Economics of Climate Change – Problem Set 1

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Question 1: Externalities (20%)

1.1 Aggregate demand:

$$\text{Demand} = D_{\text{Xavier}} + D_{\text{Yvette}} + D_{\text{Zev}}$$

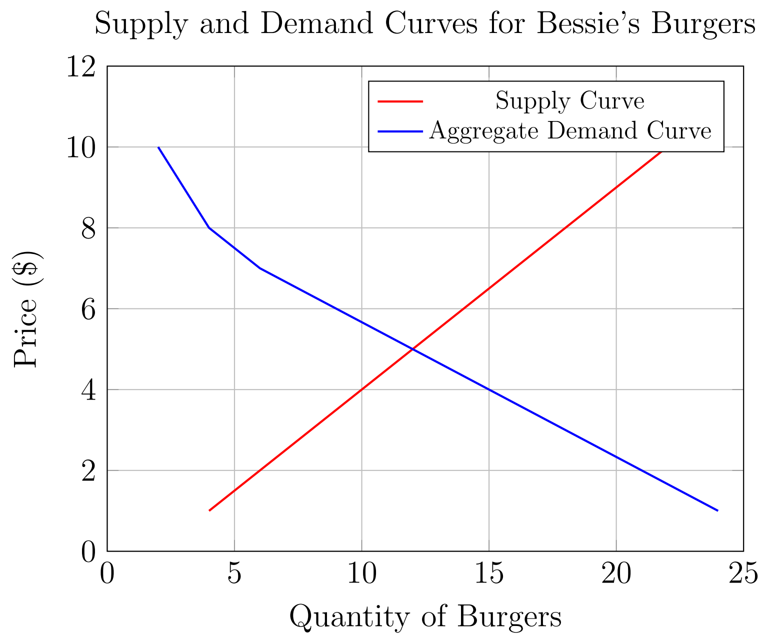
At each price point:

$$\begin{aligned}
P = 1, &\quad Q_D = 8 + 6 + 10 = 24 \\
P = 2, &\quad Q_D = 7 + 5 + 9 = 21 \\
P = 3, &\quad Q_D = 6 + 4 + 8 = 18 \\
P = 4, &\quad Q_D = 5 + 3 + 7 = 15 \\
P = 5, &\quad Q_D = 4 + 2 + 6 = 12 \\
P = 6, &\quad Q_D = 3 + 1 + 5 = 9 \\
P = 7, &\quad Q_D = 2 + 0 + 4 = 6 \\
P = 8, &\quad Q_D = 1 + 0 + 3 = 4 \\
P = 9, &\quad Q_D = 1 + 0 + 2 = 3 \\
P = 10, &\quad Q_D = 1 + 0 + 1 = 2
\end{aligned}$$

The equilibrium occurs where aggregate demand equals supply. This happens at $P = 5$, where $Q_S = 12$ and $Q_D = 12$.

Answer: In equilibrium, Bessie will sell 12 burgers.

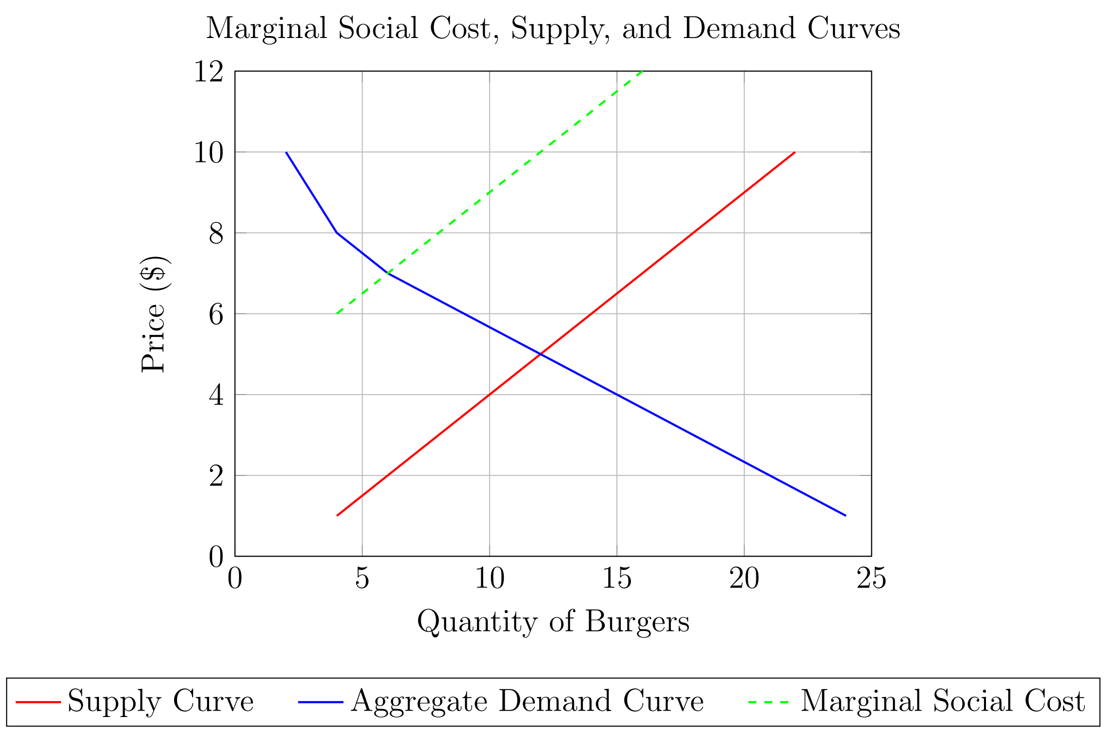
The plot for the aggregate demand and supply curves:



1.2 The marginal social cost includes both the private cost (supply curve) and the external cost. Since the external cost of each burger is \$5, the marginal social cost curve will be the supply curve shifted upward by \$5 at each quantity.

Answer: The marginal social cost curve is the same as the supply curve, shifted upward by \$5.

The plot for the supply, demand, and marginal social cost curves:



1.3 To find the socially optimal quantity, we set the aggregate demand equal to the marginal social cost curve.

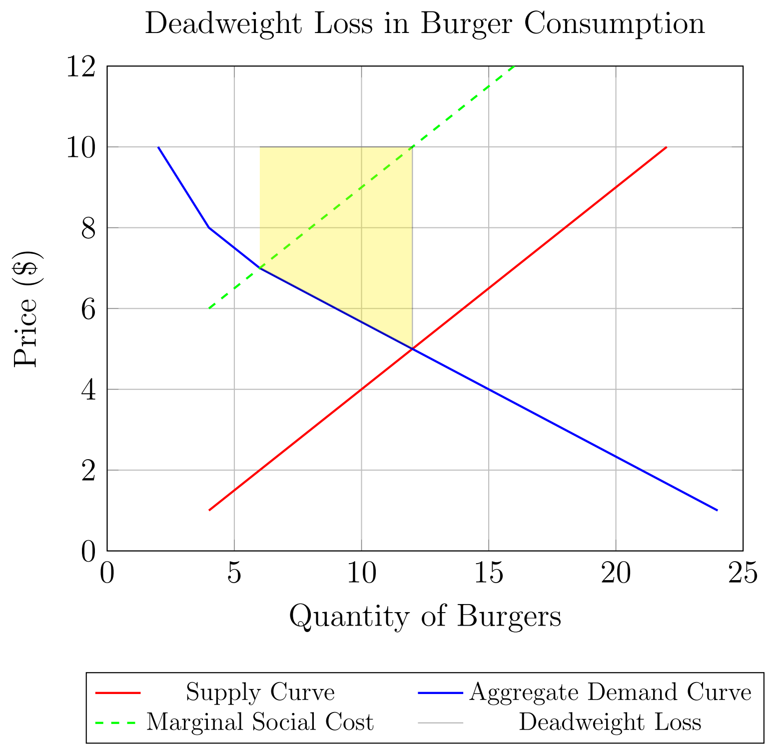
From the demand curve, at $P = 7$ (the social cost of producing 6 burgers), the demand is 6. Therefore, the socially optimal quantity is 6 burgers.

Answer: The three friends would consume 6 burgers if they internalized the social cost.

1.4 The deadweight loss is the loss of economic efficiency that occurs when the quantity of burgers consumed exceeds the socially optimal level. It is the area between the marginal social cost curve and the demand curve, for the range of quantities between the socially optimal consumption (6 burgers) and the market equilibrium consumption (12 burgers).

Answer: The deadweight loss is the triangle between 6 and 12 burgers, with a height of $5 (the external cost).

Below is a graphical representation of the DWL:



The graph shows that if the three friends act based on market conditions (i.e., consuming at the supply-demand equilibrium point), they are likely to consume more than the socially optimal quantity of burgers (about 10 units versus the socially optimal 6 units). This over-consumption leads to a deadweight loss because the additional burgers consumed after the socially optimal quantity impose a cost on society that exceeds the benefits enjoyed by the consumers.

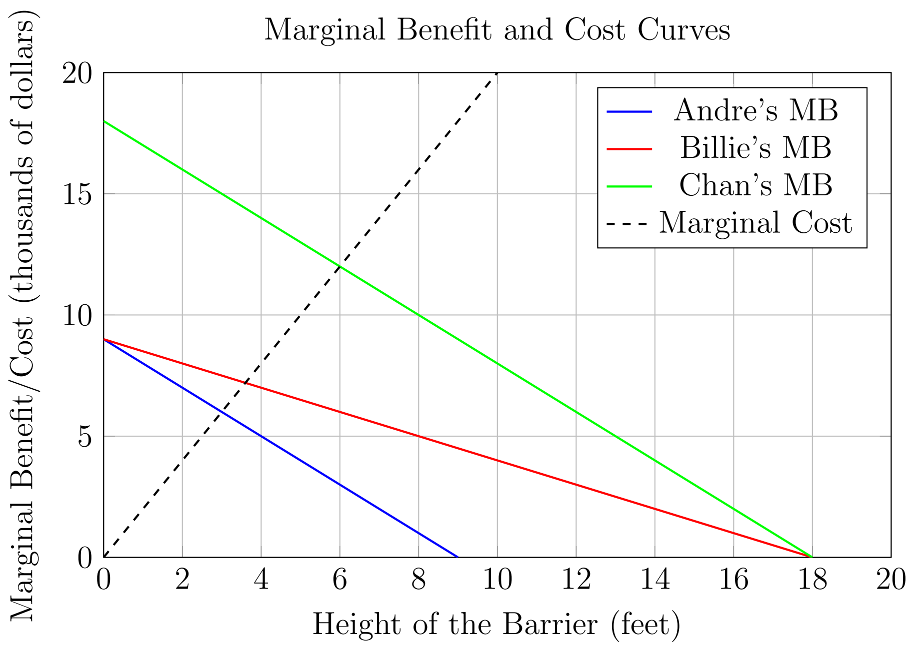
Question 2: Public Goods (30%)

2.1 The marginal benefit (MB) curves for Andre, Billie, and Chan are:

$$MBA(x) = 9 - x, \quad \text{for } 0 \leq x \leq 9$$
$$MBB(x) = 9 - 0.5x, \quad \text{for } 0 \leq x \leq 18$$
$$MBC(x) = 18 - x, \quad \text{for } 0 \leq x \leq 18$$

The marginal cost of building the flood barrier is constant at $MC = 2x$, where x is the height of the flood barrier in feet.

Marginal benefit curves for Andre, Billie, and Chan, along with the marginal cost curve:



2.2 In private equilibrium, each individual will act according to their own marginal benefit and the marginal cost. The private equilibrium occurs when an individual's marginal benefit equals the marginal cost of the flood barrier.

For Andre, the private equilibrium occurs when:

$$MBA(x) = 2x \implies 9 - x = 2x \implies x = 3 \text{ feet}$$

For Billie, the private equilibrium occurs when:

$$MBB(x) = 2x \implies 9 - 0.5x = 2x \implies 9 = 2.5x \implies x = 3.6 \text{ feet}$$

For Chan, the private equilibrium occurs when:

$$MBC(x) = 2x \implies 18 - x = 2x \implies x = 6 \text{ feet}$$

Answer: In the private equilibrium, each individual would provide the following:

- Andre: 3 feet
- Billie: 3.6 feet
- Chan: 6 feet

2.3 The consumer surplus is the area under the marginal benefit curve and above the marginal cost curve, up to the private equilibrium quantity.

- For Andre, the consumer surplus is a triangle with height $9 - 6 = 3$ and base 3:

$$CS_A = \frac{1}{2} \times 3 \times 3 = 4.5 \text{ thousand dollars}$$

- For Billie, the consumer surplus is a triangle with height $9 - 7.2 = 1.8$ and base 3.6:

$$CS_B = \frac{1}{2} \times 1.8 \times 3.6 = 3.24 \text{ thousand dollars}$$

- For Chan, the consumer surplus is a triangle with height $18 - 12 = 6$ and base 6:

$$CS_C = \frac{1}{2} \times 6 \times 6 = 18 \text{ thousand dollars}$$

Answer: The consumer surplus for each individual is as follows:

- Andre: \$4500
- Billie: \$3240
- Chan: \$18000

2.4 The social marginal benefit curve is the sum of the individual marginal benefit curves for all three individuals.

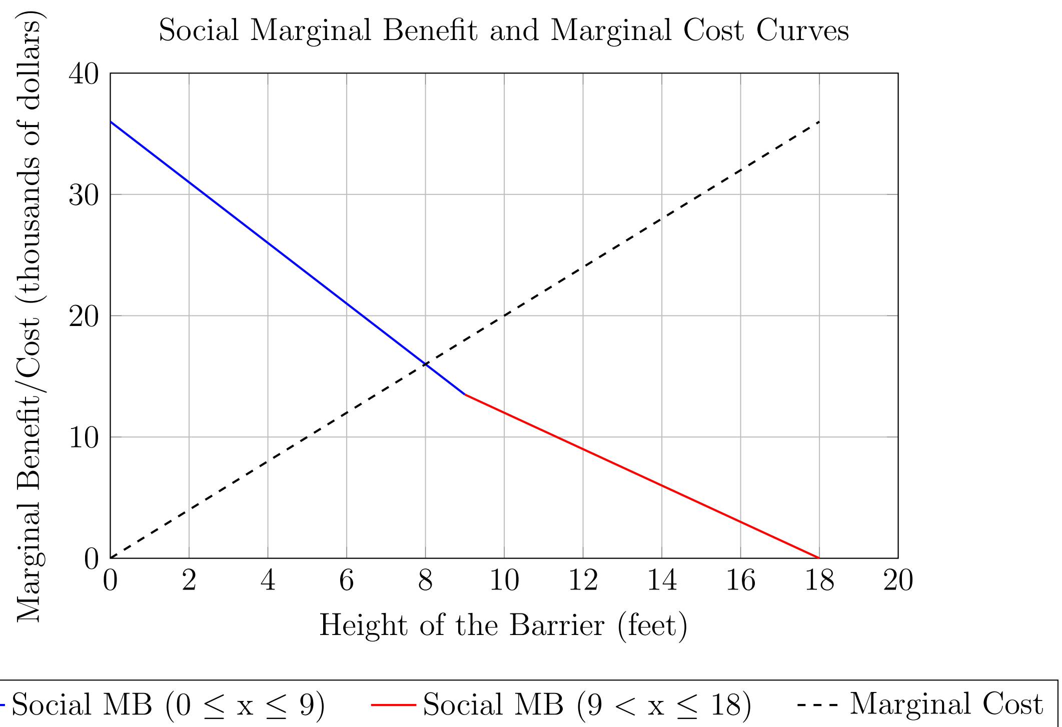
- For $0 \leq x \leq 9$, all three individuals receive positive marginal benefits:

$$SMB(x) = MBA(x)+MBB(x)+MBC(x) = (9-x)+(9-0.5x)+(18-x) = 36-2.5x$$

- For $9 < x \leq 18$, only Billie and Chan receive positive marginal benefits:

$$SMB(x) = MBB(x) + MBC(x) = (9 - 0.5x) + (18 - x) = 27 - 1.5x$$

Below is the plot for the social marginal benefit curve:



The social equilibrium occurs where the social marginal benefit equals the marginal cost. The total benefits are the area under the social marginal benefit curve, and the total costs are the area under the marginal cost curve.

$$SMB(x) = 36 - 2.5x$$

$$MC(x) = 2x$$

Equating them for the social equilibrium:

$$36 - 2.5x = 2x \implies x = 8 \text{ feet}$$

2.5

- Total Benefits at Social Equilibrium: Total Benefits $= \int_0^8 (36 - 2.5x)\,dx = 208$ thousand dollars
- Total Costs at Social Equilibrium: Total Costs $= \int_0^8 2x\,dx = 64$ thousand dollars
- Net Benefits at Social Equilibrium: Net Benefits $= 208 - 64 = 144$ thousand dollars

In the private equilibrium, Andre, Billie, and Chan will provide 3 feet, 3.6 feet, and 6 feet, respectively.

- Total Benefits in Private Equilibrium: $22.5 + 29.16 + 90 = 141.66$ thousand dollars
- Total Costs in Private Equilibrium: $9 + 12.96 + 36 = 57.96$ thousand dollars
- Net Benefits in Private Equilibrium: $141.66 - 57.96 = 83.7$ thousand dollars

Answer: The net benefits at the social equilibrium ($144 thousand) are higher than at the private equilibrium ($83.7 thousand).

Question 3: Climate Science and Fossil Fuels (20%)

3.1 "Climate change is a natural phenomenon, and there's no scientific consensus about human involvement."

While climate change has occurred naturally throughout Earth's history, the current rate of warming is unprecedented. According to the IPCC Sixth Assessment Report (AR6), there is overwhelming evidence that human activities, especially the burning of fossil fuels, are the dominant cause of recent warming. The report concludes with high confidence that human influence has warmed the atmosphere, ocean, and land, leading to widespread and rapid changes across the planet. More than 97% of climate scientists agree that humans are causing climate change, a conclusion supported by numerous scientific organizations, including NASA and the World Meteorological Organization (WMO).

3.2 "Where I'm from, we had one of the coldest winters ever measured last year. So much for global warming, eh?"

Global warming refers to long-term increases in the Earth's average surface temperature, not the day-to-day weather. While localized cold spells may still occur, they do not negate the broader trend of warming. The IPCC Special Report on Global Warming of 1.5°C highlights that even as the planet warms overall, changes in climate patterns can cause more extreme and variable weather, including colder winters in some regions due to disruptions in atmospheric circulation patterns like the polar vortex. Weather fluctuations are short-term, whereas climate refers to long-term trends.

3.3 "Environmental regulations hurt the economy and cost jobs. We should prioritize economic growth over climate action."

Contrary to this belief, studies indicate that climate action can lead to long-term economic growth. The 2018 Global Commission on the Economy and Climate Report found that bold climate action could deliver at least $26 trillion in economic benefits globally through 2030. Furthermore, the IPCC AR6 report highlights the health benefits of reducing air pollution through environmental regulations, which lower healthcare costs and increase worker productivity. The renewable energy sector has created millions of jobs worldwide, and continued investment in green technologies can drive economic growth and innovation.

3.4 "Renewable energy is too expensive and unreliable to replace fossil fuels on a large scale."

The cost of renewable energy has fallen dramatically in the past decade, making it a competitive alternative to fossil fuels. The International Renewable Energy Agency (IRENA) 2020 Renewable Power Generation Costs Report shows that the cost of electricity from solar and wind power has become cheaper than coal in many regions. Furthermore, advancements in battery storage technology and grid management are improving the reliability of renewable energy. The IPCC AR6 Mitigation of Climate Change Report also emphasizes the scalability of renewables, noting that renewable energy can meet most of the world's energy needs with the right infrastructure.

3.5 "A 2.5-degree temperature change doesn't seem like a big deal. On some days the temperature swings by 20 degrees or more."

A 2.5-degree Celsius increase in global average temperature is a significant shift with profound consequences for the planet. The IPCC Special Report on Global Warming of 1.5°C warns that even small increases in global temperatures can cause severe impacts, including more frequent and intense heatwaves, rising sea levels, and disruption of ecosystems. While day-to-day weather fluctuations are local and temporary, a sustained rise in global temperatures can destabilize climate systems, leading to long-term, irreversible changes that affect agriculture, water resources, and human health.

Question 4: Discounting (30%)

4.1 The CO_2 benefits are structured to increase linearly from \$0 in year 0 to \$200 in year 100, and then decrease linearly back to \$0 in year 300. To calculate the present value of the benefits, we need to discount future benefits using the discount rate of 5%. The formula for the present value of a stream of future benefits is:

$$PV = \sum_{t=0}^{300} \frac{B_t}{(1+r)^t} = \sum_{t=0}^{100} \frac{2t}{(1+r)^t} + \sum_{t=100}^{300} \frac{300-t}{(1+r)^t}$$

Where:

- B_t is the benefit in year t
- r is the discount rate (5%)
- t is the year

The total present value can be calculated by summing the discounted benefits over the 300 years. Running it on python we get:

$$PV(5\%) \approx \$830.41$$

Pseudocode for python:

```
# discount
r = 0.05

# first summation
pv_first_summation = sum((2 * t) / (1 + r)t for t in range(0, 100))

# second summation
pv_second_summation = sum((300 - t) / (1 + r)t for t in range(100, 300))

# total present value
pv_total = pv_first_summation + pv_second_summation
print(pv_total)
```

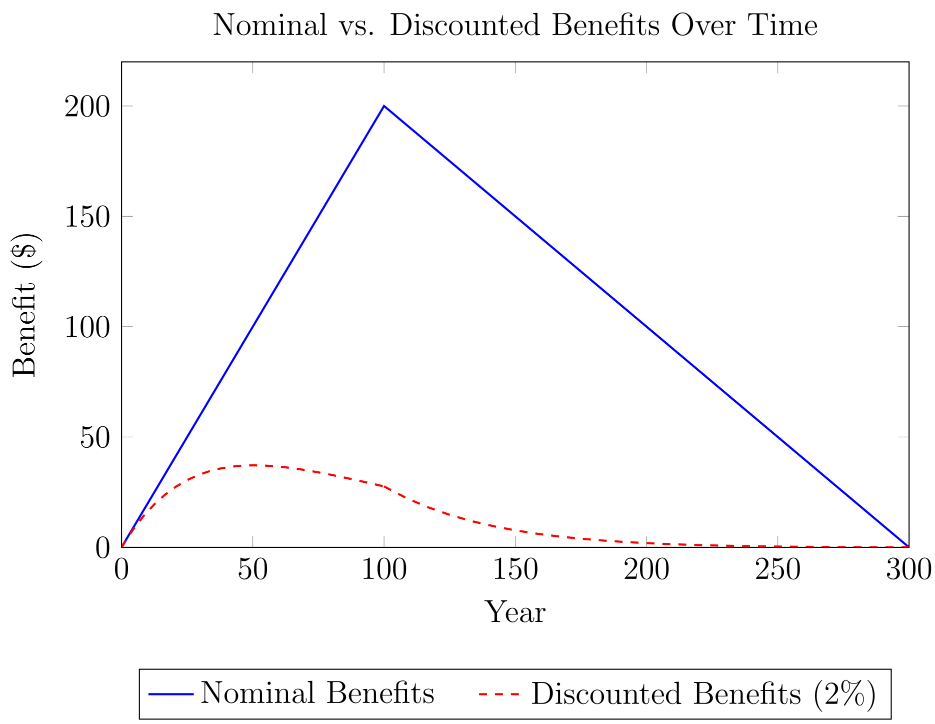
4.2 Similarly, we calculate the present value using a discount rate of 2%:

$$PV = \sum_{t=0}^{300} \frac{B_t}{(1+0.02)^t}$$

Again, summing the discounted benefits over the 300 years with python, we get:

$$PV(2\%) \approx \$4050.75$$

4.3 The following plot represents both the undiscounted benefits and the discounted benefits (at a 2% discount rate) over the 300-year period:



4.4 The present value of the benefits is lower at the 5% discount rate because future benefits are weighted less heavily. A higher discount rate places less importance on benefits that occur in the future, leading to a smaller present value. Conversely, a lower discount rate like 2% reduces the amount by which future benefits are discounted, resulting in a higher present value. Essentially, the 2% rate assumes that future benefits are more valuable relative to the present than the 5% rate does.

4.5 At both the 5% and 2% discount rates, the present value of the CO_2 benefits is positive, meaning that purchasing the electric vehicle provides a net social benefit in terms of reduced carbon emissions. The decision to purchase the EV might be more compelling at the 2% discount rate because the future benefits are valued more highly. However, even at the 5% discount rate, purchasing the EV still contributes to reducing CO_2 emissions and is aligned with long-term environmental goals.

4.6 The choice of the discount rate depends on how we value future benefits relative to current costs. A lower discount rate like 2% is often more appropriate for long-term environmental decisions, as it better accounts for the intergenerational impacts of climate change. The Stern Review on the Economics of Climate Change (2006), for example, advocates for a low discount rate (around 1.4%) to ensure that future generations are not disproportionately burdened by current emissions. On the other hand, a higher discount rate (like 5%) reflects a preference for immediate benefits and can be justified if the primary concern is current economic growth.

Ultimately, if the goal is to fully internalize the long-term social costs of CO_2 emissions, a lower discount rate is more appropriate, as it places greater value on the benefits future generations will experience from reduced emissions.