Solar Geoengineering versus Mitigation: The Role of Time Preference

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Work in progress

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Anthropogenic Climate Change: Market Failure

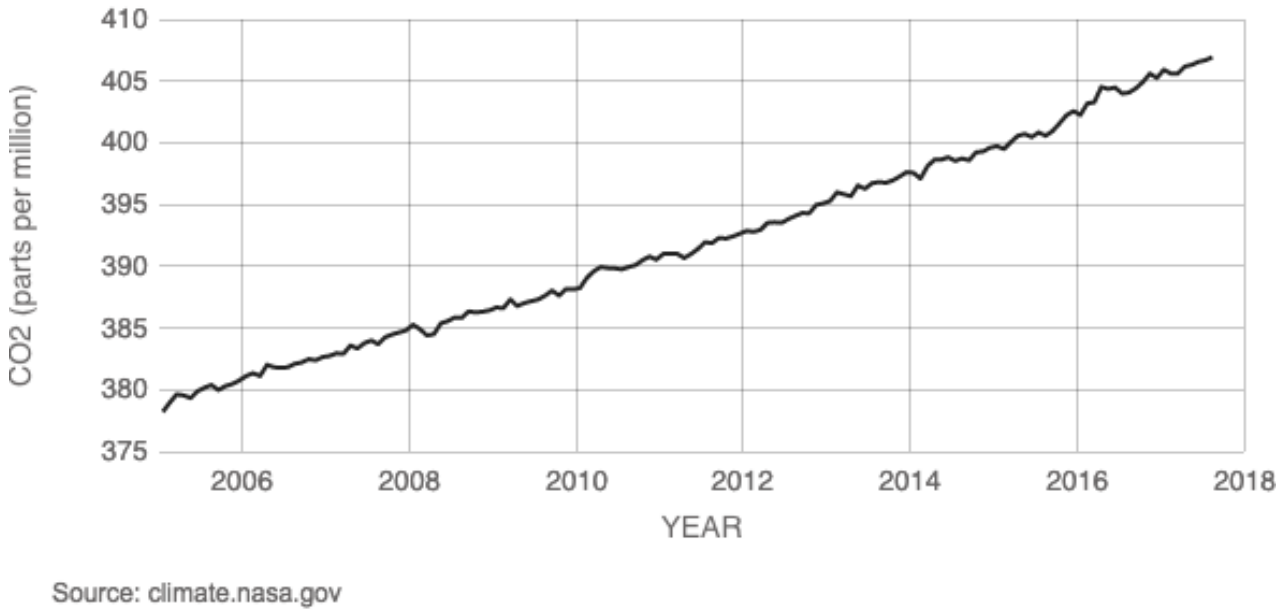


Figure 1: Direct measurements

Anthropogenic Climate Change: Market Failure

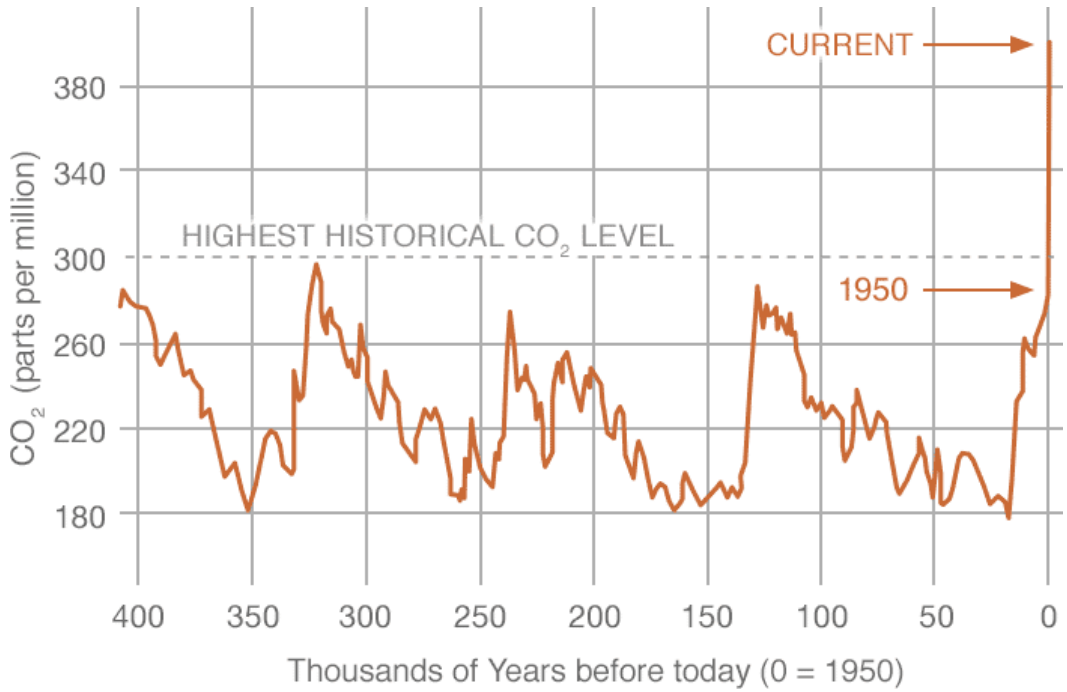
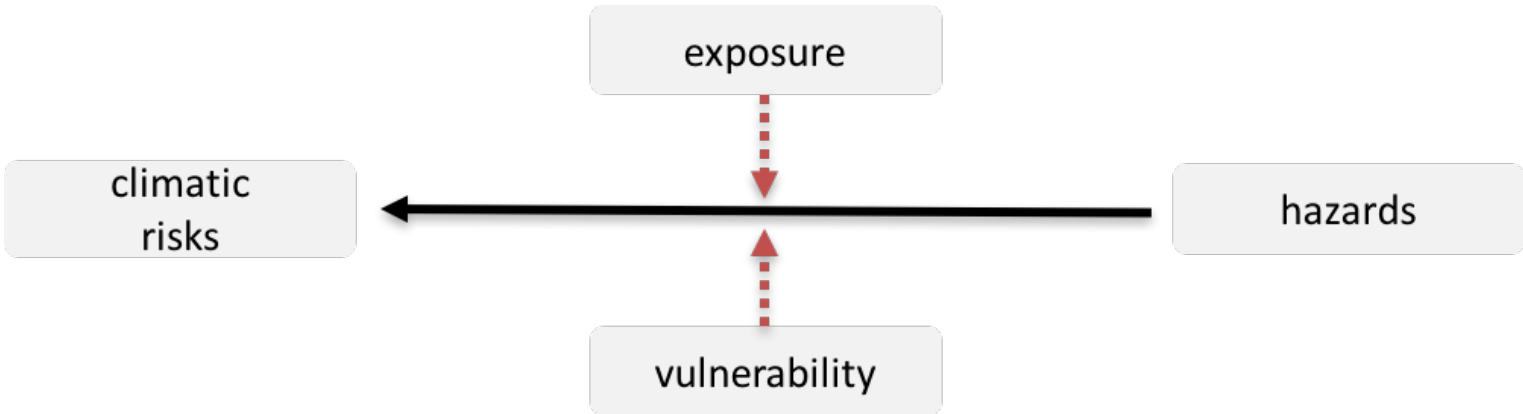


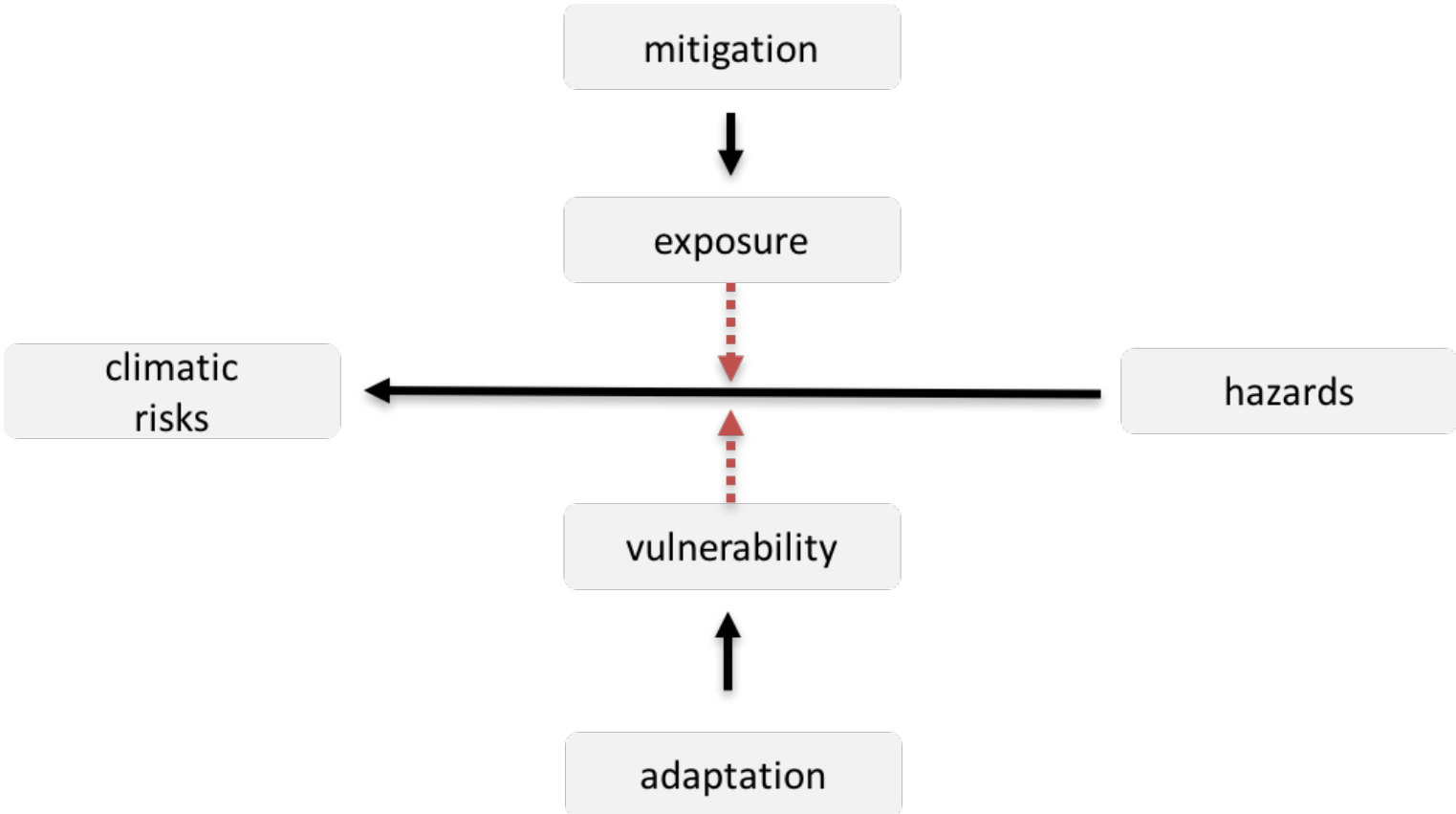
Figure 2: Proxy measurements: reconstruction from ice cores

Climatic Risk

Climatic Risk



Climatic Risk

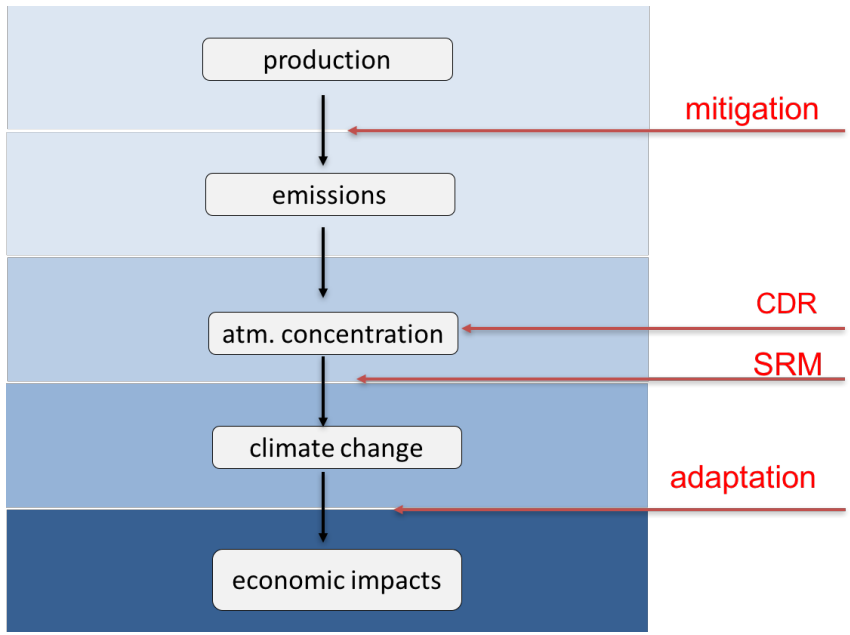


Yet ...

1. Climate inertia
2. Socio-economic inertia
3. Technological inertia
4. Population growth, increasing energy demand
5. Limits to adaptation
6. Tragedy of global commons

Geoengineering

Ultimate goal: reduce negative impacts of climate change.



Geoengineering

- Carbon dioxide removal (CDR)
- Solar radiation management (SRM)

SRM: Stratospheric aerosols injection

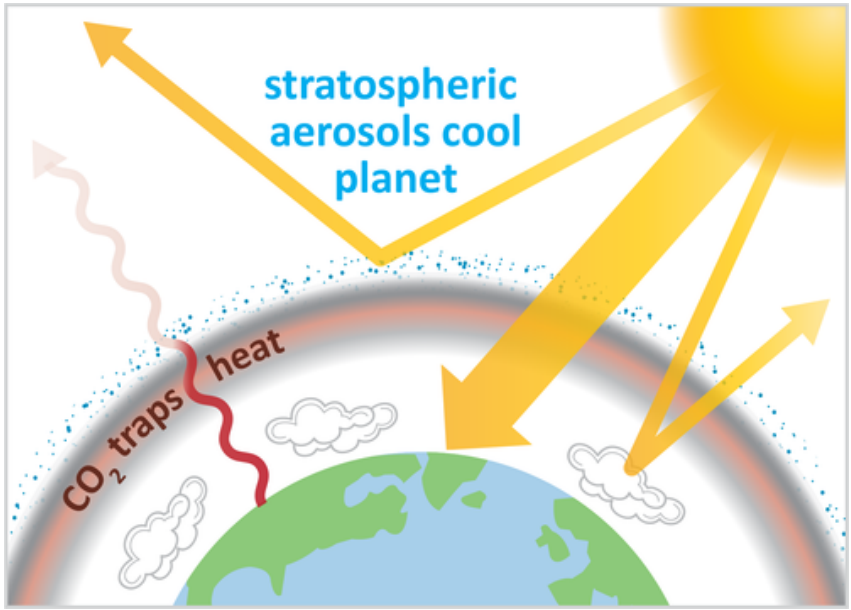


Figure 3

The DICE-SRM model:

The DICE-2016 model extended to include SG and uncertainty in climate change:

- 5- to 1-year timestep.
- SRM enters via radiative forcing changes and damage costs from the SRM side-effects.
- Uncertainty in climate sensitivity.

The DICE-SRM model

Economy:

$$
\begin{aligned}
W &= \sum_{t=1}^{T} \frac{1}{(1+\rho)^t} U(c(t))L(t) && (1)\\
U(c) &= \frac{c^{1-\eta}-1}{1-\eta} && (2)\\
Y_t^{gross} &= A_t K_t^{\gamma} L_t^{1-\gamma} && (3)\\
Y_t^{net} &= \frac{1}{1+\Omega_t} \cdot Y_t^{gross} && (4)\\
Y_t &= (1-\Lambda_t) Y_t^{net} && (5)\\
\Lambda_t &= \theta_{t,1} \mu^{\theta_2} && (6)\\
C_t &= Y_t - I_t && (7)\\
c_t &= \frac{C_t}{L_t} && (8)\\
I_t &= s_t \cdot Y_t && (9)\\
K_{t+1} &= I_t + (1-\delta_K) K_t && (10)
\end{aligned}
$$

$0 \leq \mu \leq 1$ is emissions control rate.

The DICE-SRM model:

Emissions:

$$E_t^{ind} = \sigma_t[1-\mu_t]Y_t^{gross} \quad (11)$$

$$E_t = E_t^{ind} + E_t^{land} \quad (12)$$

Carbon cycle (three-reservoir model):

$$M_t^{at} = b_{11}M_{t-1}^{at} + b_{12}M_{t-1}^{up} + E_t \quad (13)$$

$$M_t^{up} = b_{21}M_{t-1}^{at} + b_{22}M_{t-1}^{up} + b_{23}M_{t-1}^{lo} \quad (14)$$

$$M_t^{lo} = b_{31}M_{t-1}^{lo} + b_{32}M_{t-1}^{up} \quad (15)$$

Radiative Forcing:

$$F_t = \eta(\log_2(\frac{M_t^{at}}{M_{1750}^{at}})) + F_t^{ex} - F_t^G \quad (16)$$

Climate Model:

$$T_t^{at} = T_{t-1}^{at} + \psi_1[F_t - \psi_2 T_{t-1}^{at} - \psi_3(T_{t-1}^{at} - T_{t-1}^{lo})] \quad (17)$$

$$T_t^{lo} = T_{t-1}^{lo} + \psi_4(T_{t-1}^{at} - T_{t-1}^{lo}) \quad (18)$$

The DICE-SRM model

Damages costs (fraction of gross world product):

$$D_t = \alpha_1 T_t^{at} + \alpha_2 (T_t^{at})^2 + D_t^G \quad (19)$$

$$D_t^G = \beta \left| \frac{F_t^G}{F_t^{2xCO2}} \right| \quad (20)$$

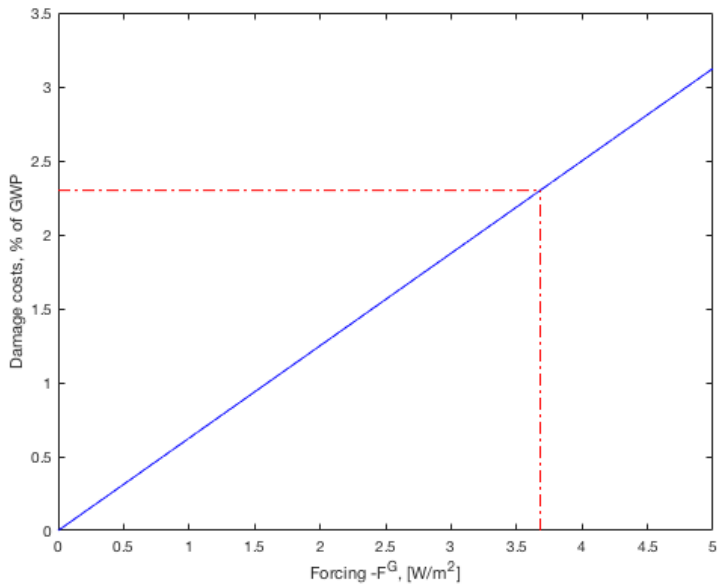
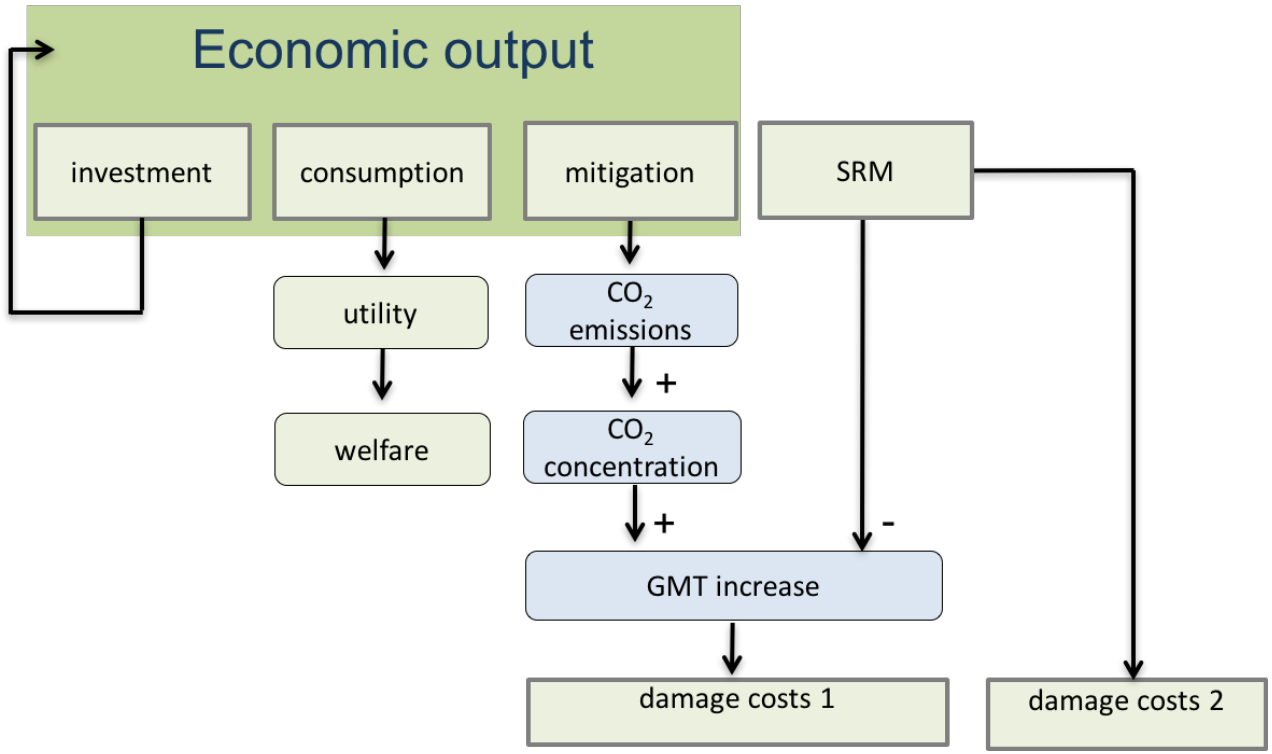


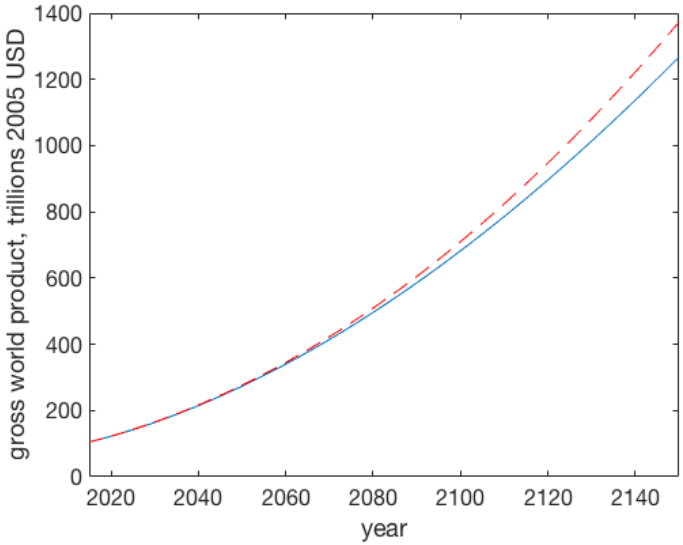
Figure 4: Function D^G

Calibration:

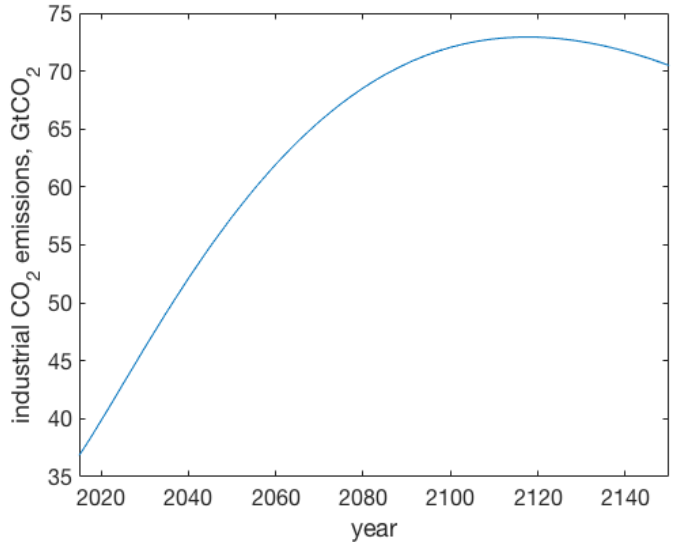
Integrated Assessment Model of Climate and Economy



I. No Climate Policy



(a)



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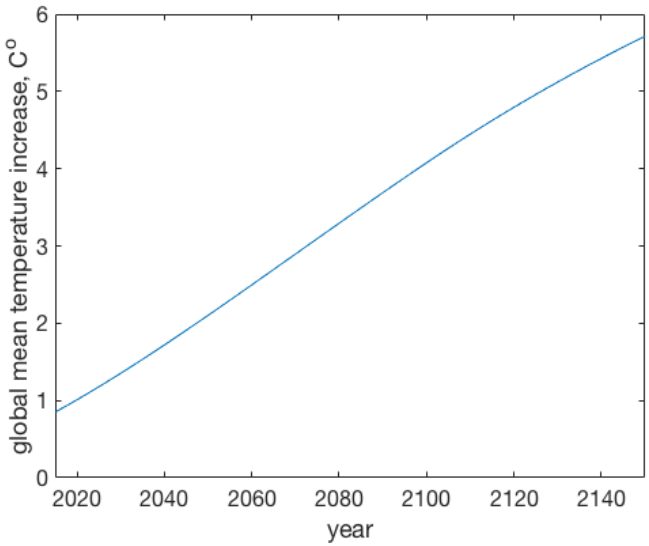

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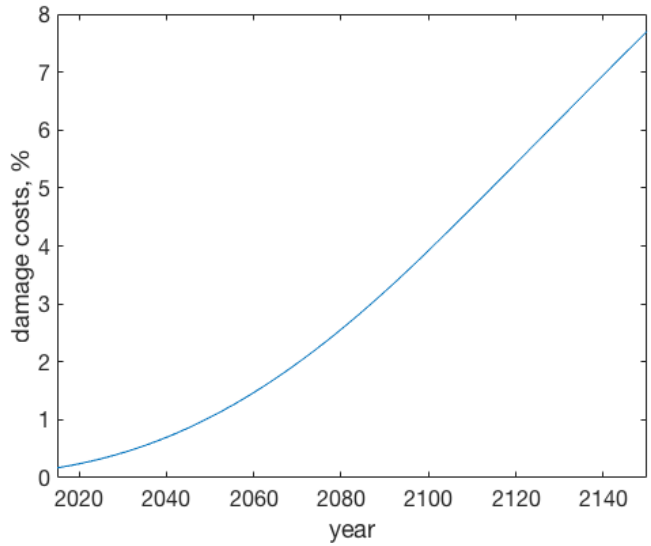
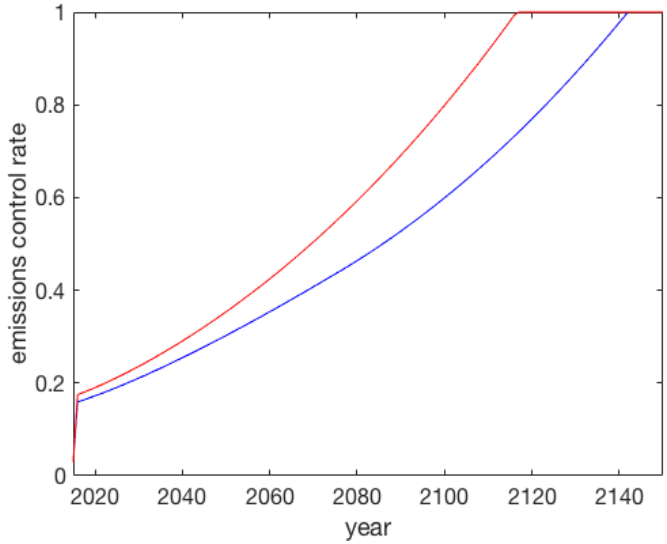
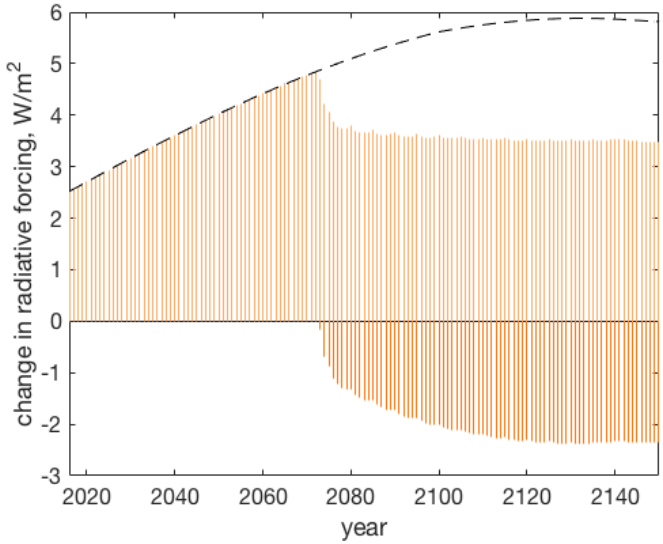


(d)

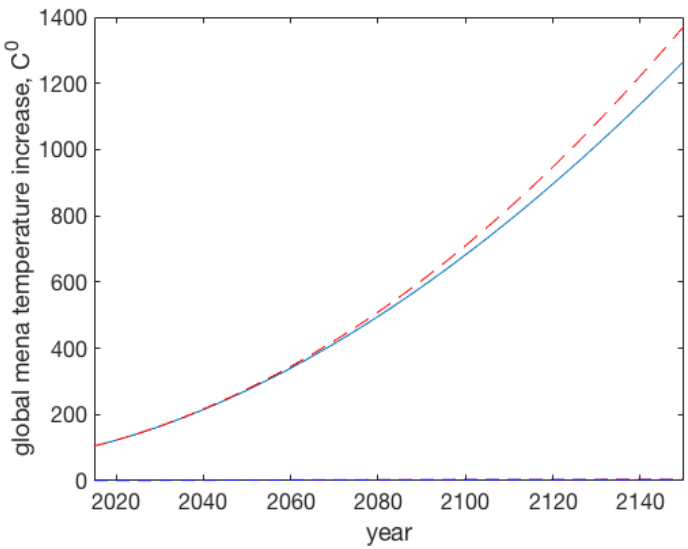
II. Optimal control. DICE-SRM (–) vs DICE (–)



(a)



(b) DICE-SRM



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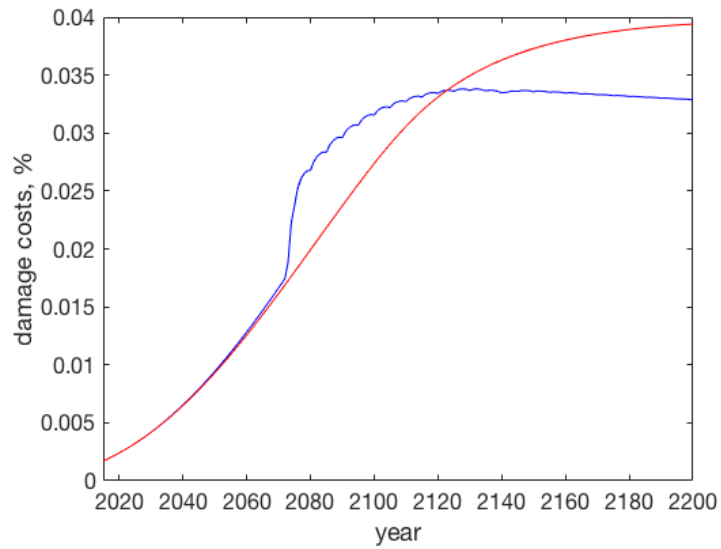
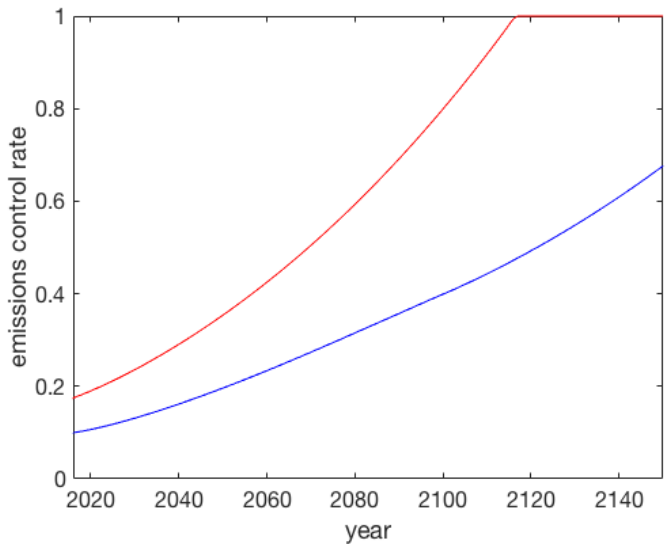
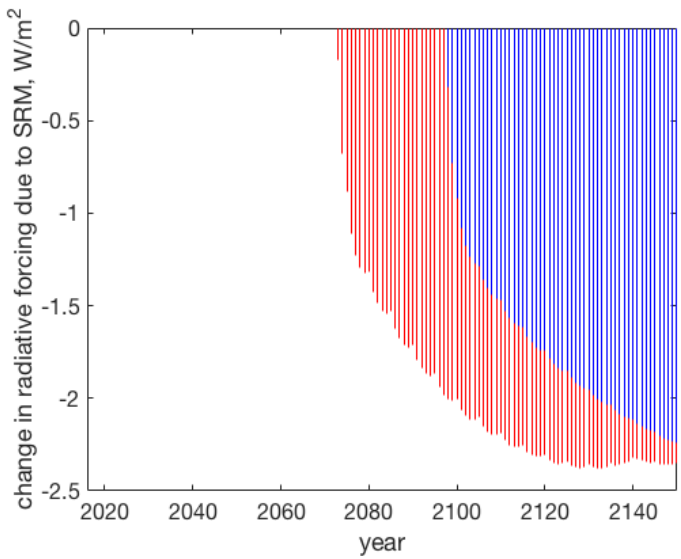


(d)

Higher ρ: 1.5% (–) vs 3% (–)

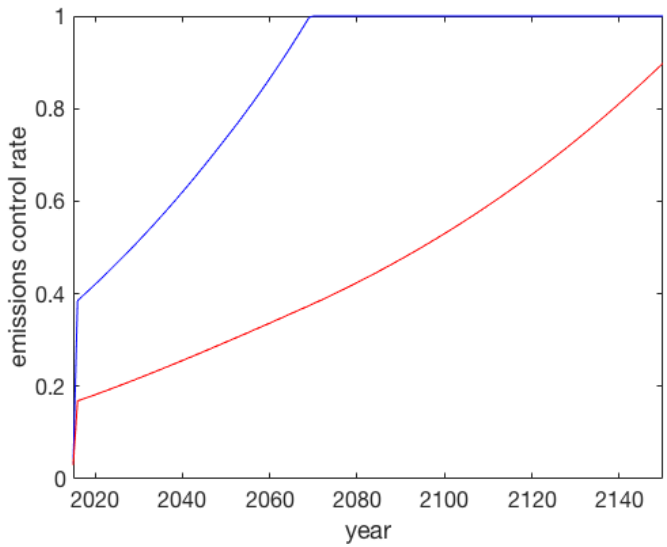


(a)



(b)

Lower ρ: 1.5% (–) vs 0.1% (–)



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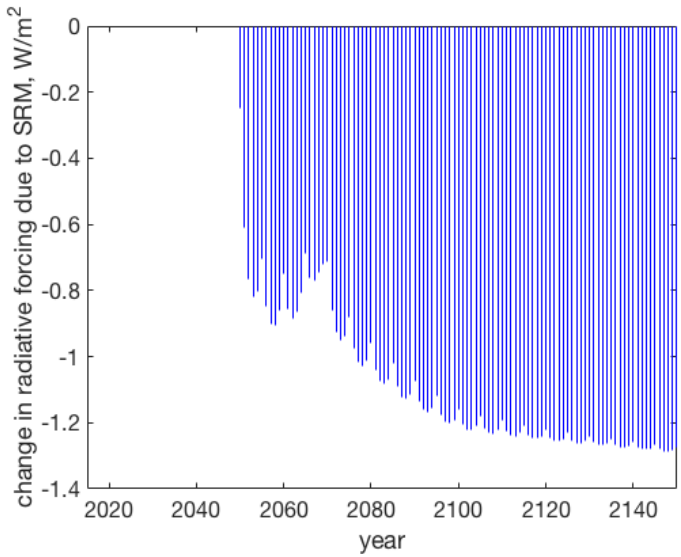
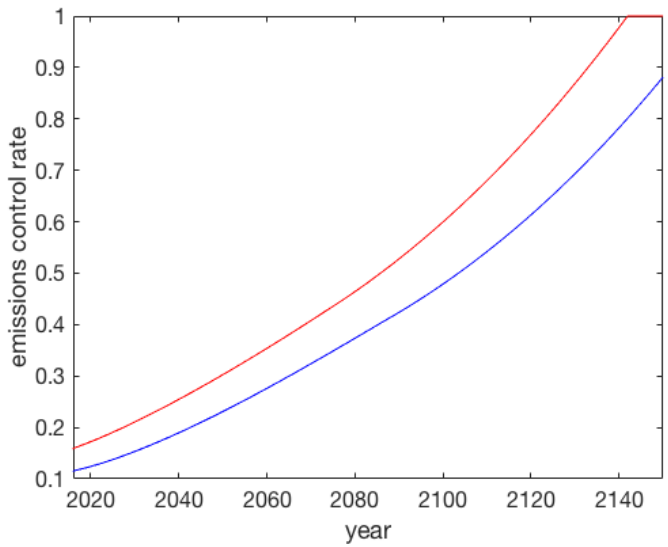
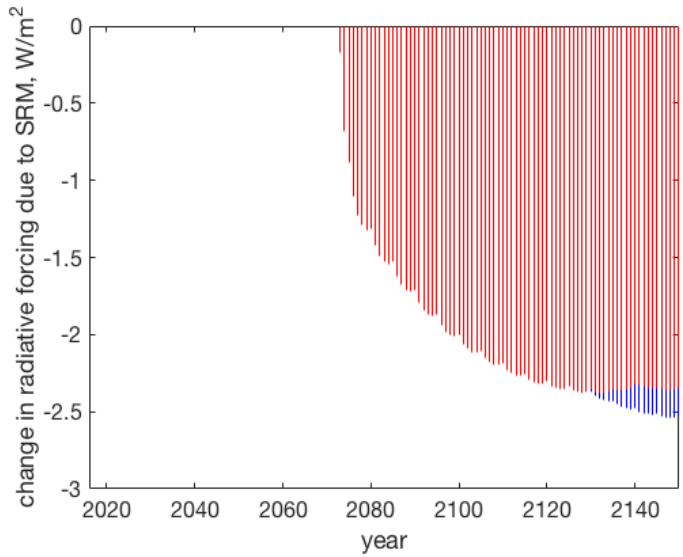


(b)

Higher η: 1.45 (–) vs 2 (–)



(a)



(b)

Social Cost of Carbon

Calibration	Model	ρ, %	η	SCC (2020) 2010 USD
Default	DICE	1.5	1.45	37.64
	DICE-SRM	1.5	1.45	32.18
Higher ρ	DICE,	3	1.45	15.31
	DICE-SRM	3	1.45	14.94
Lower ρ	DICE	1	1.45	57.57
	DICE-SRM	1	1.45	45.52
Very low ρ	DICE	0.1	1.45	178.84
	DICE-SRM	0.1	1.45	133.95
Higher η	DICE	1.5	2	20.45
	DICE-SRM	1.5	2	19.04

III. Climate Change Uncertainty

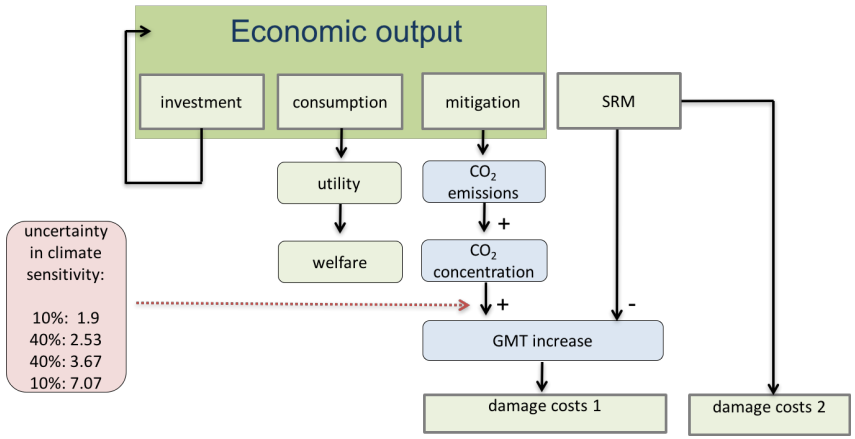


Figure 5: DICE-SRM

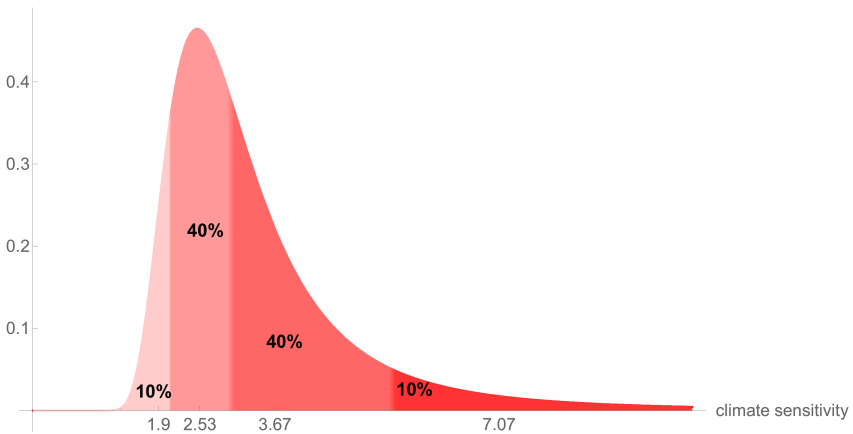
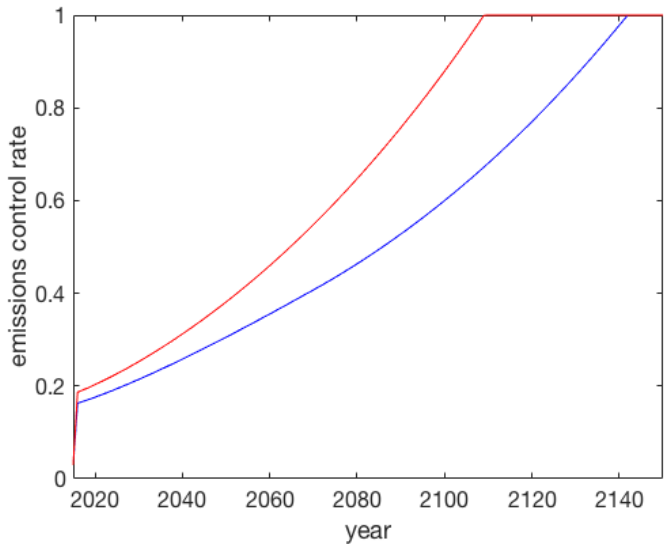


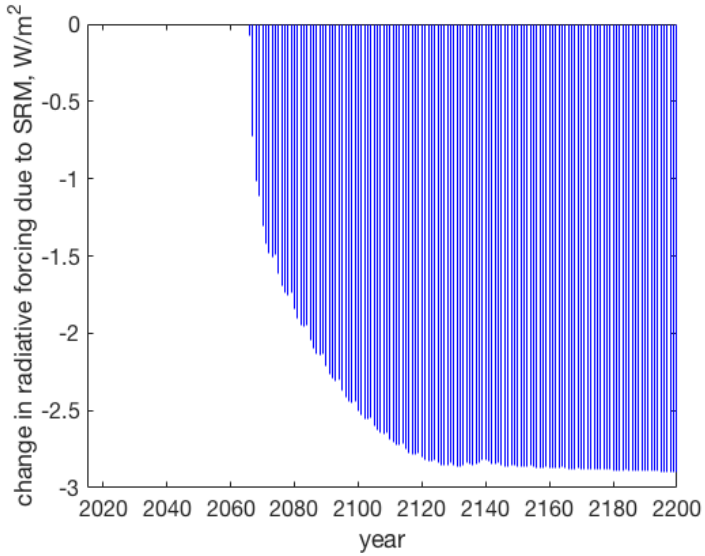
Figure 6: equilibrium climate sensitivity probability density function

Expected Utility Framework.

DICE-SRM (–) vs DICE (–)



(a)



(b)

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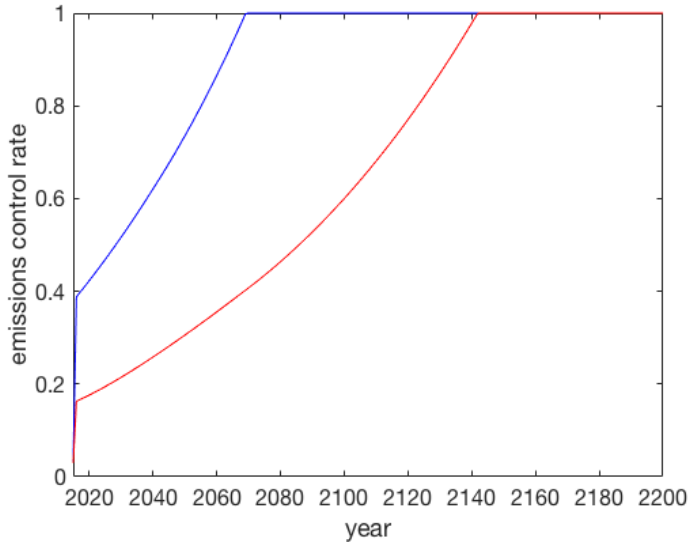
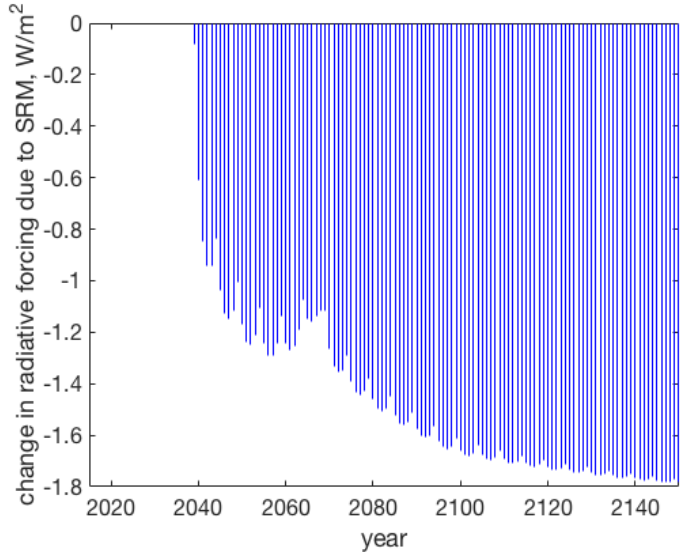


(a)



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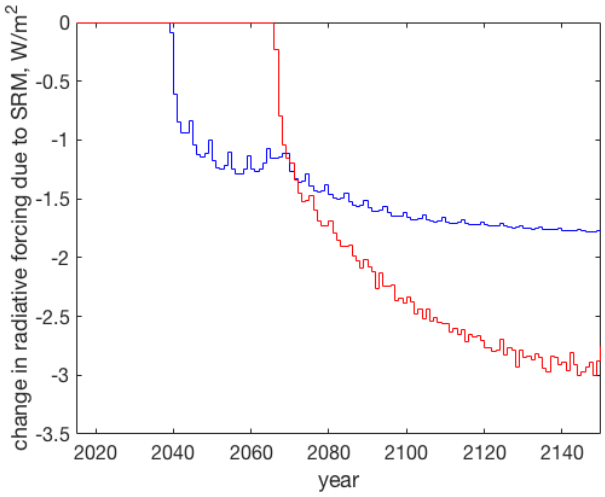

Solar Radiation Management versus Mitigation

Summary from DICE-SRM:

- SRM reduces SCC.
- SRM reduces radiative forcing during the period around the peak of industrial emissions.
- SRM reduces the rate of optimal emissions control rate, thus potentially addressing the question of limited speed of success in emissions reduction.
- Higher the discount rate, further both mitigation and SRM are delayed.
- Under climate change uncertainty: lower PRTP $\implies$ stronger abatement and early and moderate SRM. Otherwise, strong and late SRM.

Next steps:

- Introduce CDR.
- Optimal CDR-SRM-mitigation portfolio analyzes for alternative preference specifications.
- Sensitivity with respect to damage costs, CDR costs, and SRM side-effects.
- Explore Epstein-Zin utility (further).