

***A Cost-Benefit Analysis of Climate Change:  
Uncertainties and the Value of Information***

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## Climate Change CBA

A large range of climate change Cost-Benefit Analyses (CBA) have been undertaken with (top-down and bottom-up) 'integrate assessment' models (IAM) that compare streams of damage costs and abatement costs.

The Stern Review (2006) has been a landmark publication in this field, and has received both appraisal and critique.

Much of the controversy regarding the Stern Review, and climate change CBA at large, concerns uncertainties, hence our choice to let uncertainties be the focus of our study.

## To what extent do uncertainties matter?

How large is the social cost penalty if one makes the wrong choice because of uncertainties in the estimates of the costs and benefits of environmental policy measures?

- Rabl, A., J.V. Spadaro and B.C.C. van der Zwaan, “Uncertainty of Air Pollution Cost Estimates: to what extent does it matter?”, *Environmental Science and Technology*, **39**, 2, 2005, 399-408.

For CO<sub>2</sub> emissions, we preliminarily concluded:

If the true damage costs are twice as high as the ones estimated, the social cost penalty is less than 30% and in most cases much less.

## Climate Change

Our goal here is to perform a more refined climate change CBA, notably through the use of non-linear damage costs.

Even though climate change is a dynamic problem, its analysis in terms of steady-state conditions is instructive for policy purposes.

We therefore specify CO<sub>2</sub> emissions as annual averages of the time-dependent profiles of Wigley *et al.* (1996).

The resulting time-averaged cost-benefit model is simple enough to allow a fully transparent sensitivity study regarding all damage and abatement cost parameters involved.

## Total cost minimization

A cost-benefit analysis of climate change involves the minimization of the sum of abatement and damage costs associated with CO<sub>2</sub> emissions:

$$C_{tot}(E) = C_{ab}(E) + C_{dam}(E)$$

What is the optimal CO<sub>2</sub> emissions level  $E_0$  resulting from this optimization?

## Damage costs

Damage costs, the stabilization CO<sub>2</sub> concentration and stabilization temperature increase are related by:

$$C_{dam} = \rho (\Delta T_{stab})^\theta$$

Essentially all IAM  
(top-down, bottom-up)

$$\frac{P_{stab}}{P_{280}} = 2^{\left(\frac{\Delta T_{stab}}{\Delta T_{2X}}\right)}$$

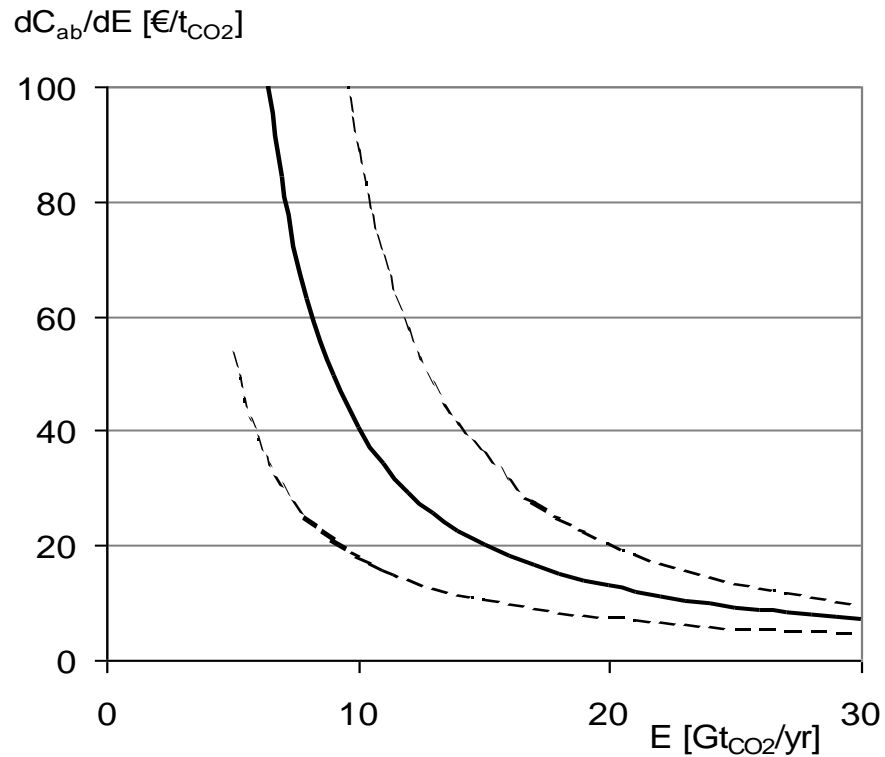
Houghton *et al.* (1996)  
Caldeira *et al.* (2003)

## Damage costs

Assuming a linear relationship between the average  $E$ , 1990-2300, and  $P_{stab}$ , these equations result in an expression for  $C_{dam}$ :

$$C_{dam}(E) = \rho \left[ \Delta T_{2X} \left( \varepsilon + \delta \frac{E}{E_s} \right) \right]^2$$

## Abatement costs



$$\frac{dC_{ab}}{d(-E)} = \frac{1}{G} \alpha \left( \frac{E - \beta}{E_s} \right)^\gamma$$

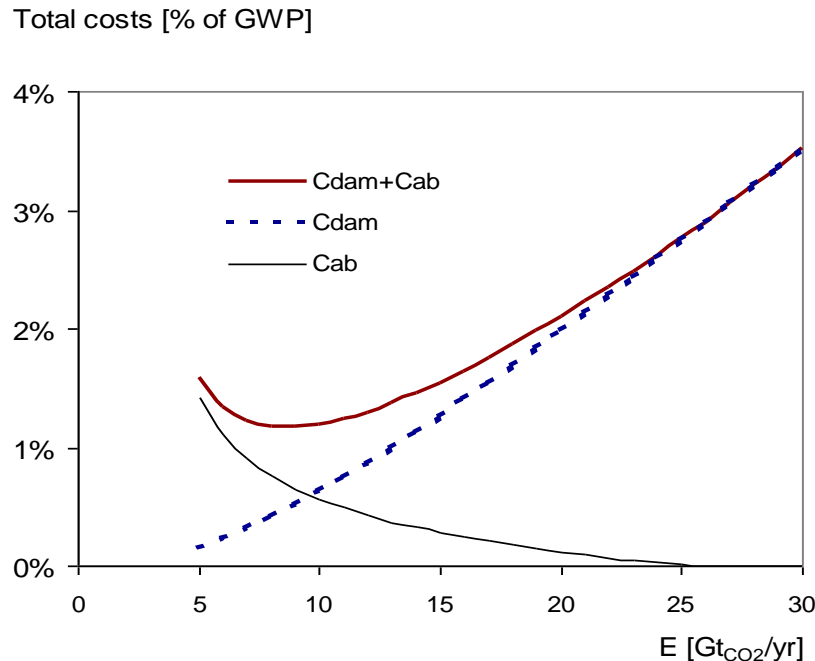
## Abatement costs

Integrating this equation from starting point  $E_s$  to  $E$ , results in a relation for  $C_{ab}$ :

$$C_{ab}(E) = \frac{1}{G} \frac{\alpha E_s}{\gamma + 1} \left[ \left( \frac{E_s - \beta}{E_s} \right)^{\gamma + 1} - \left( \frac{E - \beta}{E_s} \right)^{\gamma + 1} \right]$$

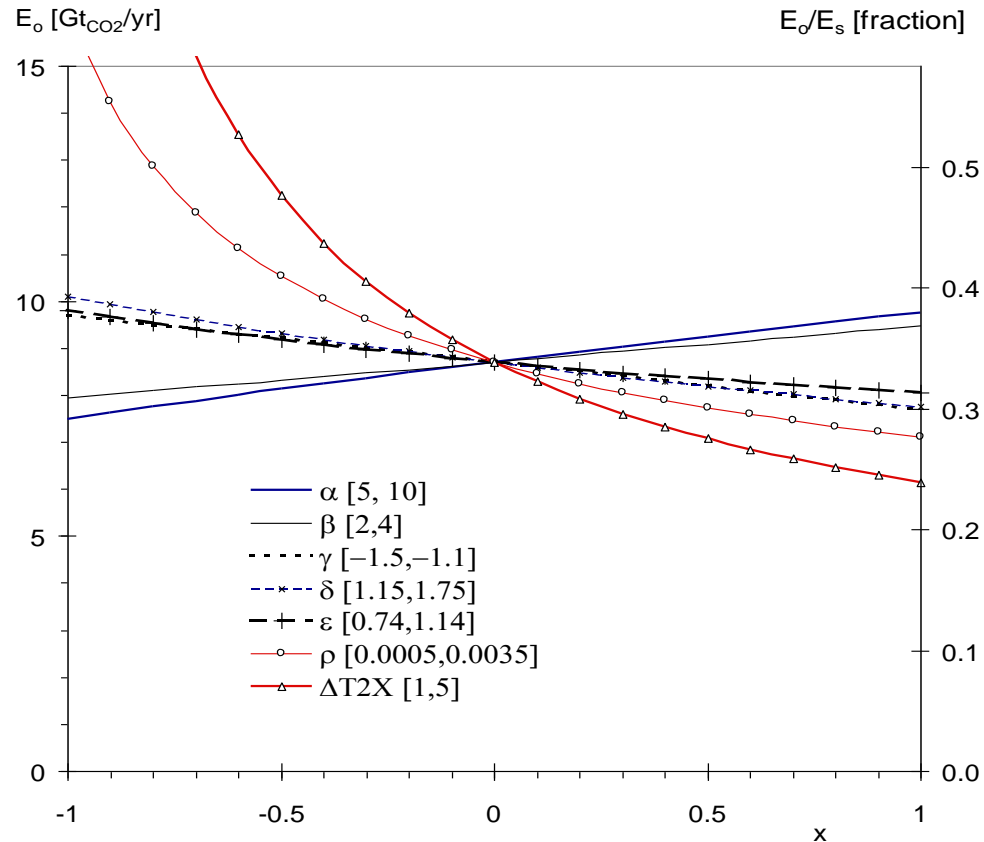
## Solving for the optimal emission level

With relations for  $C_{ab}$  and  $C_{dam}$  we can solve the cost minimization problem and derive  $E_0$ :



$E_0 = 8.7 \text{ GtCO}_2/\text{yr}$ , i.e. about one third of current global emissions.

# Sensitivity analysis



$E_0$  varies by at most 2.3 GtCO<sub>2</sub>/yr for a wide range of parameter values.

## Abatement and damage cost uncertainties

What is the cost penalty as a result of differences between the estimated and true values of the damage and abatement costs?

$$X_{\text{dam}} = C_{\text{dam,true}}(E)/C_{\text{dam,est}}(E)$$

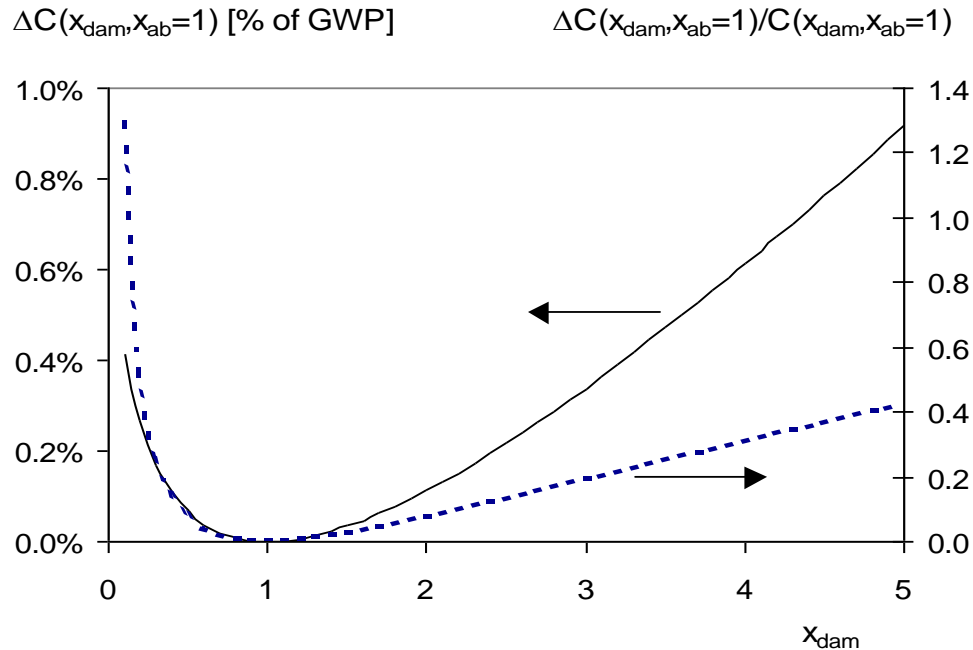
$$X_{\text{ab}} = C_{\text{ab,true}}(E)/C_{\text{ab,est}}(E)$$

The cost penalty can be expressed as function of  $x_{\text{dam}}$  and  $x_{\text{ab}}$  :

$$\Delta C(x_{\text{dam}}, x_{\text{ab}})$$

## Social cost penalty

The cost penalty proves to be low in relative terms:



In absolute terms, however, the cost penalty can still be very high, hence the importance of continuing damage cost analysis.

## Summary CBA

- CO<sub>2</sub> emissions should be reduced to about 1/3.
- Reductions should go down to at least 2/5.
- Reductions do not need to go below 1/4.
- Hence in any case below the proclaimed 1/2.

## Conclusions

- CO<sub>2</sub> emissions need to be significantly reduced with respect to current levels, let alone to expected future levels.
- Uncertainty exists regarding the optimal reduction level, but the error margin is small, even under large parameter changes.
- Hence, uncertainties on several fronts constitute no reason for not acting – i.e. starting to reduce emissions – today.
- It is necessary to increase our understanding of damage costs, given the magnitude of the total costs of climate change.
- Reducing the uncertainty (geometric standard deviation) of relative damage costs by half saves 0.5% of GWP (250 billion €).
- We find  $P_{stab} = 400 \pm 40$  ppmv, while the Stern Review reports  $P_{stab} = 500 \pm 50$  ppmv.