Principles of sustainability economics: Extended correction guide

Chapter 2

Problem 2.1: CBA and river protection

i. There are at least two ways to calculate TC, TB and $NB = TB - TC$.

Method 1: drawing the diagram and calculating areas (see problem_2.1.xlsx)

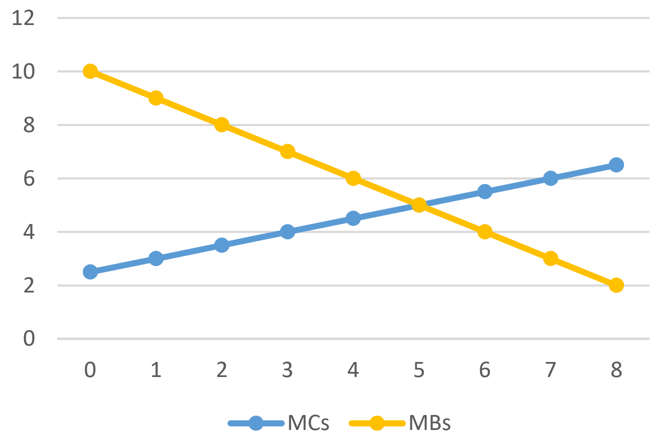

Figure C2.1: River protection

In each case (TC or TB) we calculate the area of a trapezium (see Appendix A1) below the corresponding schedule. This leads to:

case	Km (height)	TC [thousand CHF per km]	TB [thousand CHF per km]	$NB = TB - TC$
a	4	$4 \cdot (2.5 + 4.5)/2 = 14$	$4 \cdot (10 + 6)/2 = 32$	18
b	5	$5 \cdot (2.5 + 5)/2 = 18.75$	$5 \cdot (10 + 5)/2 = 37.5$	18.75
c	6	$6 \cdot (2.5 + 5.5)/2 = 24$	$6 \cdot (10 + 4)/2 = 42$	18

Method 2: solving the corresponding integrals

$$TC(Q) = \int_0^Q MC(v)\, dv = [2.5v + 0.25v^2]_0^Q = 2.5Q + 0.25Q^2$$

$$TB(Q) = \int_0^Q MB(v)\, dv = [10v - 0.5v^2]_0^Q = 10Q - 0.5Q^2$$

See sheet 2 of the excel file: gives the same results as Method 1 (i.e. a maximum of net social benefit of CHF 18'750 when $Q = 5$).

Static efficiency (maximum net social benefit) is achieved when $Q = 5$, which satisfies indeed the principle of $TNBM$ i.e. $MCs = MBs$ ($= 5$ in that specific case).

ii. For the MCs, applying the principle of TCM, we want an expression of the MCs of action j such that, if we sum up the two quantities $q_1 + q_2$, we obtain the total quantity Q. Moreover, we know that the two actions are identical so that $q_1 = q_2 = \frac{Q}{2}$. Thus, in order to obtain MCs_j, we just need to take the expression of the marginal cost, $MCs = 2.5 + 0.5Q$, and replace Q by $2q_1$ or $2q_2$ to obtain either $MCs_1 = 2.5 + q_1$ or $MCs_2 = 2.5 + q_2$. In other words, the MCs of the individual action has the same intercept, but twice the slope of the $MCs(Q)$ curve. For the MBs, applying the principle of TBM, the same reasoning applies, so we obtain either $MBs_1 = 10 - 2q_1$ or $MBs_2 = 10 - 2q_2$. In other words, the MBs of the individual agent has the same intercept, but twice the slope of the $MBs(Q)$ curve.

iii. As we have only one agent and one action, we have to use the dashed curves MCs_1, MBs_1 as represented in the diagram below (see excel sheet number 3).

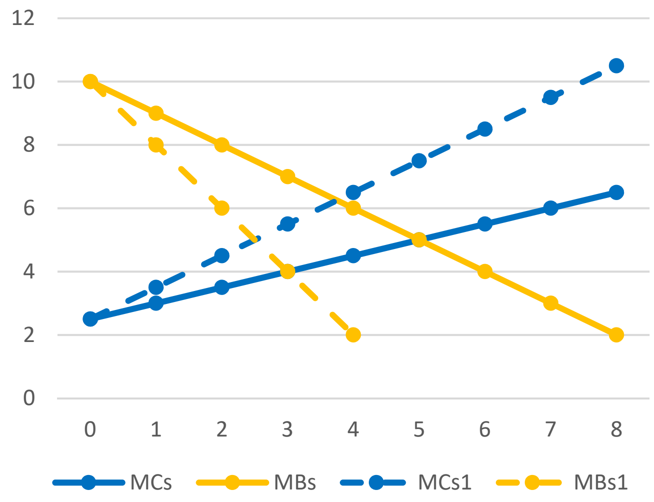

Figure C2.2: Only one agent and one action

The intersection between MCs_1 and MBs_1 is obtained at $q* = 2.5$, $MCs_1 = MBs_1 = 5$. The optimum level of the marginal cost or benefit does not change, but the optimal level of protection is reduced by half, and so is the level of total net benefit (which becomes equal to $TNB = 10(2.5) - (2.5)^2 - [0.5(2.5)^2 + 2.5(2.5)] = 9.375$, using the same types of calculations as in the table of the previous page).

Practical implications: the more different agents benefit from the project, and the more different actions can be undertaken to achieve it, the larger the net social benefits. Or the reverse: if for X reasons some agents are excluded and/or some actions cannot be undertaken, then the net social benefit decreases, as in the numerical problem of point iii.

Problem 2.2: Perpetual future flow

The NPV of the project is given by $NPV = \left(\frac{A}{r}\right) - C_0$. As $A = \frac{C_0}{50}$ we obtain: $NPV = C_0\left[\left(\frac{1}{50r}\right) - 1\right] = C_0\left[\frac{(1-50r)}{50r}\right]$, which leads to the following values (C_0 = USD 36 trillions)

r	NPV (in USD trillions)
1%	36
2%	0
3%	-12

The complete NPV schedule as a function of r is given by the following curve:

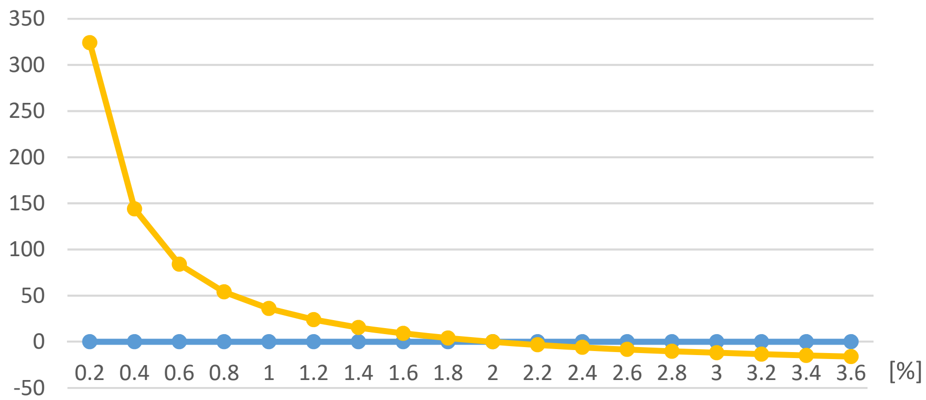

Figure C2.3: NPV of the project

Bottom line: depending on the value of the discount rate, you may end up with strikingly different conclusions regarding project evaluation. A famous debate among economists following the publication of the Stern review (2006) illustrates the point. This report reviewed the literature on climate change mitigation (https://en.wikipedia.org/wiki/Stern_Review). One of its major conclusions was that the cost-benefit ratio for early and immediate action was very favorable, around 1% of world GDP for costs and in between 5% and 20% for benefits. This favorable outcome was much criticized on the ground that the used discount rate in the review calculations was quite low, at 1.4%. Having used a more traditional discount rate of around 3% in those days would have considerably reduced the net benefits, as in the present stylized problem (by the way, world GDP in 2006 was around USD 51.5 trillion, and 1% of that as a perpetual cost at a 1.4% discount rate leads roughly to USD 36 trillion; from there the proposed order of magnitude for C_0, with the difference that in our problem all the costs happen only once i.e. in the current period).

Problem 2.3: VSL

i. $VSL = \frac{\Delta W}{\Delta p} = \frac{50}{1/100'000} =$ CHF 5 million = monetary valuation of one life saved

ii. the cost per life saved should be smaller that CHF 5 million. The number of persons saved is $X \cdot (\frac{6}{100'000} - \frac{2}{100'000}) = \frac{1}{25'000} X$ where X is population size. Thus, the maximal total cost, $TC_{\max}$, is such that $\frac{TC_{\max}}{X/25'000} < 5$ million i.e. $TC_{max} < 200X$. For example, if the population is 4 million persons, the maximal cost for the new regulation is CHF 800 million.

Problem 2.4: CBA and climate change

What we know:

- 10 identical countries
- Costs: 4, private = accrue only to one country
- Benefits: 20, public = accrue to all countries

Is it worthwhile to contribute?

- For a single country: NO ($2 < 4$, so net loss of -2)
- For the world: YES ($20 > 4$, net gain of 16)

= collective action problem

To illustrate, we can construct a payoff matrix, where the first element in each cell is the net payoff of the considered country and the second the payoff for its partners. We obtain:

Table C2.1: The Prisoner's dilemma with 10 countries

		Number of other countries reducing emissions									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Country 1	**Reduce**	(-2;18)	(0;32)	(2;46)	(4;60)	(6;74)	(8;88)	(10;102)	(12;116)	(14;130)	**(16;144)**
	Do not reduce	**(0;0)**	(2;14)	(4;28)	(6;42)	(8;56)	(10;70)	(12;84)	(14;98)	(16;112)	(18;126)

Whatever the number of other countries reducing emissions, it is always beneficial for the country not to contribute. The dominant strategy is to play "does not reduce", and this is true for all and every country as they are identical. Thus, there is a unique Nash equilibrium (0;0), at the bottom left of the table, where the first number corresponds to the payoff of the one country and the second of the 9 other countries. This is quite distinct from the social optimum (16;144) where the sum of payoffs is maximized i.e. on the upper right of the table. Each country experiences a net gain of 20-4=16 in comparison with the Nash equilibrium, which means a total net benefit of 160 for the world (i.e. (16, 144)). The opposition between the two constitutes a typical Prisoner's dilemma.

The social loss from non-cooperation (Prisoner's dilemma) is thus large, and would be even larger if there were more countries. However, even if the reward from cooperation is large, incentives at the national level are misaligned, as illustrated by the decision of the Trump administration 2016-2020 to revise downwards estimates of the SCC.

Generalization: If one notes b the benefit and c the cost per agent (country or person), with b being public, c private and $c > b > 0.5c$, then a Prisoner's dilemma ensues, and the net social loss of non-cooperation is given by $n(nb - c)$ i.e. a quadratic function of n. The losses from non-cooperation grow more than proportionately with the size of the population. This is particularly worrying when total population is large (e.g. vaccines or social distancing practices in the case of covid-19).