimal protection:

(1) \[ \frac{D_t}{Y_t} = a_1 T E_t + a_2 (T E_t)^2 \]

AD-DICE:
Gross damages \( \rightarrow \) adapt \( \rightarrow \) residual damages

\[ \frac{D_t}{Y_t} = \frac{RD_t(GD_t(T E_t), P_t)}{Y_t} + \frac{PC_t(P_t)}{Y_t} \]
Explicitating adaptation (II)

The gross damages are a function of temperature change compared to 1900 levels:

$$\frac{GD_t}{Y_t} = \alpha_1 TE_t + \alpha_2 TE_t^{\alpha_3}, \text{ where } \alpha_2 > 0 \text{ and } \alpha_3 > 1$$

Gross damages are decreased by protection leaving residual damages:

(4) \( RD_t = GD_t \cdot (1 - P_t) \), where \( 0 \leq P_t \leq 1 \).
Adaptation (P) is thus given as:

\[ P_t = \frac{GD_t - RD_t}{GD_t} \]

Adaptation cost function: \( \frac{\partial PC_t}{\partial P_t} > 0 \) and \( \frac{\partial^2 PC_t}{\partial P_t^2} > 0 \) need to hold. We choose:

\[ \frac{PC_t}{Y_t} = \gamma_1 P_t^{\gamma_2} \text{, where } \gamma_1 > 0 \text{ and } \gamma_2 > 1. \]