Professional Career Program

Environmental Economic Theory No. 3

The Economics of Environmental Quality

Instructor: Eiji HOSODA

Textbook: Barry .C. Field & Martha K. Fields (2009) ***Environmental Economics - an introduction***, McGraw-Hill, International Edition

PCP Environmental Economic Theory
Homework 4
16 October 2018

1. Theme: Describe what benefit-cost analysis is, and show how it works. Explain merits and demerits of the benefit-cost analysis. Language: English.
2. Volume: A4 two pages. Single space. 12 points.
3. Submission period: 9 a.m. 22 October 2018~ 9 a.m. 23 October 2018.
4. Submission: Submit your paper in an pdf. file. A file name must be "HW4.xxx.pdf" (xxx=your name). Send your file to hosoda@econ.keio.ac.jp.
5. Remark: Sources other than internet documents are recommendable. If you use internet information, check plural sources and compare them. List references you have used. "References" must not be skipped.

The purpose of this lecture

- Markets do not always promise good environmental quality.
- There is a gap between the welfare level (the total surplus) attained in markets and the level which could be attained in a ideal situation.
- Why so? We should analyze why and how such a gap has appeared. (Positive analysis)
- Next, we should consider what should be done to fill the gap? (A policy question.)

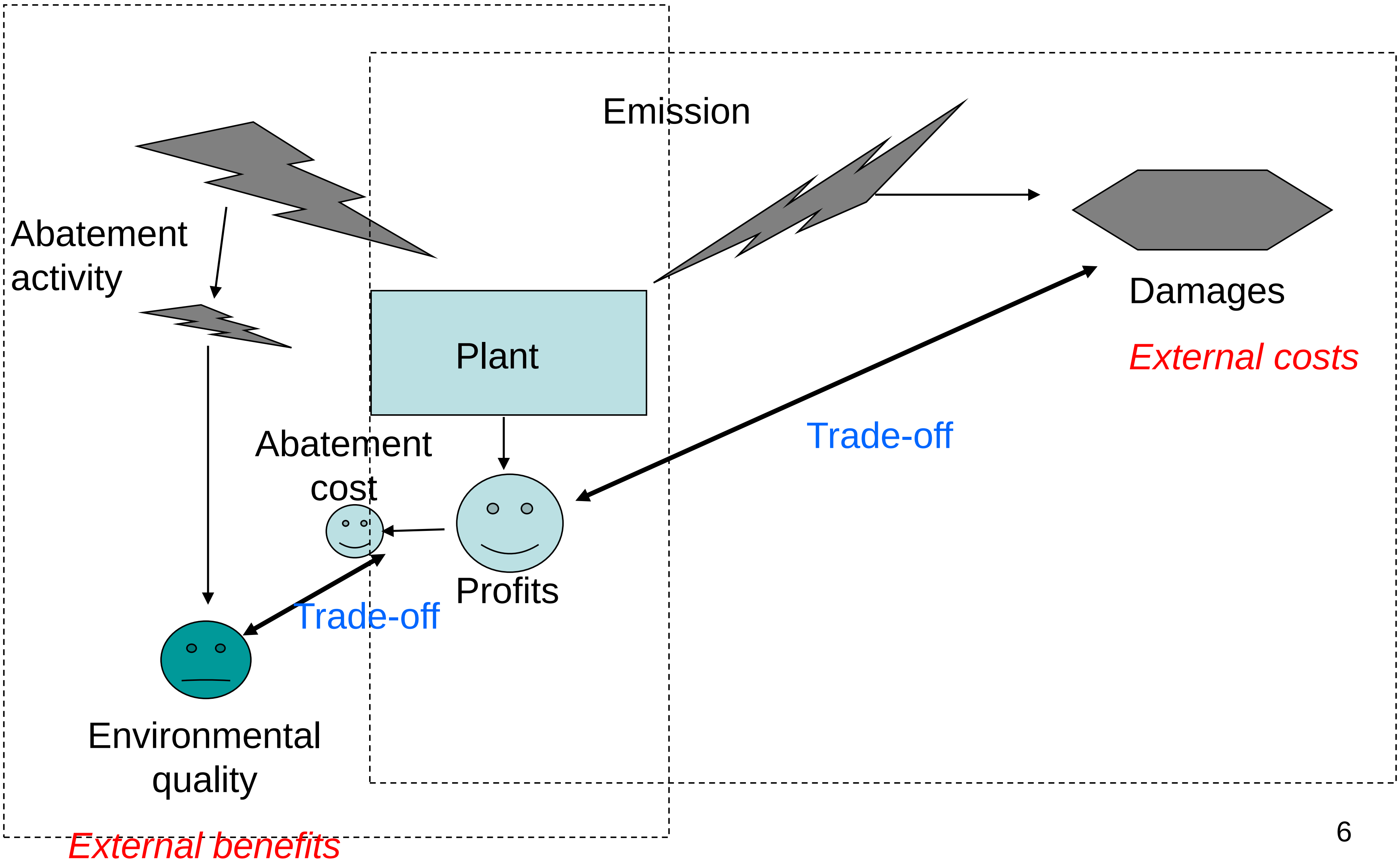
The purpose of this lecture (cont.)

- The followings are required:
- (1) To identify the most appropriate level of environmental quality.
- (2) To allocate environmental quality goals among polluters.
- (3) To decide how the benefits and costs of environmental programs be distributed across society.

Trade-off and pollution control

- The essence of environmental issues is, often, characterized as trade-off between two factors.
- One aspect of the trade-off: benefits and damages from environmental disruption (*e.g.* coal burning).
- Another aspect of the trade-off: benefits of keeping good environmental quality and costs to do so (*e.g.* abatement costs).
- Pollution control always faces the above trade-off, particularly *in a short-run*.

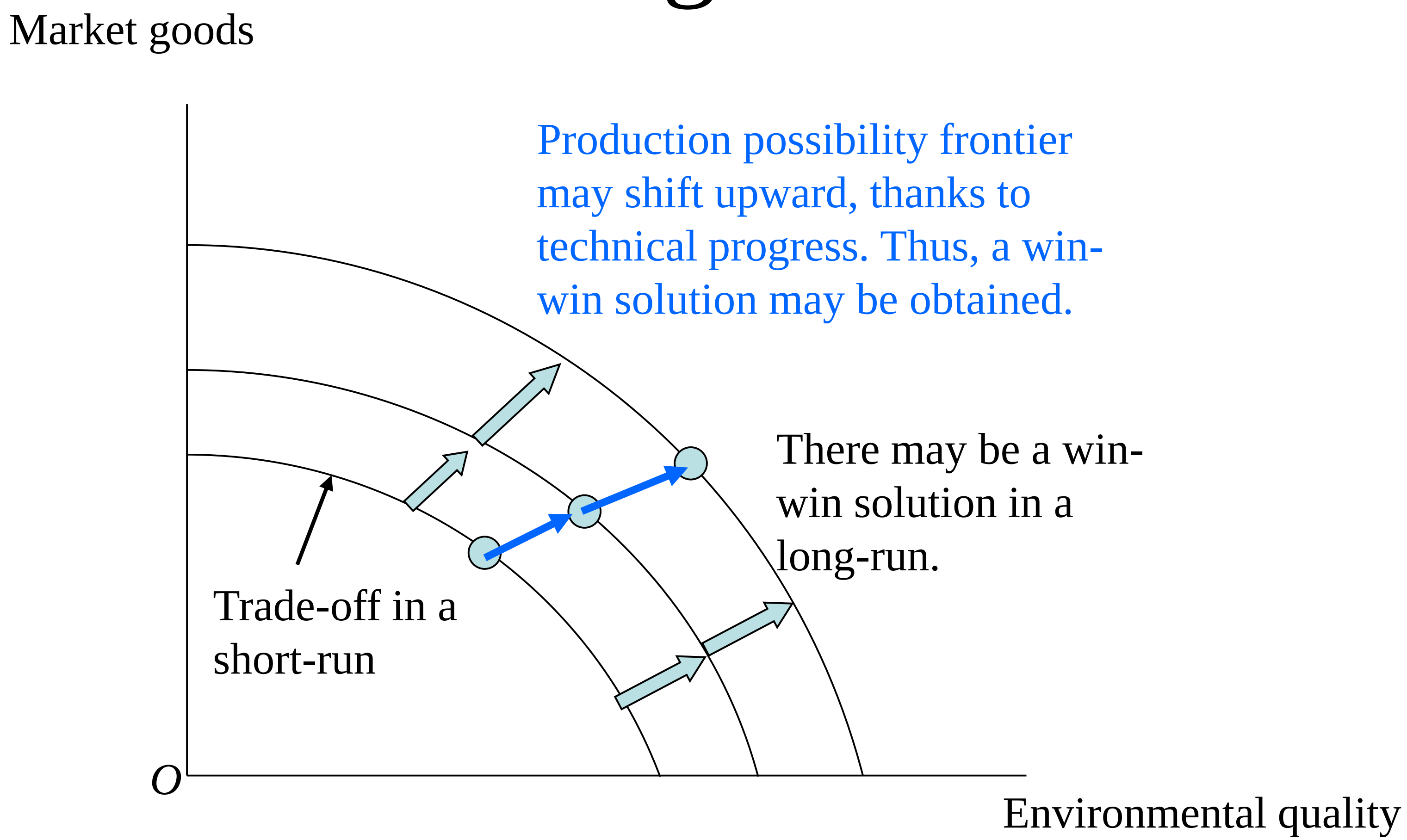
Explanation by means of a figure



A few remarks

- Trade-off which is often seen in environmental problems in a short-run may possibly disappear in a long-run.
- This is because production possibility frontier shifts upward, thanks to technical progress, new arrangement of social structure and so on.
- Thus, economic growth and environmental conservation may go together, hand in hand.

The Trade-off may disappear in the long run



Porter hypothesis

- If well-planned environmental regulation is introduced in an economy, efficiency and innovations are induced so that commercial competitiveness can be improved and strengthened. This hypothesis was formulated by the Harvard Univ. professor Michael Porter in 1995, so that it is called Porter Hypothesis. This hypothesis implies that the production frontier could expand thanks to properly planned regulation.

What are pollution damages?

- There are many types of pollution damages; health damages, damages of constructions, amenity loss, damages of eco-systems, and so on.
- Actually, it is very hard to evaluate environmental damages, since we do not know how to give weight to each types of pollution damages.
- Damages are not comparable to each other in many cases.
- Particularly, it is not easy to evaluate pollution damages in pecuniary terms.

The relationship between a residual and damages

- There are two types of damage function: (1) an emission damage function, (2) an ambient damage function.
- The former describes a relationship between the amount of emission and damages.
- The latter describes a relationship between concentration of a certain pollutant and damages.
- Which type of function should be used depends upon what circumstances should be considered.
- Usually, damages are valued by money terms *if possible*.

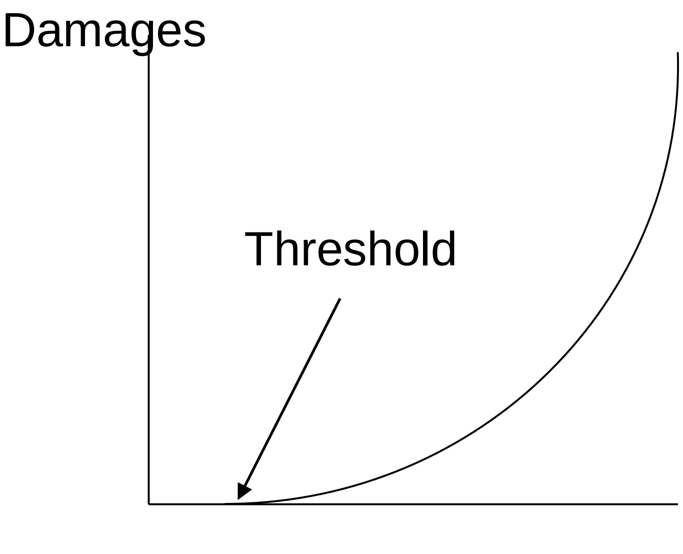
Flow type of pollution vs. stock type of pollution

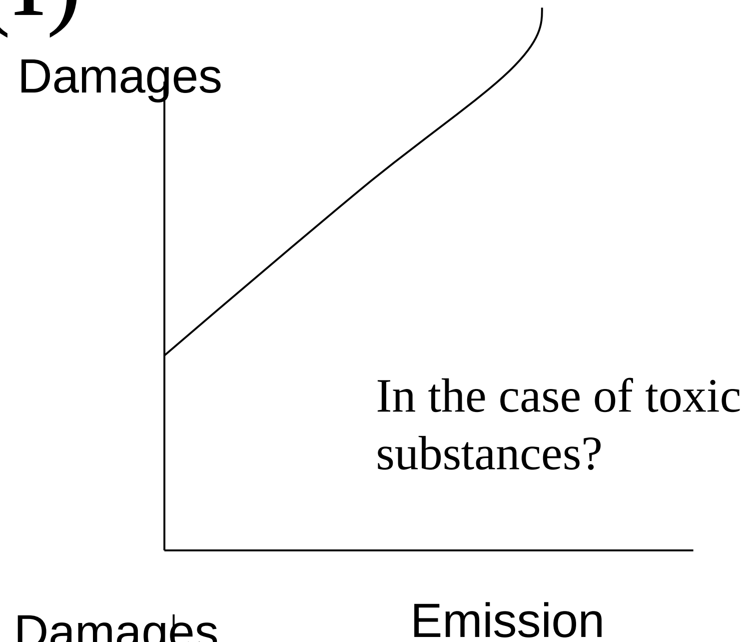
- Flow type of pollution: a source of pollution affects victims directly by discharged substances. Eg., noise pollution, smoke pollution and so on.
- Stock type of pollution: a source of pollution contributes the accumulation of substances, which affects victims. Eg., global warming caused by CO2 concentration and so on.

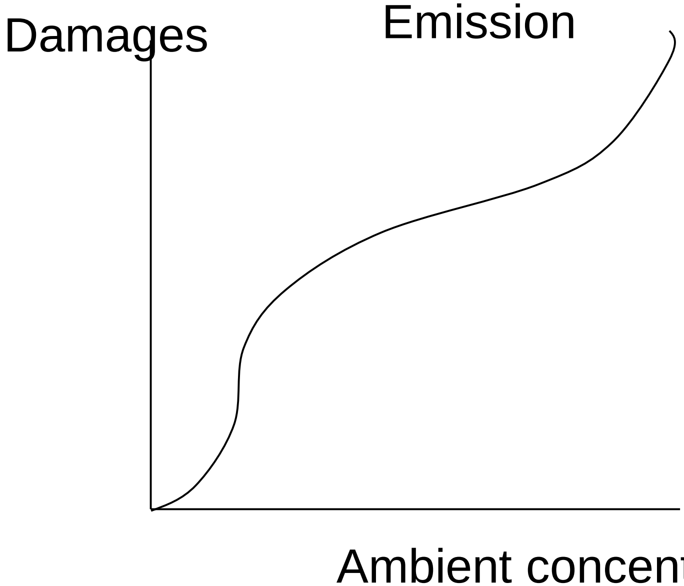
A Remark

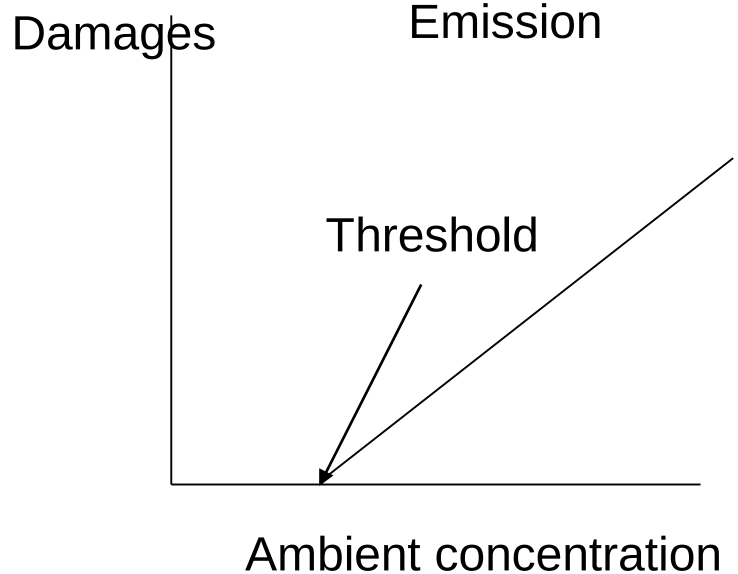
- If we try to analyze a stock type of pollution, we have to take a time structure into account.
- This is because a stock of pollution changes as time goes, and the change of stock affects the pollution level.
- Thus, a dynamic feature must be taken into consideration, and so an analysis becomes much more difficult.

Shapes of marginal damage functions (I)





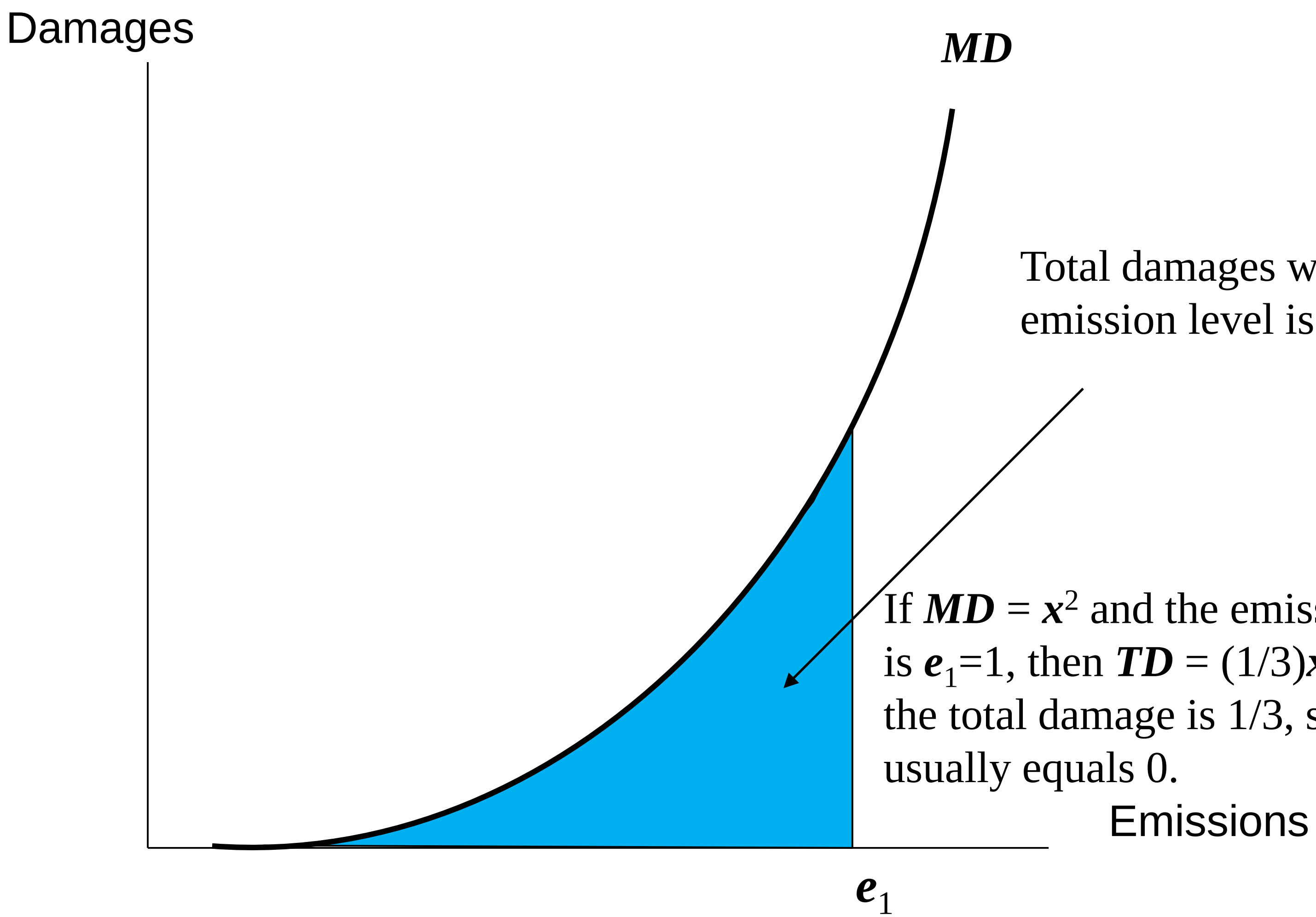




A remark

- Suppose that there is a threshold level of emission or concentration and that damages appear only when the actual emission or concentration goes beyond the level.
- Then, it may possibly be easy to determine the regulation level which prevents damages from appearing by setting the regulation level at the threshold level.

Marginal and total damages (1)



Total damages when the emission level is e_1.

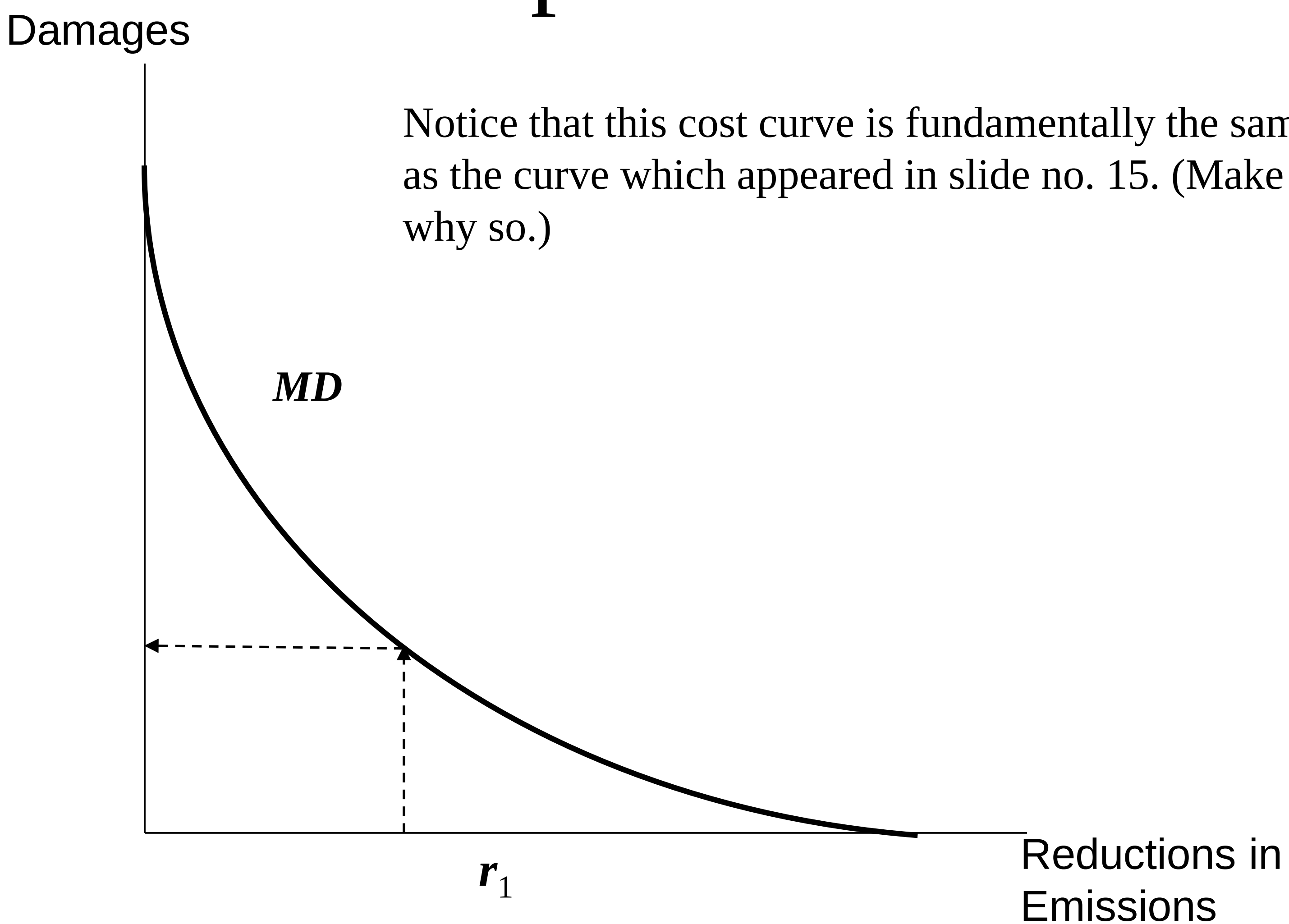
If $MD = x^2$ and the emission level is e_1=1, then $TD = (1/3)x^3 + c$ and the total damage is 1/3, since c usually equals 0.

Marginal and total damages (2)

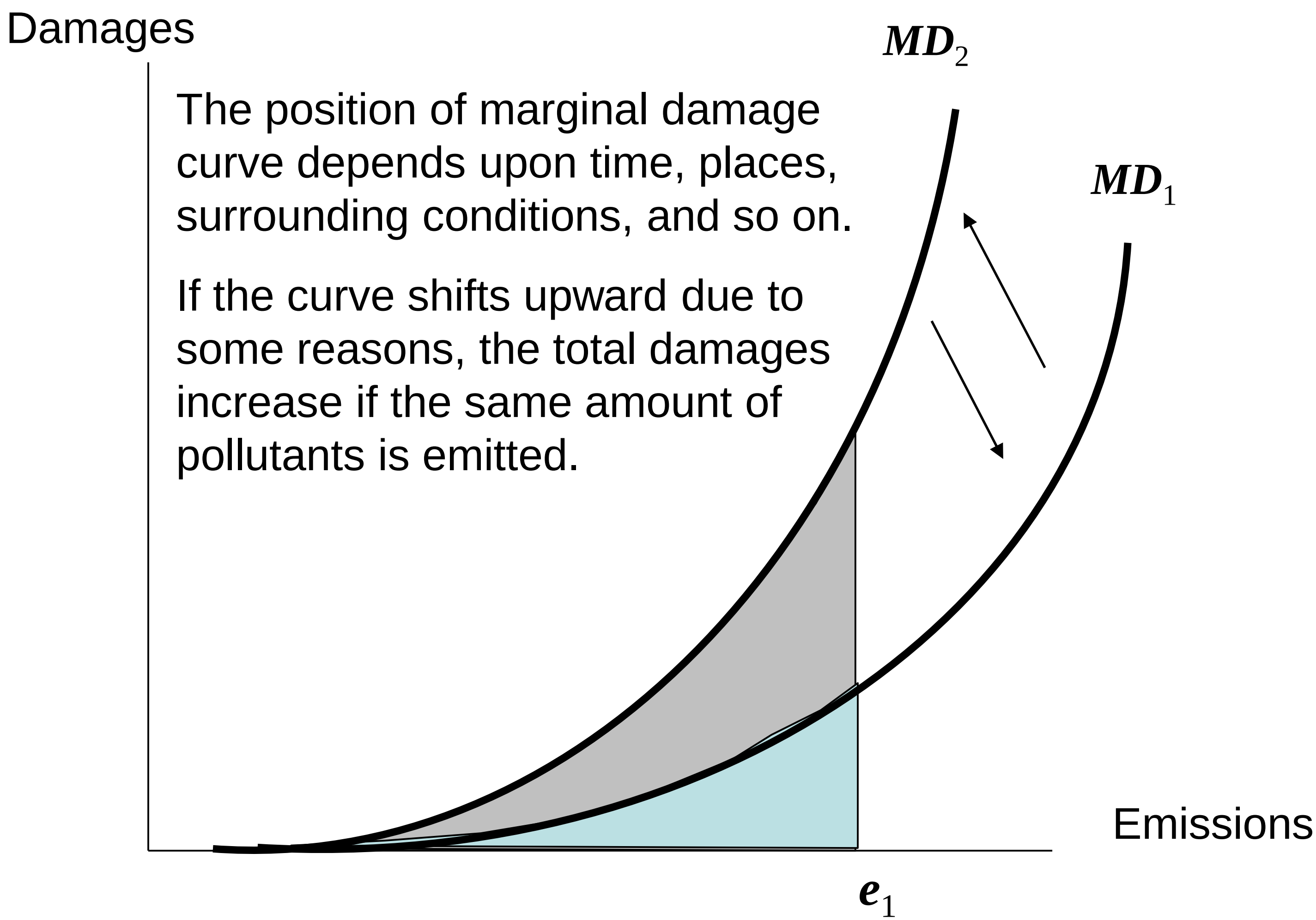
- If a marginal damage curve takes a form in the former slide, damages increase more than proportionately.
- Clearly, there is a cost curve which does not take that shape.

Marginal damage curve; another expression

Notice that this cost curve is fundamentally the same as the curve which appeared in slide no. 15. (Make sure why so.)



Position of a marginal damage curve



Uncertainty, non-measurability and irreversibility

- Uncertainty is often unavoidable for damages caused by pollutions. (*e.g*. global warming.)
- No one knows *exactly* what damages will be caused by pollutions.
- Furthermore, some damages are difficult to measure (*e.g*. loss of scarce plants).
- Things would be complicated due to the fact that some pollution damages are irreversible. (Some damages are reversible.)

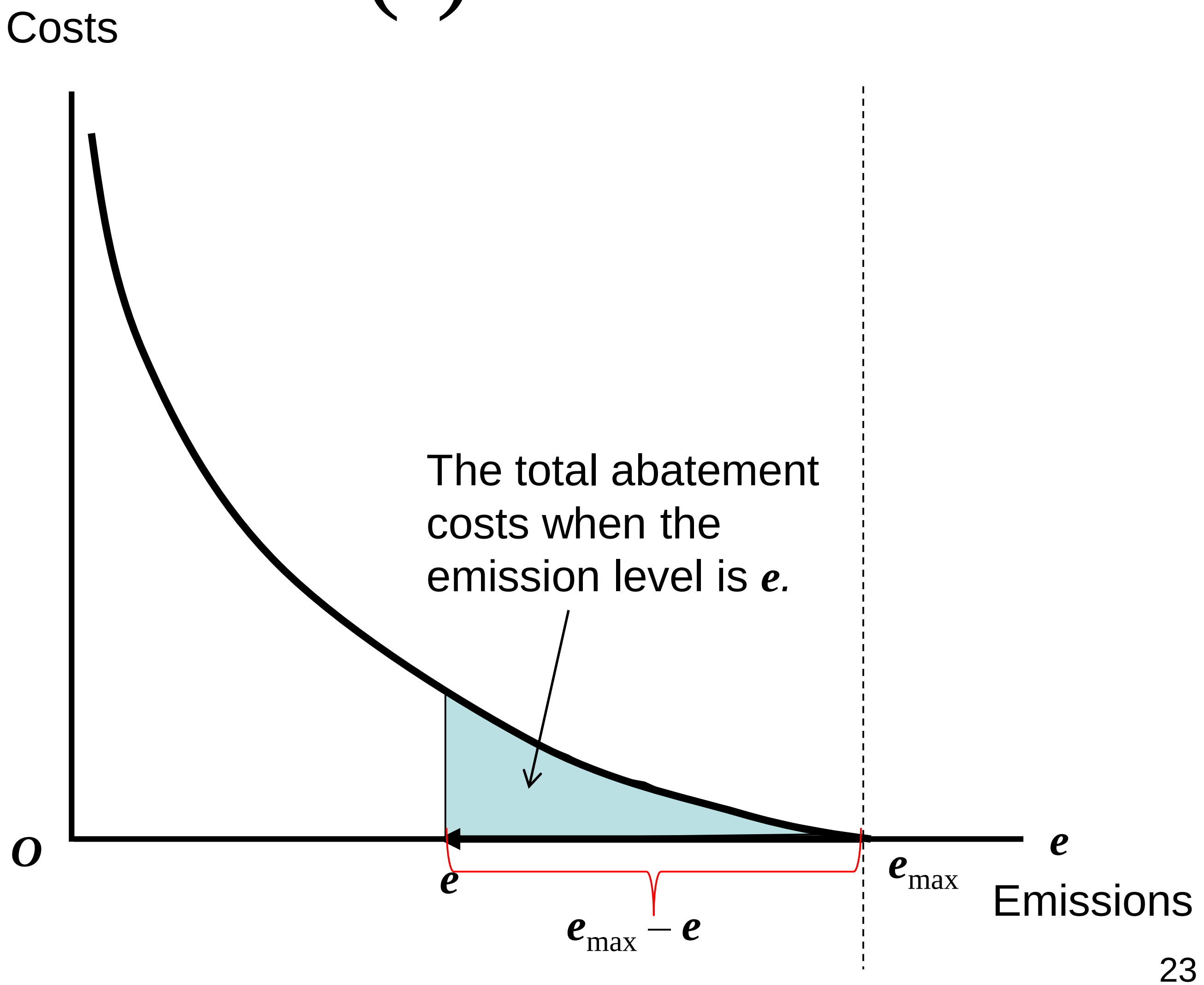
Another type of trade-off: abatement costs

- Abatement costs are costs which are required to cut off the amount of residuals, pollutants and so on.
- Scrubbers are used to reduce the amount of SO_2 emission. Then, the plants can abate SO_2 emission at a *cost* of running scrubber.
- CCS (carbon capture and storage) can fix carbon underground, but at a huge cost, at least now.
- Usually, the concept of marginal abatement costs is used more often than total abatement costs.

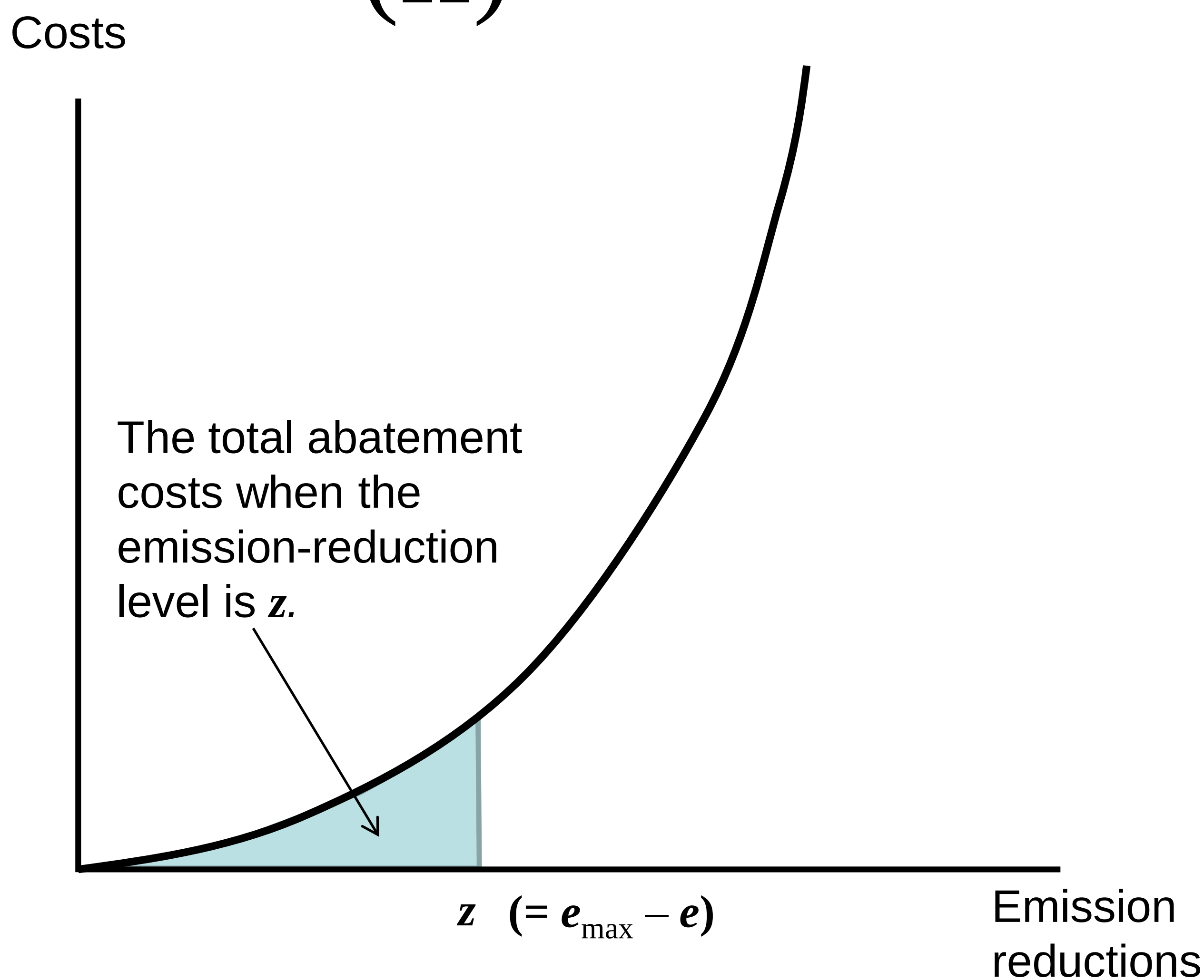
Marginal abatement cost function

- Marginal abatement cost function is expressed as $\boldsymbol{MAC} = \boldsymbol{F}(\boldsymbol{e}_{\max} - \boldsymbol{e})$, where $\boldsymbol{e}_{\max}$ is the maximum amount of emission, and $\boldsymbol{e}$ is the actual amount of emission. Clearly, $(\boldsymbol{e}_{\max} - \boldsymbol{e})$ is the amount of abated residuals or pollutants.
- ***MAC*** is assumed to be an increasing function of $(\boldsymbol{e}_{\max} - \boldsymbol{e})$, or a decreasing function of $\boldsymbol{e}$ (Please do not be confused!)

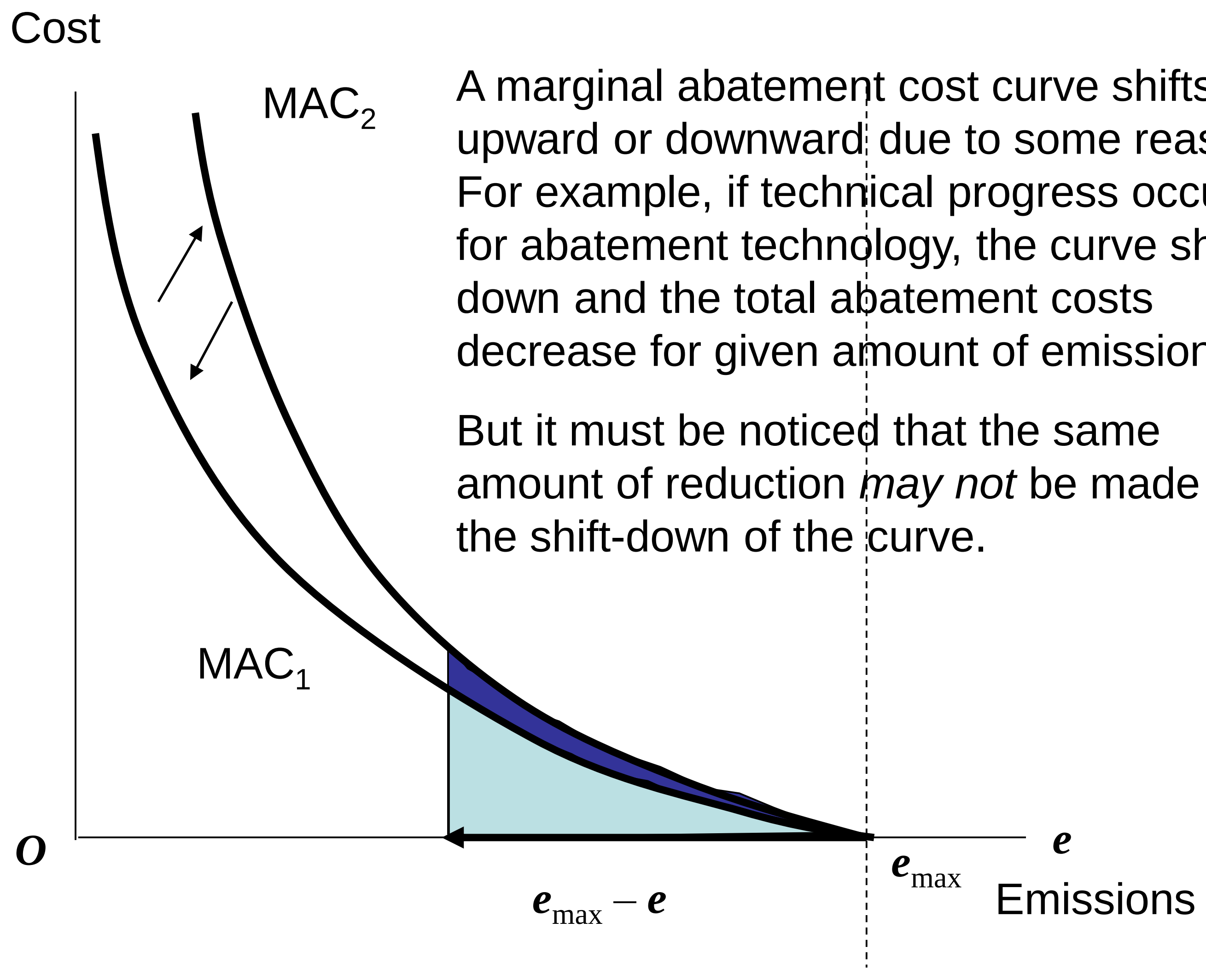
Shapes of abatement cost functions (I)



Shapes of abatement cost functions (II)



Position of a marginal abatement cost curve



A marginal abatement cost curve shifts upward or downward due to some reasons. For example, if technical progress occurs for abatement technology, the curve shifts down and the total abatement costs decrease for given amount of emission.

But it must be noticed that the same amount of reduction *may not* be made after the shift-down of the curve.

Aggregate marginal abatement costs

- Consider there are two plants both of which emit pollutants, and the total amounts of emission is $\boldsymbol{e} = \boldsymbol{e_a} + \boldsymbol{e_b}$.
- Thus, amount of reduction must be allocated to each plant.
- $\mathrm{TAC}(\boldsymbol{e}_{\mathrm{max}} - \boldsymbol{e})$ is obtained by minimizing $\mathrm{TAC}_{\mathrm{a}}(\boldsymbol{e}_{\mathrm{max}} - \boldsymbol{e_a}) + \mathrm{TAC}_{\mathrm{b}}(\boldsymbol{e}_{\mathrm{max}} - \boldsymbol{e_b})$. (We suppose that $\boldsymbol{e}_{\mathrm{max}}$ is the same for the two plants.)
- Minimize $\{\mathrm{TAC}_{\mathrm{a}}(\boldsymbol{e}_{\mathrm{max}} - \boldsymbol{e_a}) + \mathrm{TAC}_{\mathrm{b}}(\boldsymbol{e}_{\mathrm{max}} - \boldsymbol{e_b}) - \lambda (\boldsymbol{e} - \boldsymbol{e_a} - \boldsymbol{e_b}.)\}$

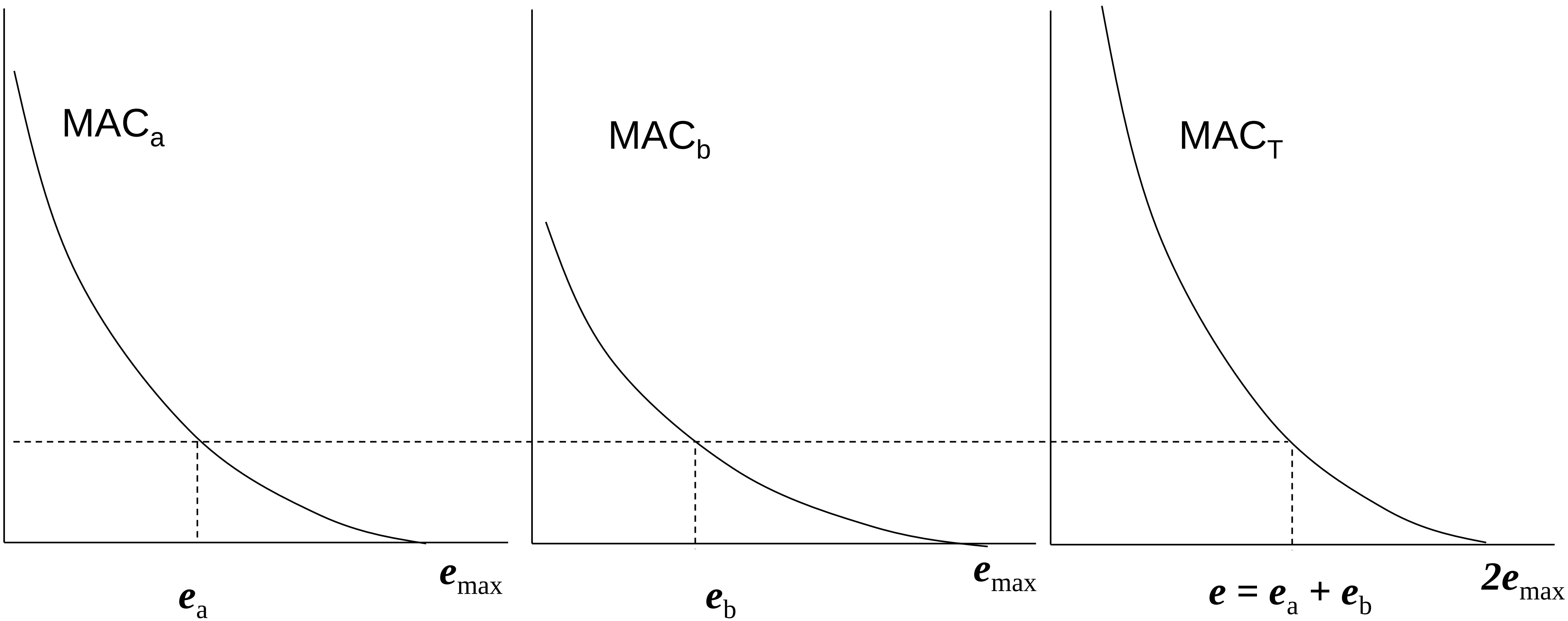
Equi-marginal principle holds again!

- Solving the above, we have $MAC_a(\boldsymbol{e}_{max} - \boldsymbol{e_a}) = MAC_b(\boldsymbol{e}_{max} - \boldsymbol{e_b}) = \lambda$.
- This means the *equi-marginal principle*, which we have already learned.
- $MAC(\boldsymbol{e}_{max} - \boldsymbol{e}) = MAC_a(\boldsymbol{e}_{max} - \boldsymbol{e_a}) = MAC_b(\boldsymbol{e}_{max} - \boldsymbol{e_b})$ where $\boldsymbol{e} = \boldsymbol{e_a} + \boldsymbol{e_b}$.
- This is a very important result, and must be understood clearly.

Aggregate marginal abatement function

- From $\boldsymbol{e} = \boldsymbol{e_a} + \boldsymbol{e_b}$ and $\mathrm{MAC_a}(\boldsymbol{e}_{\max} - \boldsymbol{e_a}) = \mathrm{MAC_b}(\boldsymbol{e}_{\max} - \boldsymbol{e_b}) = \lambda$, we can get a vector $(\boldsymbol{e_a}, \boldsymbol{e_b})$ for given $\boldsymbol{e}$.
- Then, we have a relationship between $\boldsymbol{e}$ and $(\boldsymbol{e_a}, \boldsymbol{e_b})$.
- This means that we have a relationship between $\boldsymbol{e}$ and $\mathrm{MAC}\,(\boldsymbol{e}_{\max} - \boldsymbol{e})$, which equals $\mathrm{MAC_a}(\boldsymbol{e}_{\max} - \boldsymbol{e_a}) = \mathrm{MAC_b}(\boldsymbol{e}_{\max} - \boldsymbol{e_b})$.
- This is nothing but aggregate marginal abatement function.

Explanation by means of a figure



Summary: How to deduce TAC and MAC.

- From the equi-marginal principle and $\boldsymbol{e} = \boldsymbol{e_a} + \boldsymbol{e_b}$, we have the relationship $\boldsymbol{e} \longrightarrow (\boldsymbol{e_a}, \boldsymbol{e_b})$.
- Then, we can define TAC = $\mathrm{TAC_a}\,(\boldsymbol{z_a}) + \mathrm{TAC_b}\,(\boldsymbol{z_b})$ ($\boldsymbol{i} = \boldsymbol{a}, \boldsymbol{b}$) and differentiate it.

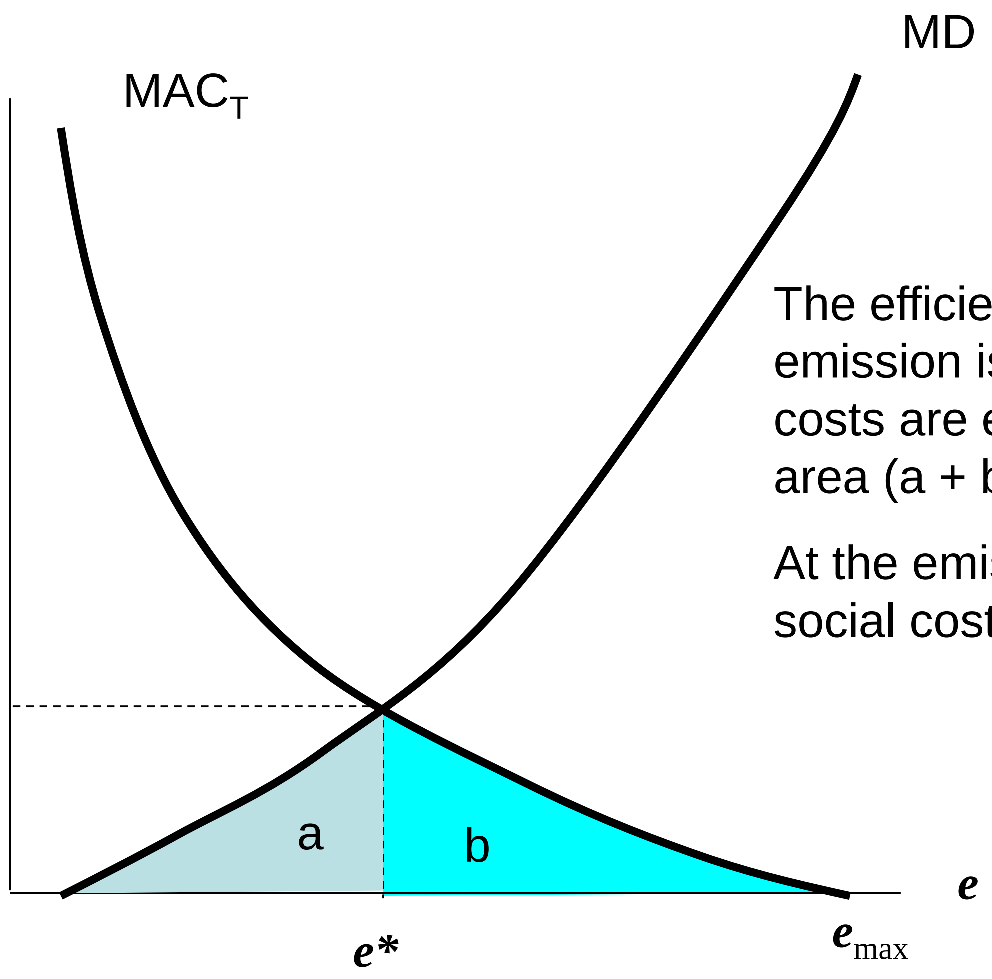
(= – 1)

- MAC = $\mathrm{MAC_a}\,(\mathrm{d}\,\boldsymbol{z_a} / \boldsymbol{e_a})\,\{\mathrm{d}\boldsymbol{e_a}/\mathrm{d}(\boldsymbol{e}_{\max} - \boldsymbol{e})\} + \mathrm{MAC_b}\,(\mathrm{d}\boldsymbol{z_b} / \boldsymbol{e_b})\,(\mathrm{d}\boldsymbol{e_b}/\mathrm{d}(\boldsymbol{e}_{\max} - \boldsymbol{e})\}) = \lambda\,(-1)\,\{\mathrm{d}\,(\boldsymbol{e_a} + \boldsymbol{e_b})/\mathrm{d}(\boldsymbol{e}_{\max} - \boldsymbol{e})\} = \lambda$.
- Notice that $\boldsymbol{z_i} = \boldsymbol{e}_{\max} - \boldsymbol{e_i}$ **($\boldsymbol{i} = \boldsymbol{a}, \boldsymbol{b}$).**

The socially desirable level of emissions: an efficiency criterion

- The social costs of pollution damages and abatement costs are expressed by the addition of the two types of costs.
- Then, the socially desirable level of emissions is determined by the cost minimization if an efficiency criterion is adopted.
- Minimize TD($\boldsymbol{e}$) + TAC ($\boldsymbol{e}_{\max} - \boldsymbol{e}$) .
- Then, MD($\boldsymbol{e}$) = MAC_T ($\boldsymbol{e}_{\max} - \boldsymbol{e}$) is obtained.

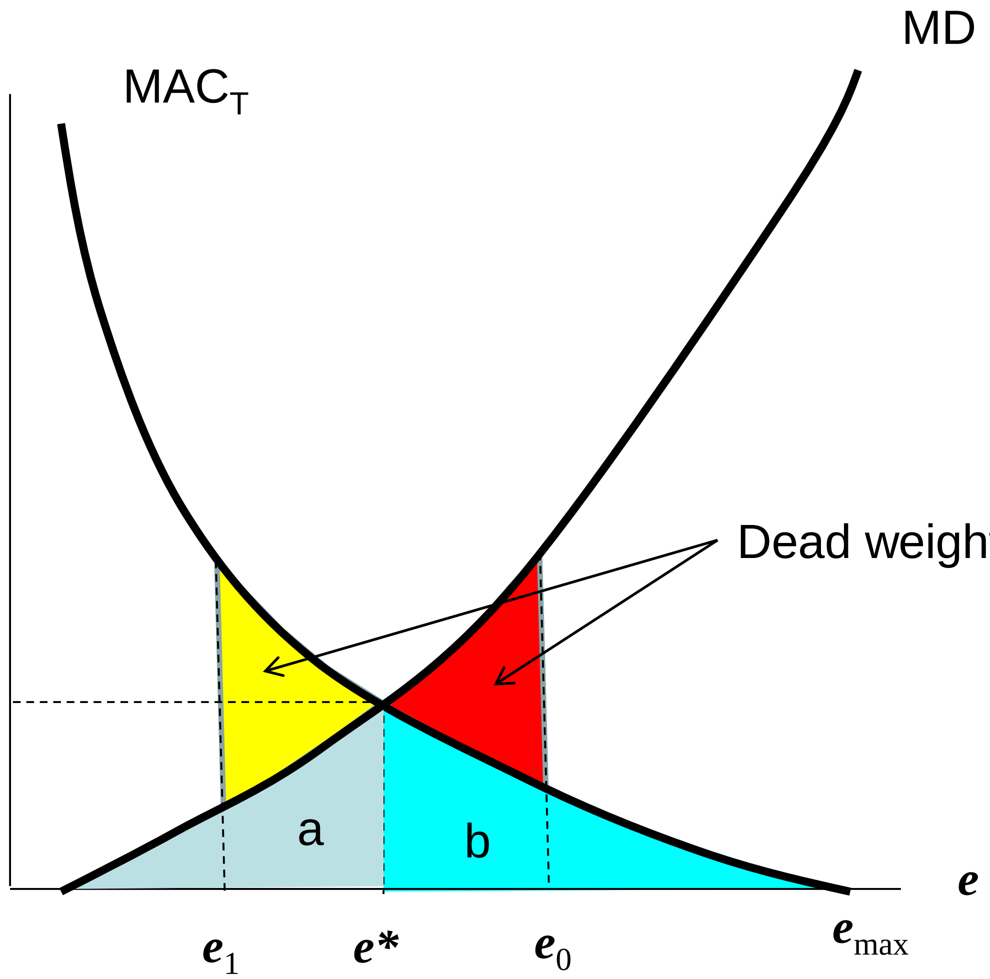
Explanation by means of a figure



The efficient level of the emission is ***e****, and the social costs are expressed by the area (a + b).

At the emission level ***e****, the social costs are minimized.

What if *e* which does not equal *e** is emitted?



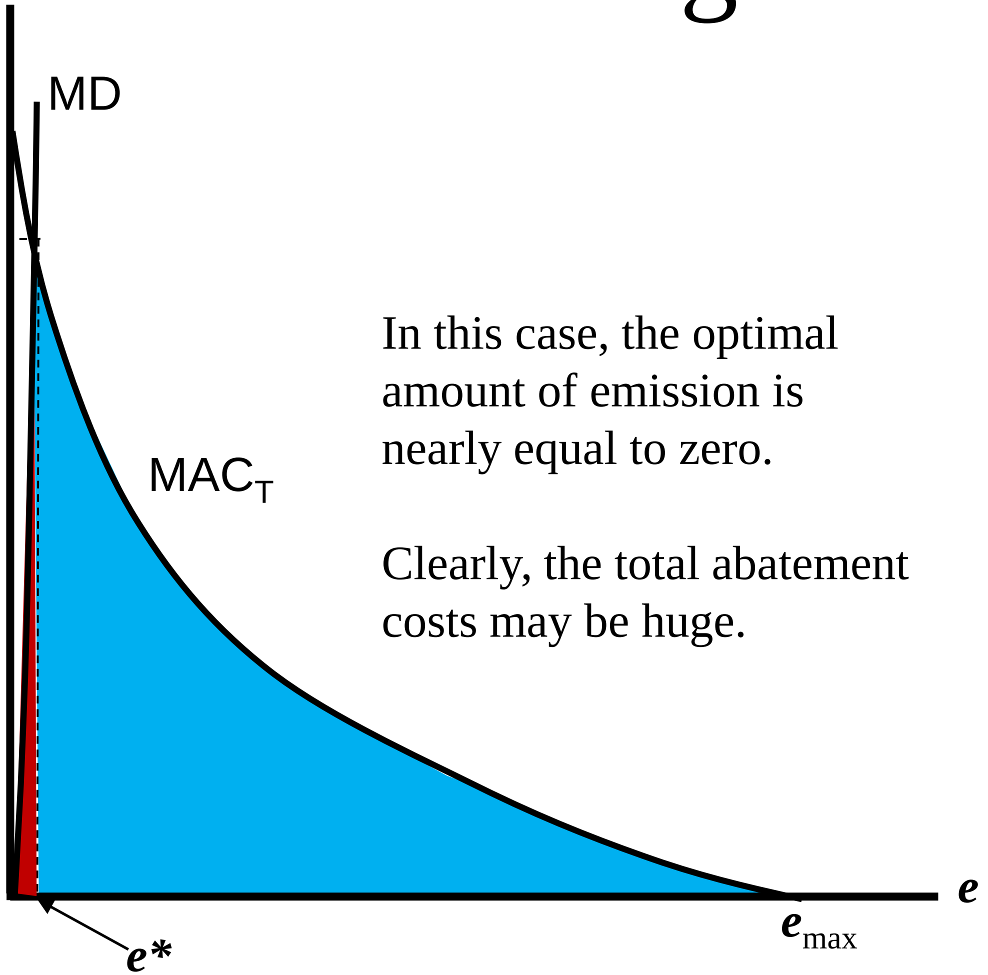
Some remarks

- The socially desirable or efficient level of emissions are basically *defined* by the social cost minimization.
- The socially desirable or efficient level of emissions is not attained in a market economy where no environmental concern is reflected in actors’ behavior in a market.
- We must distinguish between a *positive analysis* (an analysis of what is) and a *normative analysis* (an analysis of what ought to be).

Some remarks (cont.)

- The socially optimal solution does not necessarily mean so-called zero emission of pollution.
- This is because that zero emission implies too costly reduction of pollution, and is not optimal from a viewpoint of social welfare.
- For very toxic substances, zero emission is possible as an socially optimal solution.

Zero emission: Explanation by means of a figure



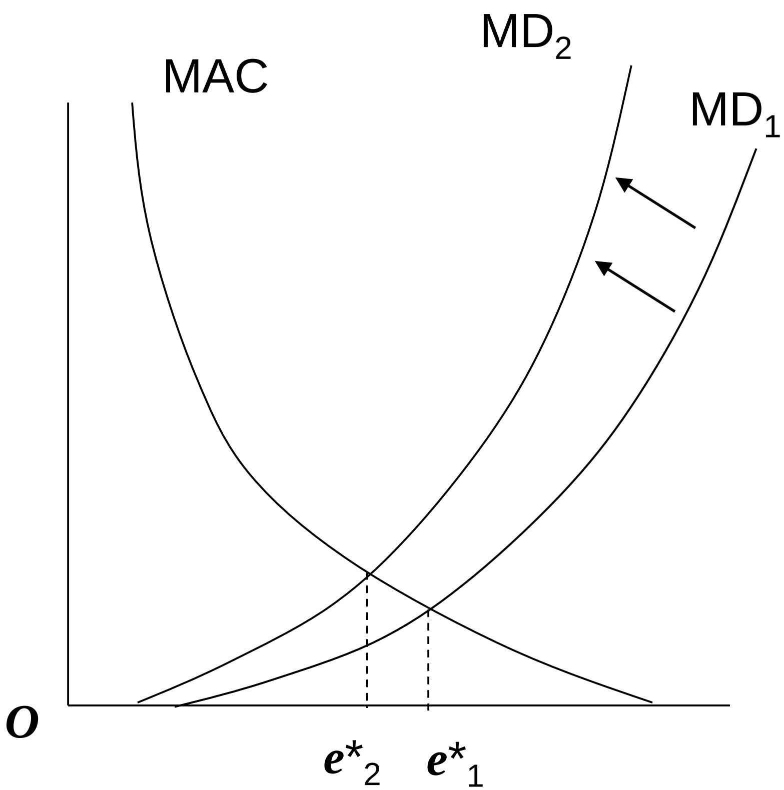
In this case, the optimal amount of emission is nearly equal to zero.

Clearly, the total abatement costs may be huge.

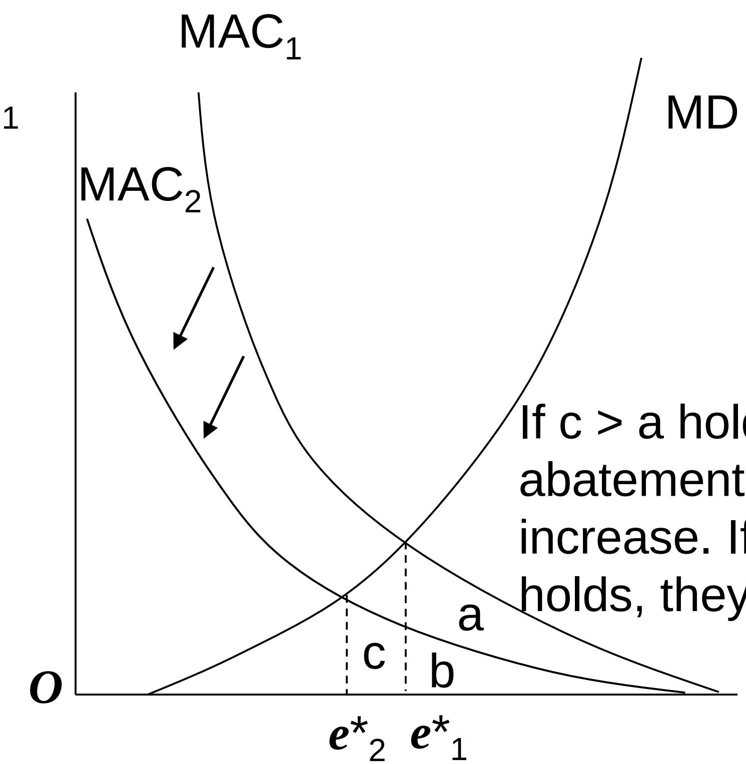
Change of circumstances and shift of curves

- If there is a change in circumstances which affects marginal damage curves or marginal abatement curves, the socially desirable or efficient level of emissions will change.
- If a marginal damage curve shifts upward owing to deterioration of the surrounding conditions, the social costs will increase.
- If a technical progress occurs in abatement technology, causing shift-down of a marginal abatement cost curve, the social costs will decrease.

Explanation by means of figures



If a marginal damage curve shifts upward, the socially desirable or efficient level of emissions decreases, and the social costs increase.



If c > a holds, the abatement costs increase. If c < a holds, they decrease.

If a marginal abatement cost curve shifts downward, the socially desirable or efficient level of emissions decreases, and the social costs also decrease.

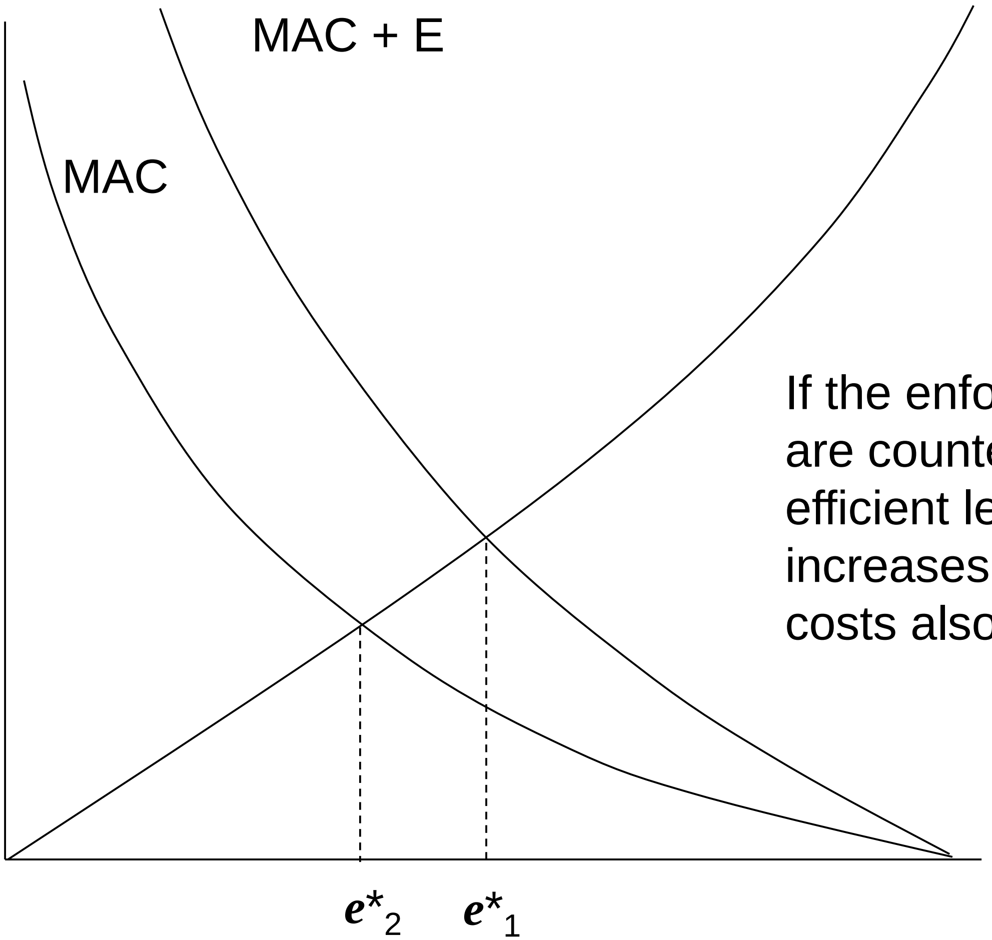
An incentive of technical progress

- If $c > a$ holds in the former figure, the abatement costs increase even though the social costs decrease.
- The efficient level of emission after the technical progress requires more abatement costs.
- Then, the firm may not have incentives to pursue the technical progress for abatement technology.

Enforcement costs

- To implement pollution preventing activities, part of resources must be allocated to the enforcement activity.
- This expense must be counted as costs, in addition to the abatement costs.
- Thus, the abatement costs in a broad sense increase, and marginal abatement cost curve shifts up.

Explanation by means of a figure



If the enforcement costs are counted, the socially efficient level of emissions increases, and the social costs also increase.