

Discounting and the Value of Time

EES 3310/5310

Global Climate Change

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Review of Market-Based Regulations

Marginal and Cumulative Costs & Benefits

CO ₂ emissions	Marginal cost	Marginal benefit	Gross cost	Gross benefit	Net benefit
0	—	—	0	0	0
1	20	120	20	120	100
2	40	90	60	210	150
3	60	60	120	270	150
4	80	30	200	300	100
5	100	0	300	300	0

- Gross (cumulative) costs and benefits are the sum of marginal costs and benefits from zero to the current level.
- Net benefit is the gross benefit minus the gross cost.
- What is the optimal number of permits to issue?
- What is the optimal emissions tax?

Two Companies

Emissions	MB
0	—
1	120
2	100
3	80
4	60
5	40

Emissions	MB
0	—
1	130
2	104
3	78
4	52
5	26

Emissions	MC
0	—
1	21
2	42
3	63
4	84
5	105
6	126
7	147
8	168
9	189
10	210

Two Companies

Emissions	Company	MB	MC	Gross Benefits	Gross Costs	Net Benefits
1	B	130	21	130	21	109
2	A	120	42	250	63	187
3	B	104	63	354	126	228
4	A	100	84	454	210	244
5	A	80	105	534	315	219
6	B	78	126	612	441	171
7	A	60	147	672	588	84
8	B	52	168	724	756	-32
9	A	40	189	764	945	-181
10	B	26	210	790	1155	-365

- Benefits depend on which company produces the emissions
- Costs only depend on the total emissions
- Put emissions in descending order of marginal benefit.
- What is the optimum emissions level?
- What is the optimum emissions tax?

Discounting:
Should we spend more today
to offset damages in the future?

Should we pay \$100 for a bond today that will pay \$1000 in 50 years?

- What would you expect to earn if you invested \$100 today in something else?
 - ***“Opportunity cost”***
- Compounding interest:

$$V_{\text{future}} = V_{\text{present}} \times (1 + r)^n,$$

where:

- V is value
- r is interest rate (4% $\rightarrow r = 0.04$)
- n is number of years
- Rule of 72:
 - The number of years to double your investment is roughly $72 / (\text{percent interest rate})$

Should we pay \$100 for a bond today that will pay \$1000 in 50 years?

- What would you expect to earn if you invested \$100 today in something else?
- Assume real interest rate is 4%
 - Compounding interest:

$$V_{\text{future}} = V_{\text{present}} \times (1 + r)^n,$$

$$V_{\text{present}} = \$100$$

$$\begin{aligned} V_{\text{future}} &= V_{\text{present}} \times (1 + r)^n \\ &= \$100 \times 1.04^{50} \\ &= \$711. \end{aligned}$$

- **\$1000 > \$711**, so it's a good deal.

Should we pay \$100 for a bond today that will pay \$1000 in 50 years?

- Formula for net present value (NPV) is the inverse of the interest formula:

$$V_{\text{future}} = V_{\text{present}} \times (1 + r)^n$$

$$V_{\text{present}} = \frac{V_{\text{future}}}{(1 + r)^n}$$

$$V_{\text{future}} = \$1000$$

$$V_{\text{present}} = \frac{\$1000}{1.04^{50}}$$

$$= \frac{\$1000}{7.11}$$

$$= \$141 > \$100.$$

Different Discount Rates

- Higher rate (10%)

$$V_{\text{present}} = \frac{V_{\text{future}}}{(1 + r)^n} = \frac{1000}{1.10^{50}} = \$9 < \$100$$

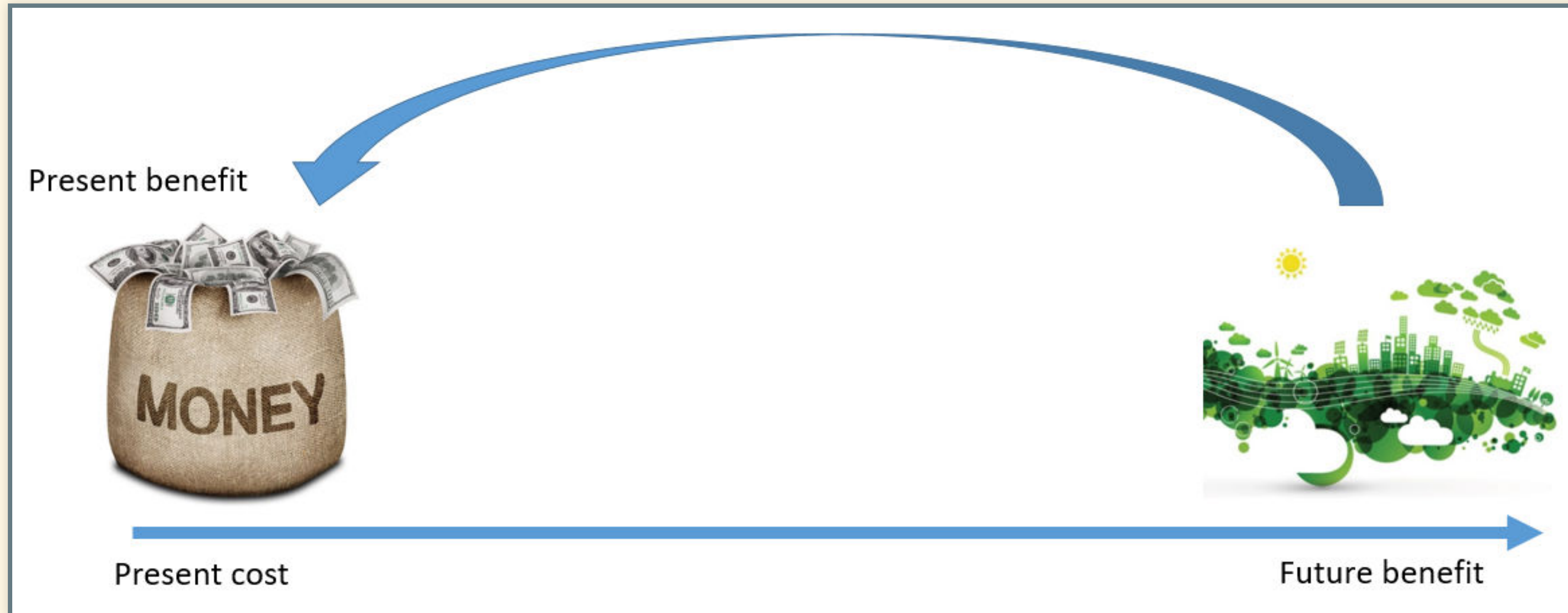
- Lower rate (1%)

$$V_{\text{present}} = \frac{V_{\text{future}}}{(1 + r)^n} = \frac{1000}{1.01^{50}} = \$608 > \$100$$

Future Generations

Should we spend money today to offset damages in the future?

How much is it worth to us **today** to avoid climate disruption **in 100 years**?

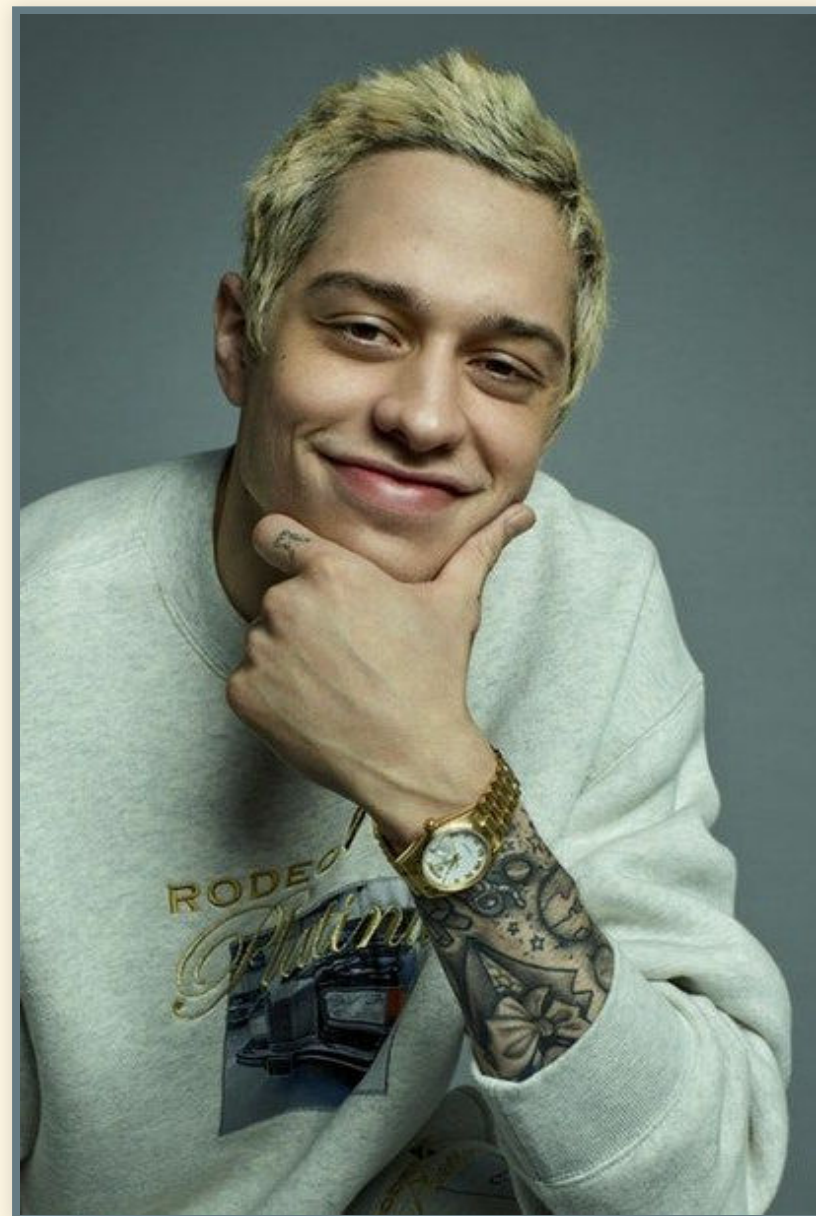


Future Generations

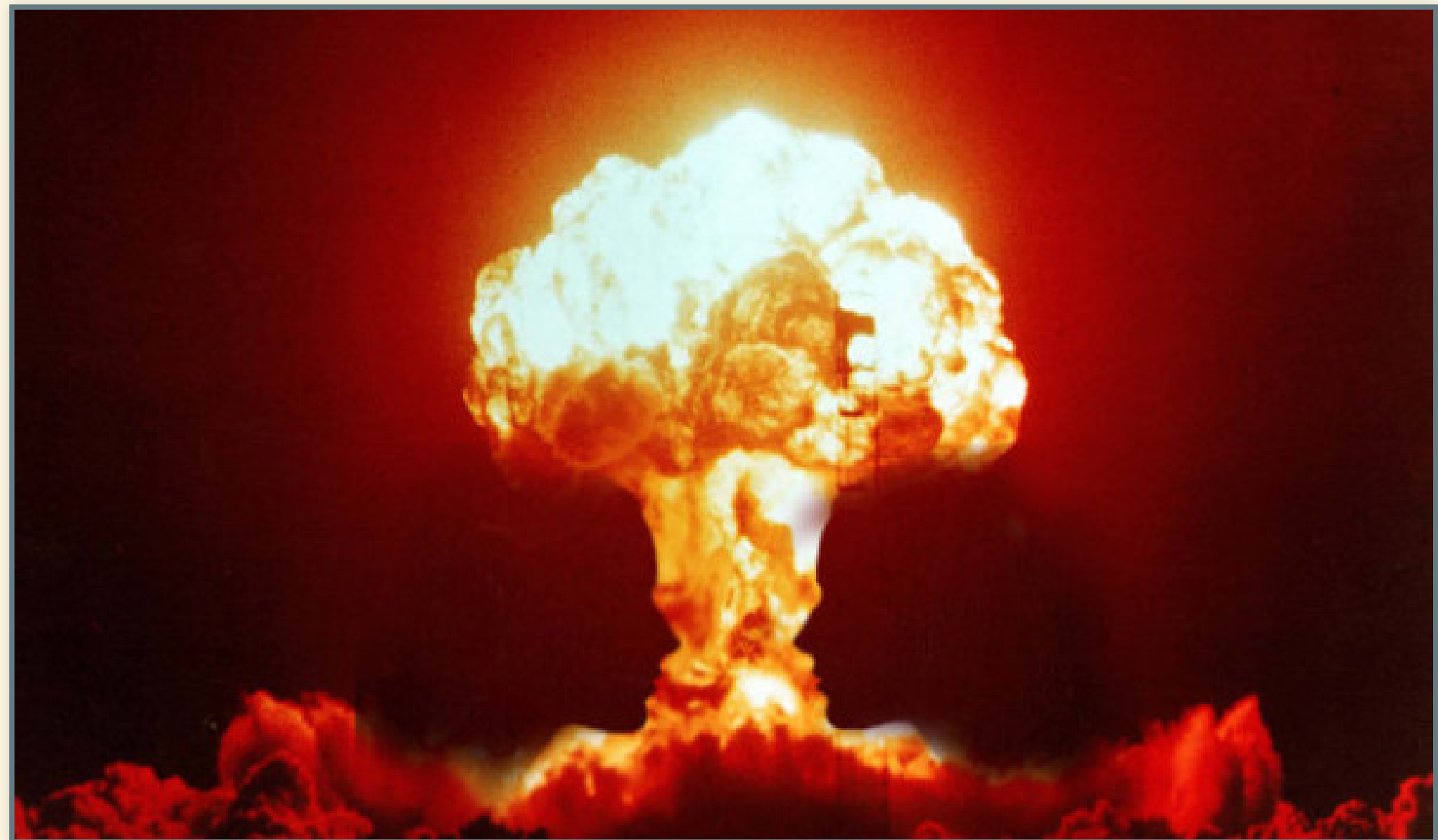
- How much is the welfare of your children worth, relative to your own welfare?
- Your grandchildren?
- Your great-grandchildren?
- Your great-great grandchildren?
- Your great³ grandchildren?
- At what greatⁿ do we stop?

Assume each future generation is worth half of the
previous generation

$$1 + \frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3} + \dots = 2$$



=



Assume each generation is equal

$$1 + 1 + 1 + 1 + \dots = \infty$$

Valuing the present (high discount rate)

- We're poor relative to the future!
- Don't take from the **poor** (*that's us*) to give to the **rich** (*future generations*)
- But if we apply this to **spatial** inequalities that exist **now** ... justifies massive wasteful transfers from rich to poor

Rates Matter!

Stern vs. Nordhaus



Stern vs. Nordhaus

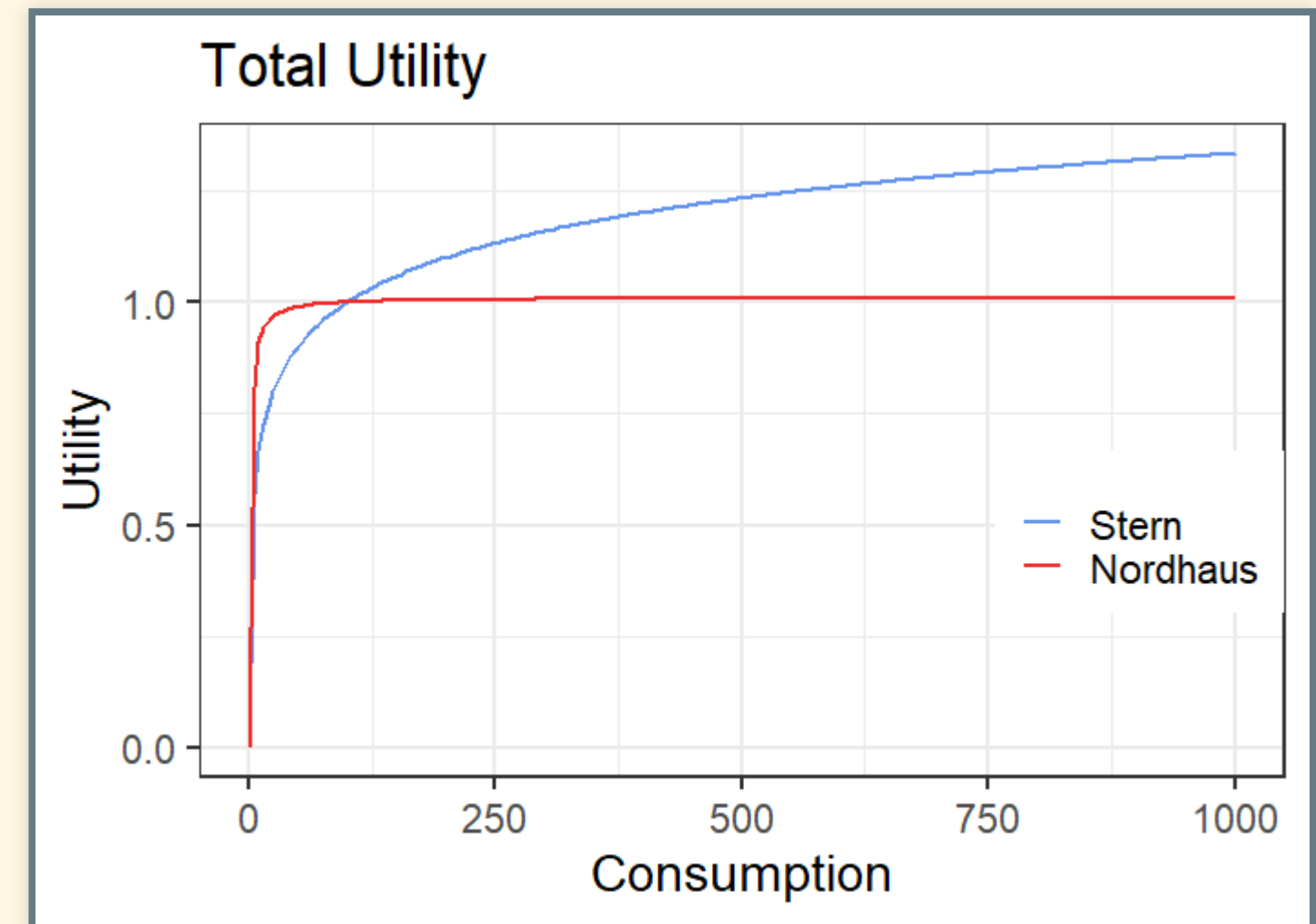


$$r = \rho + \eta g$$



Consumption elasticity η

- Proportional rate at which marginal utility of consumption is reduced as consumption increases (**What?**)
- Giving \$100 to someone in poverty adds more to total well-being than giving \$100 to Jeff Bezos
- High η :
 - Value *current consumption*,
 - *Strong* benefits for redistribution from rich to poor
- Low η :
 - Value *future consumption*,
 - *Weak* benefits for redistribution from rich to poor



- Stern: $\eta = 1$
- Nordhaus: $\eta = 2$

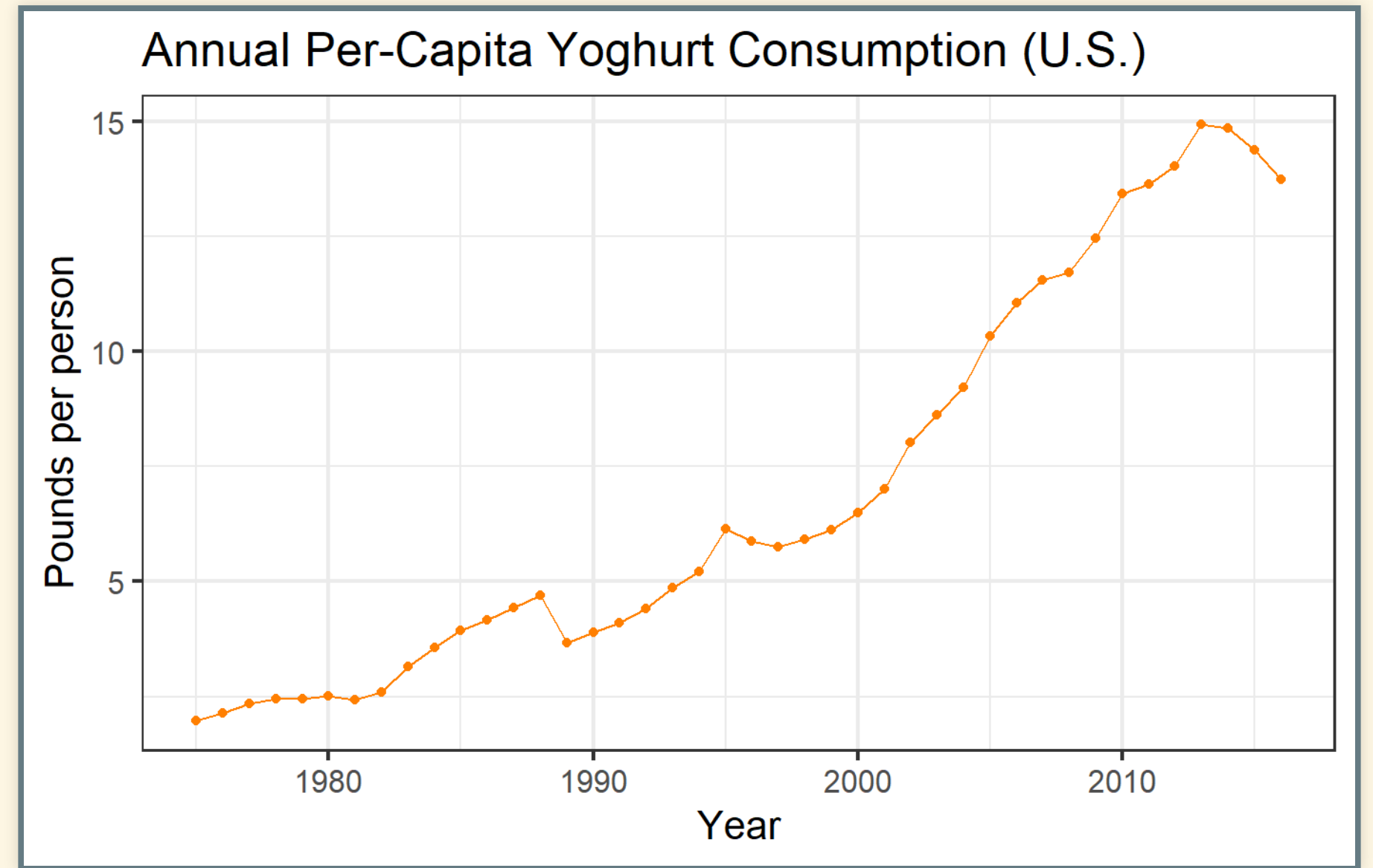
Time discount rate ρ

- How do we value future welfare, relative to our own?
- $\rho = 0$: All generations equal
- $\rho > 0$: Future generations count less than our own
- $\rho < 0$: Future generations count more than our own

- Stern: $\rho = 0.1\%$
- Nordhaus: $\rho = 1.5\%$

Per-capita consumption growth rate, g

- Stern: $g = 1.3\%$
- Nordhaus: $g = 1.3\%$



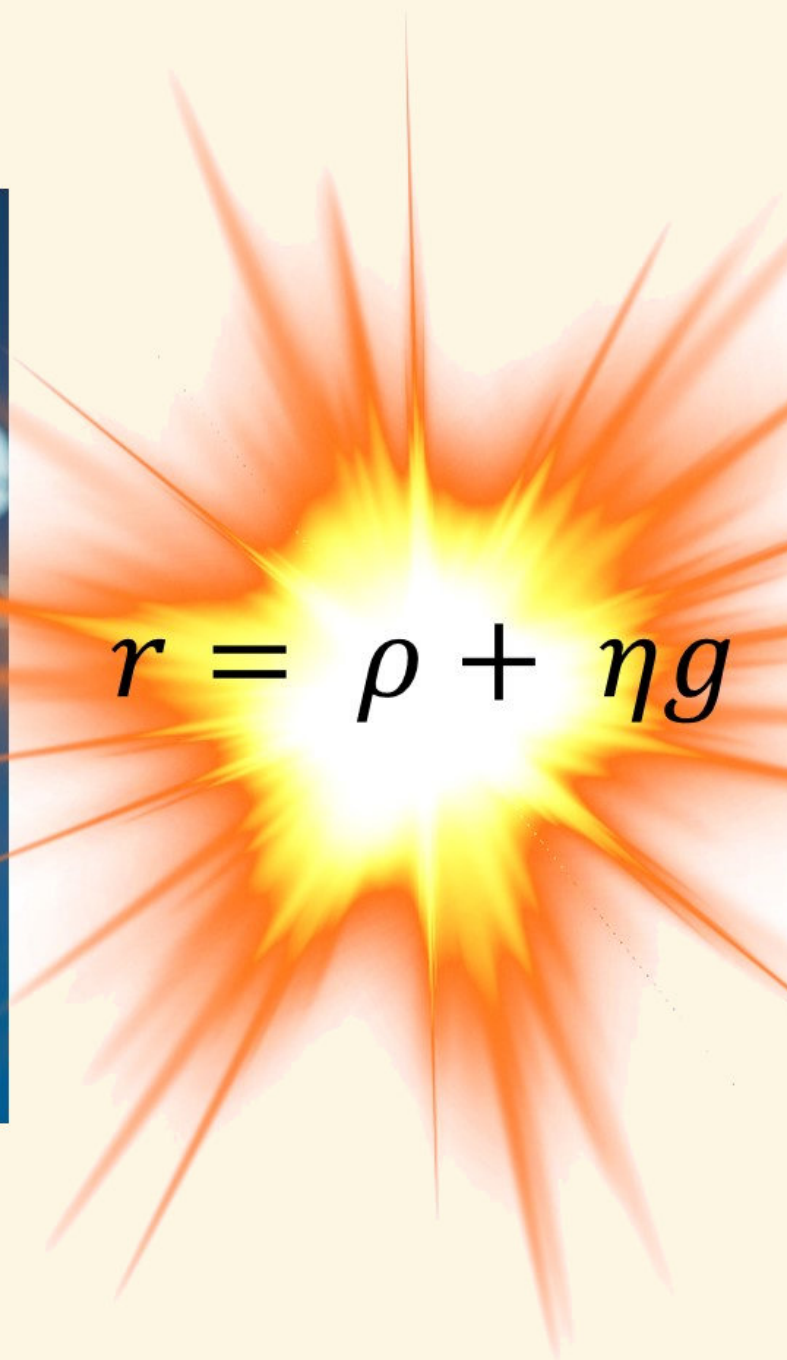
Real return on capital r

- Potential of capital to create value
- High $r \rightarrow$ Wait and reduce emissions in the **future** (capital yield is higher in future)
- Low $r \rightarrow$ Reduce emissions in the **present** (future damages likely to exceed future output)

Stern vs. Nordhaus



$$\begin{aligned} r &= 0.1 + 1 \times 1.3 \\ &= 1.4 \end{aligned}$$





$$\begin{aligned} r &= 1.5 + 2 \times 1.3 \\ &= 4.1 \end{aligned}$$

Discount Rates and Decarbonization

Discount Rates and Decarbonization

- Investing \$10 million in wind today produces \$100 million in real value 50 years from now

- Rate of 1%: $V_{\text{present}} = \frac{\$100\text{M}}{1.01^{50}} = \$61\text{M} > \$10\text{M}$ 

- Rate of 4%: $V_{\text{present}} = \frac{\$100\text{M}}{1.04^{50}} = \$14\text{M} > \$10\text{M}$ 

- Rate of 7%: $V_{\text{present}} = \frac{\$100\text{M}}{1.07^{50}} = \$3\text{M} < \$10\text{M}$



Stern vs. Nordhaus on Implications of Discount Rate

Nordhaus

... we need to use a discount rate that reflects the actual market opportunities that societies face, not an abstract definition of equity taken out of the context of market realities.



Stern



... the benefits of strong early action far outweigh the economic costs of not acting.

... even at moderate levels of warming, all the evidence ... shows that climate change will have serious impacts on world output, on human life, and on the environment.

Stern Review, pp. xv–xvi

Stern



... we should go beyond the narrow framework of social welfare functions to consider other ethical approaches, including those involving rights and sustainability.

... disaggregated approach to consequences — looking at different dimensions, places, and times — and a broad ethical approach.

Trump vs. Obama and Biden

Social Cost of Carbon

Obama, Biden

- Count global damages
- Use 3% discount rate
- Social cost: \$51 per ton

Trump

- Count only domestic damages
- Use 7% discount rate
- Social cost: \$1–7 per ton.