Carbon prices, preferences, and the timing of uncertainty

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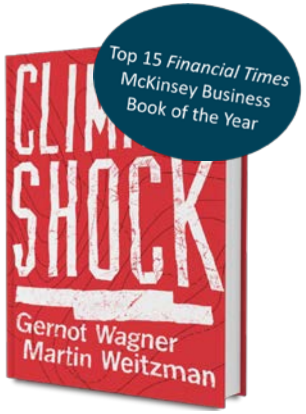

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$40

~$40 Social Cost of CO_2

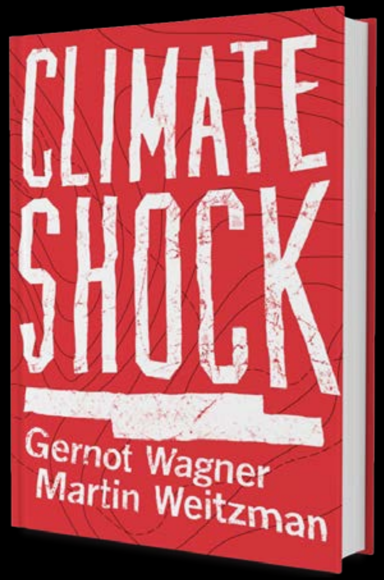
Based on 3% constant discount rate, and an average of 3 climate-economy models, including DICE

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	32	51	89
2015	11	37	57	109
2020	12	43	64	128
2025	14	47	69	143
2030	16	52	75	159
2035	19	56	80	175
2040	21	61	86	191
2045	24	66	92	206
2050	26	71	97	220

~$40 Obama White House SC-$CO_2$
> 10x official Trump figure

Source: "Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" (November 1, 2013; updated 2016).

>>$40

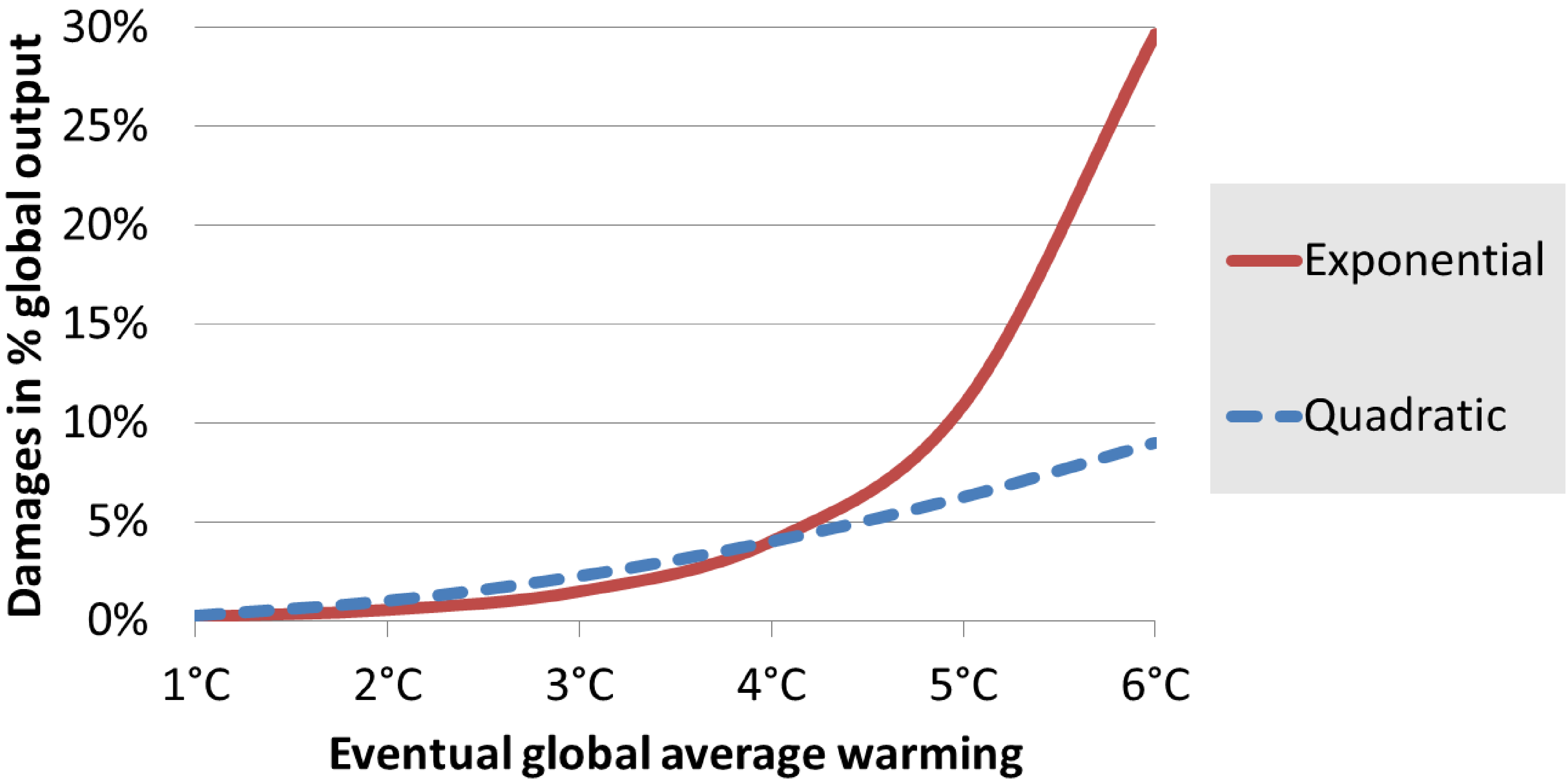


>>$40, two ways:

1. Tail risk
2. “Proper” preference calibration

1 Choice of damage function critical

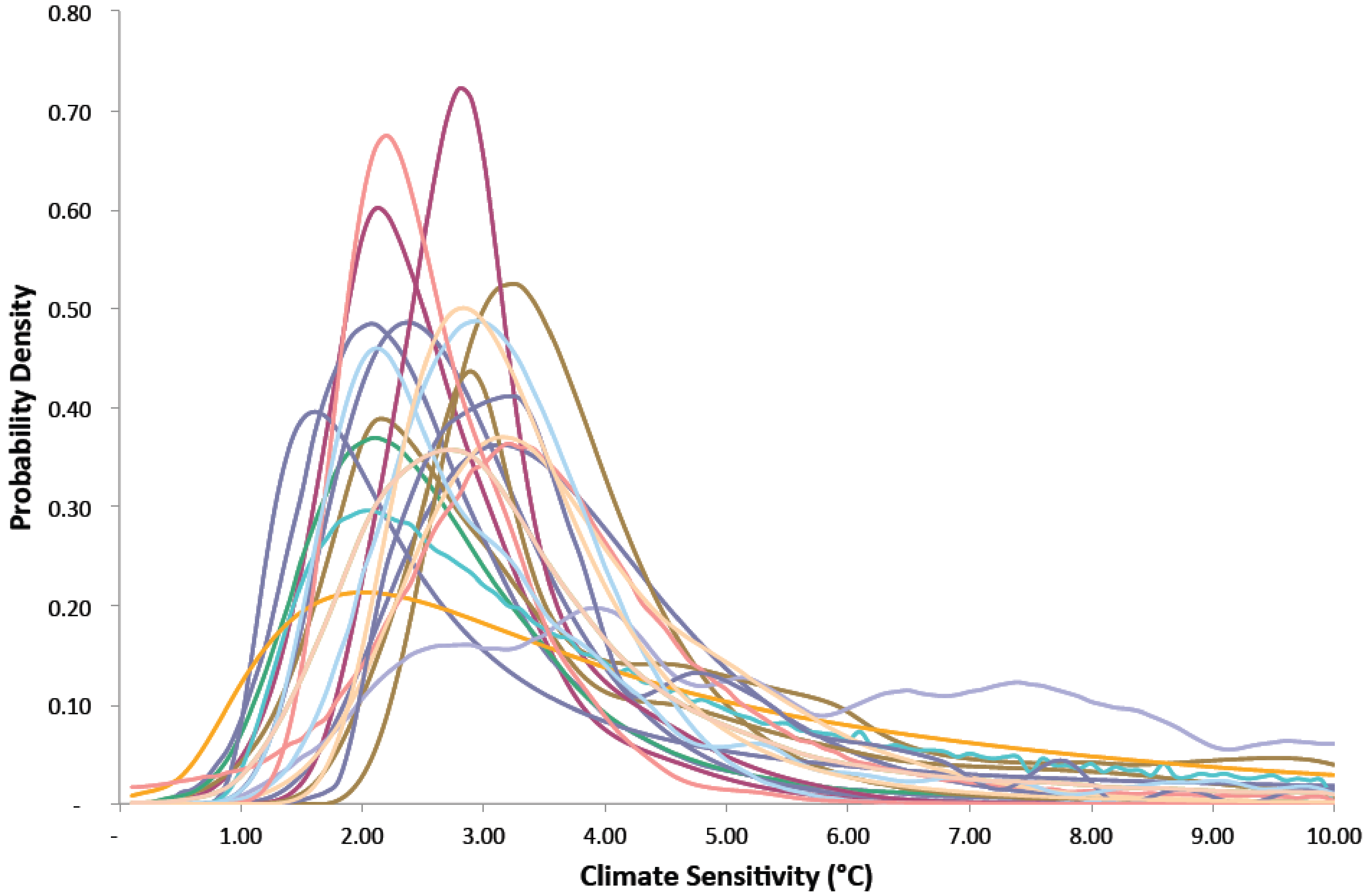
Integrated Assessment Models beginning with Nordhaus (1992) have assumed quadratic damage extrapolations



Exponential not any more "correct"; point is we don't—can't(?)—know.

Source: Wagner & Weitzman 's *Climate Shock* (2015)

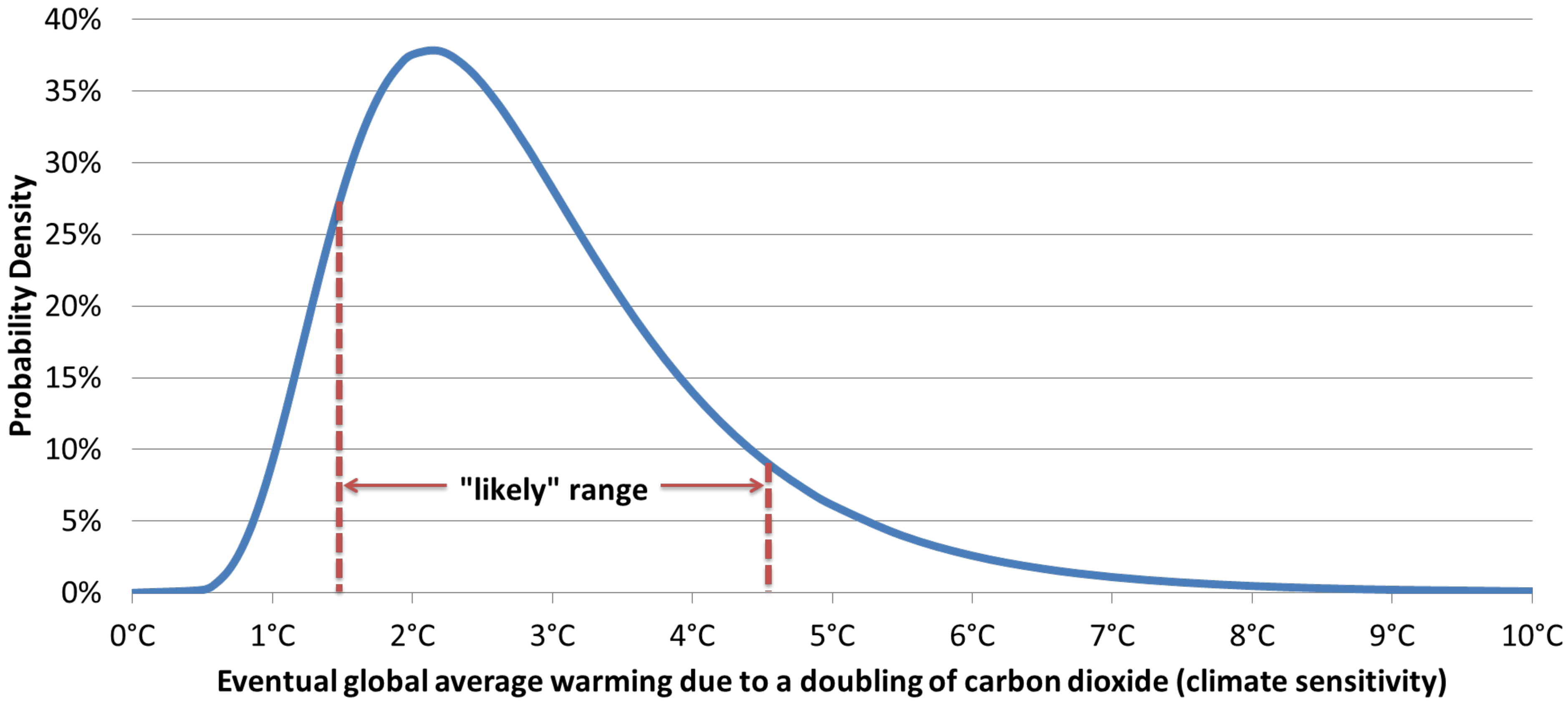
1



Source: Meinshausen *et al* (2009)

1 IPCC’s “likely” range 1.5-4.5°C

‘Heavy-tailed’ climate sensitivity calibration using log-normal, mirroring effects of Roe-Baker

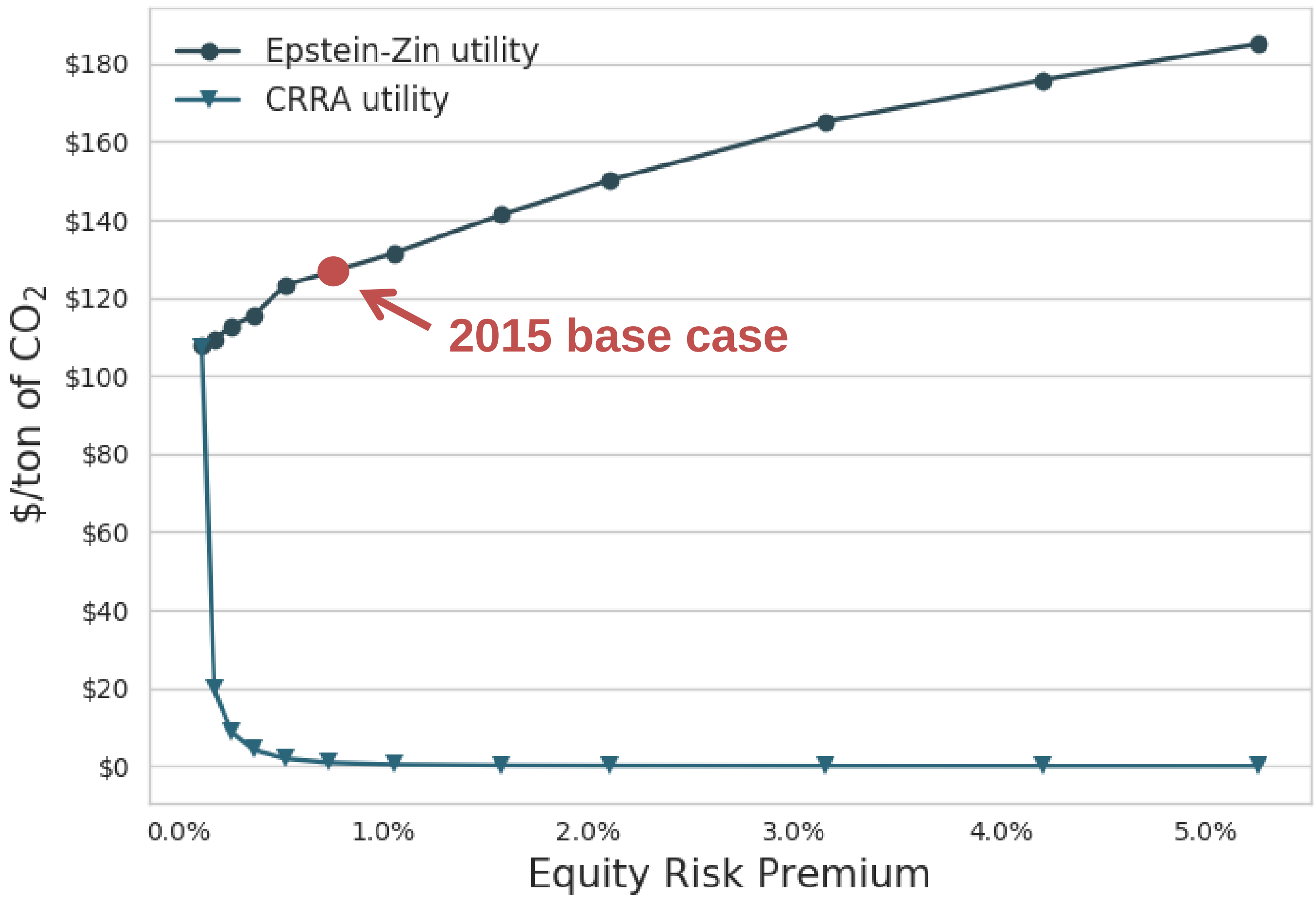


Tail risk might dwarf importance in “likely” range

Source: Wagner & Weitzman’s *Climate Shock* (2015)

2 Standard utility specifications misrepresent (climate) risk

Constant Relative Risk Aversion (CRRA) utility conflates risk across time and across states of nature



Source: Daniel, Litterman & Wagner (NBER 2016; latest version: March 2018)

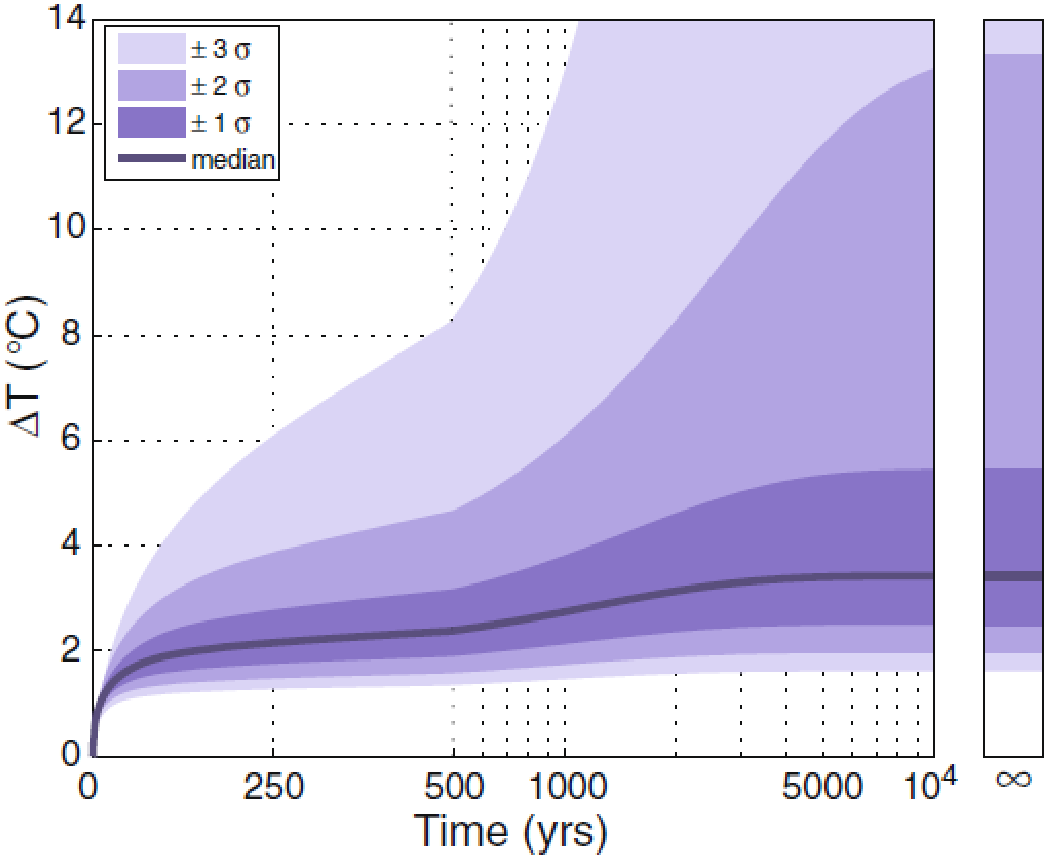
Two critical examinations:

1. “Roe-Bauman” time component
2. Closer look at discounting

1 Roe-Bauman critique of “fat tails” argument

“Climate sensitivity: should the climate tail wag the policy dog?”

“**Fig. 2 a** The time evolution of uncertainty in global temperature in response to an instantaneous doubling of CO_2 at t = 0, and for standard parameters. The shading reflects the range of feedbacks considered (symmetric in feedbacks, but not in climate response), as explained in the text. Note the change to a logarithmic x-axis after t = 500 yr. The panel illustrates that **for high climate sensitivity it takes a very long time to come to equilibrium**.” (Roe & Bauman, 2013, p. 651)



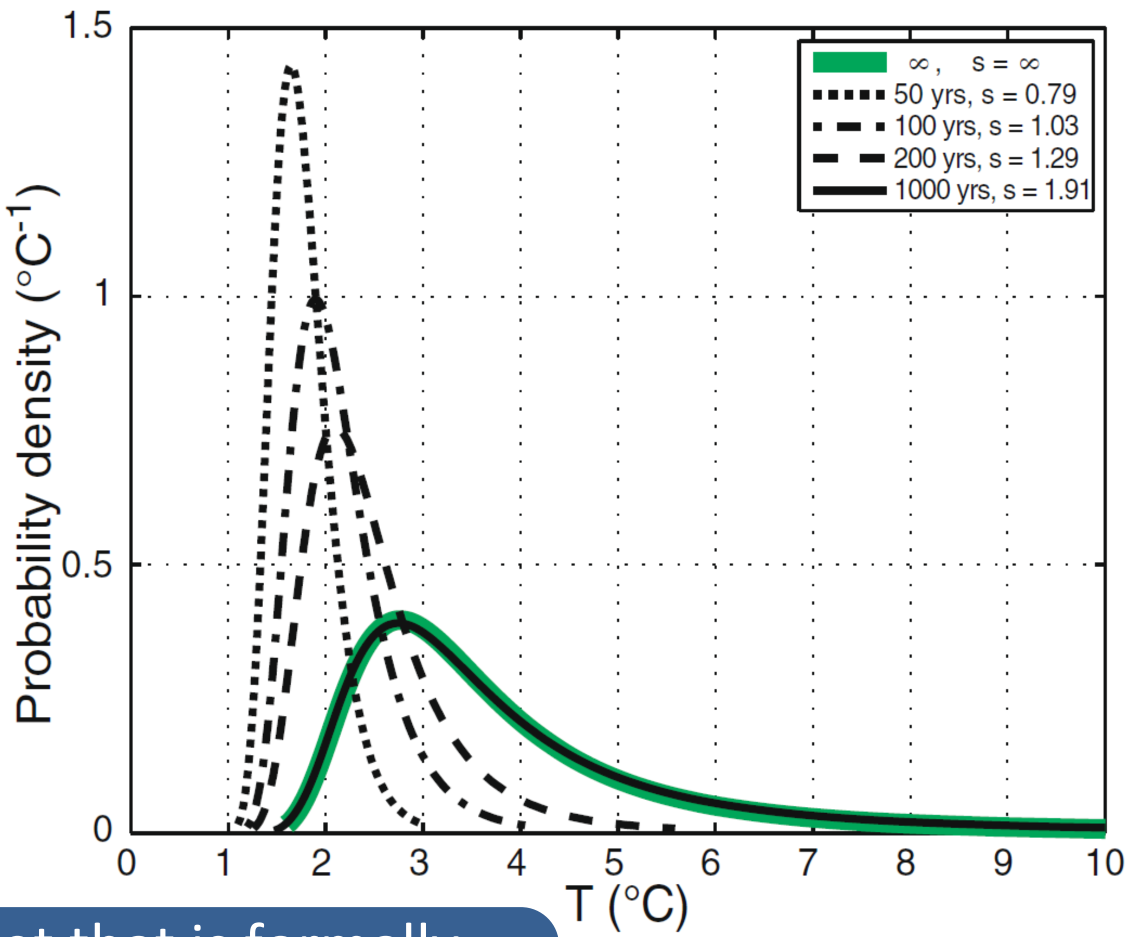
The farther out the climate damage, the more discounting matters

Source: Roe & Bauman (2013); see also e.g.: Baker & Roe (2009)

1 Roe-Bauman critique of “fat tails” argument

“Climate sensitivity: should the climate tail wag the policy dog?”

“**Fig. 2 b** The shape of the [climate sensitivity] distribution at particular times. The skewness of the distributions are also shown in the legend; as described in the text, **the upper bound on possible temperatures is finite at finite time, limiting the skewness**” (Roe & Bauman, 2013, p. 651)



“even for a planet that is formally headed to[ward] oblivion, it can take a very long time to get there”

Source: Roe & Bauman (2013)

Carbon prices, preferences, and the timing of uncertainty

3 questions

1 Does the Roe-Bauman (RB) critique matter?

2 Does the separation of risk and time *a la* Epstein-Zin (EZ) matter?

1 & 2 What about the combination of the two?

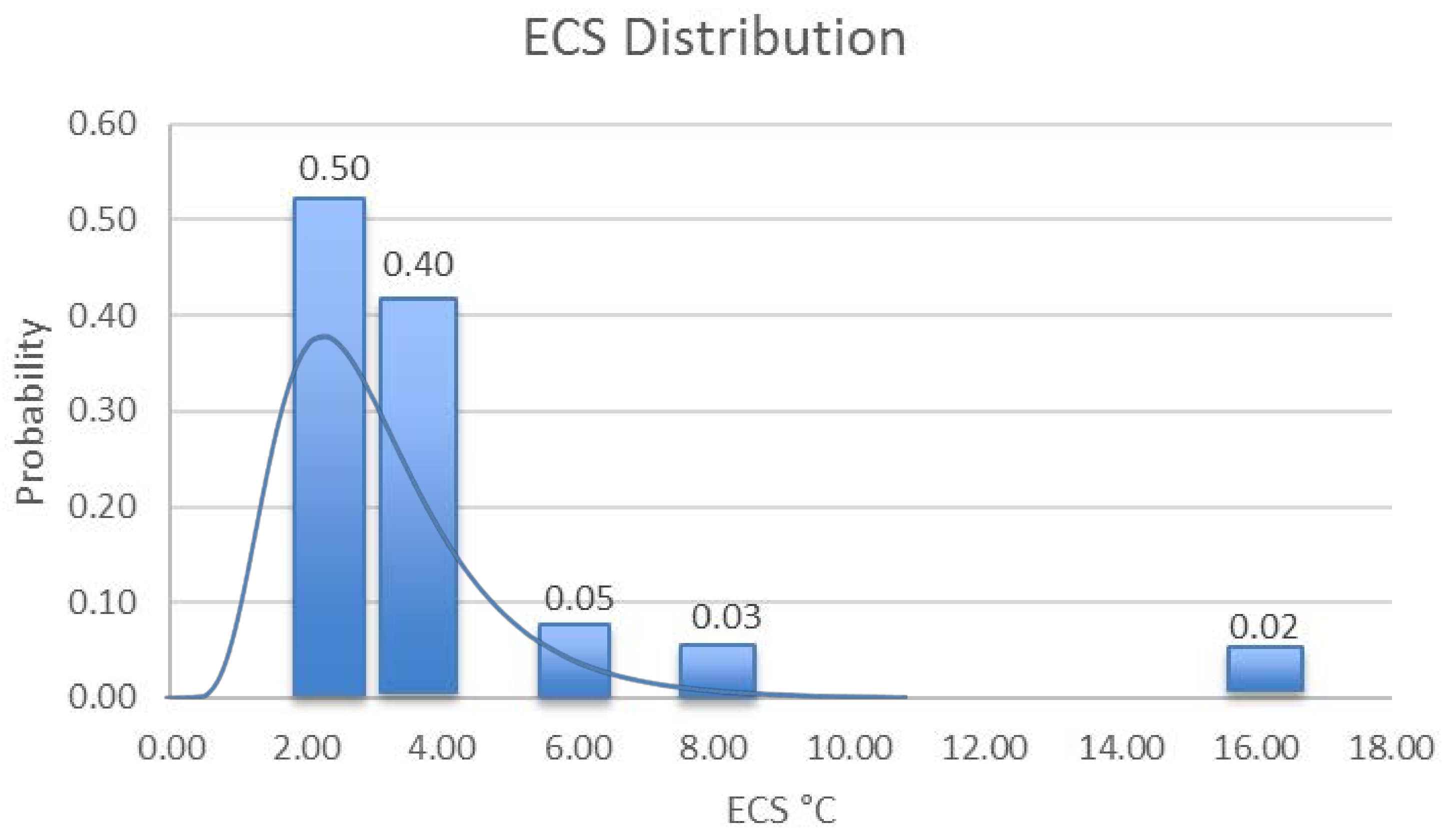
We build "DICE-EZ-RB" to help answer these questions

Source: Hogan & Wagner (Mimeo)

1

Rough Roe-Baker ECS calibration

Recursive DICE-EZ implementation calls for simple scenarios: 5 scenarios, with ECS uncertainty resolved in 50yrs (2065)

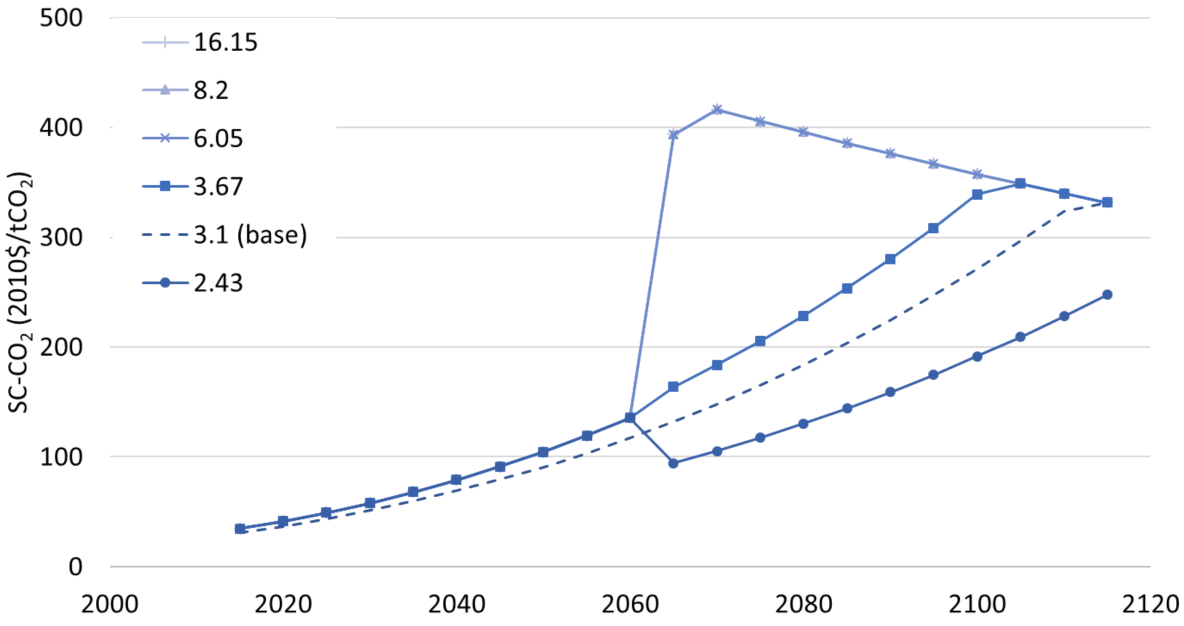


Source: Hogan & Wagner (Mimeo)

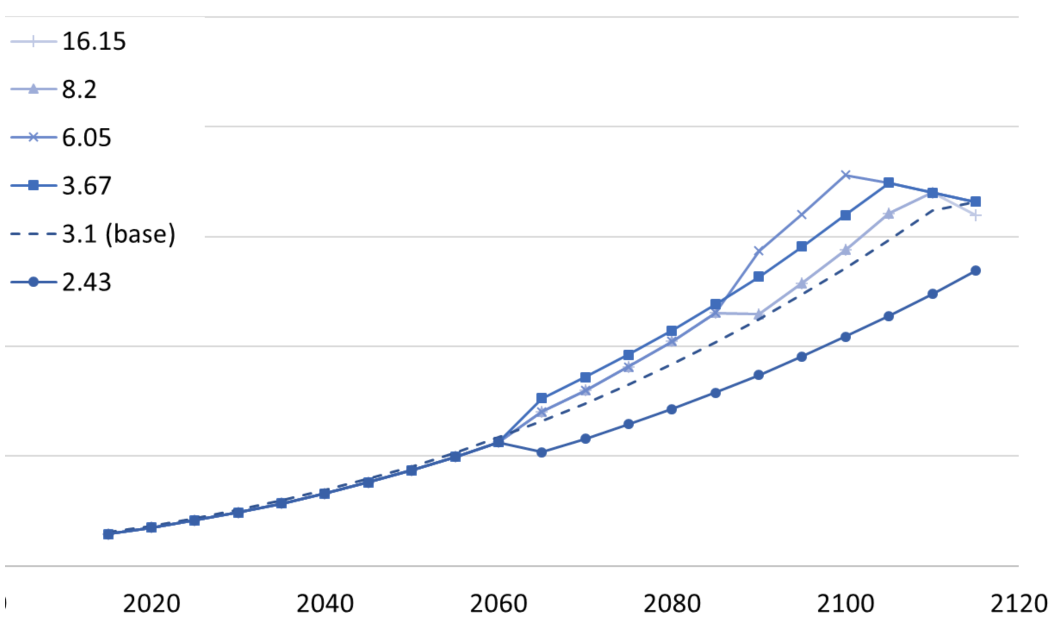
1 Roe-Bauman time dynamics dramatically reduce $SC\text{-}CO_2$ uncertainty

$SC\text{-}CO_2$ smaller in expectations, less uncertain after resolution of uncertainty

DICE with Roe-Baker tail uncertainty



DICE with Roe-Bauman time dynamics



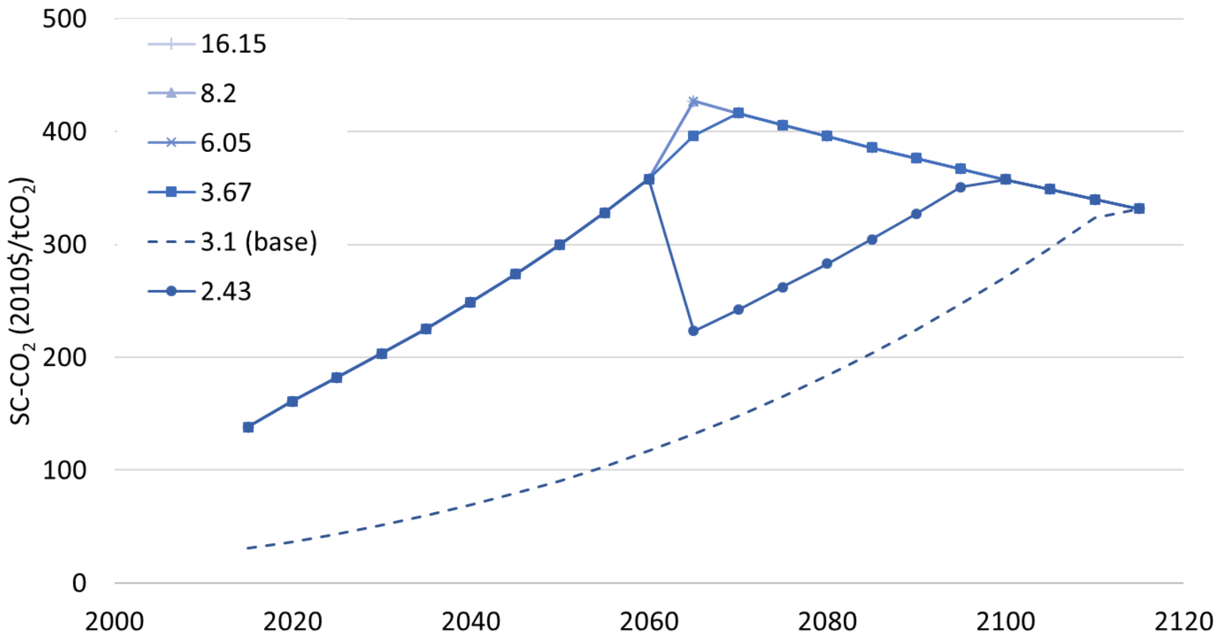
Tail risks much less significant, given time interaction (discounting!)

Source: Hogan & Wagner (Mimeo)

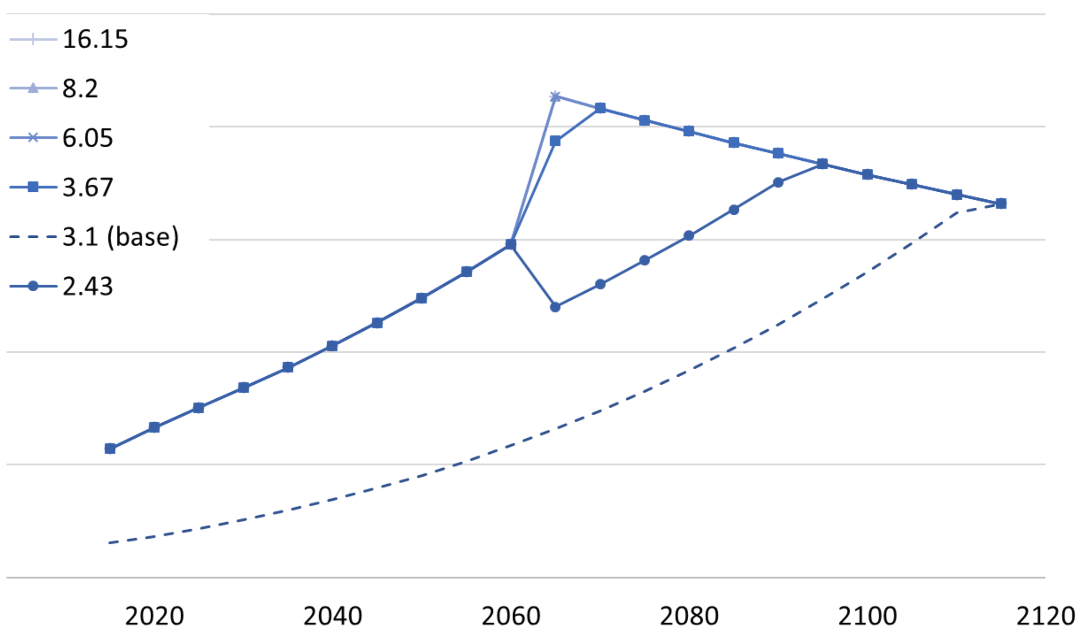
1 & 2 Impact of EZ preferences much larger than RB dynamics

Initial SC-CO_2 jumps to over $100

DICE-EZ



DICE-EZ-RB



Switch to EZ appears to have large impact on SC-CO_2

Source: Hogan & Wagner (Mimeo)

1 & 2

Roe-Bauman (RB) time-delay decreases SCC by >30%

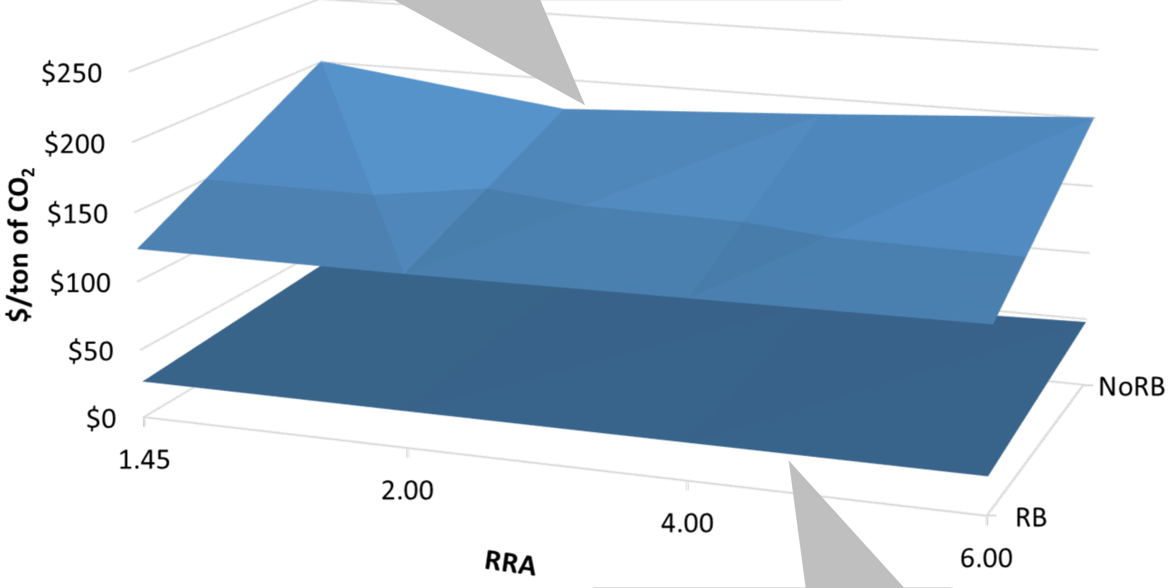
DICE calibration (EIS = 0.69 and RRA = 1.45) changes from $31

DICE calibration (SCC = $31)

EIS =	0.69			
RRA =	1.45	2	4	6
RB	$ 26	$ 26	$ 27	$ 27
no RB	$ 38	$ 39	$ 43	$ 48

EIS =	1.5			
RRA =	1.45	2	4	6
RB	$ 123	$ 124	$ 126	$ 128
no RB	$ 201	$ 177	$ 188	$ 201

Elasticity of Intertemporal Substitution (EIS) = 1.5



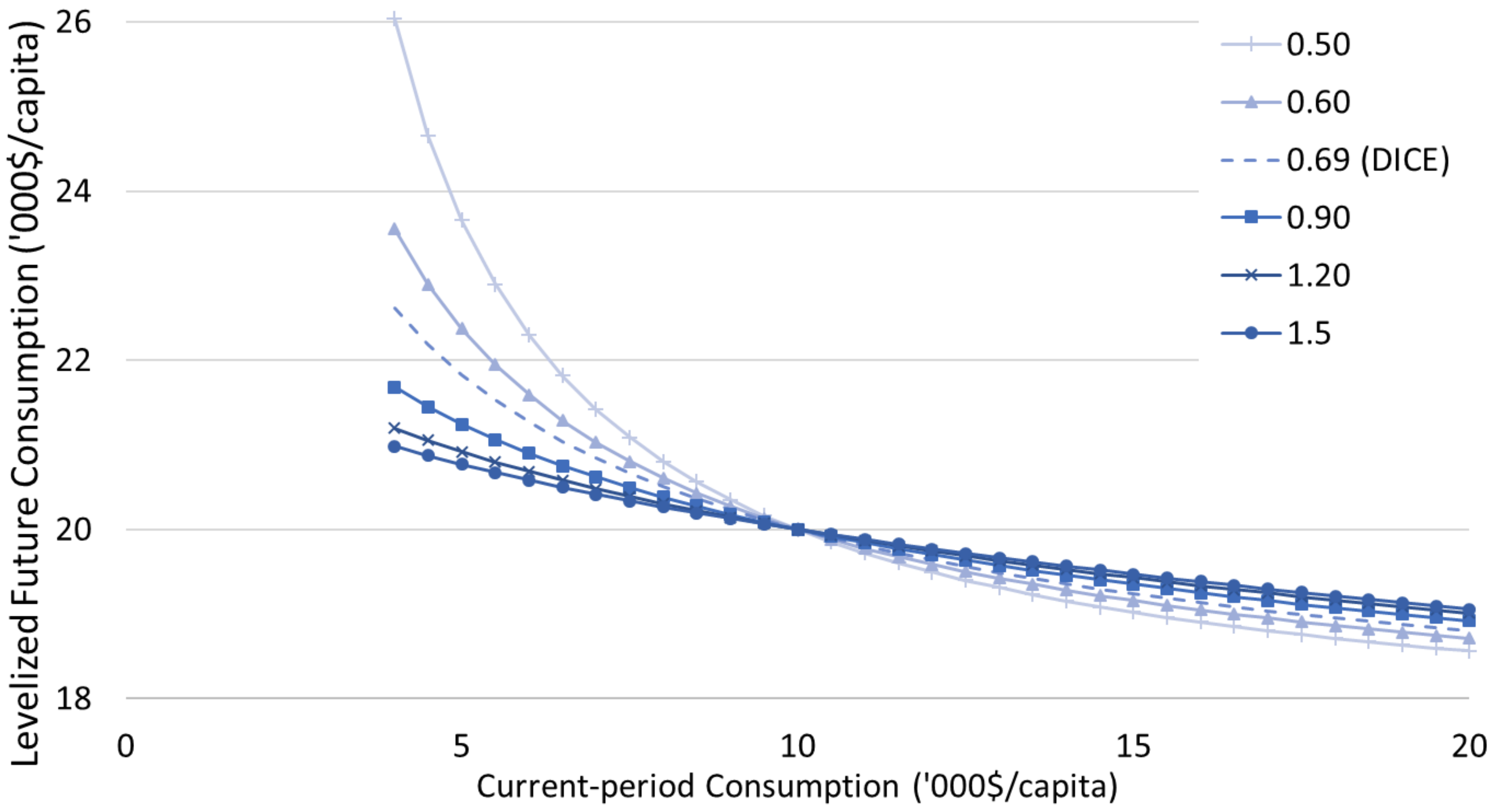
EIS = 0.69

Impact of changes to EIS (far) greater than RB/noRB and RRA?

Source: Hogan & Wagner (Mimeo)

Elasticity of Intertemporal Substitution (EIS) drives all

SC-CO_2 very sensitive to EIS parameters; EIS meanwhile, anywhere from ~0.50 to >1.5 (Thimme 2017)



What's the right EIS? aka
There appears to be no escaping economics' philosophical roots.

Source: Hogan & Wagner (Mimeo)

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Backup

“DICE-EZ-RB” based on DICE with modified utility & calibration (1/2)

Based on Ackerman *et al.* (2013) and Roe & Bauman (2013), and Nordhaus (2013, 2016)

Epstein-Zin utility:

$$U_t = \left[(1-\beta) c_t^{\rho} + \beta \left(\mu_t [U_{t+1}]^{\rho} \right) \right]^{1/\rho}$$

$$\mu_t [U_{t+1}] = \left(E_t \left[U_{t+1}^{\alpha} \right] \right)^{1/\alpha}$$

modified to allow for intra-period uncertainty in consumption:

$$U_t = \left[(1-\beta) \mu_t (c_t)^{\rho} + \beta \left(\mu_t [U_{t+1}]^{\rho} \right) \right]^{1/\rho}$$

$$\mu_t [U_{t+1}] = \left(E_t \left[U_{t+1}^{\alpha} \right] \right)^{1/\alpha}$$

$$\mu_t [c_t] = \left(E_t \left[c_t^{\alpha} \right] \right)^{1/\alpha}$$

Utility of c_t is uncertain in each period, not just in its present value

Source: Hogan & Wagner (Mimeo)

“DICE-EZ-RB” based on DICE with modified utility & calibration (2/2)

Based on Ackerman *et al.* (2013) and Roe & Bauman (2013), and Nordhaus (2013, 2016)

Modify temperature pathway from “ΔT_{DICE}” to “$\Delta T'$” in:

$$T_{AT}(t) = T_{AT}(t-1) + \xi_1\left\{F(t) - \xi_2 T_{AT}(t-1) - \xi_3\left[T_{AT}(t-1) - T_{LO}(t-1)\right]\right\}$$

$$T_{LO}(t) = T_{LO}(t-1) + \xi_4\left[T_{AT}(t-1) - T_{LO}(t-1)\right].$$

by scaling parameters, *e.g.*:

$$\xi_2' = \xi_2\left(\frac{\Delta T'}{\Delta T_{DICE}}\right)^{-1} \qquad \xi_3' = \xi_3\left(\frac{\Delta T'}{\Delta T_{DICE}}\right)^{\lambda_{RB}}$$

We instead scale based on fraction of asymptotic adjustment; i.e. time it takes to get to 1 − 1/e, or ~ 63 %.

→ Choose parameters ξ_1', ξ_3', ξ_4' to minimize squared deviation from DICE parameters: $\frac{T(ECS, p)}{T(3.1, p)} = \left(\frac{y}{3.1}\right)^2$

Source: Hogan & Wagner (Mimeo)