Frontiers in Environmental Economics and Natural Resources Management
2008 AFSE Thematic Meeting, June 9-11, Toulouse, France.

# Optimal growth with adaptation to climate change

Patrice Dumas
LMD

Minh Ha-Duong
CIRED

(dumas,haduong)@centre-cired.fr

# Introduction

I. What is adaptation ?

II. Which part of the economy needs it ?

III. Adaptation in a DICE-like model

IV. Optimal adaptation trajectories

# I. Adaptation to climate change is

Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects

Initiatives et mesures pour réduire la vulnérabilité des systèmes humains et naturels face au effets immédiats ou attendus du changement climatique.

# Adaptation to climate change

- Some is already occuring
- Is necessary, as is mitigation
- Can be proactive or reactive
- Is costly

# Reilly & Schimmelpfennig [2000]

Assumptions on adaptation are key to assess climate change impacts:

- No adaptation $\rightarrow$ permanent damages due to climate change
- Perfect adaptation $\rightarrow$ lower damages

# West, Small & Dowlatabadi [2001]

- Investor decisions over repairing storm damage do not influence significantly the storm damages attributed to sea level rise, nor do they affect the total damages significantly.
- This results from the fact that, in the vast majority of cases, investors are expected to repair storm damage rather than abandon the property. This conclusion is made with a rational actor model of private investor decisions.

# Kelly, Kolstad & Mitchell [2005]

- Agents are slowed in their ability to instantly adapt to the changed climate for two reasons: input (e.g., capital) fixity and incomplete knowledge of the climate change.
- For agriculture in the US midwest, change in climate increases annual expected profits by 3.7% (540M$), but the net present value of adjustment costs is 1.4% of annual land rents (0.24M$).

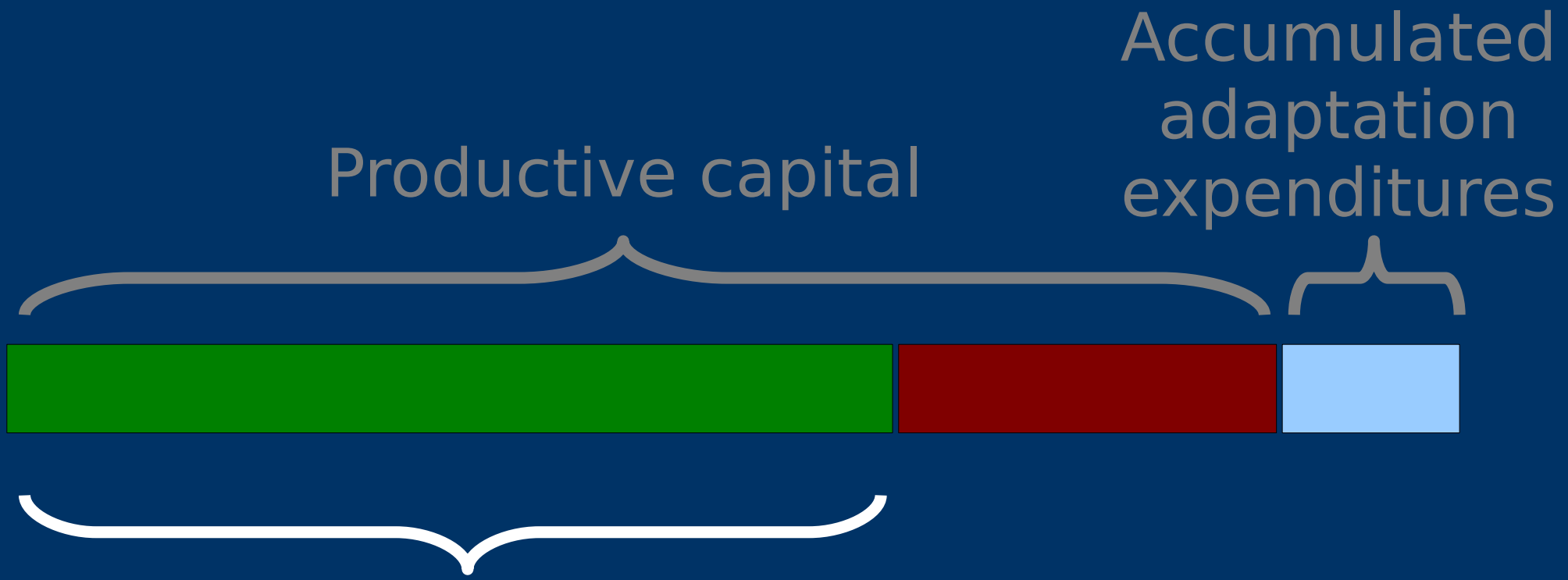
# This study looks at

- The issue of capital fixity, assuming perfect information
- Adaptability in all sectors of the economy, using a DICE-like model

# II. Capital and adaptation


$$K_{total} = K_{productive} + K_{protection}$$

# Some capital is not exposed




$$K_{total} = (1-\nu)\, K_{productive} + \nu\, K_{productive} + K_{protection}$$

# Estimating $\nu$ a multicriteria sectoral approach

- GTAP data, 26 sectors
- Sensitivity to climate depends on 3 criteria:
  - **O**: Outdoors
  - **E**: vulnerable to climate Extremes
  - **S**: Specific to a climate, technically
- We conducted a qualitative assessment, each criteria adds 0%, 20% or 33% to the sector's share of exposed capital $\nu$

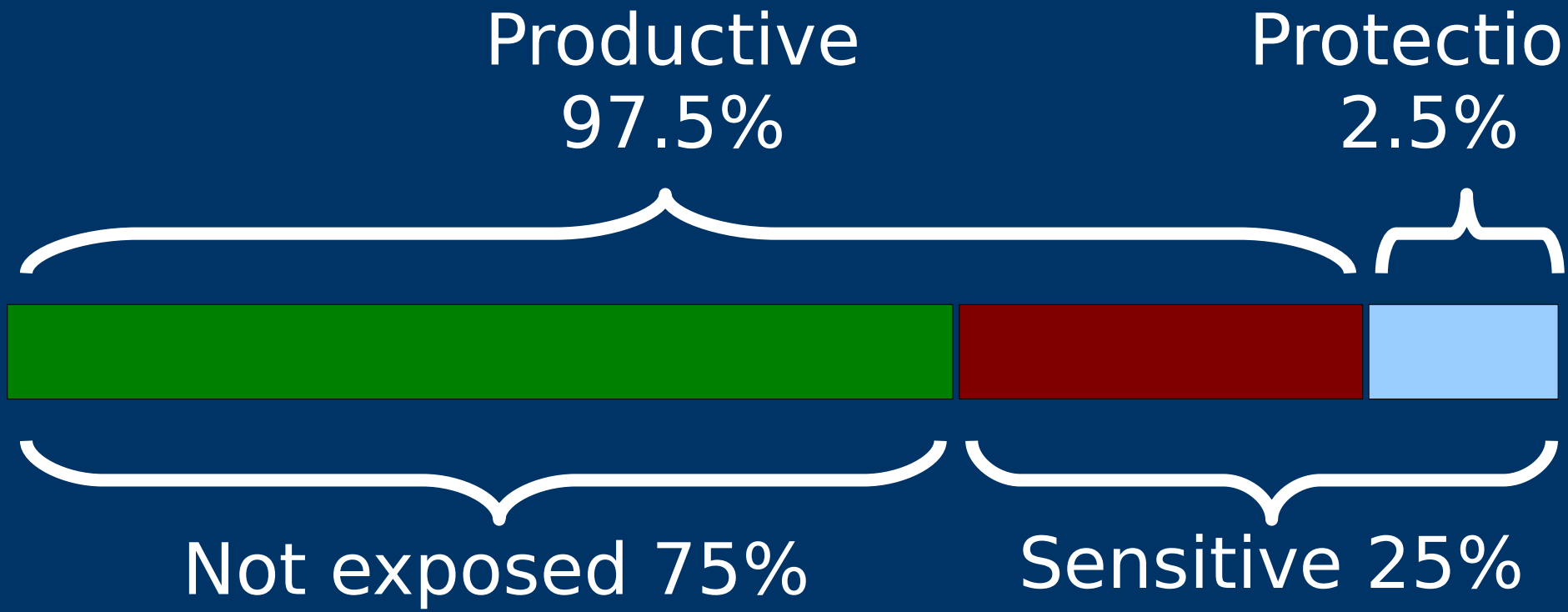
| Sector | S | O | E | ν | ν $K_i$ / K |
|---|---|---|---|---|---|
| Dwellings | + | --- | + | 40,00% | 5,23% |
| Construction | ++ | ++ | + | 86,00% | 4,00% |
| Business services | --- | --- | + | 20,00% | 3,00% |
| Recreational srvcs | + | + | + | 60,00% | 2,88% |
| Transport | --- | + | ++ | 53,00% | 2,66% |
| Agriculture | ++ | ++ | + | 86,00% | 2,02% |
| Electricity | + | --- | ++ | 53,00% | 1,69% |
| Public | --- | --- | + | 20,00% | 1,41% |
| Wood products | ++ | + | ++ | 86,00% | 0,97% |
| Communication | --- | --- | + | 20,00% | 0,56% |
| Water | ++ | --- | + | 53,00% | 0,24% |
| Insurance | --- | --- | ++ | 33,00% | 0,19% |
| **Total** | | | | | **24,85%** |

# About 25% of capital is sensitive

- Exposure varies a lot across sectors
- World economy is not only Textile, Processed food, Minerals, Oil products, Coal, Gas, Paper, Plastic, Vehicles, Electronic, Machinery, Manufacture, Trade and Financial.
- System-wide interdependencies & business network disruption unaccounted for

# Protection capital: same method

10% of sensitive capital (25%) = 2.5%



# III. Adaptation in a growth model

- Maximize the sum of discounted utility
- Balancing the costs and benefits of adaptation
  - Costs: More adaptation means less consumption or productive investment
  - Benefits: More adaptation means more efficient sensitive capital

# (emissions → temperature omited)

$$\max_{i_t^j, i_t, c_t} \sum_{t=0}^{140} \beta^t P_t u\left(c_t \mu (1+\kappa)^t\right) \tag{4}$$

Such that:

$$y_t = c_t + i_t + \sum_j i_t^j \tag{5}$$

$$k_{t+1} = \frac{P_t}{P_{t+1}(1+\kappa)}((1-\delta)k_t + i_t) \tag{6}$$

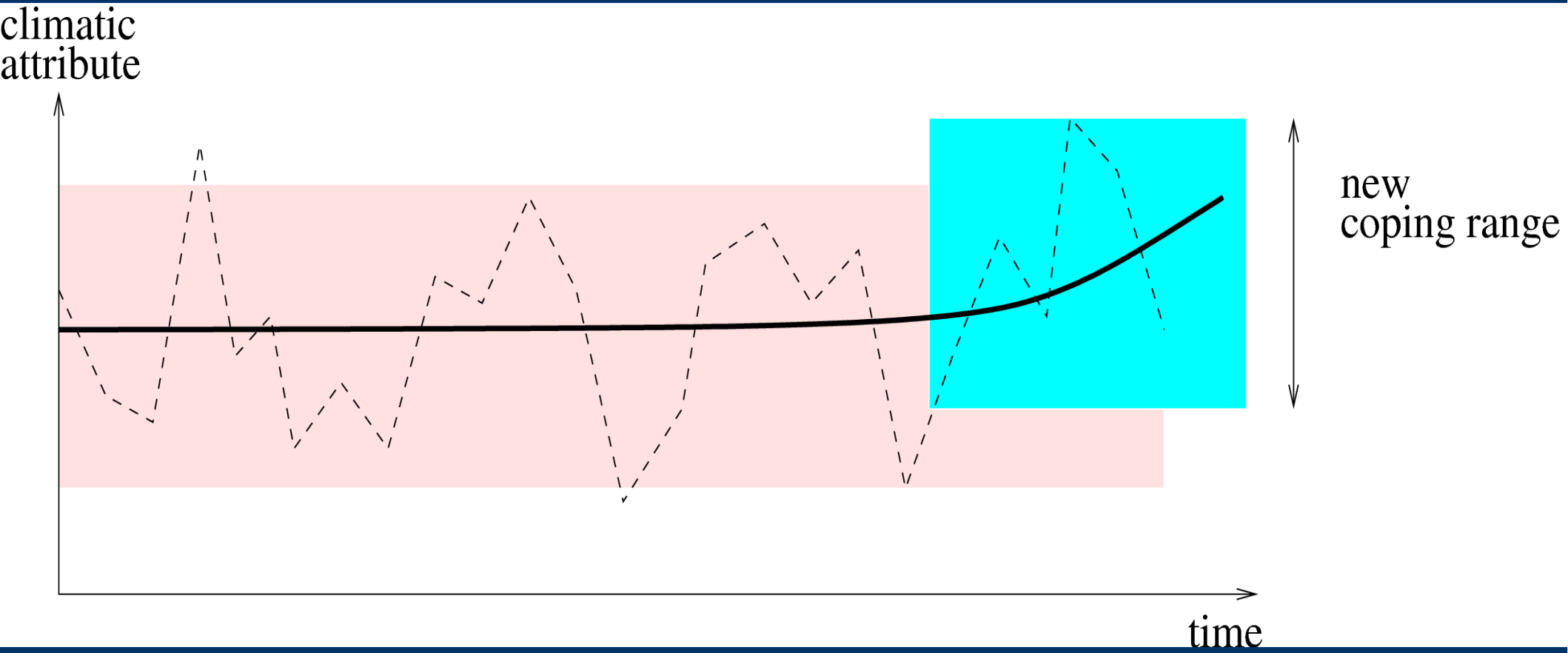
$$k_{t+1}^j = \frac{P_t}{P_{t+1}(1+\kappa)}((1-\delta)k_t^j + i_t^j) \quad \forall j \tag{7}$$

$$\frac{E_t}{E_0} = \xi_t e^{\psi t} \frac{y_t P_t (1+\kappa)^t}{y_0 P_0} \tag{8}$$

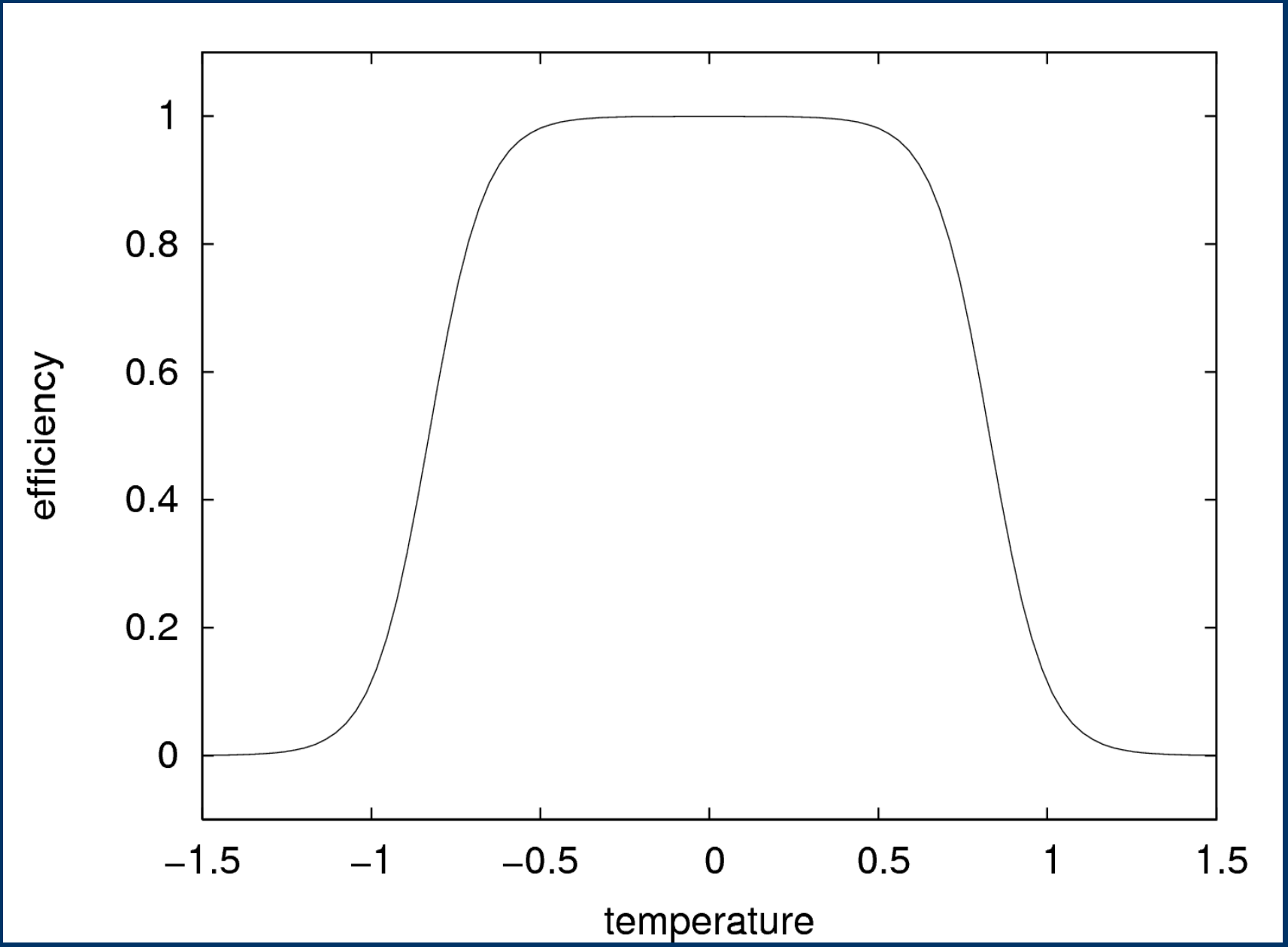
# Costs of adaptation

- Production $y_t$ goes to
  - Consumption $c_t$
  - Production $i_t$
  - Adaptation $i_t^j$ to different levels of climate change

# Benefits: staying in a coping range



# Protection capital efficiency $g(\Delta T)$



# Assume a portfolio of protection capital types, adapted to different levels of warming

Efficiency of « type *j* protection capital » depends on the difference between its design point $\theta^j$ and the realized temperature $\theta_t$

$$\text{Protection capital stock} = \sum_j g(\theta_t - \theta^j) K^j$$

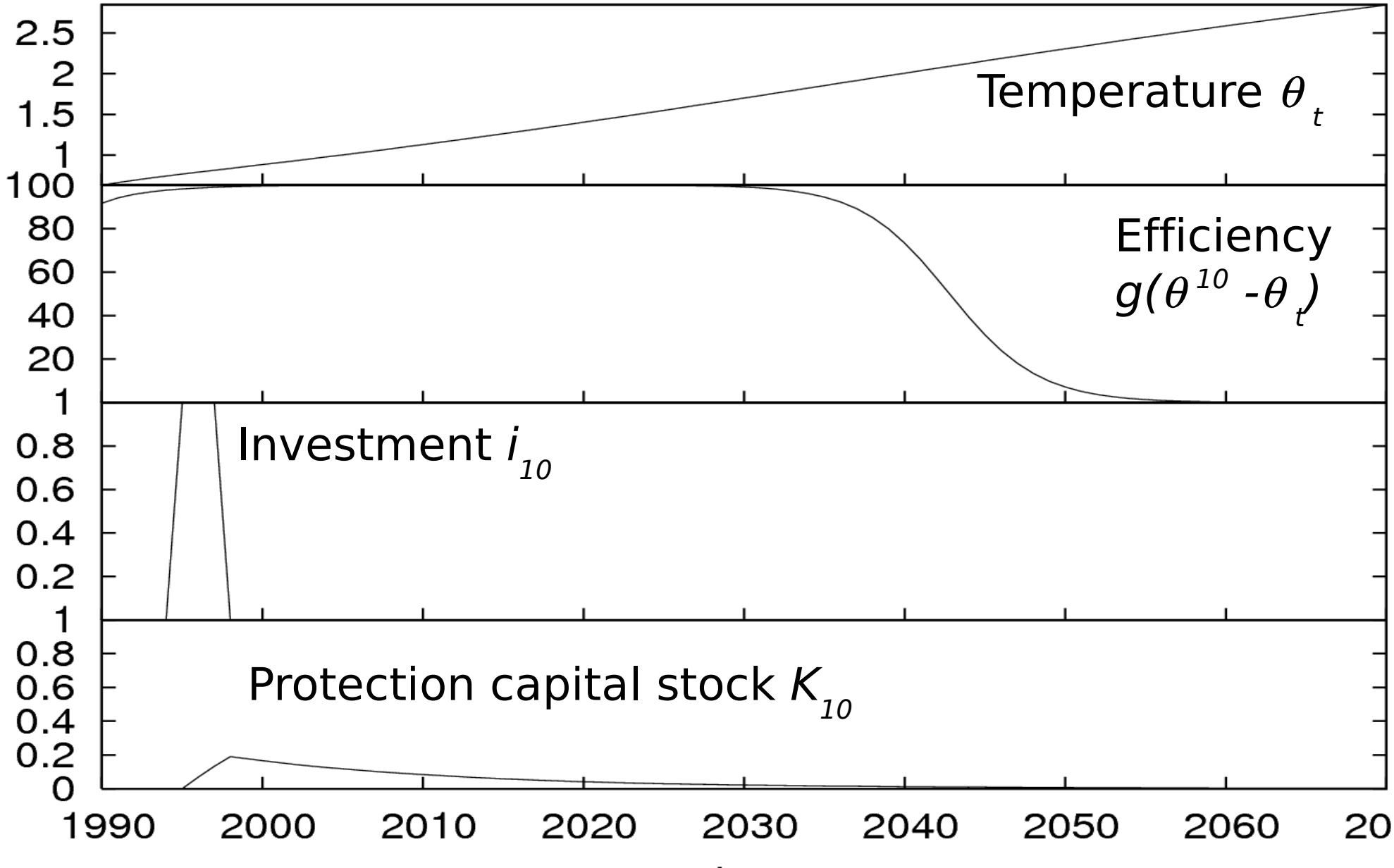
# Production function

Total protection capital is CES combined with exposed capital $\nu K$

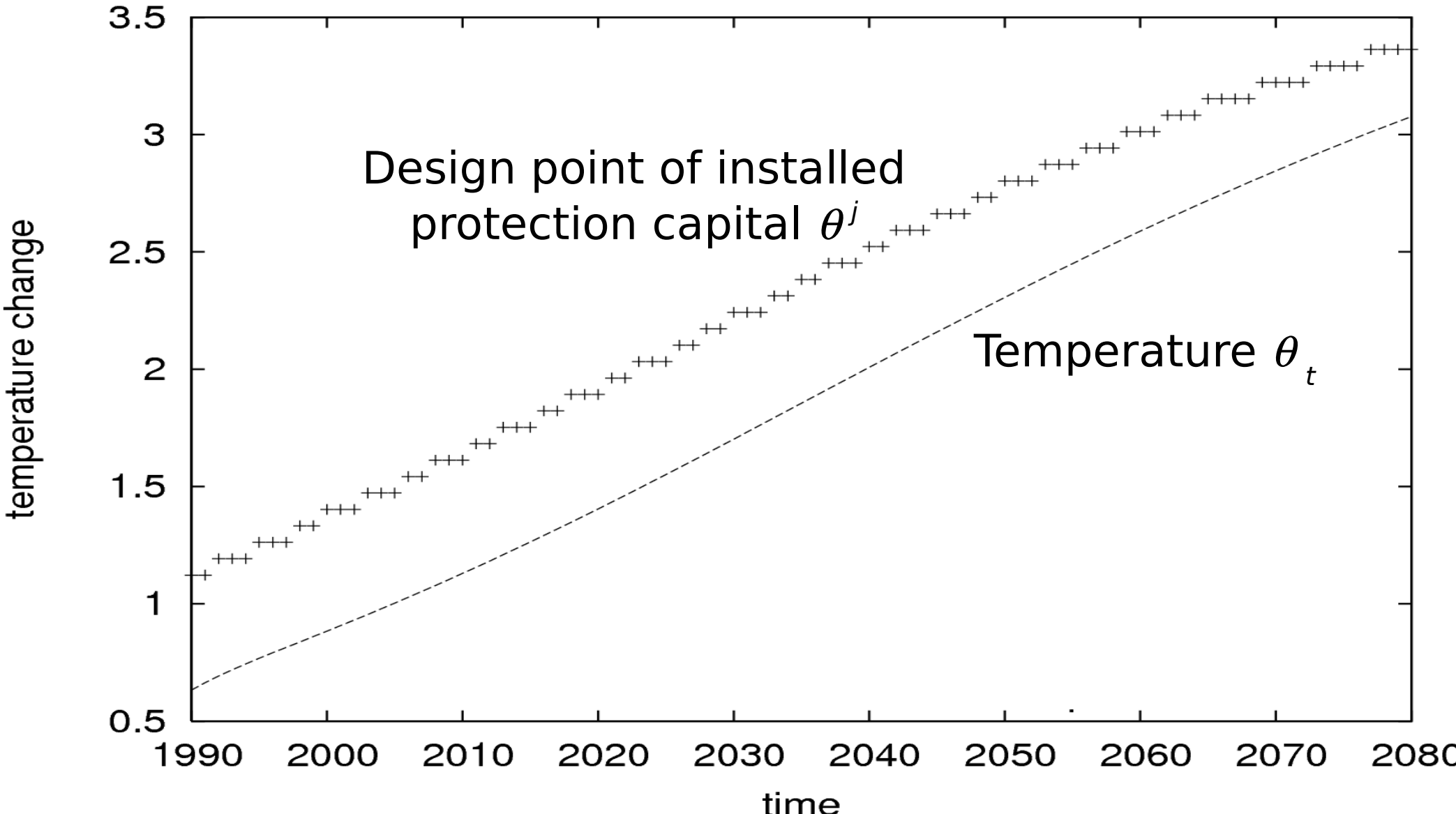
$$\text{Protection capital stock } = \sum_j g(\theta_t - \theta^j) K^j$$

$$y_t = \left[ (1-\nu)k_t + \left( \eta(\nu k_t)^\rho + \gamma \left( \sum_j g(\theta_t - \theta^j) k_t^j \right)^\rho \right)^{\frac{1}{\rho}} \right]^\alpha$$

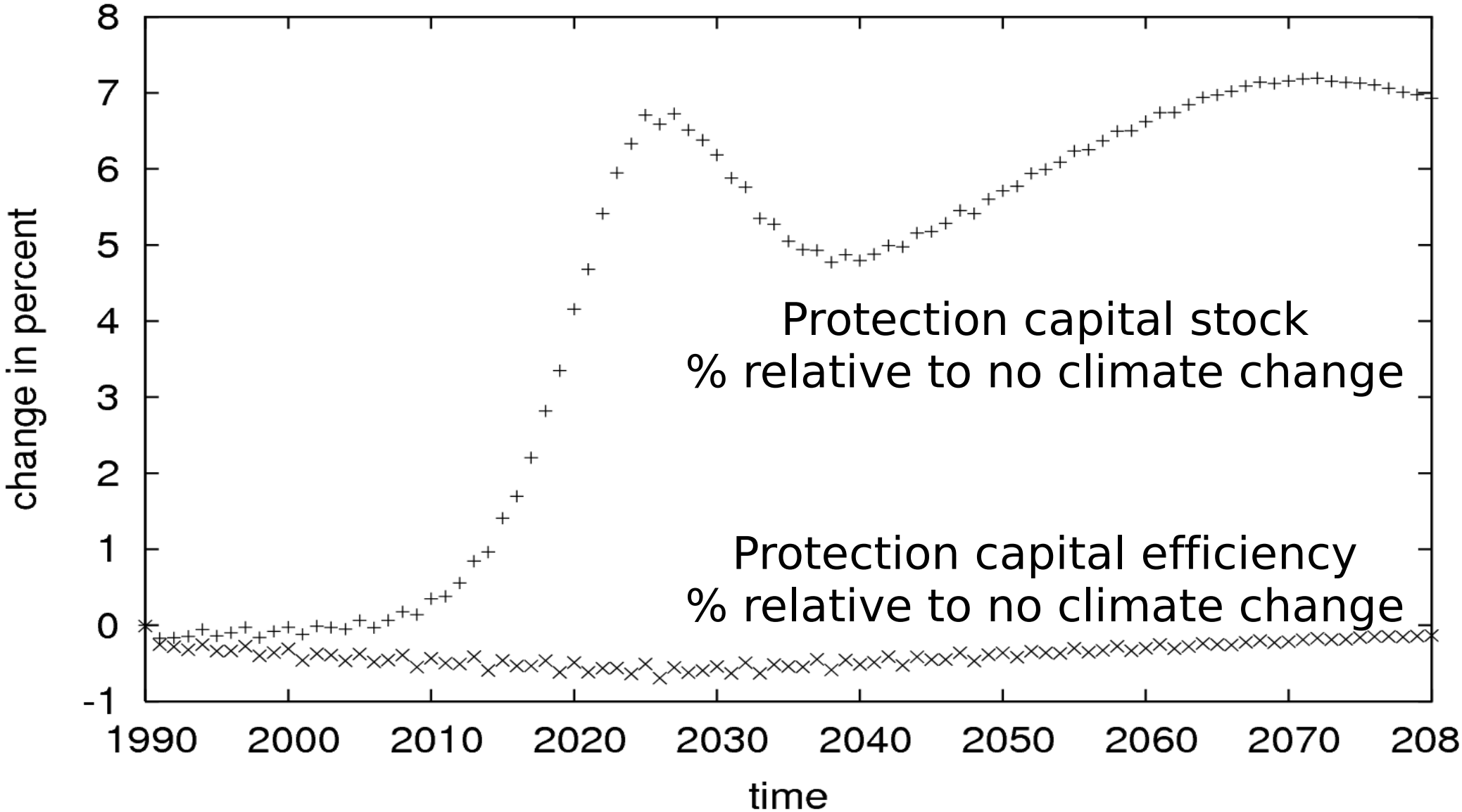
# IV. Optimal trajectory protection capital type $j$=10



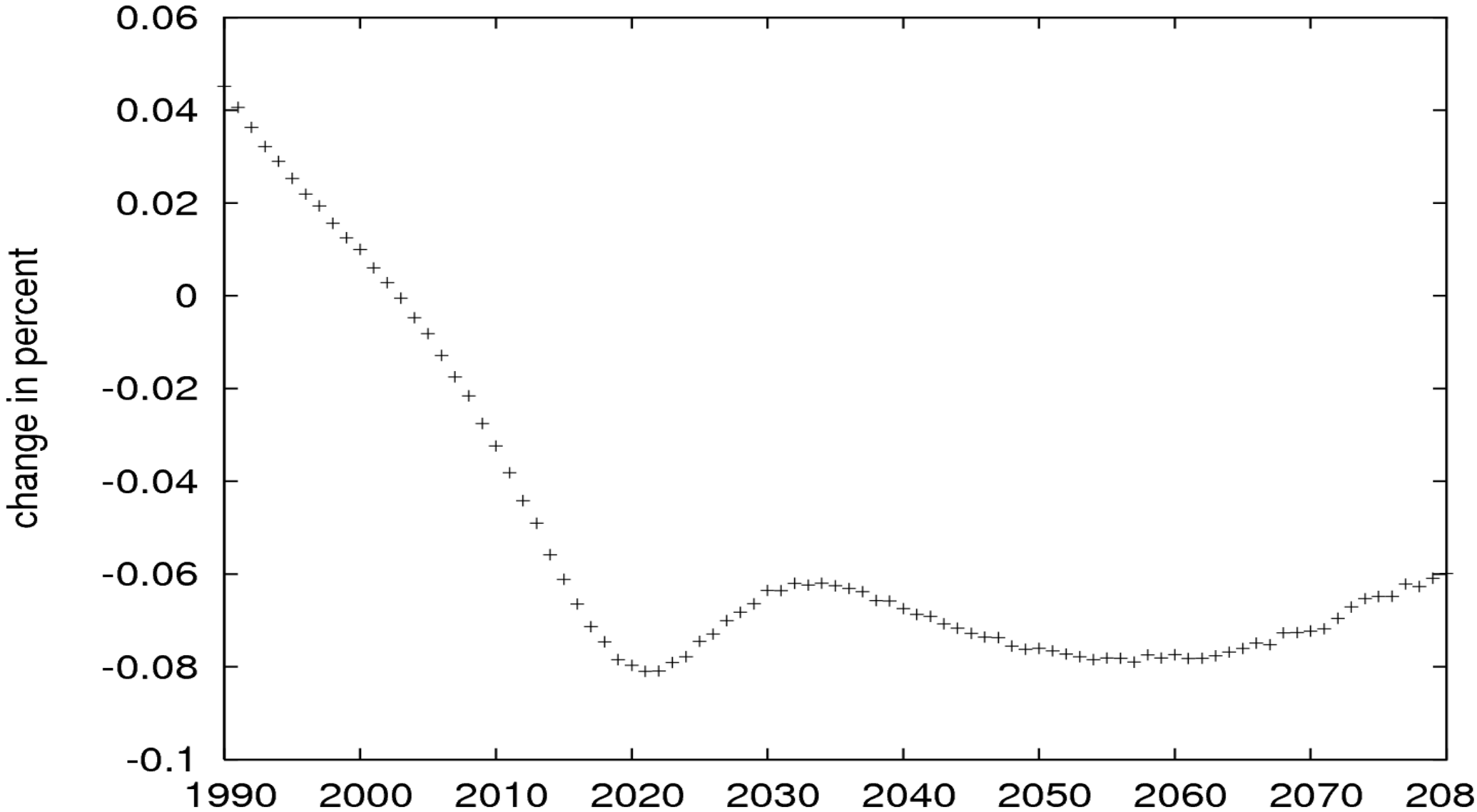
# Optimal adaptation is proactive



# Pay and stay adapted



# Consumption losses remain small



# Sensitivity analysis

| scenario | Coping range | Protection capital | $\nu$ | $T_{2s}$ | Utility loss |
|---|---|---|---|---|---|
| worst case | 1.44 | 0.15 | 0.5 | 4.5 | 0.044 |
| central case | 1.66 | 0.1 | 0.24 | 3.5 | 0.005 |
| best case | 2.66 | 0.05 | 0.12 | 2.5 | 0.00005 |
| reactive | same as central case | | | | 0.03 |

# Summary and conclusion

- ~25% of world's capital sensitive to climate
- Over-invest in protection to stay adapted
- Climate change costs may remain small if
  - Anticipation are perfect
  - Change is slow
  - Protection capital is separable