ETH
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IED
Institut für Umweltentscheidungen
Institute for Environmental Decision

The Economics of Climate Change

Lecture 4: Optimal Emission Levels (ctd.)

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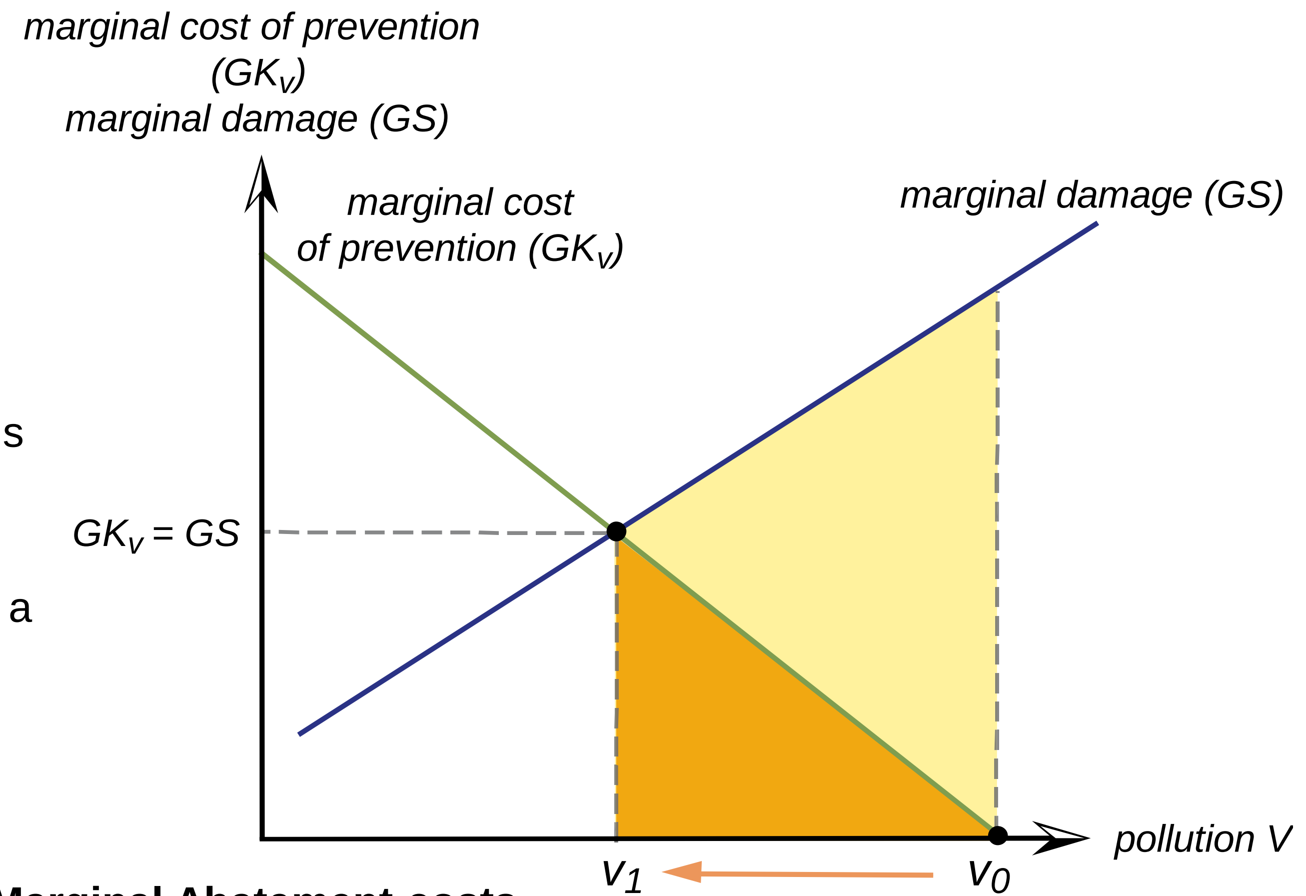
Optimal level when damages can be anticipated (Welfare maximization)



- Optimal Emission level V_1 is to be incentivized.
- This is achieved by putting a «price on carbon»
- Optimal carbon price p:

p = Marginal Damages = Marginal Abatement costs

Damages and Uncertainty

		Uncertainty in Valuation →		
Uncertainty in Predicting Climate Change ↓		**Market**	**Non Market**	**(Socially Contingent)**
	Projection (e,g, sea level Rise)	Coastal protection Loss of dryland Energy (heating/cooling)	Heat stress Loss of wetland	Regional costs Investment
	Bounded Risks (e.g. droughts, floods, storms)	Agriculture Water Variability (drought, flood, storms)	Ecosystem change Biodiversity Loss of life Secondary social effects	Comparative advantage & market structures
	System change & surprises (e.g. major events)	Above, plus Significant loss of land and resources Non- marginal effects	Higher order social effects Regional collapse Irreversible losses	Regional collapse

Source: Downing and Watkiss, 2003

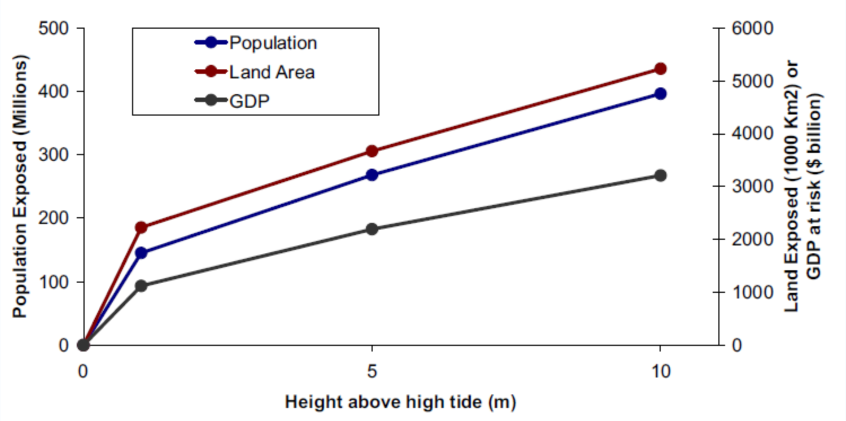
The problem of specifying the damage curve

Table 3.3 Potential temperature triggers for large-scale and abrupt changes in climate system

Phenomenon	Global Temperature Rise (above pre-industrial)	Relative Confidence*	References
Shifts in regional weather regimes (e.g. changes in monsoons or the El Niño)	Uncertain (although some changes are expected)	Medium	Hoskins (2003)
Onset of irreversible melting of Greenland	2 - 3°C	Medium	Lowe *et al.* (2006)
Substantial melting threatening the stability of the West Antarctic Ice Sheet	> 2 - 5°C	Low	Oppenheimer (2005)
Weakening of North Atlantic Thermohaline Circulation	Gradual weakening from present	High	Wood *et al.* (2006)
Complete collapse of North Atlantic Thermohaline Circulation	> 3 - 5°C	Low	O'Neill and Oppenheimer (2002)

Source: Adapted from Schneider and Lane (2006)

Figure 3.11 Global flood exposure from major sea level rise (based on present conditions)

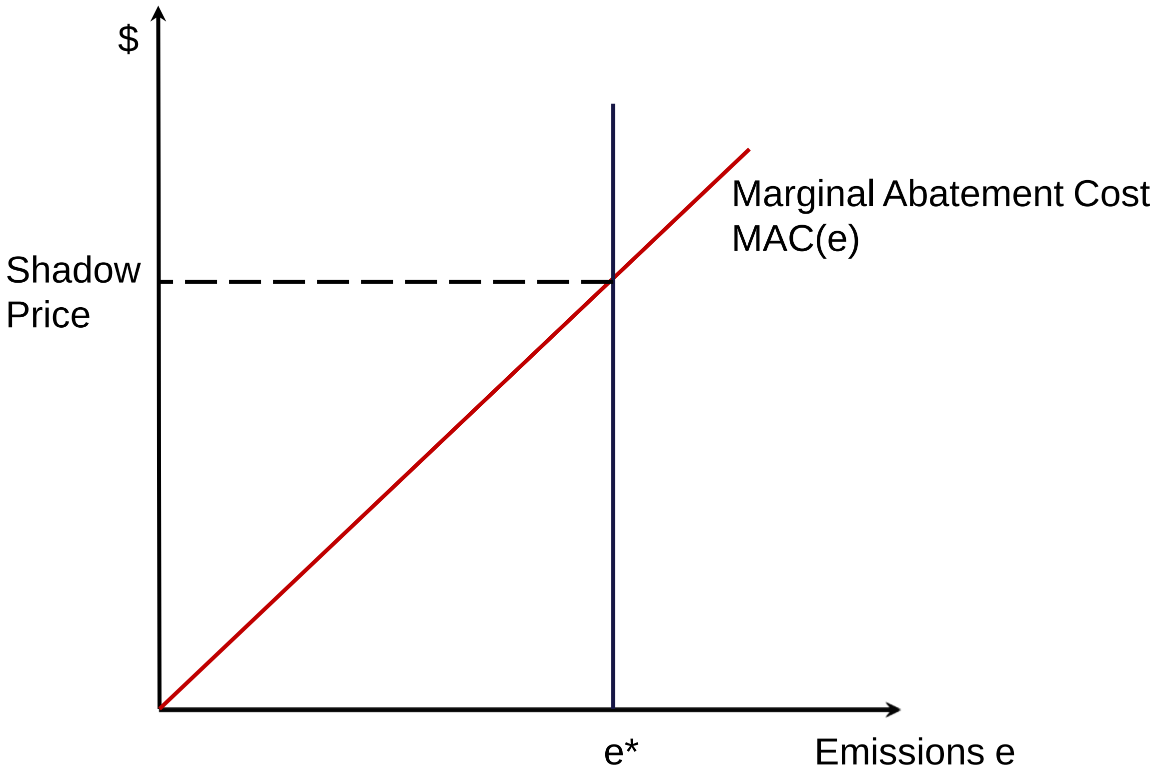


Source: Anthoff *et al.* (2006)

Minimizing Abatement costs under an environmental constraint

Environmental constraints:

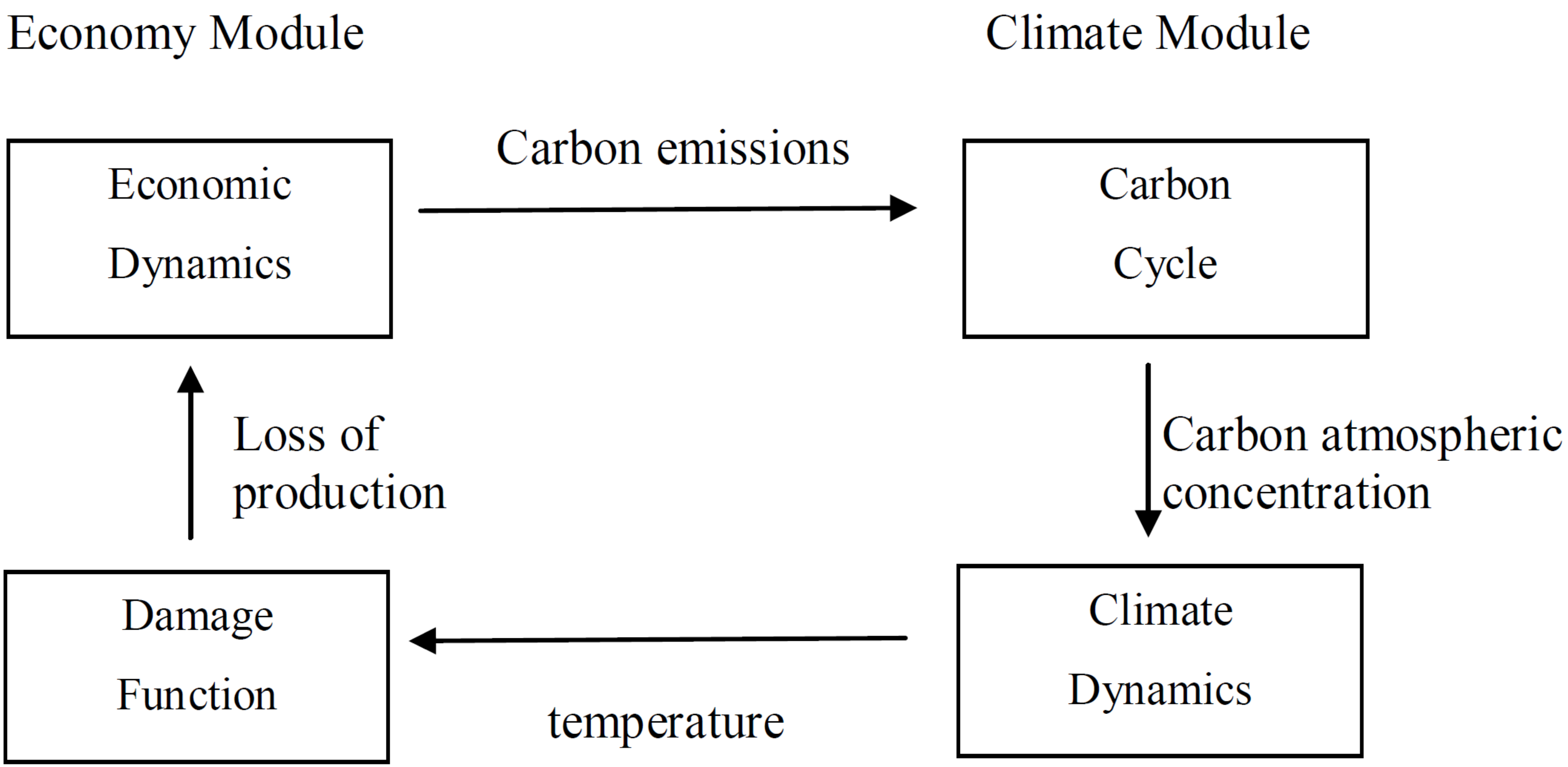
- Temperature not exceeding 2°C
- Concentration not exceeding 550 ppmv
- Constraints are usually probabilistic, e.g. target is met with x% probability



Integrated Assessment Models

- IAMs are combined climate and economic models which allow a joint modelling of natural and socio-economic processes
- Primary analytical tool for quantitative climate policy analysis
- Used to predict the impacts of GHG emissions and to evaluate the optimal abatement path (when, where and how much to abate)
- First climate-economy IAM developed by Nordhaus (1991)

Simplified structure of IAMs



Source: Arigoni Ortiz and Markandya (2009)

Strenghts of IAMs

- Consistent modelling of economy, climate and biosphere
- Consideration of feedbacks between the different domains
- Often global coverage, sometimes regionally disaggregated
- Long time scales

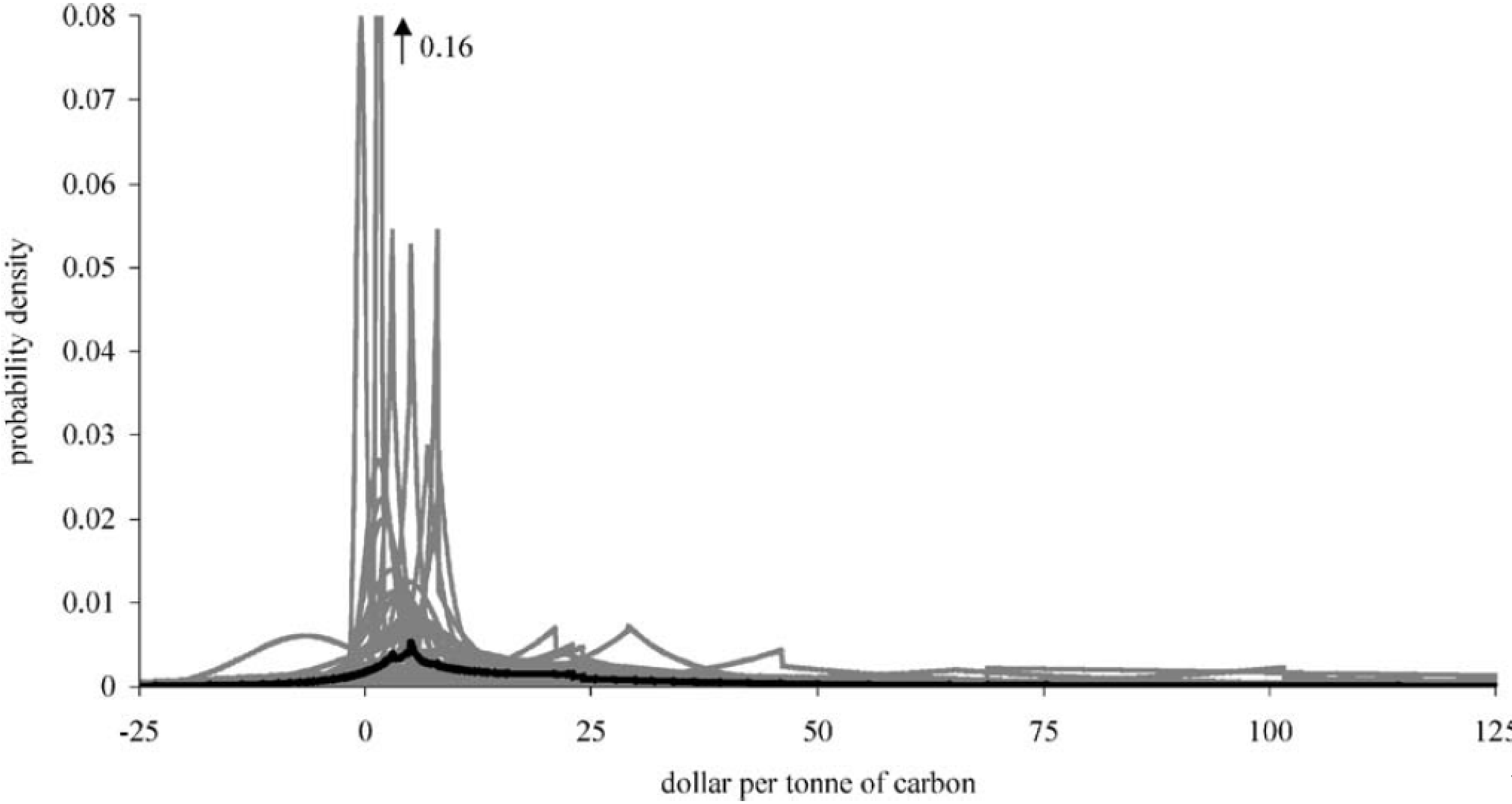
Weaknesses of IAMs

- Trade-off between level of accuracy within the sub-models and width of coverage
- High complexity, sometimes low transparency with respect to assumptions made → «black box»
- Requirement of high computer power to solve models
- Adequate uncertainty analysis often difficult

Differences in IAM results

Estimates for the social cost of carbon (SCC) diverge:

\$93/tC (mean), \$14/tC (median), \$350/tC (95 percentile) (Tol, 2005)



Source: Tol (2005)

Main drivers of differences in IAM results

1) Choice of model structure
2) Treatment of abatement costs and assumptions on technological change
3) Way of handling uncertainty in climate outcomes (9.10.)
4) Way of handling equity across time and space (9.10.)

1) Typical model structures of IAMs

a) Welfare maximization models

b) General equilibrium models

c) Partial equilibrium models

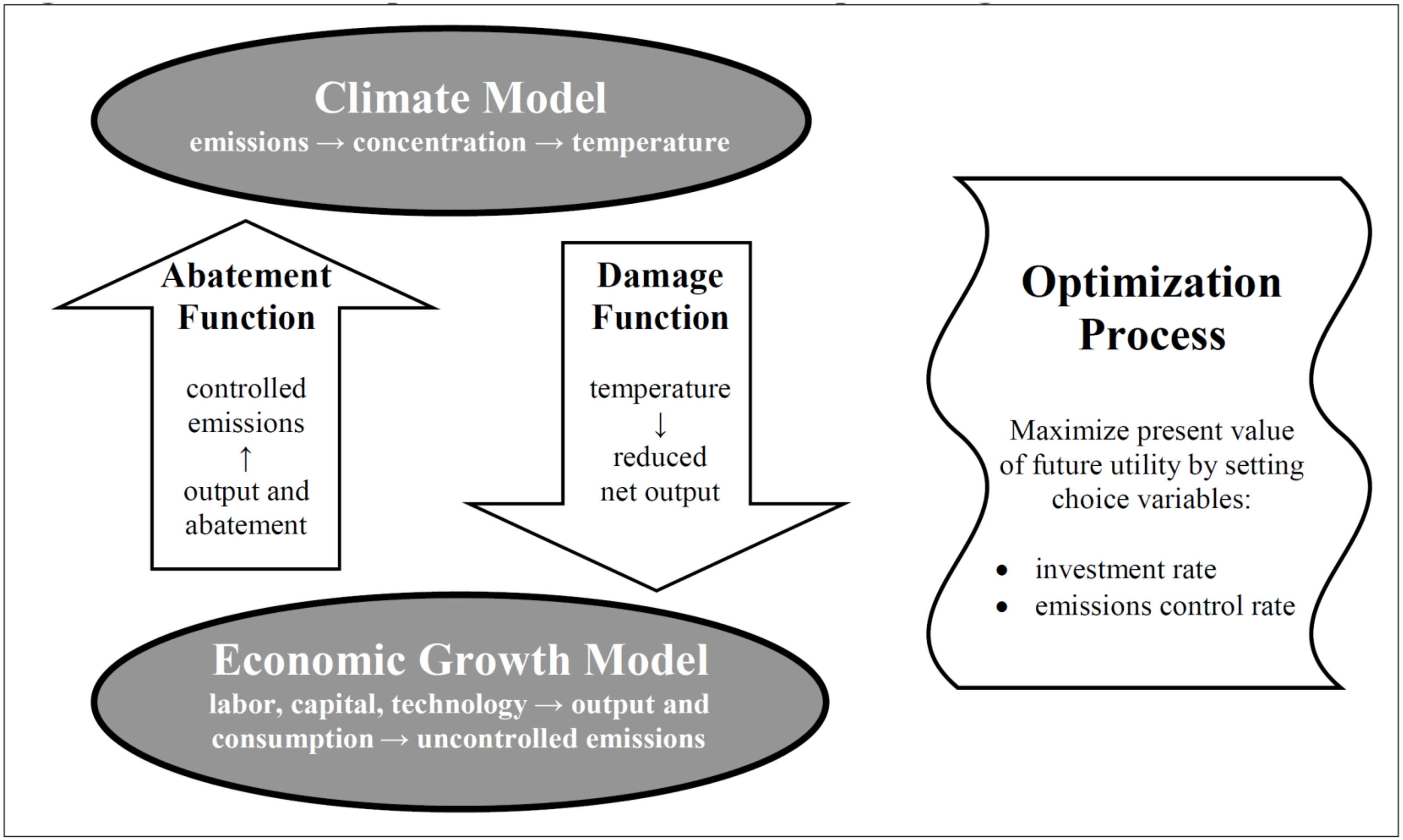
d) Simulation models

e) Cost minimization models

a) Welfare maximization models

- The economy is represented in a growth model
- The discounted present value of welfare is maximized across all time periods → Optimization over the amount of abatement in each period
- All time periods are solved simultaneously (perfect foresight)

Structure of welfare maximization model

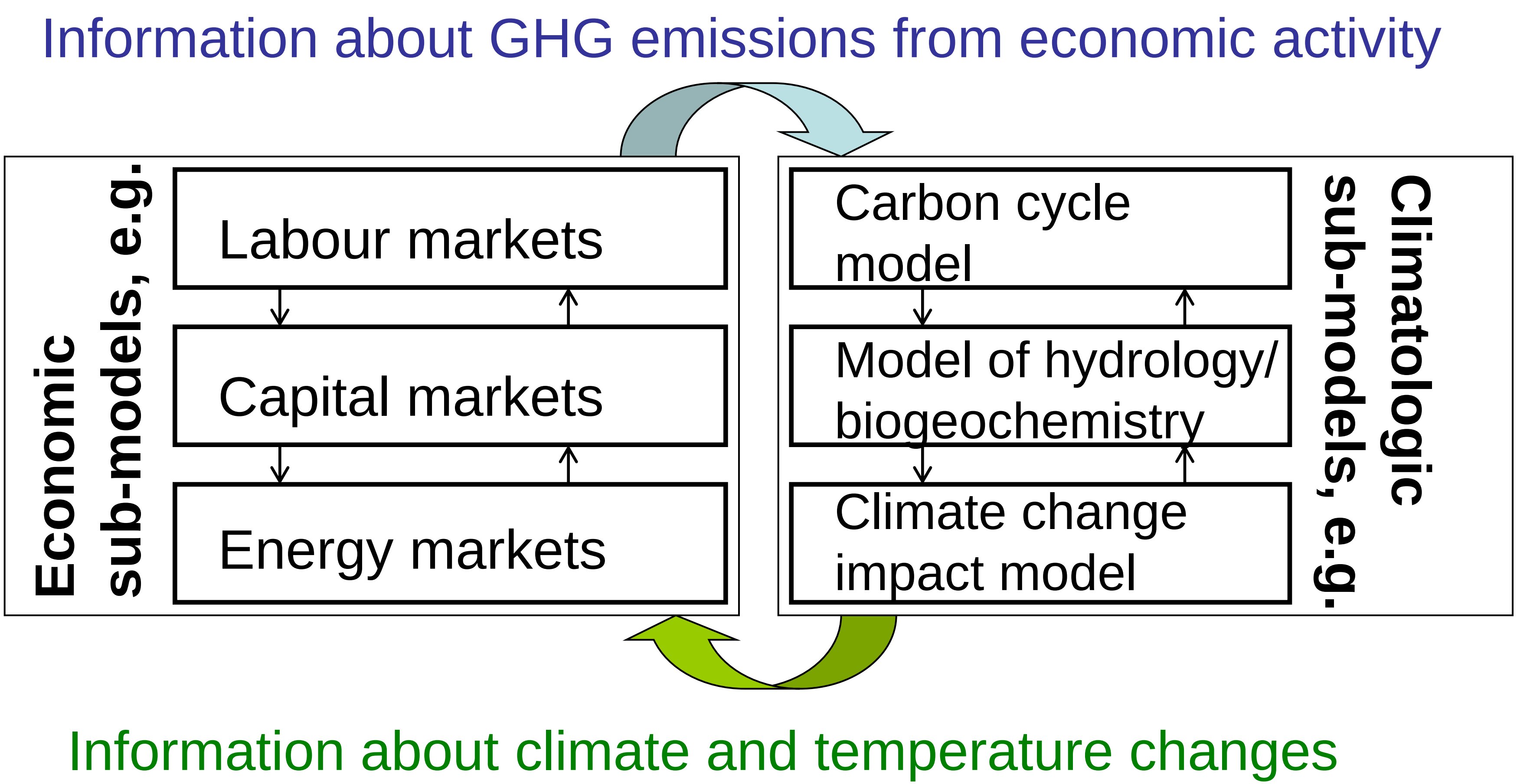


Source: Stanton et al., 2008

b) General equilibrium models

- Economy is represented in a set of linked economic sub-models (different sectors)
- Models are solved by finding a set of prices for which all markets are cleared
- «Recursive dynamics»: prices are set for each time period; results are used as inputs for next time period (no perfect foresight assumed)
- GE models are often very complex

Simplified structure of GEM



c) Partial equilibrium models

- PE models correspond to reduced GE models, i.e. they use only a subset of the economic sectors
- Prices of economic sectors not represented in the model are taken as exogenously given (fixed)

d) Simulation models

- Based on predictions about future emissions and climate conditions
- No feedback between climate and economic models, i.e. climate and emission parameters are exogenous to the model (Scenarios)
- Estimation of the potential costs of different future emission paths

e) Cost minimization models

- In most cases, no feedback between climate and economic models → only emissions are represented
- Very detailed modelling of energy sector and different industries
- Identify the most cost effective solution to achieve a certain stabilization target

Overview of some recent IAMs

Model Category	Global	Regionally Disaggregated
Welfare Maximization	DICE-2008 ENTICE-BR DEMETER-1CCS *MIND*	RICE-2004 FEEM-RICE FUND MERGE CETA-M GRAPE AIM/Dynamic Global
General equilibrium	JAM IGEM	IGS/EPPA SMG WORLDSCAN ABARE-GTEM G-CUBED/MSG3 MS-MRT AIM IMACLIM-R WIAGEM
Partial Equilibrium		MiniCAM *GIM*
Simulation		PAGE-2002 ICAM-3 E3MG *GIM*
Cost MInimization	GET-LFL *MIND*	DNE21+ MESSAGE-MACRO

Note: Italics indicate that a model falls under more than one category

Source: Stanton et al., 2008

Handling equity across time in economic climate models → MO

- Valuing gains and losses from different time periods →Discounting

- Discount rate: $r(t) = \rho + \eta\, g(t)$

  ρ = rate of pure time preference

  η = elasticity of marginal utility of consumption

  $g(t)$ = growth rate of income

- Because of long time horizon of climate change, IAMs are extremely sensitive to relatively small changes in $r(t)$

Handling equity across space in economic climate models

- Regionally disaggregated IAMs include separate utility functions for each world region
- Weights are put on the regional utility functions to account for interregional differences in per capita income
- Weights aim at equalizing the marginal product of capital across regions
- Equity weighting implies ethical judgements

2) Treatment of abatement costs and assumptions on technological change

- Characterization of technologies by decreasing or increasing returns to scale?
- Level of detail in technology sub-models: How many regions, industries, fuels, abatement technologies and end uses are included?
- Does the model include macroeconomic feedback from investment in abatement technology?
- Is technological change exogenous or endogenous?

Decreasing vs. increasing returns to scale

- Many IAMs characterize technologies with decreasing returns to scale
- Decreasing returns to scale are usually used for convenience (to avoid path dependence and multiple equilibria)
- Increasing returns to scale is more realistic, esp. when representing knowledge-based technologies

Accounting for macroeconomic feedback

- In many IAMs, abatement costs are considered as loss of income
- More realistic approach:
  - Account for job and income generating effects of abatement
  - Consider abatement costs as additions to capital rather than subtractions from income

Endogeneity of technological change

- In many IAMs, technological change is exogenous → technological learning curves are taken as given
- More realistic approach: make technological change dependent on investment and R&D efforts → model technological change as an outcome of economic activity
- In tendency, models including endogenous technological change provide lower estimates of abatement costs (Edenhofer et al., 2006; Barker et al., 2006)

Conclusion

- Even without taking more uncertain effects into account, theoretically optimal carbon prices seem to suggest that quite stringent climate policy should be implemented.
- When also considering non-linear effects and the fact that such policies also trigger innovation, the need for global climate policy seems to be more and more undisputable.