Optimal Climate Change Policy: R&D Investments and Abatement under Uncertainty

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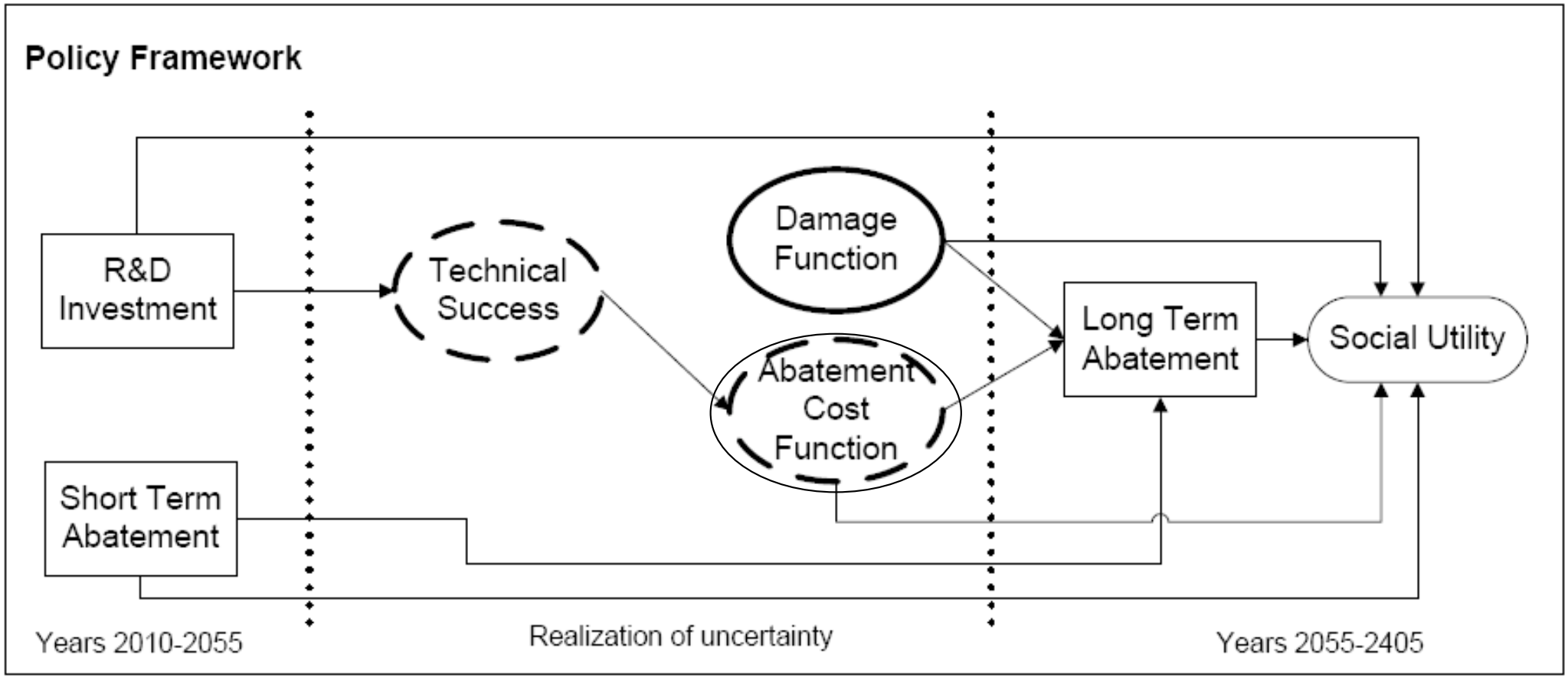
What to do about climate change?

- What is the optimal path for a carbon tax and/or an emissions path?
  - Emissions taxes
  - Cap and trade
  - Emissions standards
- What is the optimal investment in a portfolio of technology R&D projects?
  - Government funded R&D
  - R&D subsidies
  - Technology standards

Paradigm: Act – Learn – Act



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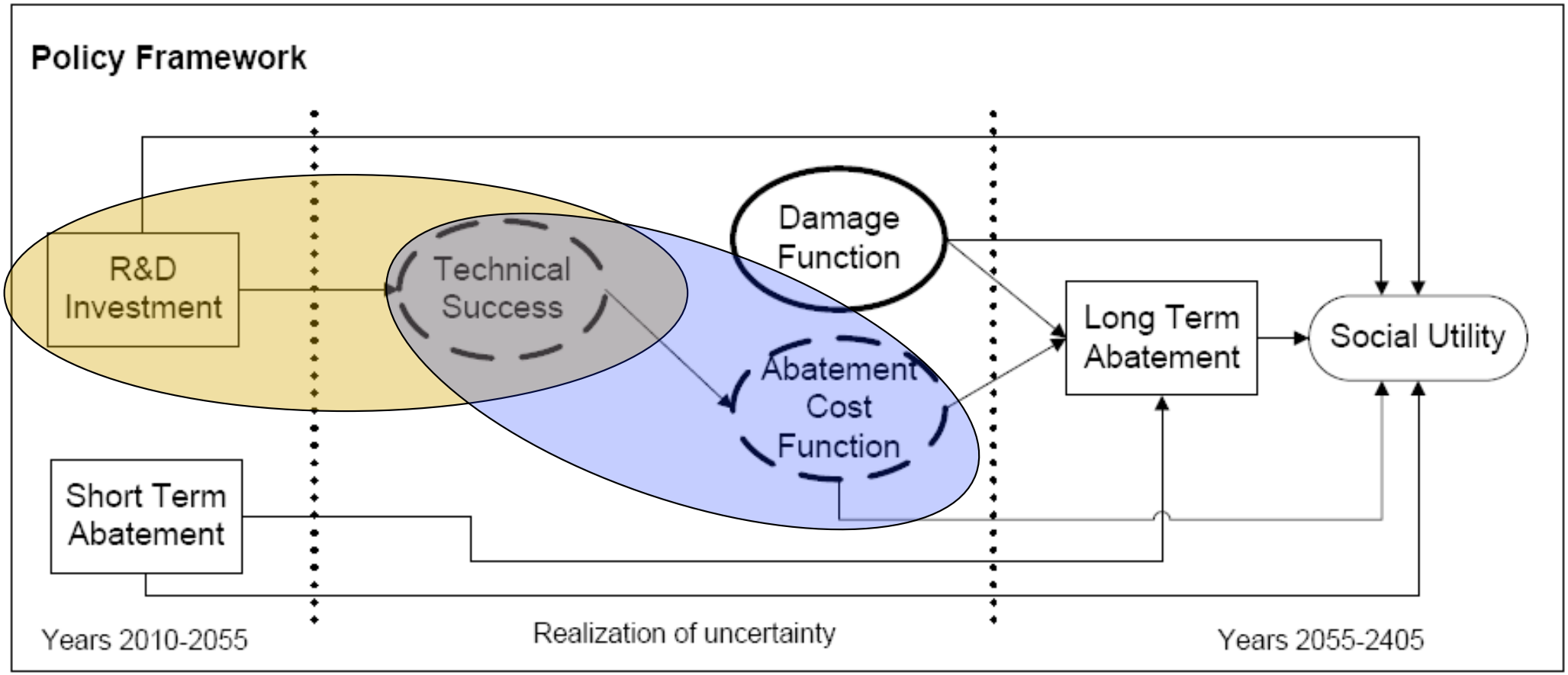
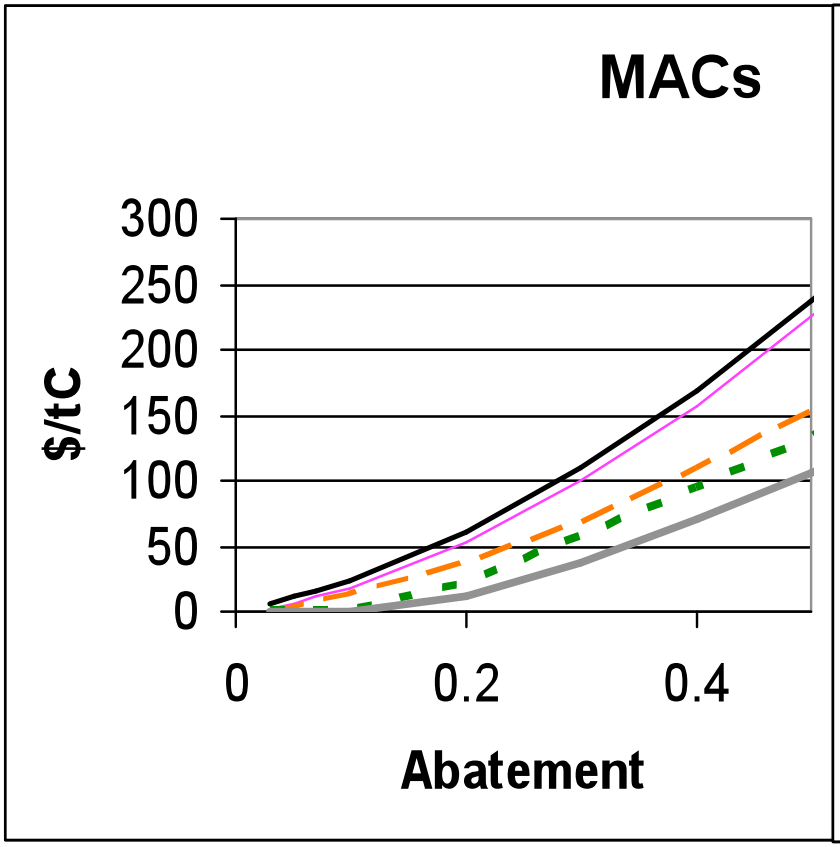
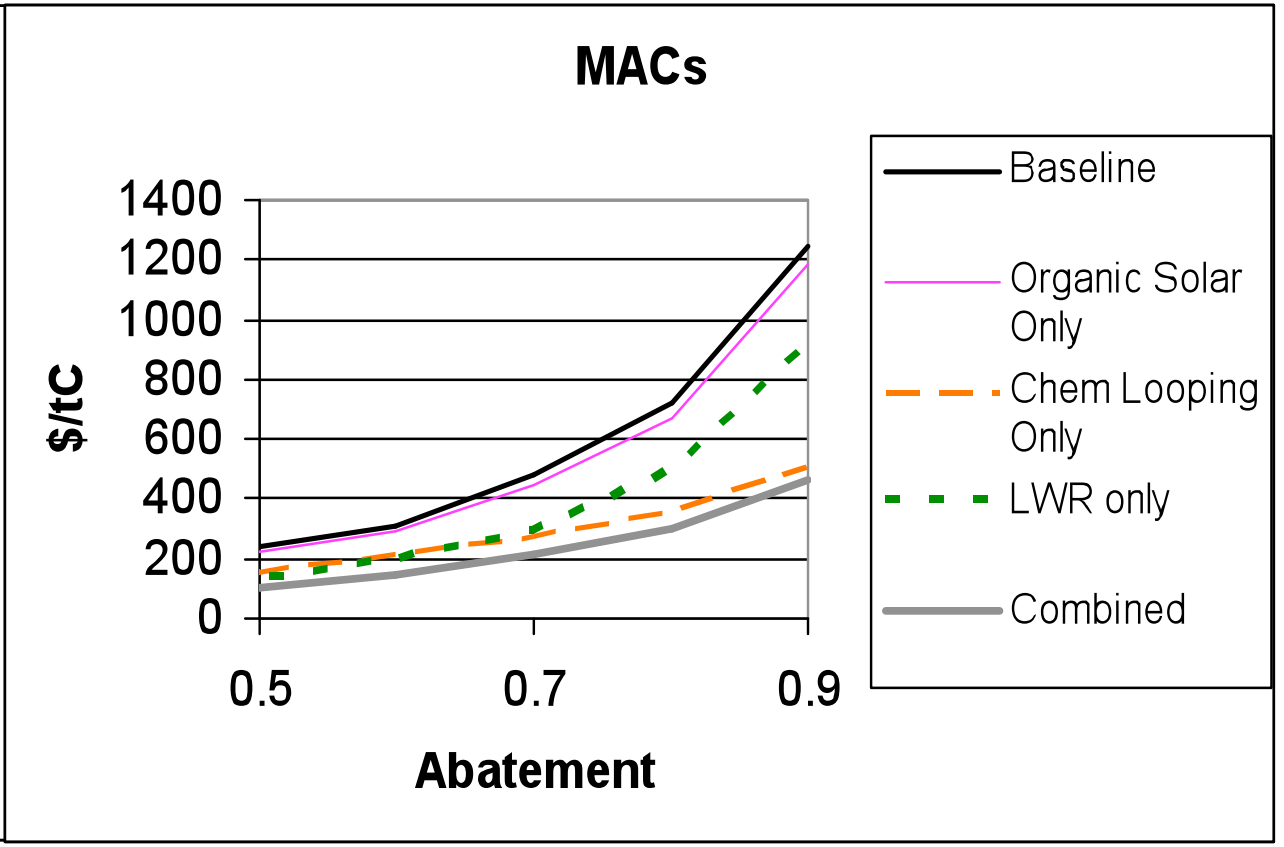


We performed expert elicitations on potential R&D projects

- Solar PV
  - purely organic
  - new inorganic
  - 3rd generation
- CCS
  - pre-combustion
  - chemical looping
  - post-combustion
- Nuclear
  - advanced LWR
  - HTR
  - FR

Impact of technology on the MAC





Current Work: Dynamic Detailed IAM with R&D

- Based on well-known DICE model
  - 25 10-yr periods
  - Add R&D and uncertainty
- Two-stage stochastic nonlinear programming problem
  - Uncertainty in technologies and damages resolved after 50 years

Technical change, represented by α, pivots and shifts the MAC

pivot shift

$$c\left(\mu_t,\vec{\alpha}\right)=\left(1-.08\alpha_1-0.92\alpha_2\right)c\left(\mu_t\right)-\left(0.02-0.06\alpha_1-0.14\alpha_2\right)c\left(0.5\right)\mu_t$$

Damages depend on temp τ, and have a random shift parameter, π

$$D\left(\tau\right)=1+\tilde{\pi}\tau^2$$

Unadjusted output is reduced by the cost of abatement and by damages

$$y_t=\frac{1-c\left(\mu_t,\vec{\alpha}\right)}{D\left(\tau_t,\tilde{\pi}\right)}y_t^{\,g}$$

Output is divided between consumption, investment in capital, and R&D for the first 5 period.

$$y_t=c_t+I_t+\kappa\gamma_t$$

Symbol	Definition
c()	cost of abatement
D()	Damages from climate change
μ	abatement, as a fraction
α	parameter representing technical change
τ	temperature change
π	random damage parameter
y, y^g	output, adjusted and unadjusted
c	consumption
I	investment in capital
κ	opportunity cost of R&D
γ	R&D investment cost

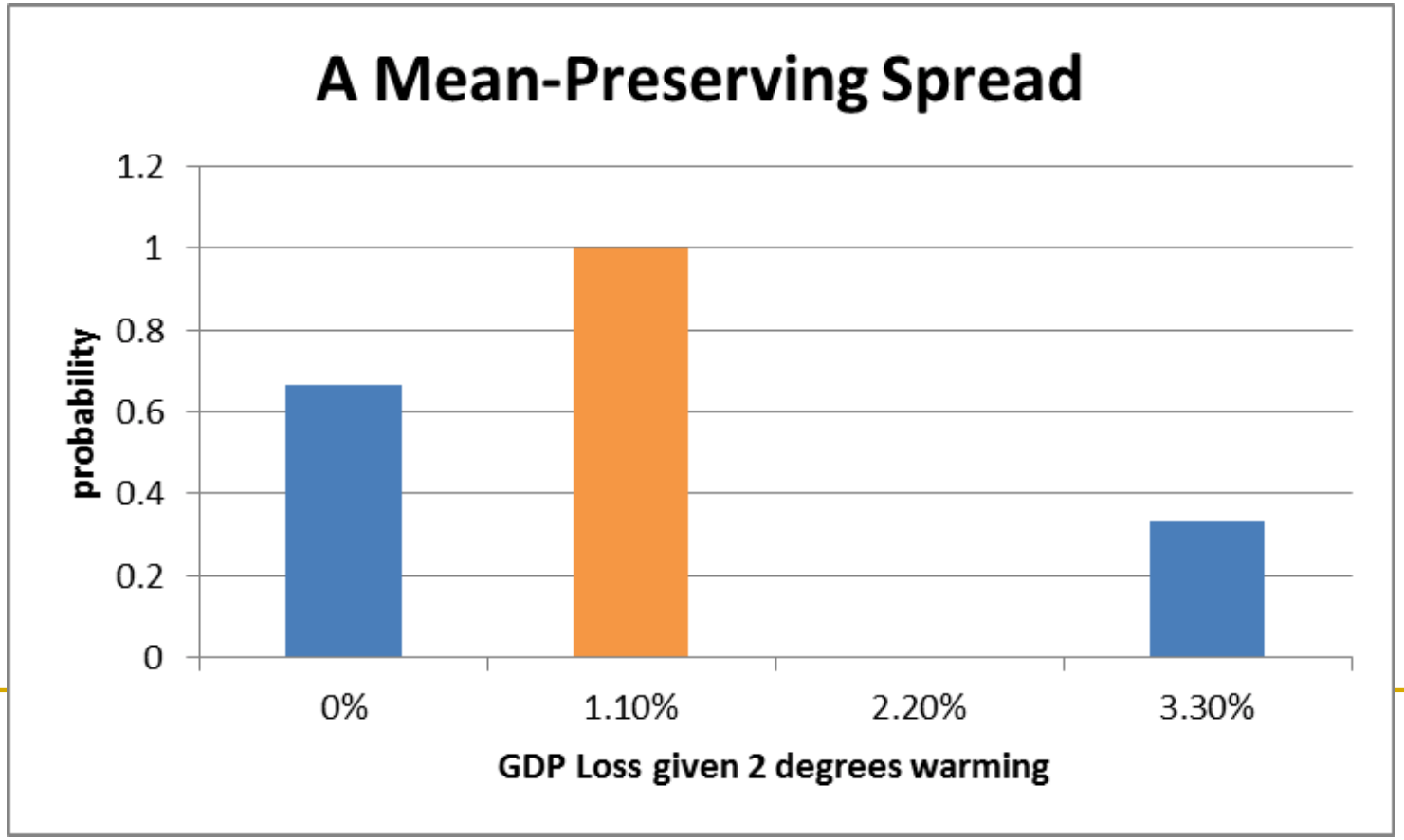
Experiments

Focus on comparing different policy environments

Policy	Abatement	Key characterisitcs
Baseline no-controls	0	
DICE Optimal	optimal	
Stern	optimal	Abatement chosen under low interest rate
Stern Fixed	optimal	Abatement and R&D chosen under low interest rate
Gore	Lower bound between 0.25 - 0.95	Limited participation
Kyoto Strong	fixed for 150 years	Limited participation
2 degrees	optimal	Upper bound on temperature

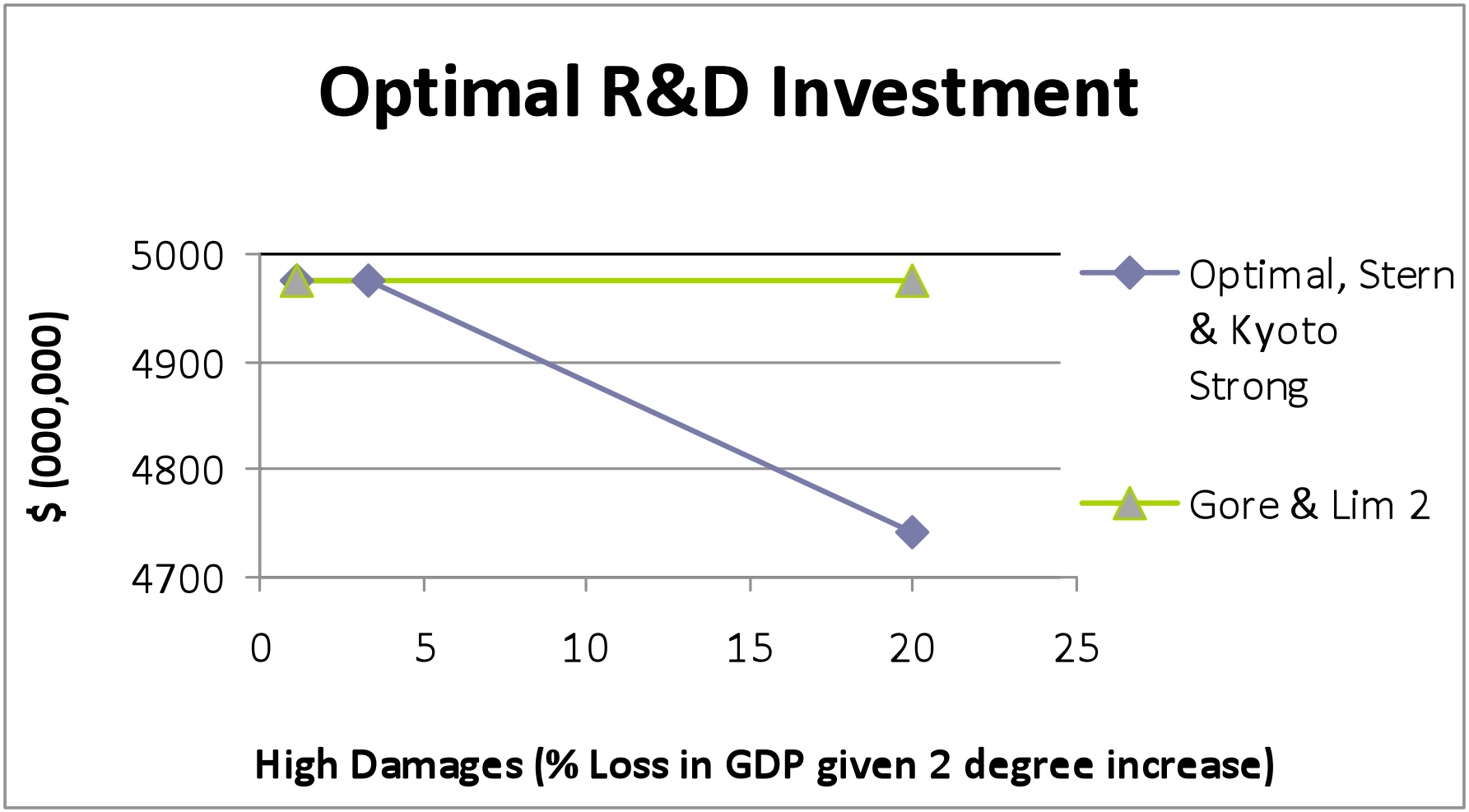
Different representations of climate risk

	No risk (1)	Medium risk (2)		High risk (3)		Very high risk (4)		Intermediate (5)		
Probability	1.000	0.667	0.333	0.945	0.055	0.973	0.028	0.309	0.673	0.018
GDP Loss	1.1%	0.0%	3.3%	0.0%	20.0%	0.0%	40.0%	0.0%	1.1%	20.0%
π	0.003	0.000	0.009	0.000	0.063	0.000	0.167	0.000	0.003	0.063

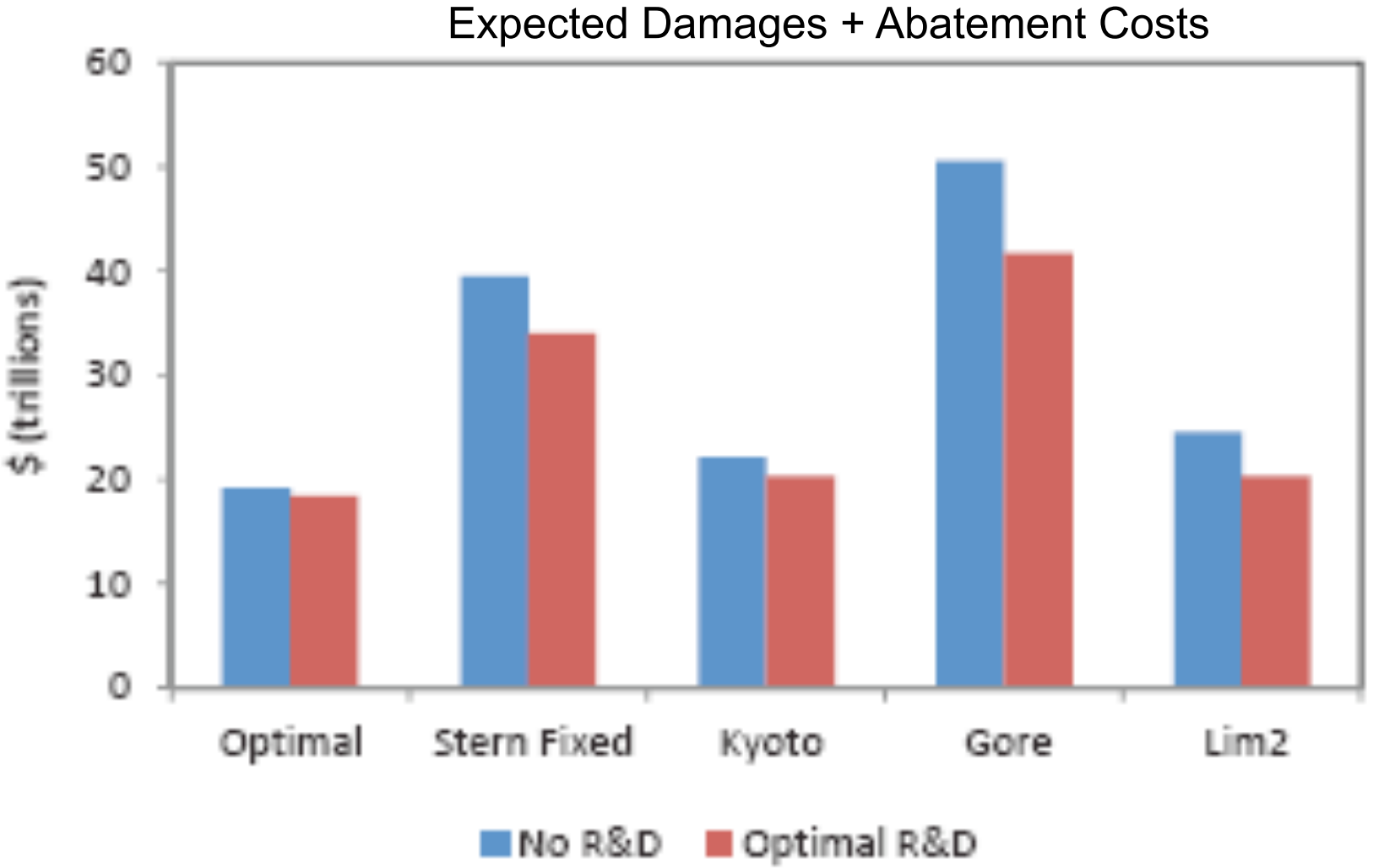


Results

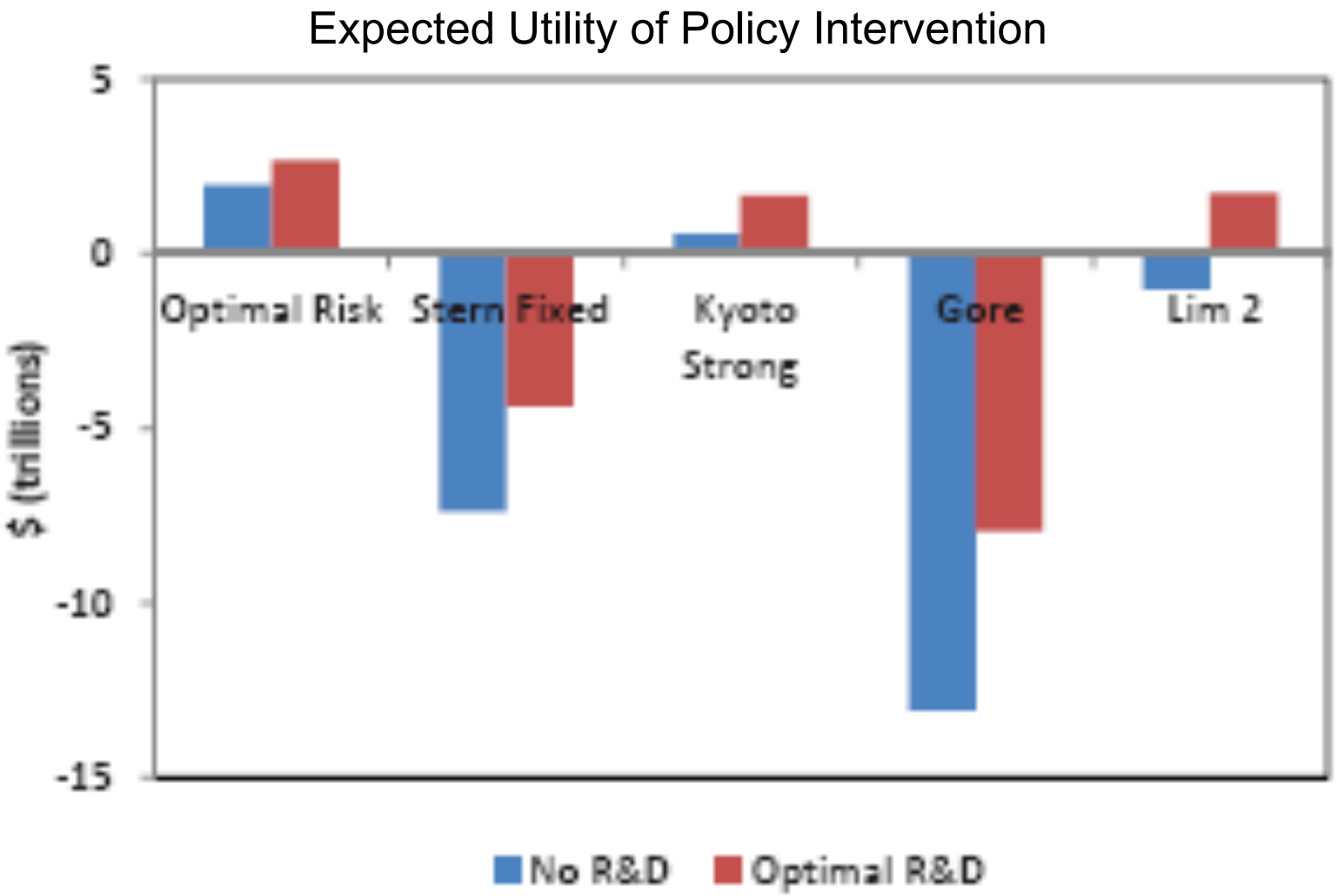
Optimal R&D Investment is robust



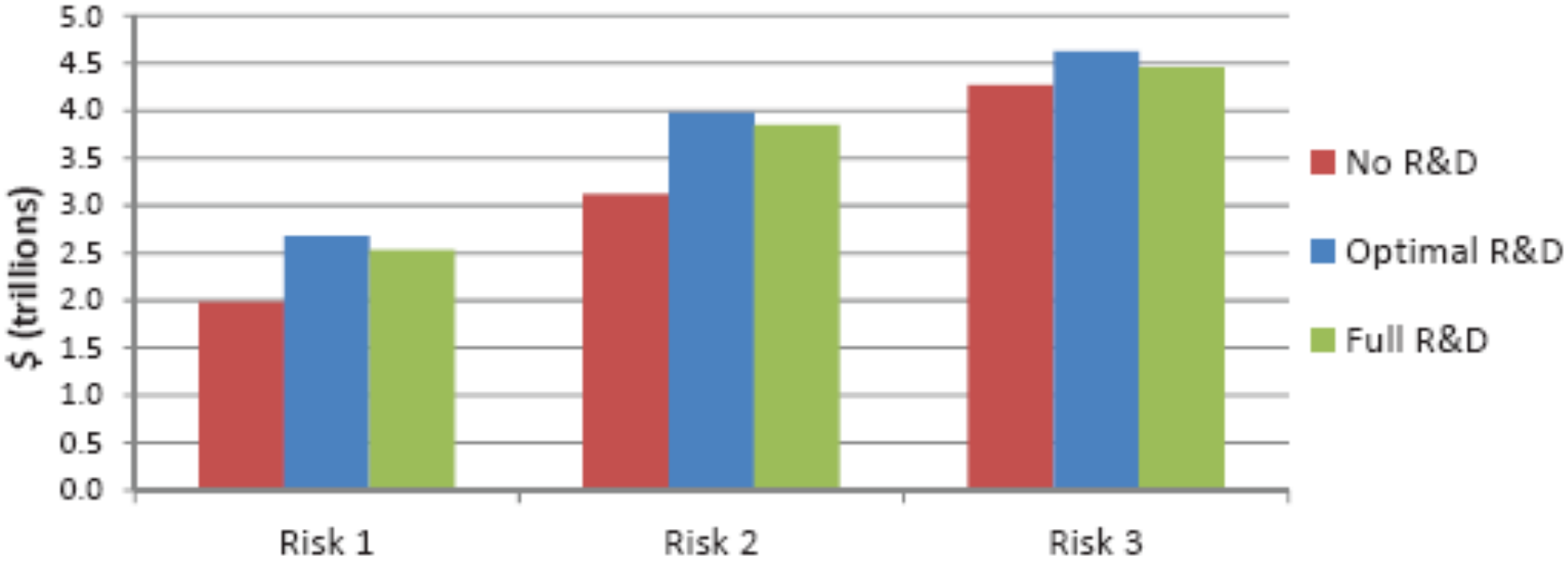
R&D has larger impact in "2nd best" policy environments



R&D might save a Kyoto-type agreement

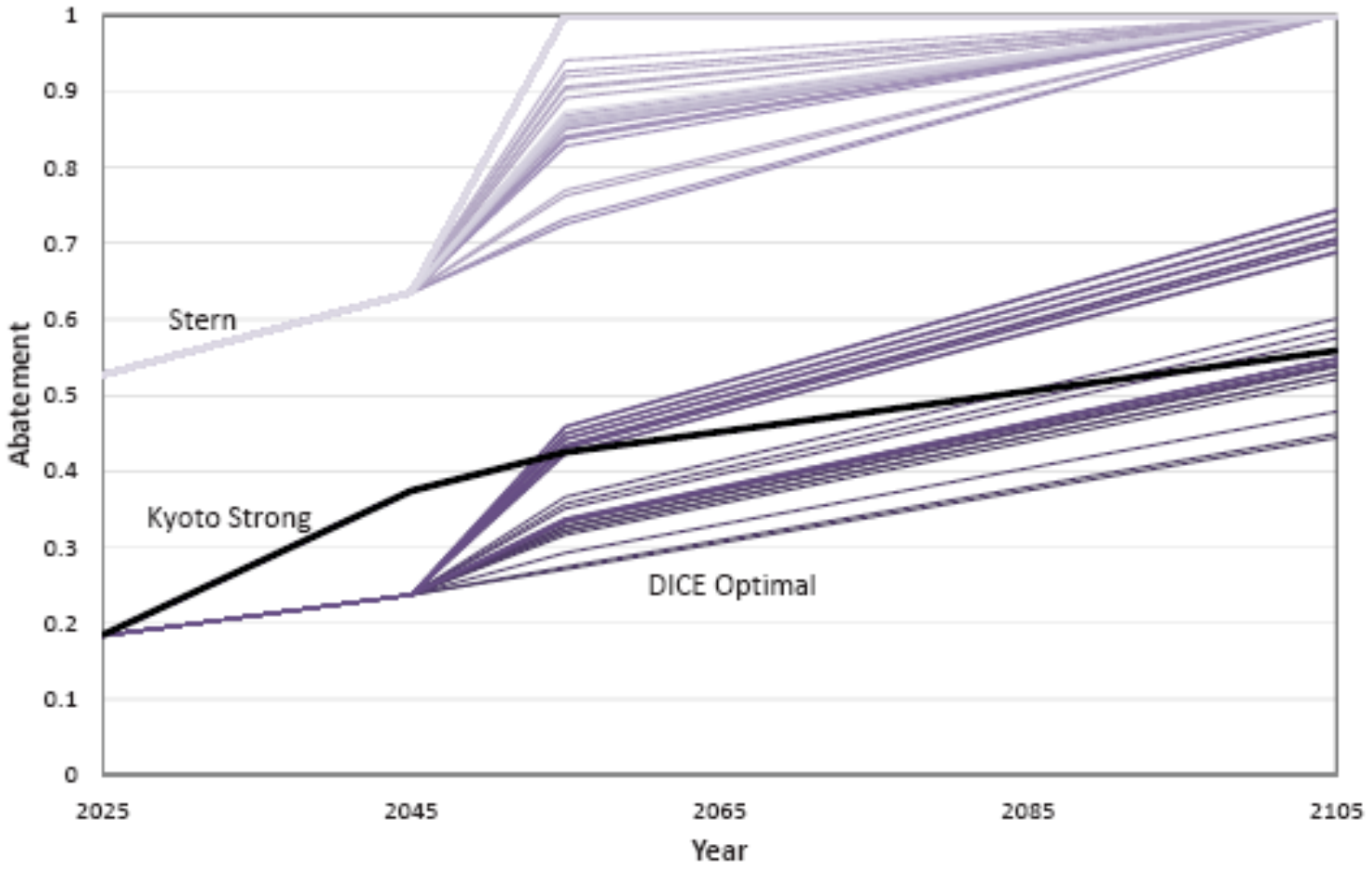


Under-investment and over-investment have an asymmetric impact



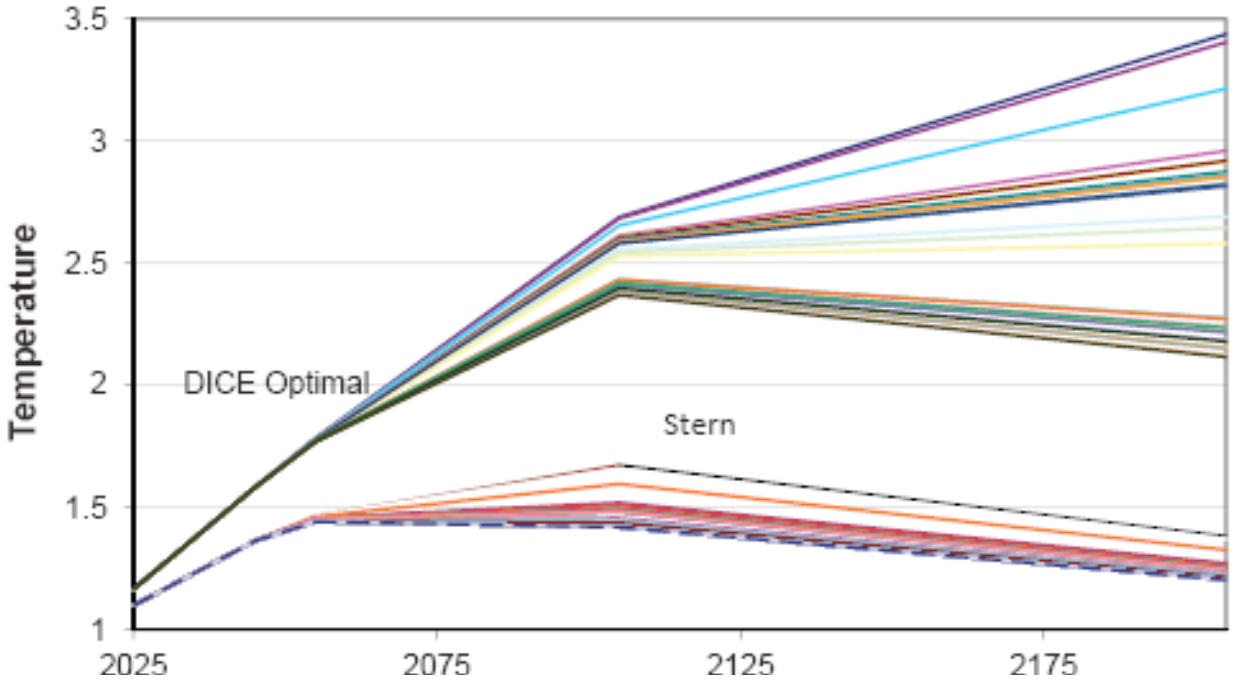
Expected Utility of Optimal Policy under different risk cases and different R&D investments

Abatement path depends on technology (and damages).

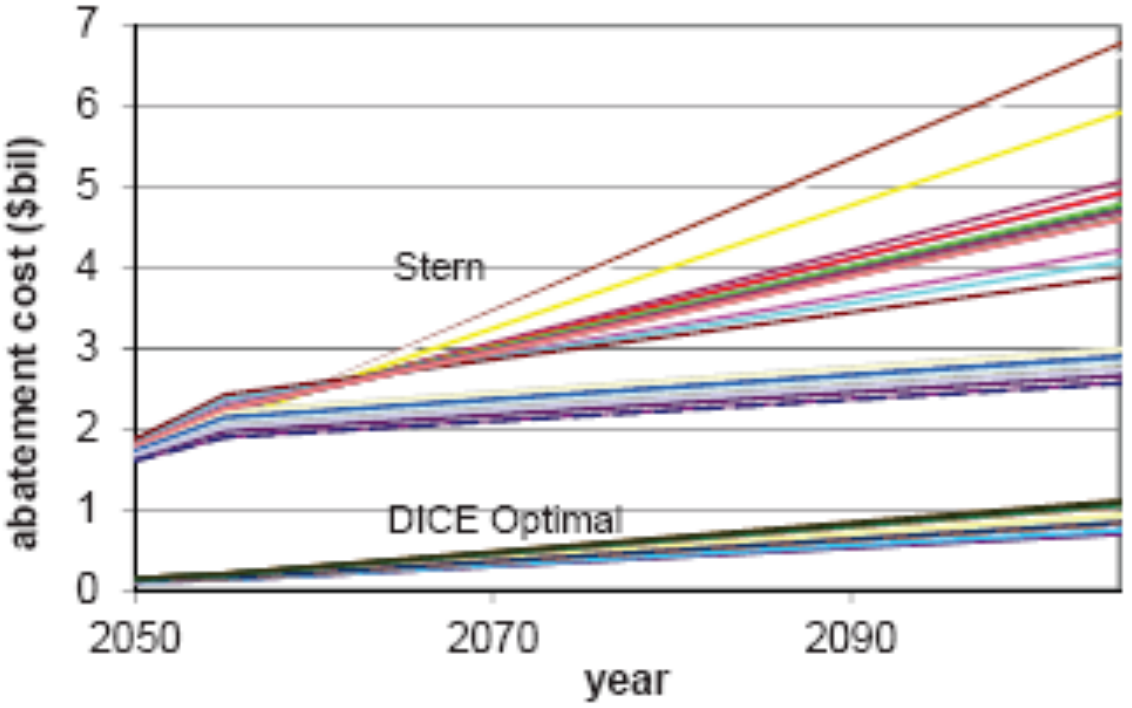


R&D has different impacts in the different policy environments

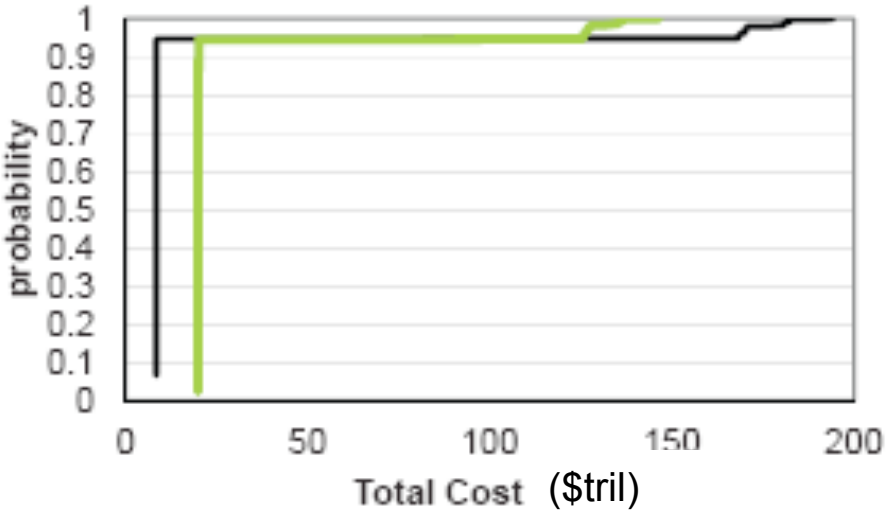
Temperature Paths

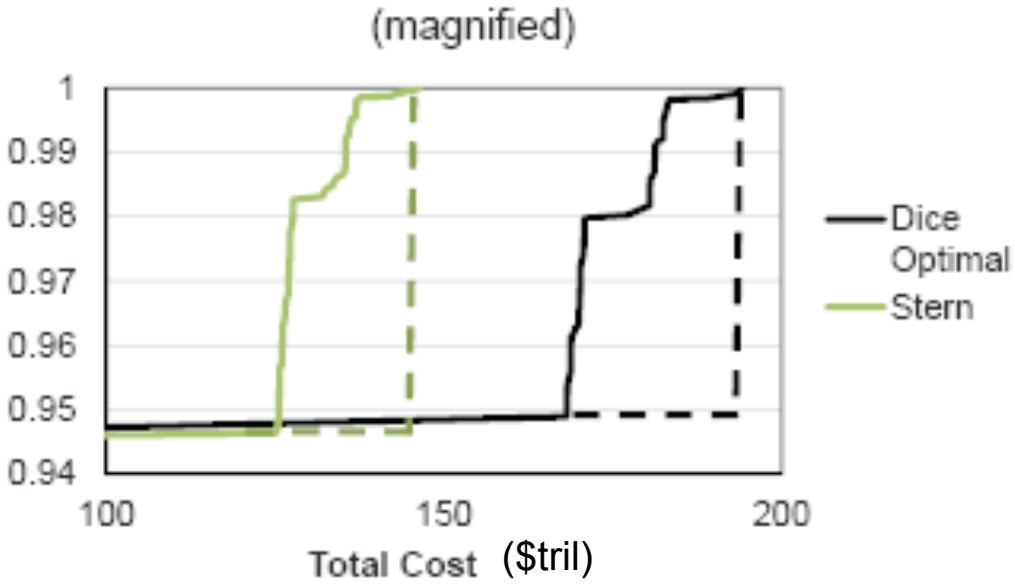


Abatement Cost Paths



Total costs depend on technology, damages, and policy





Policy Implications

- Optimal R&D investment is fairly robust to risk, policy, opportunity costs.
  - Under-investment appears more costly and risky than over investment
- R&D has more value in "2nd best" policy environments.
  - Kyoto Strong and 2 degrees go from negative or flat to positive
- The role of R&D is different in different policy environments and risk cases
  - If abatement is high, it mostly effects costs
  - If abatement is low, it mostly effects environmental variables.
- The Stern policy can be seen as response to risk aversion.
  - R&D can be seen as in investment in risk reduction.