Fondazione Eni Enrico Mattei

The Optimal Timing and Investment Size of Mitigation and Adaptation Strategies

Francesco Bosello, Carlo Carraro, Enrica De Cian

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Overview

- Some definitions
- The problem
- Modelling adaptation
- Data and calibration
- Simulation results
- Conclusions

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Defining adaptation

"Adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli, and their effects or impacts. […] refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantages of opportunities associated with changes in climate" (IPCC TAR, 2001)

"Changes in a system in response to some force or perturbation, in our case related to climate" (Smithers and Smit, 1997)

Autonomous vs Planned Adaptation

Autonomous Adaptation: natural automatic response to a "shock". Also socio-economic systems react partly autonomously. There are substitution possibilities triggered by price (scarcity) signals.

Planned Adaptation: anticipatory or reactive strategies apt to alleviating the damage once it is (or will be) materialized via proper modifications of the impacted socio-economic-environmental system. Undertaken by public agencies – agents.

Objectives of planned adaptation (Klein and Tol, 1997):

- ✓ increasing the robustness of infrastructural design and long term investment,
- ✓ increasing the flexibility of vulnerable managed system,
- ✓ enhancing the adaptability of vulnerable natural systems,
- ✓ reversing trends that increase vulnerability ("maladaptation"),
- ✓ improving societal awareness and preparedness.

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The policy "mix"

Today is commonly accepted that: …"a precautionary policy would avoid both the extremes of total inaction or drastic action and would be a combination of mitigation and adaptation where possible at low cost" (Kane and Shogren 2000; McKibbin and Wilcoxen, 2004)

POSITIVE APPROACH: How much to mitigate, adapt (anticipating and reacting) and residual damage to accept? When/where to adopt each of these strategies?

NORMATIVE APPROACH: What are the driving forces behind these decisions? How should the "optimal" mix look like?

The literature (1)

Theoretical literature (see Kane and Shogren (2000), Ingham et al. (2005) Lecoq and Shalizi (2007),) concludes that the "mix characteristics" are an "empirical matter". In principle everything is possible even though non perfect substitutability is more reasonable.

Few "empirical works" on domain specific adaptation: mitigations makes adaptation in the health sector more difficult (Tol and Dowlatabady 2001), mitigations reduces the need to adapt and vice-versa in the case of sea level rise (Tol, 2007)

Only three empirical contributions analyze adaptation as "a" strategy within hard linked IA models (Hope 2006, De Bruin et al. (2007), Bosello (2008))
Only in the last two, mitigation and adaptation choices are endogenously determined.

This Work

Introduces adaptation in the WITCH (optimal-growth, climate-economic hard-linked, hybrid) model.

It compounds and expand existing modeling approaches:

adaptation can take three forms: anticipatory adaptation (like Bosello 2008), reactive adaptation (like De Bruin et al. 2007) and R&D in adaptation → the decision maker is endowed with three additional tools to reduce climate change damages.

Adaptation functions are calibrated through extrapolations and meta analyses of the latest available quantitative information

Modelling Adaptation

$$YN_{n,t} = \frac{1}{1+CCDA_{n,t}} \cdot YG_{n,t}$$

Climate Change Damage NET of adaptation (residual damage) drives a wedge between gross (*YG*) and net output (*YN*)

$$CCDA_{n,t} = \frac{1}{1+AD_{n,t}} CCD_{n,t}$$

Adaptation can reduce damages from climate change

$$CCD_{n,t} = \theta_{1n} \cdot T_t + \theta_{2n} T_t^{\gamma 3n}$$

Climate change damage depends on temperature

***Adaptation (AD) is* a combination of different adaptation strategies**

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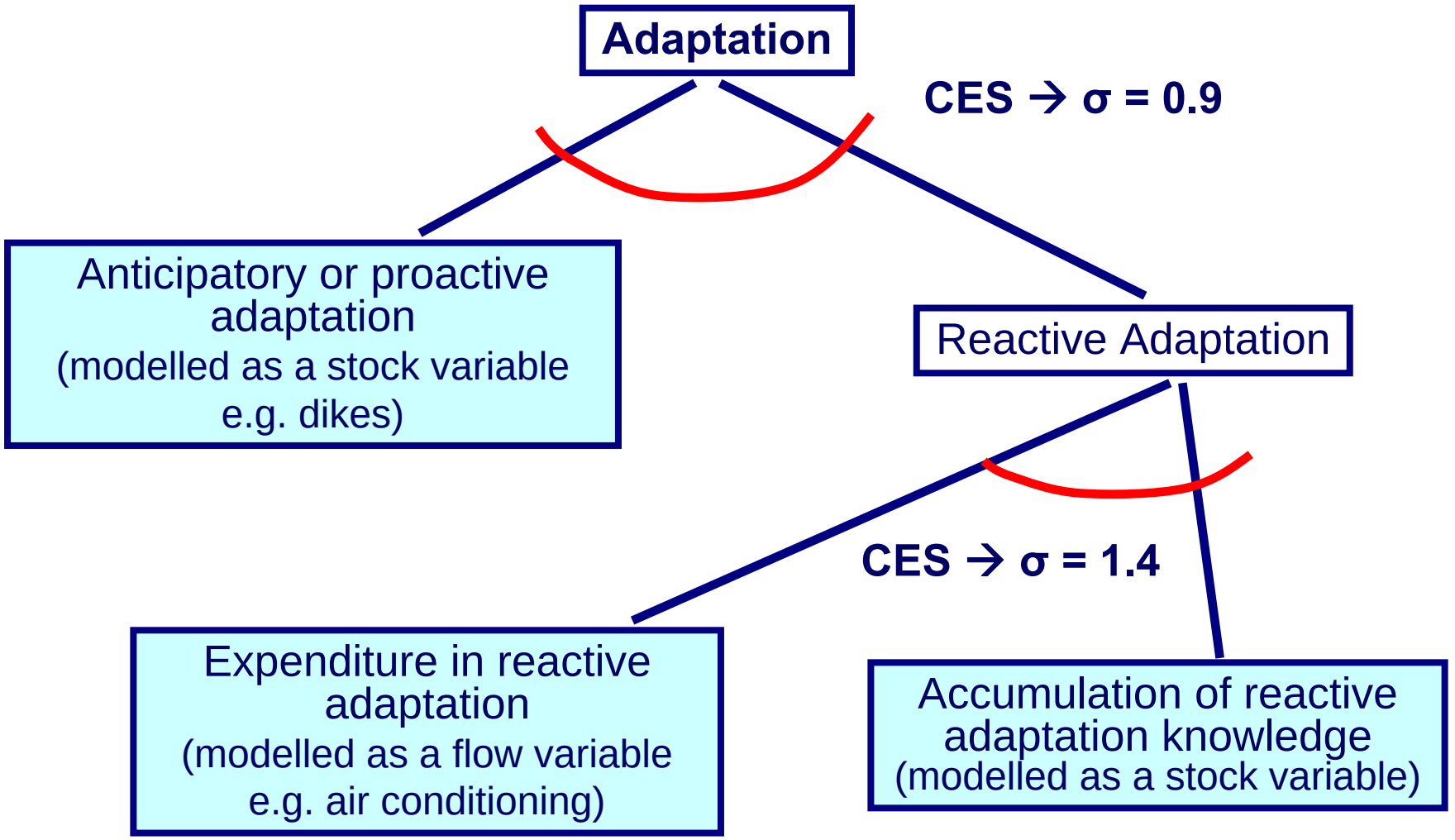
The Adaptation Tree



Specifying the adaptation module: (1) effectiveness

Top nest: adaptation is a CES combination of proactive (SAD) and reactive (FRAD) adaptation

$$AD_{n,t} = \mathrm{A}_{ADA,n}(\alpha_{1,n} SAD_{n,t}^{\ \rho_{ADA}} + \alpha_{2,n} FRAD_{n,t}^{\rho_{ADA}})^{1/\rho_{ADA}}$$

Bottom nest: reactive adaptation is a CES combination of "flow" expenditure for adaptation (ERAD) and a dedicated knowledge (KRAD) making reactive adaptation more effective

$$FRAD_{n,t} = \mathrm{B}_{SRAD,n}(\beta_{1,n} KRAD_{n,t}^{\ \rho_{RAD}} + \beta_{2,n} ERAD_{n,t}^{\rho_{RAD}})^{1/\rho_{RAD}}$$

SAD and KRAD are modelled as stock variables cumulating over time following two specific investment processes

$$SAD_{n,t} = (1-\delta)\cdot SAD_{n,t-1} + IA_{n,t}$$

$$KRAD_{n,t} = (1-\delta)\cdot KRAD_{n,t-1} + IKRAD_{n,t}$$

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Specifying the adaptation module: (2) costs

Adaptation is costly =>

- ERAD → expenditure in reactive adaptation
- IA → investment in proactive adaptation
- IKRAD → investment in adaptation-specific knowledge

compete with alternative uses of regional income

$$YN_{n,t} = C_{n,t} + I_{n,t} + IR\&D_{n,t} + \sum_{J} I_{j_{n,t}} + ERAD_{n,t} + IA_{n,t} + IKRAD_{n,t}$$

- ERAD → expenditure in reactive adaptation
- IA → investment in proactive adaptation
- IKRAD → investment in adaptation-specific knowledge

Are the tree new decision variables of the model

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Calibration (1)

A set of adaptation strategies has been identified for each "type" of adaptation

Proactive Adaptation Activities Constituting $SAD_{n,t}$ → Modelled as "stock" variable
Coastal Protection Activities
Settlements and Other Infrastructures (Excluding Water) Protection Activities
Water Supply (Agriculture and Other) Protection Activities
Setting-up of Early Warning Systems
Reactive adaptation activities constituting $ERAD_{n,t}$, → Modelled as "flow" variable
Agricultural Adaptation Practices
Treatment of Climate-Related Diseases
Space Heating and Cooling (OWM)
Innovation in adaptation constituting $KRAD_{n,t}$, → Modelled as "stock" variable
Research Activities for the Development of Climate-Resilient Crops
Research Activities in the Health Sector

Calibration (2)

For each of them and for each region of the WITCH model, costs and effectiveness (% of damage reduced) has been specified according to extrapolations and meta analysis of the latest available literature

Then the parameters of the adaptation function(s) have been calibrated in order to replicate with the model observed data in one point in time = 2060 corresponding to a doubling of CO2 concentration

Calibration (3): Main Data Sources

Adams, R. M., L.L. Houston and B. A. McCarl, (2000). The benefits to Mexican agriculture of an El Niño-southern oscillation (ENSO) early warning system, *Agricultural and Forest Meteorology* 115 (2003) 183–194.

Agrawala, S. and S. Fankhauser, (2008). Economics aspects of adaptation to climate change. Costs, benefits and policy instrument, OECD, Paris.

De Cian, E., Lanzi, E. and Roson R. (2007). The impact of Temperature CHange on Energy Demand: a dynamic panel analysis, FEEM Working Paper 46/2007, Milan.

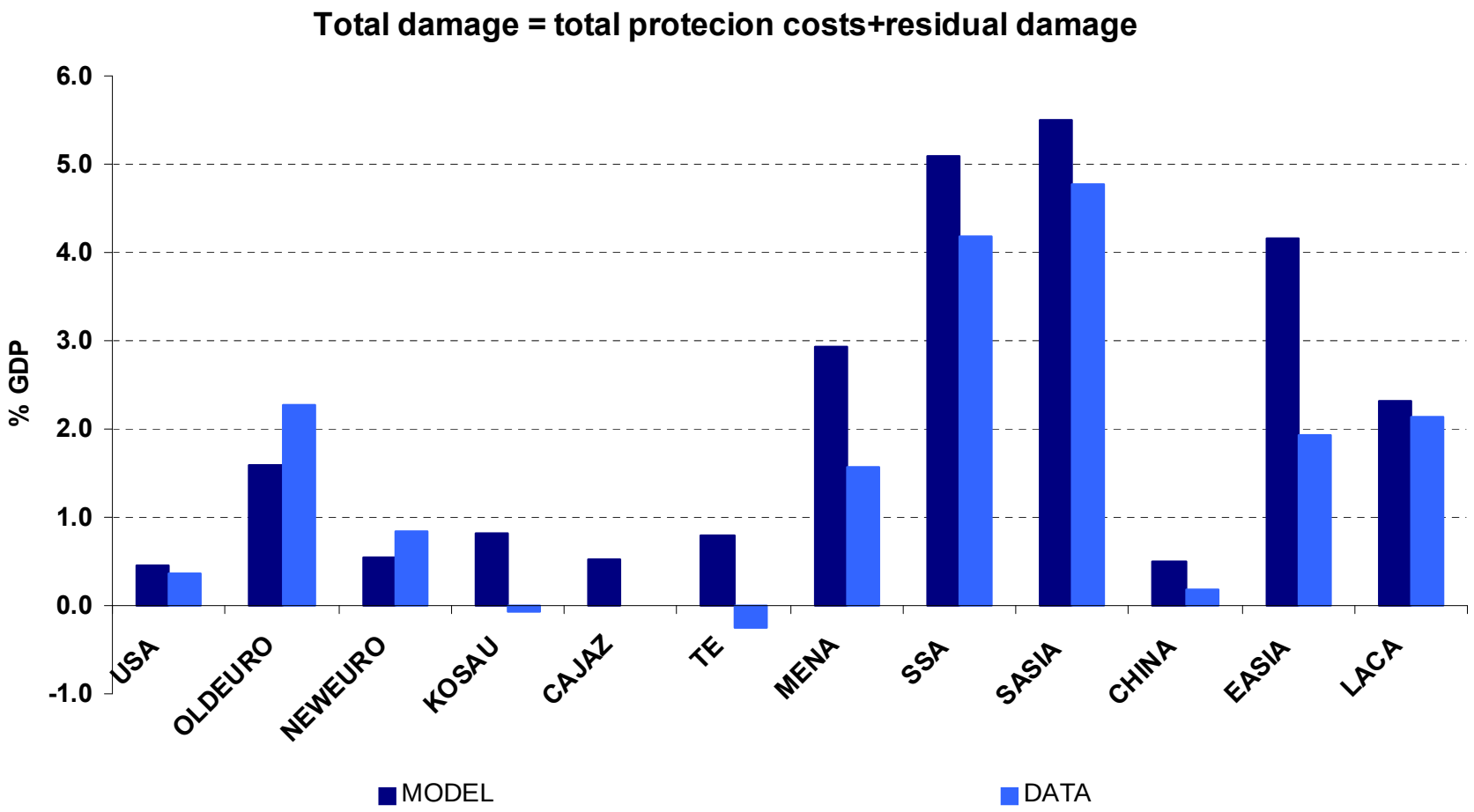
Kirshen, (2007). *Adaptation Options and Cost of Water Supply*, Tuft University, MA.

Nordhaus, W.D. and J.G. Boyer (2000): Warming the World: the Economics of the Greenhouse Effect, Cambridge, MA: MIT Press.

UNFCCC, (2007). *Investments and Financial Flows to Address Climate Change,* background paper on analysis of existing and planned investments and financial flows relevant to the development of effective and appropriate international response to climate change, p. 273.

World Bank (2006). Clean energy and development: towards an investment framework, World Bank, Washington, DC, 2006.

Calibration (4): cost of adaptation + residual damage



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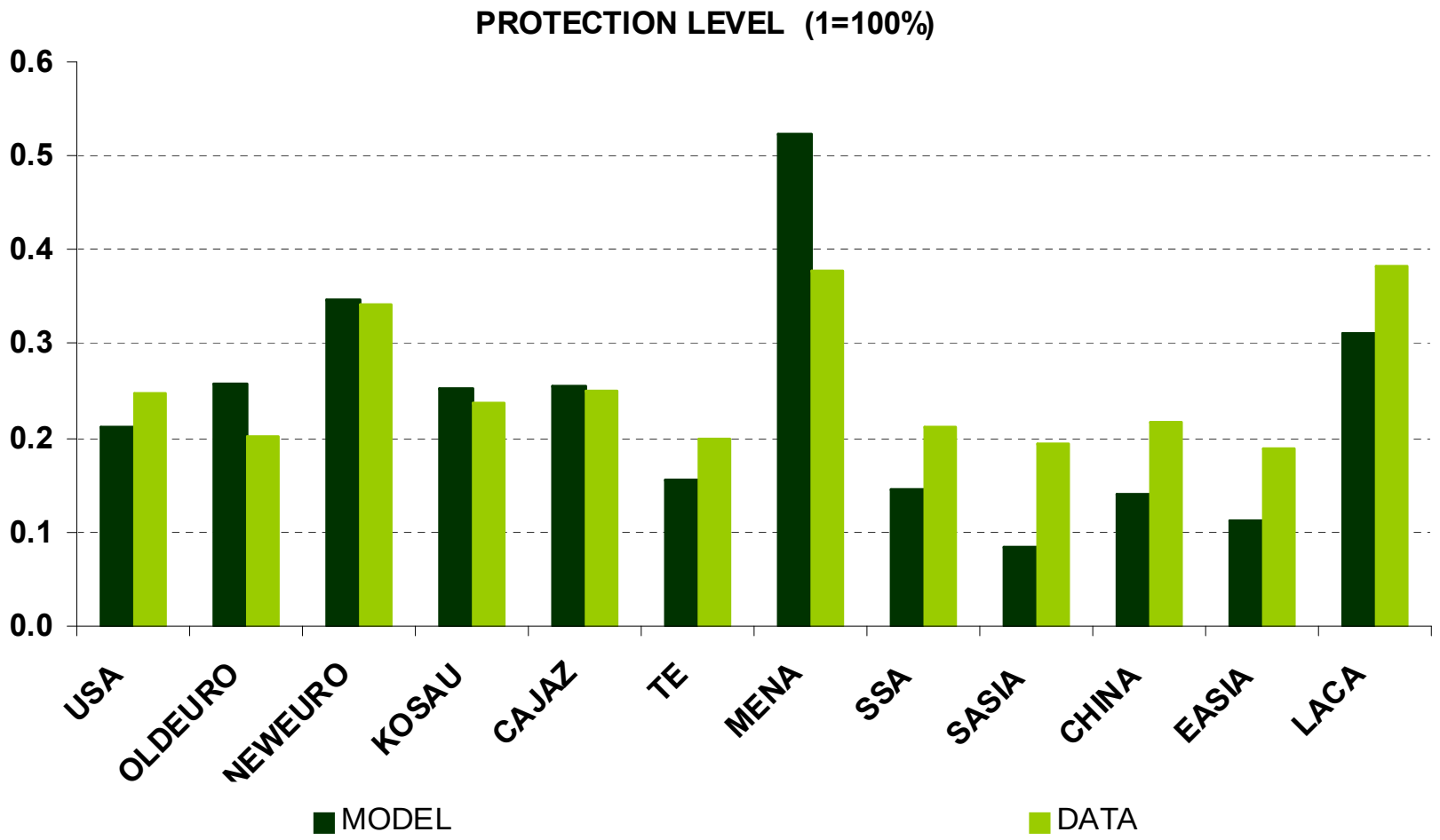
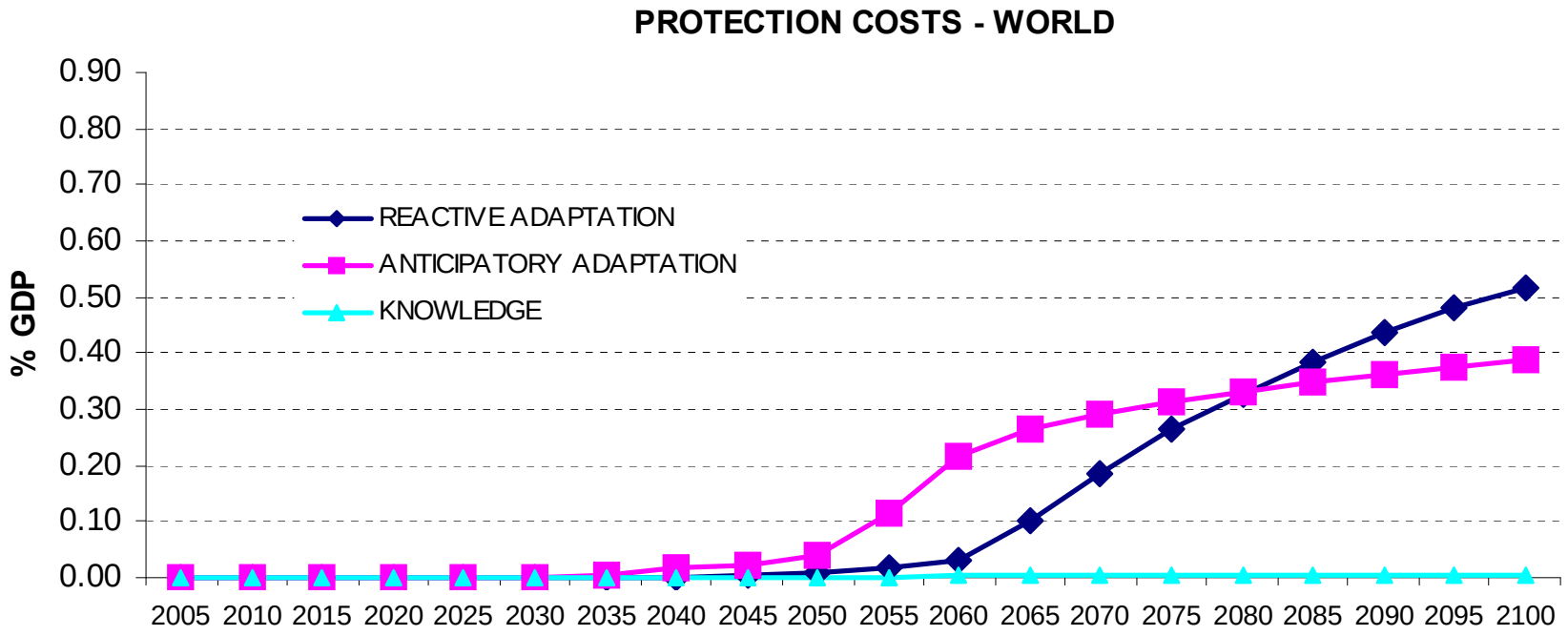
Calibration (5): effectiveness of adaptation



BASELINE



All three adapation forms are used, however proactive adaptation is anticipated and is the main adaptation force until 2080. Reactive measures prevail afterwards.

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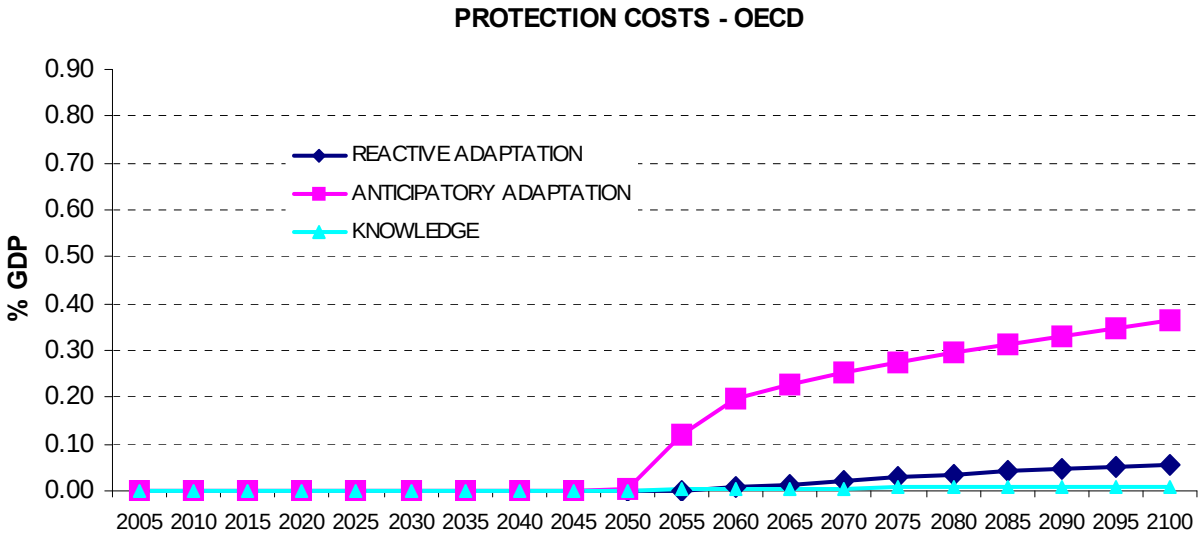
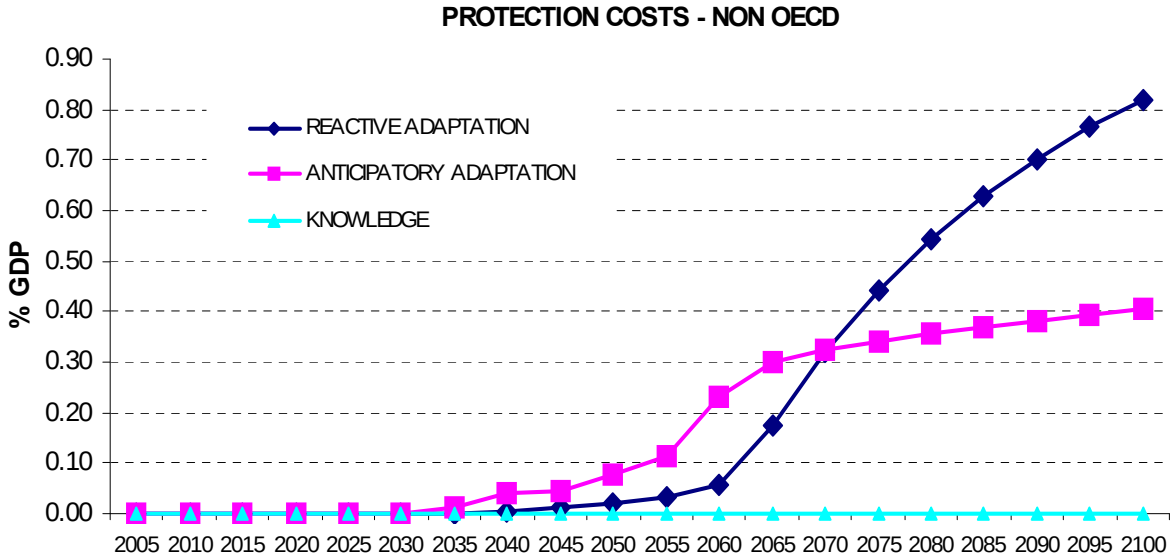
Explaining Fact # 1

Anticipatory adaptation implies to build a stock of defensive capital that must be ready when the damage materializes. Given the “economic inertia” investment in defensive capital needs to be undertaken before the damage.

Reactive adaptation is more rapidly effective it can be put in place when the damage effectively materializes.

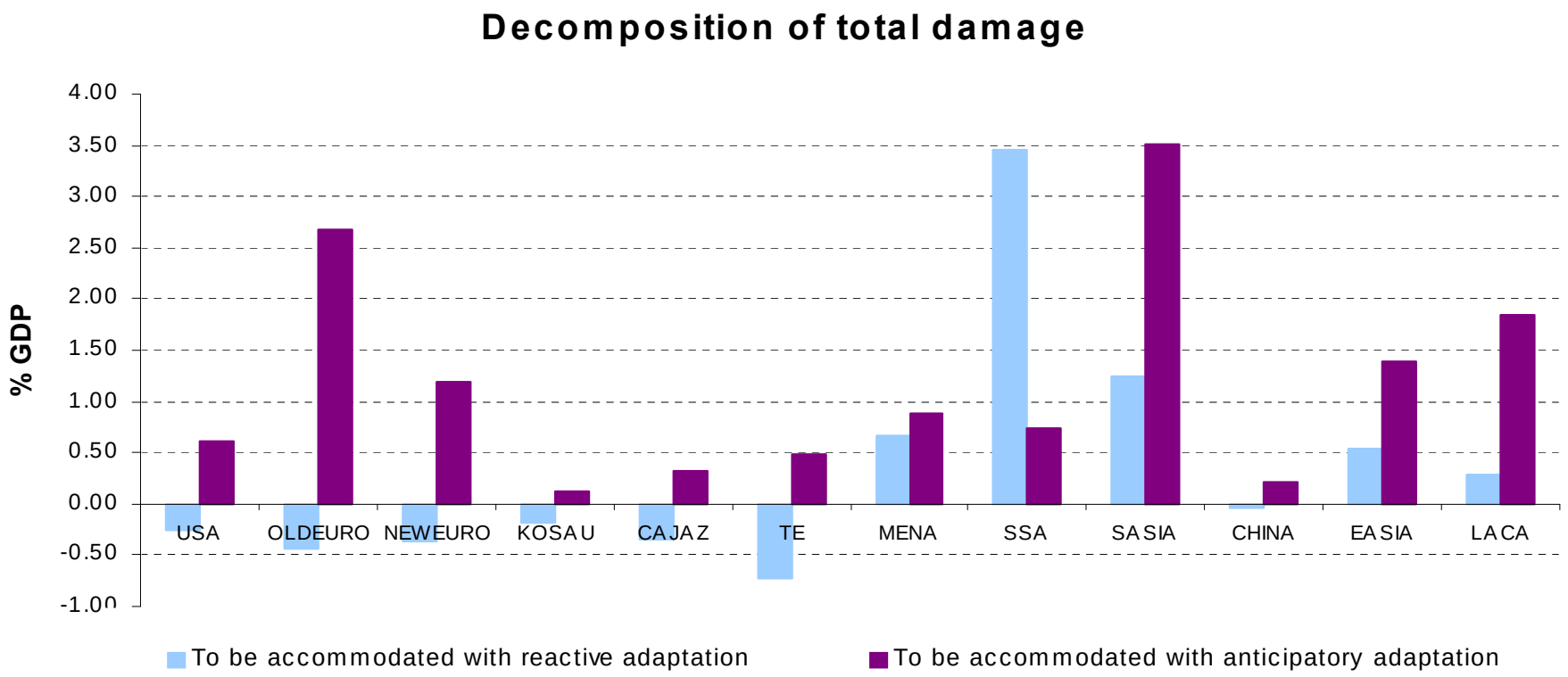
Fact #2





OECD countries spend a higher fraction of their GDP on anticipatory adaptation than NON-OECD countries which allocate more resources to reactive adaptation

Explaining fact # 2

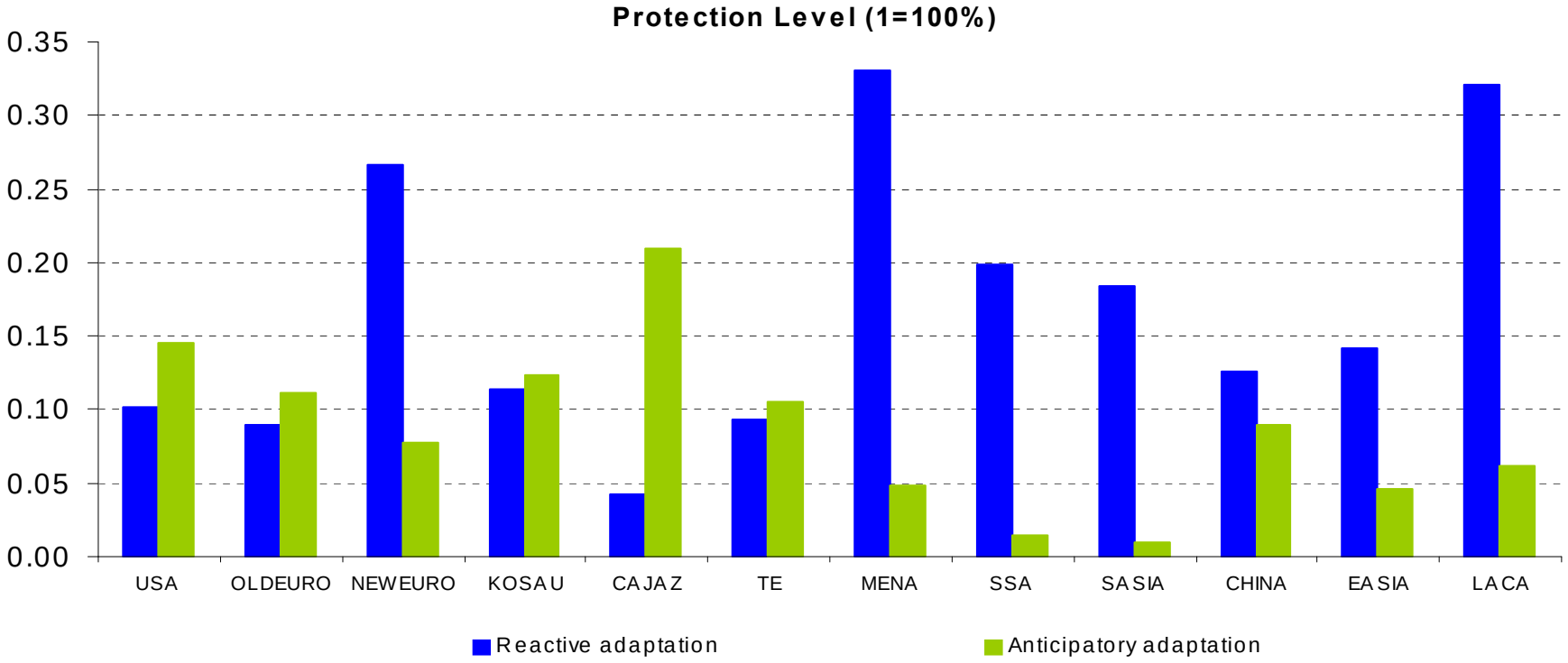


In OECD countries the higher share of CC damages originates from infrastructures and coastal areas, whose protection requires a form of adaptation that is largely anticipatory (of the stock type)

In NON-OECD countries a higher share of CC damages originates from agriculture, health, and energy sector (space heating and cooling). These types of damages can be accommodated more effectively with reactive measures (of the flow type)

As a consequence:

Anticipatory adaptation reduces the higher share of CC damage in OECD countries than in non-OECD countries



NEWEURO is an outlier among developed countries, but this is exactly because of its high vulnerability of the agriculture sector

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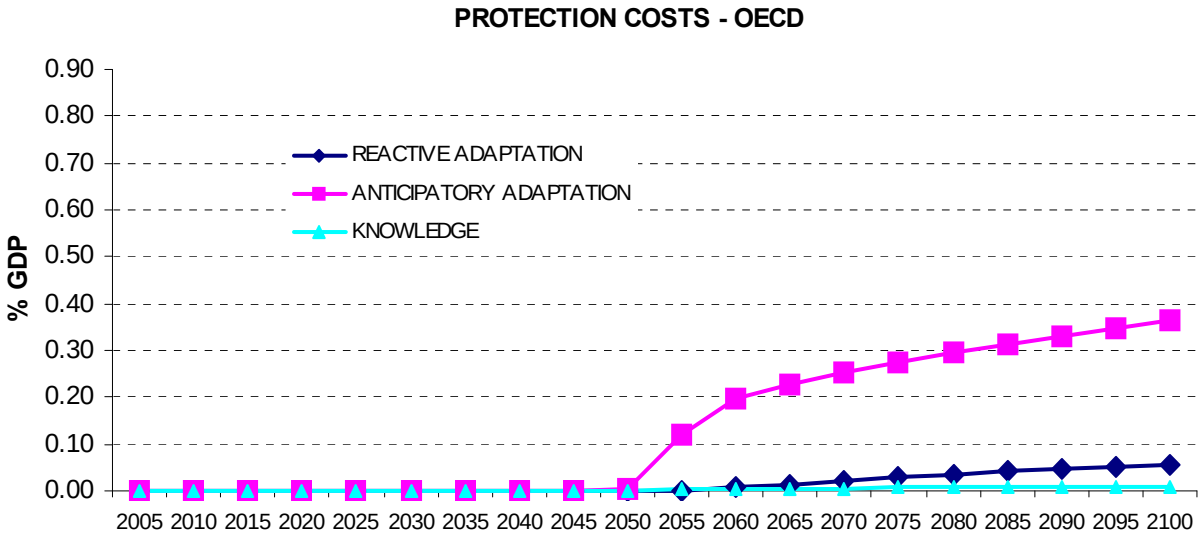
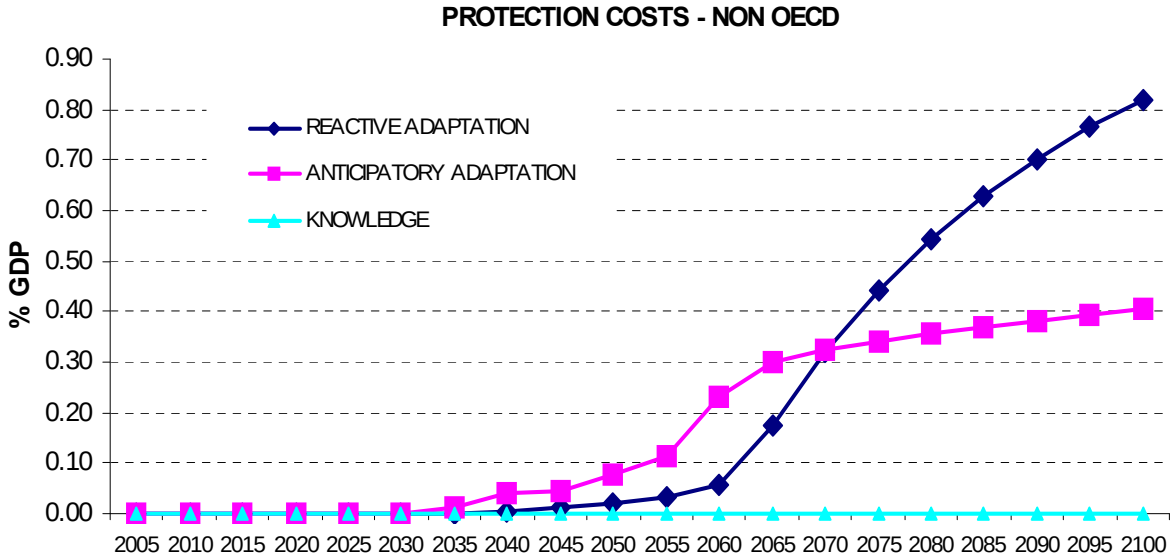




OECD countries only spend some fraction of their GDP on adaptation R&D

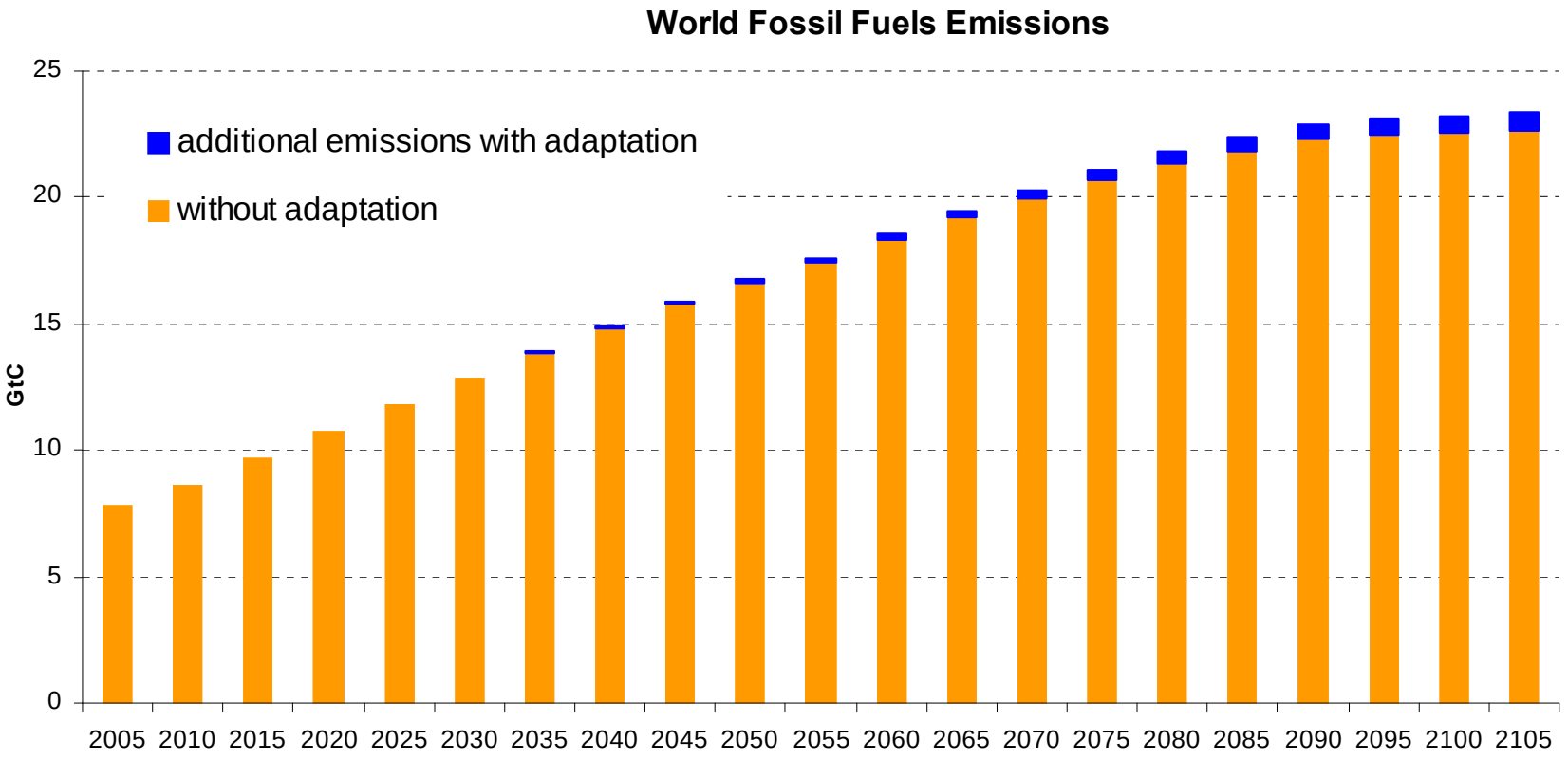
Explaining Fact # 3

The model mimics an observed fact: no adaptation R&D in the calibration year in NON-OECD countries.

Investments in R&D increase the “productivity” of reactive adaptation. They would be particularly needed in developing countries, but they are performed where the are the resources and the infrastructure to do them, namely in developed countries.

This result is a clear example of market failure that could be corrected with an appropriate policy aimed at pushing R&D expenditure.

The presence of adaptation increases CO2 emissions



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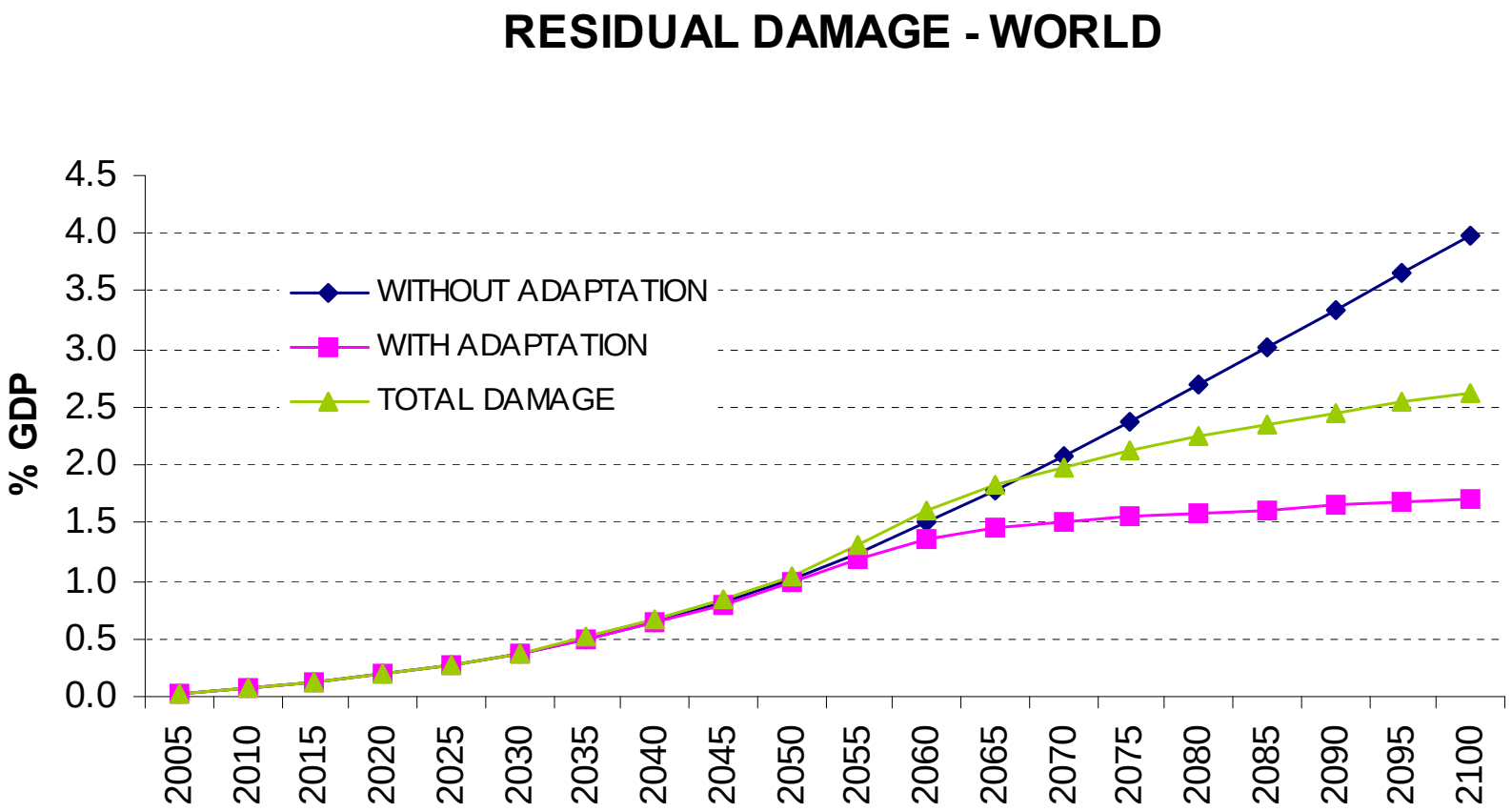
Adaptation reduces the damage originated by emissions (which with adaptation is lower than without adaptation even in the presence of additional emissions)



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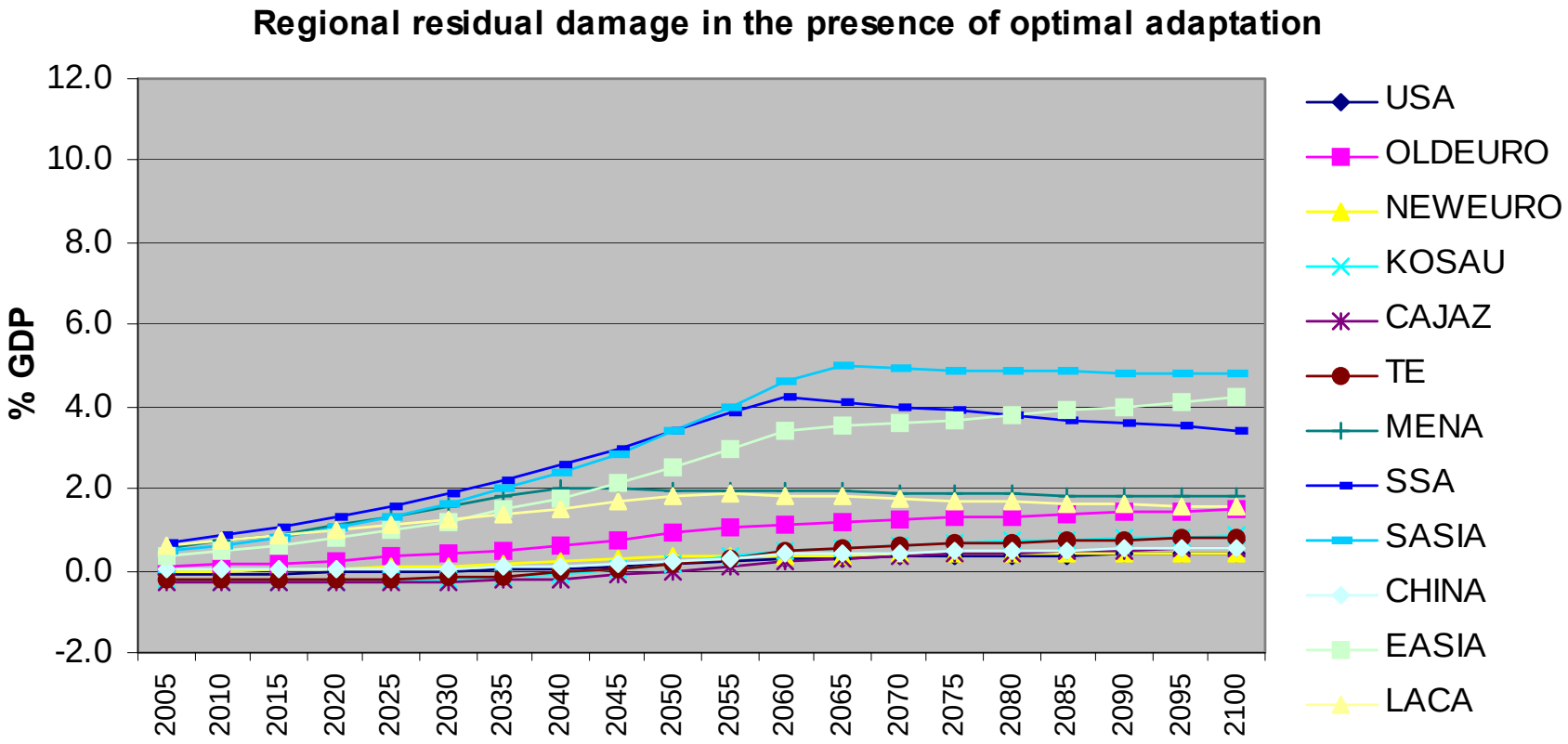
A regional snapshot



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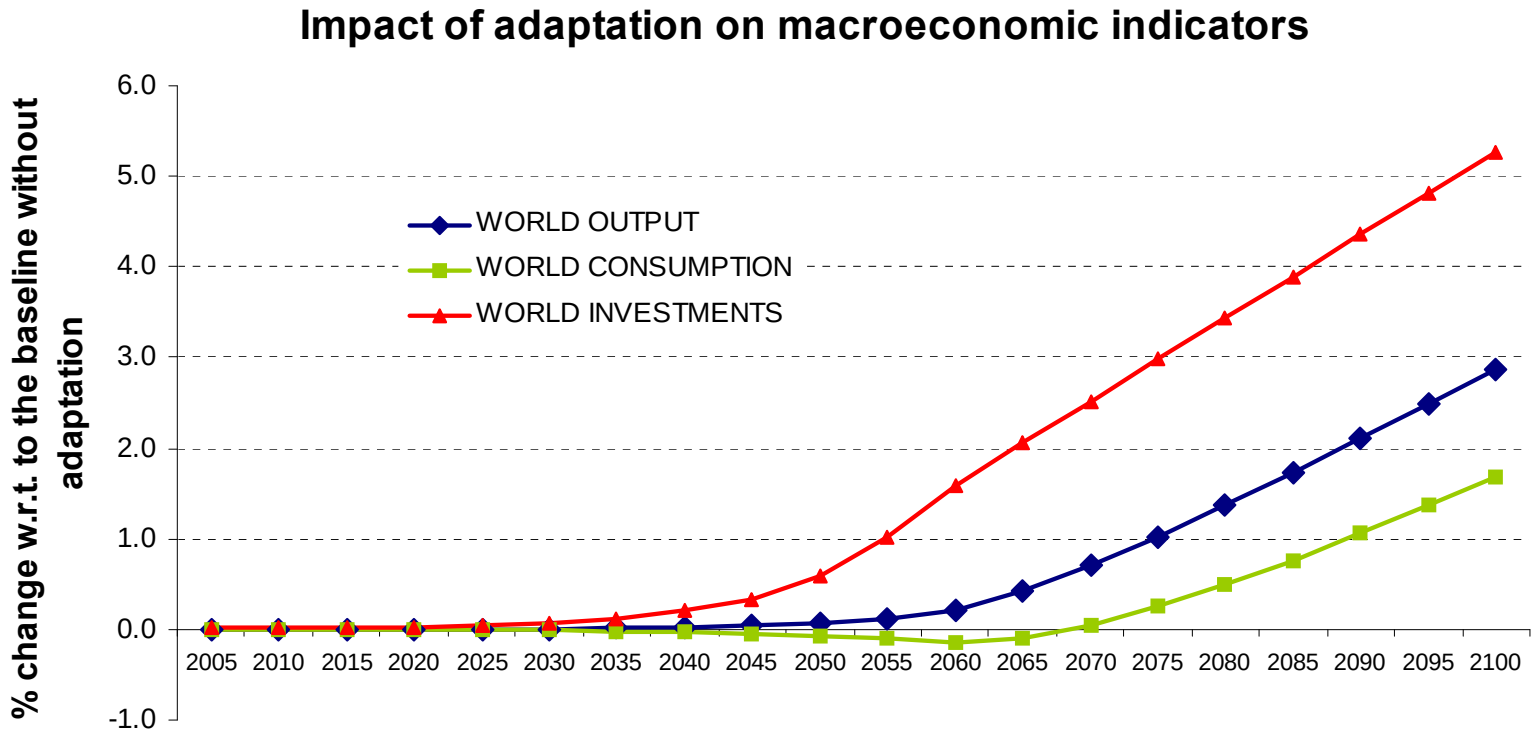
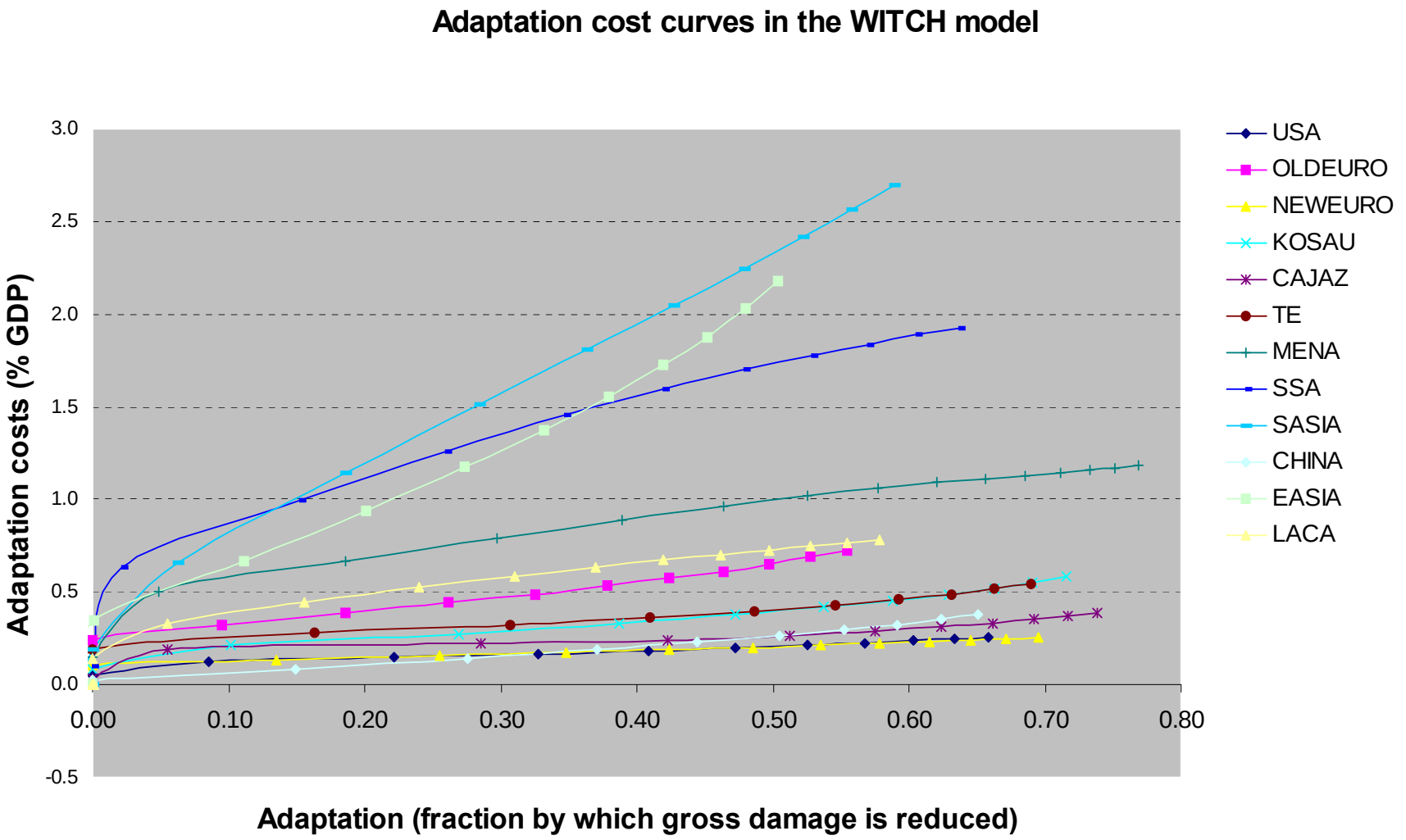
=> There is a lower need to emit/pollute less and accordingly output and consumption (in the longer term) are also higher



Adaptation cost curves

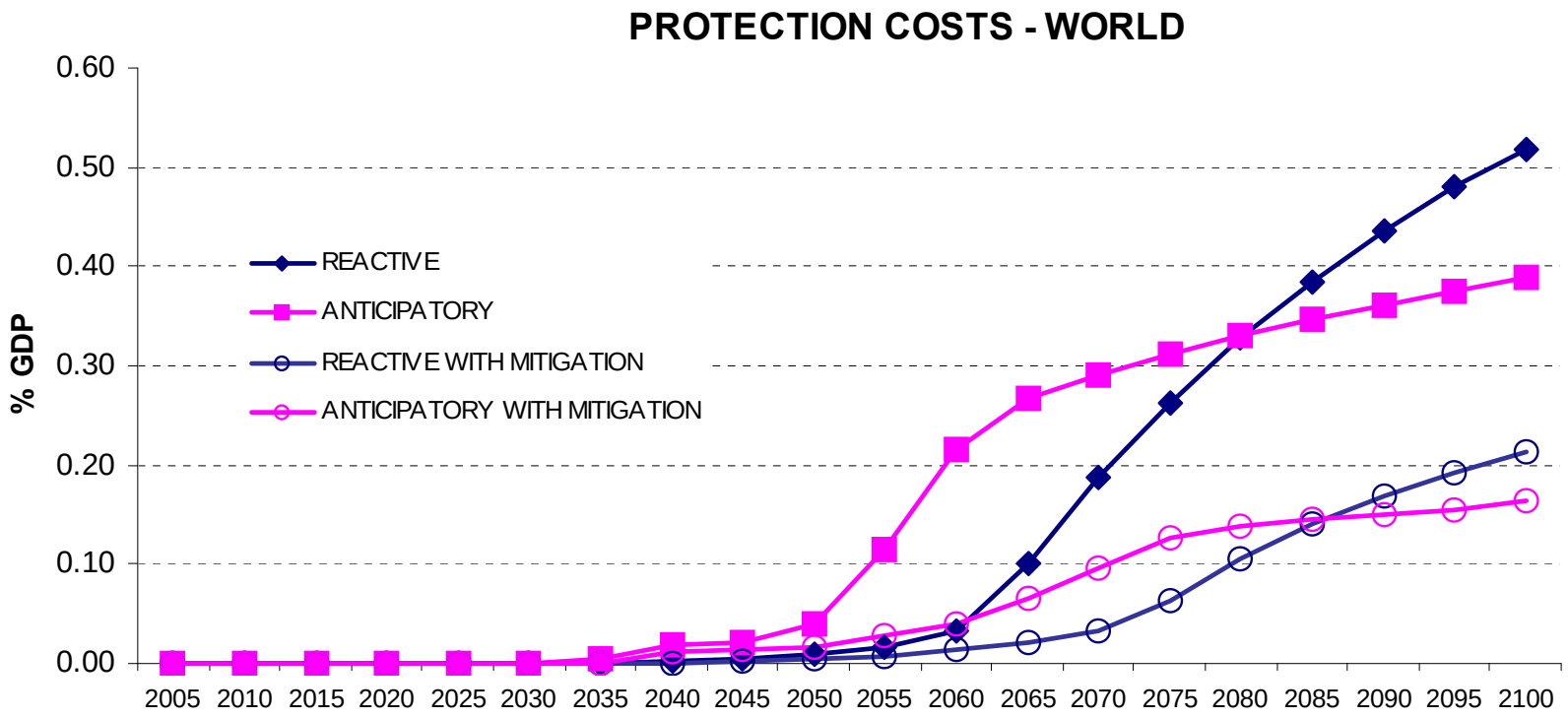


Explaining adaptation cost curves

- The same percent of GDP spent on adaptation leads to more resources devoted to adaptation in richer countries
- When a region experience a low damage => higher damage reduction is accomplishable with lower expenditure
- OECD countries are both richer and experiencing lower damages

TRADE-OFF BETWEEN MITIGATON AND ADAPTATION

- This has been tested simulating the impact on the (optimal) baseline adaption(s) of a policy aimed at stabilising concentrations at 550 ppm CO2-eq within the century



Mitigation reduces the size, but not the timing/composition of optimal adaptation → They are substitutes

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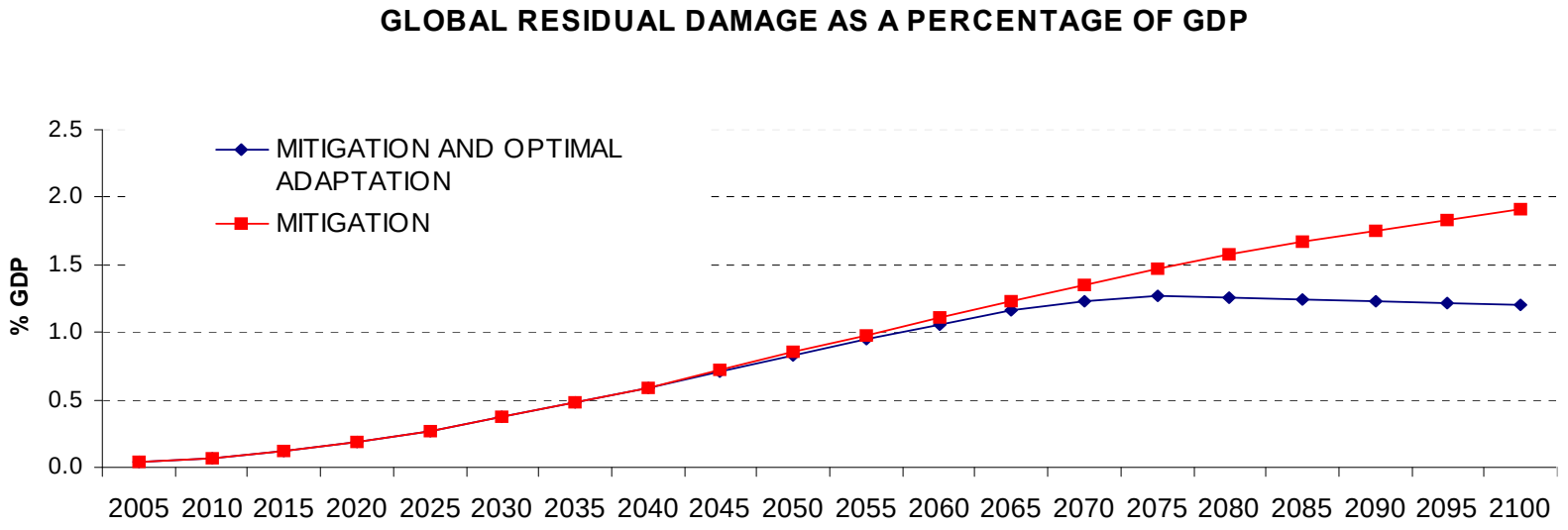
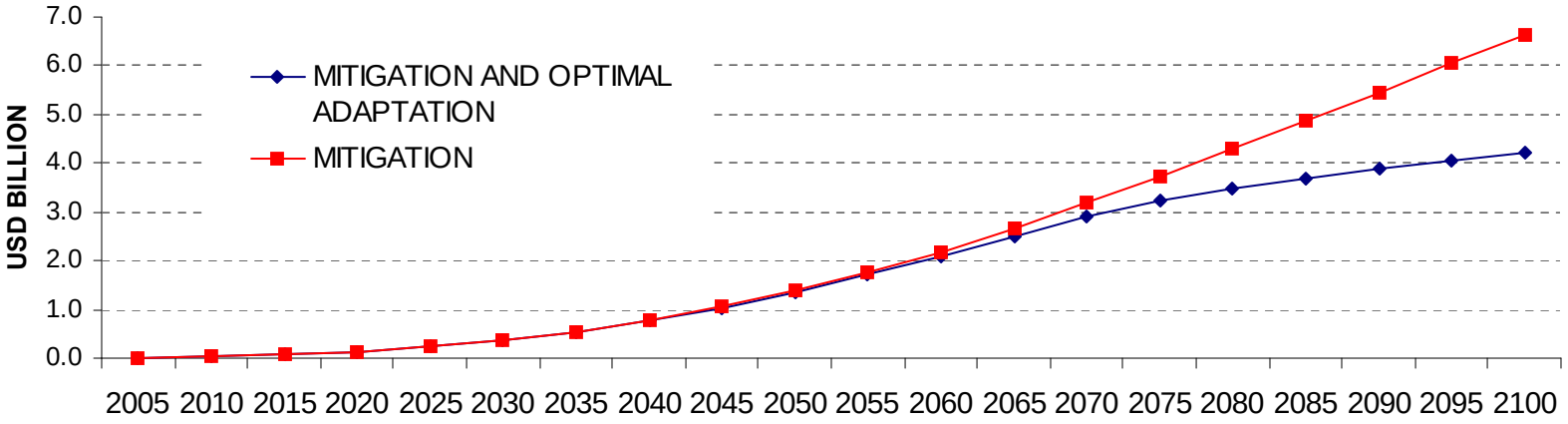
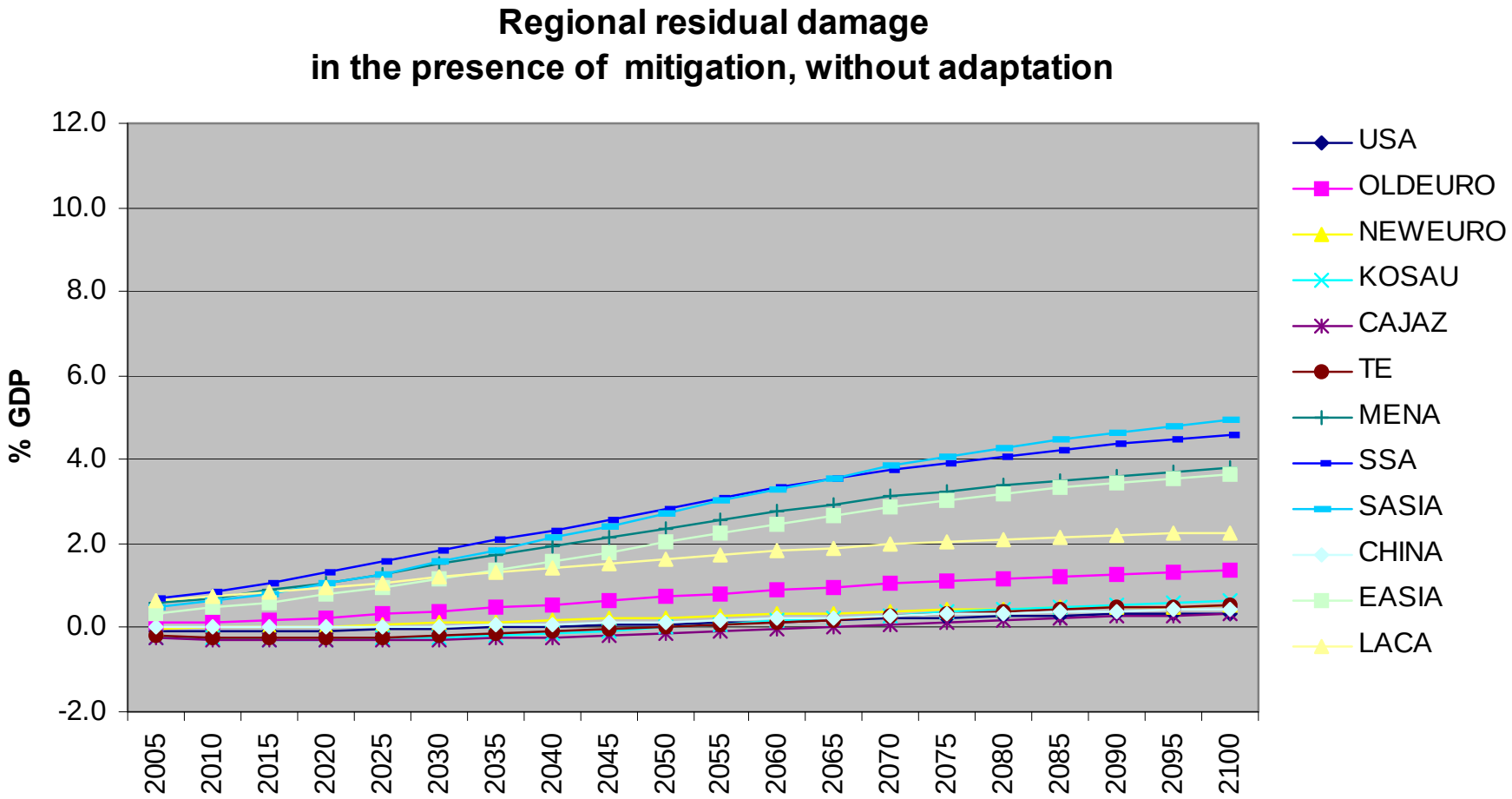
Residual Damage





Damage with mitigation only



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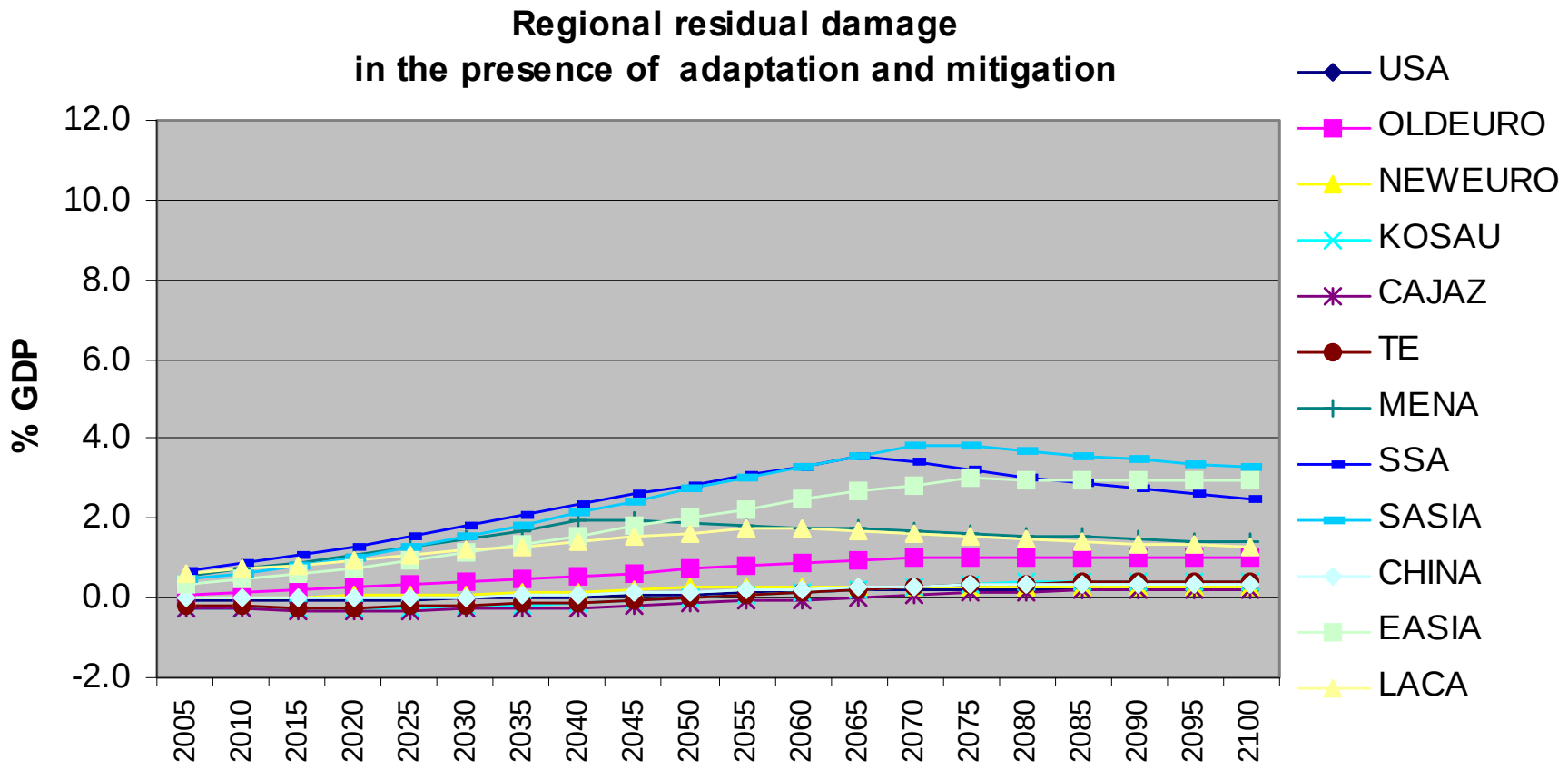
Damage with mitigation and adaptation



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Preliminary conclusions

Composition

The optimal mix of adaptation strategies consists of reactive, anticipatory measures and investments in dedicated knowledge

Timing

Proactive adaptation is anticipated and is the main adaptation force until 2080. Reactive measures prevail afterwards, when the damage is higher

Regional patterns

Regional patterns of adaptation modes are determined by regional vulnerability. In NON-OECD regions reactive adaptation is more effective

Dedicated R&D

R&D is not performed where it would be needed the most, but where there are the required resources and infrastructure, namely OECD regions

Trade-off

Adaptation and mitigation are strategic complements => more mitigation implies less adaptation and viceversa

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Next

- Compute marginal costs and benefits of adaptation
- Sensitivity (analysis) of the mitigation adaptation mix to climate damage and the discount rate
- Exercises where the policy target is the stabilisation of the damage
- “Adaptation fund” financed by developed countries to foster adaptation in developing countries