ENVIRONMENTAL ECONOMICS

Pollution Control

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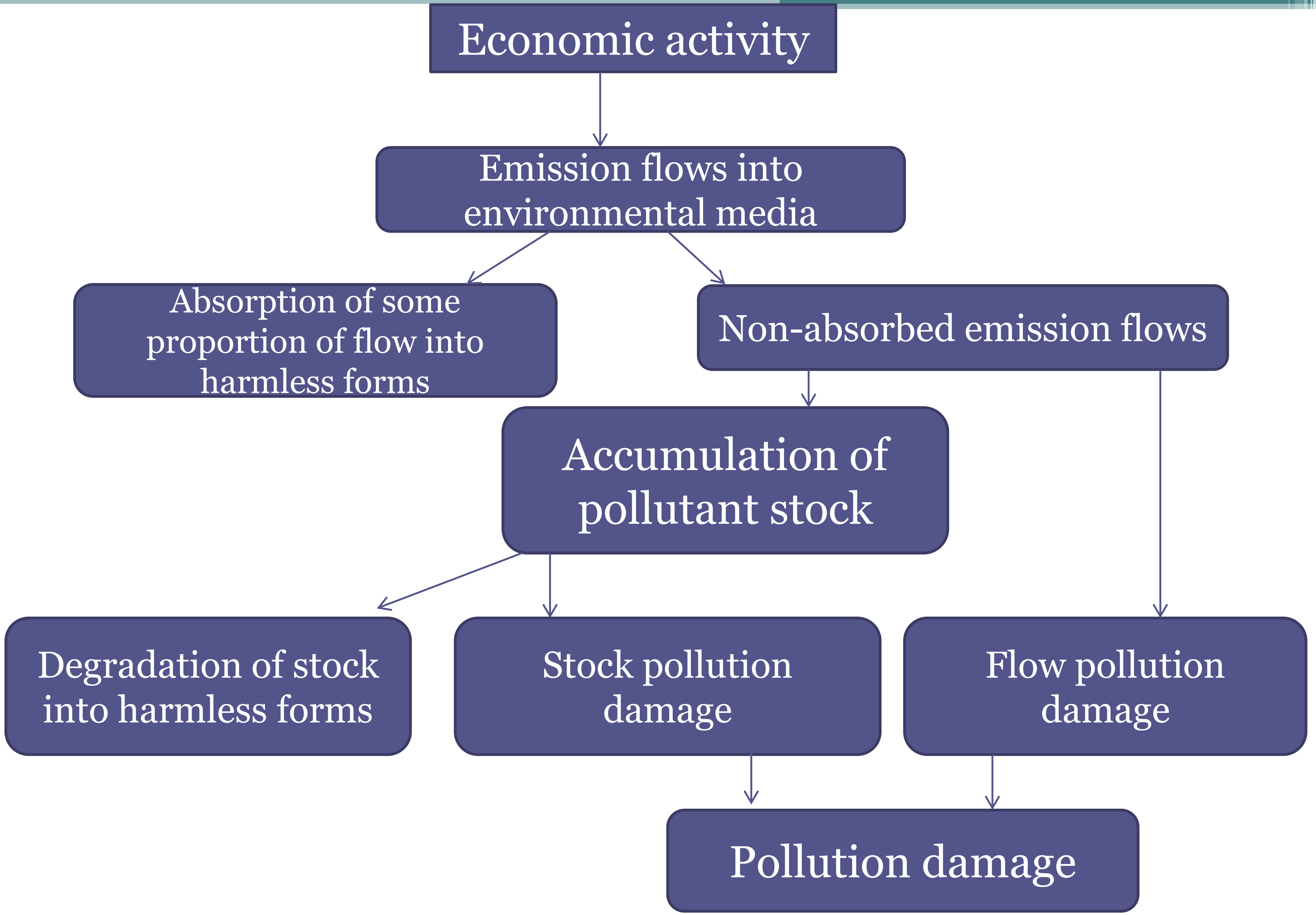
What is Pollution?

- ✓ Those residual flows, arising from human behaviour that enter environmental systems
- ✓ Not all of the mass of inputs is combined into useful output; some of the input is converted into unwanted or residual outputs.
- ✓ Pollution through materials balance model


Economic activity
Emission flows into environmental media
Absorption of some proportion of flow into harmless forms
Non-absorbed emission flows
Accumulation of pollutant stock
Degradation of stock into harmless forms
Stock pollution damage
Flow pollution damage
Pollution damage

What is Pollution? -two more things

- ✓ Pollution flows may not exist as material wastes from economic activities (they may not be residual)
  - ✓ Noise due to open-air orchestra
  - ✓ Light pollution from urban lighting
- ✓ Economist is ultimately interested in the impacts of production and consumption processes upon welfare
- ✓ Thus, pollution may be defined as the net flows- those exceeding the absorptive capacity of the environment and which have damaging effects on human welfare or upon ecological system in general

What is Pollution? –depletion of quantity and quality

- ✓ Sometimes, pollution affects the quantity of an environmental resource
  - ✓ Magnitude of plant and timber growth,
  - ✓ Size of marine population,
- ✓ Quantity of cleaning capacity of the environment is affected by quantity of waste emissions

What is Pollution? –depletion of quantity and quality

- ✓ Pollution affects the quality of an environmental resource
    - ✓ Extent of biological diversity, the health of animal or plant population, air quality, etc.

- ✓ Changes in the quality of environmental resources may have effects upon welfare even more profound than changes in the quantity

    - ✓ Health damage due to air pollution

Forms of Pollution

- ✓ Flow pollution
  - ✓ When damages result from the level of flow of residuals (i.e. the rate at which they are discharged into the environment)
  - ✓ Noise

- ✓ Stock pollution
  - ✓ When damages are functions of the stock of the residuals in the relevant environment at any point in time.
  - ✓ Emissions are produced at a rate higher than the absorptive capacity (lead, pcbs, ddt, etc.)
- ✓ Also from a mixture of flow and stock effects

Forms of Pollution

- Horizontal Zone of Influence:
  - Local (sound, light, etc.), regional (sulphur and nitrogen oxides) and global pollution damage

- Degree of atmospheric mix of pollutants:
  - Surface pollutant (water pollution) and global pollutant damage (in the upper atmospheric levels, e.g. CO2, CFC, etc.)

- Mobility of emission sources:
  - Stationary (power stations, pesticide use in agriculture) and mobile source of pollution (vehicle traffic pollution)

The efficient level of Pollution

- ✓ Efficiency in terms of Pareto efficiency
- ✓ Society's costs or damages of pollution and the social cost of controlling or abating pollution are to be considered
- ✓ Environmental damage- cost (should be as low as possible)
- ✓ Production or consumption of goods and services are associated with generation of residuals
- ✓ Output should be as high as possible
- ✓ An efficient output level would be one that maximises the net output (pollution)

  Net benefit of pollution (NB)= Benefit of the output with which the pollution is associated (B) - Damages resulting from pollution (D)

Regulating Pollution

Rationale for Regulation:

- Economic Regulation: refers to government intervention in private actions of firms and individuals.

- Two theories of regulation:

  Public Interest Theory and Interest Group Theory

  Public Interest Theory: main purpose of regulation is the promotion of public interest.

Rationale for Regulation:

Interest Group Theory: main purpose of regulation is the promotion of narrow interest of particular groups in a society such as individual industries.

Major point of distinction between these two approaches is:

Public Interest Theory is the normative Theory (which seeks to explain what should happen in an ideal world) while the Interest Group Theory is the positive theory (which seeks to explain why the world works as it does)

Regulating Pollution

Under Public Interest Theory three general reasons justify for government regulation:

a. Imperfect competition
b. Imperfect information
c. Externalities

Imperfect Competition or Natural Monopoly:

Role of the government, in the presence of natural monopoly, is to control prices in order to protect the consumers and prevent collusion and restrict mergers that may create excessive market power in the hands of the monopolists.

Regulating Pollution

Imperfect Information:

Here the role is to establish a set of liability rules to encourage the provision of safety-related quality.

Direct intervention in the market specifying acceptable levels of quality.

Regulating Pollution

Externalities:

Main problem is with the provision of public goods and bads because private provision of these goods (with the element of publicness: non-rivalry and non-excludability) is inefficient.

In the case of public bads, the usual approach is for government to define a set of institutions and regulation to govern provision of these public bads, e.g., the government establishes a set of regulations to restrict the production of pollution.

Regulating Pollution

Externalities:

Interest Group Theory of regulation maintains that rent-seeking is the primary rationale for regulation.

Rent-seeking:

It involves private individuals or firms using the government to guarantee extra profits (rent) through government mandated restrictions on economic activity.

Regulating Pollution

A Political Economy Model of Regulation:

The basic problem of environmental regulation involves the government trying to induce a polluter to take socially desirable actions, which ostensibly are not in the best interest of the polluter.

The main problem, therefore, is determination of exact level of pollution which is best for the society.

In reality the government faces pressures from consumers and polluters.

Figure 1 presents a highly stylized schematic diagram of the interactions among government, polluting firms and consumer citizens.

Regulating Pollution

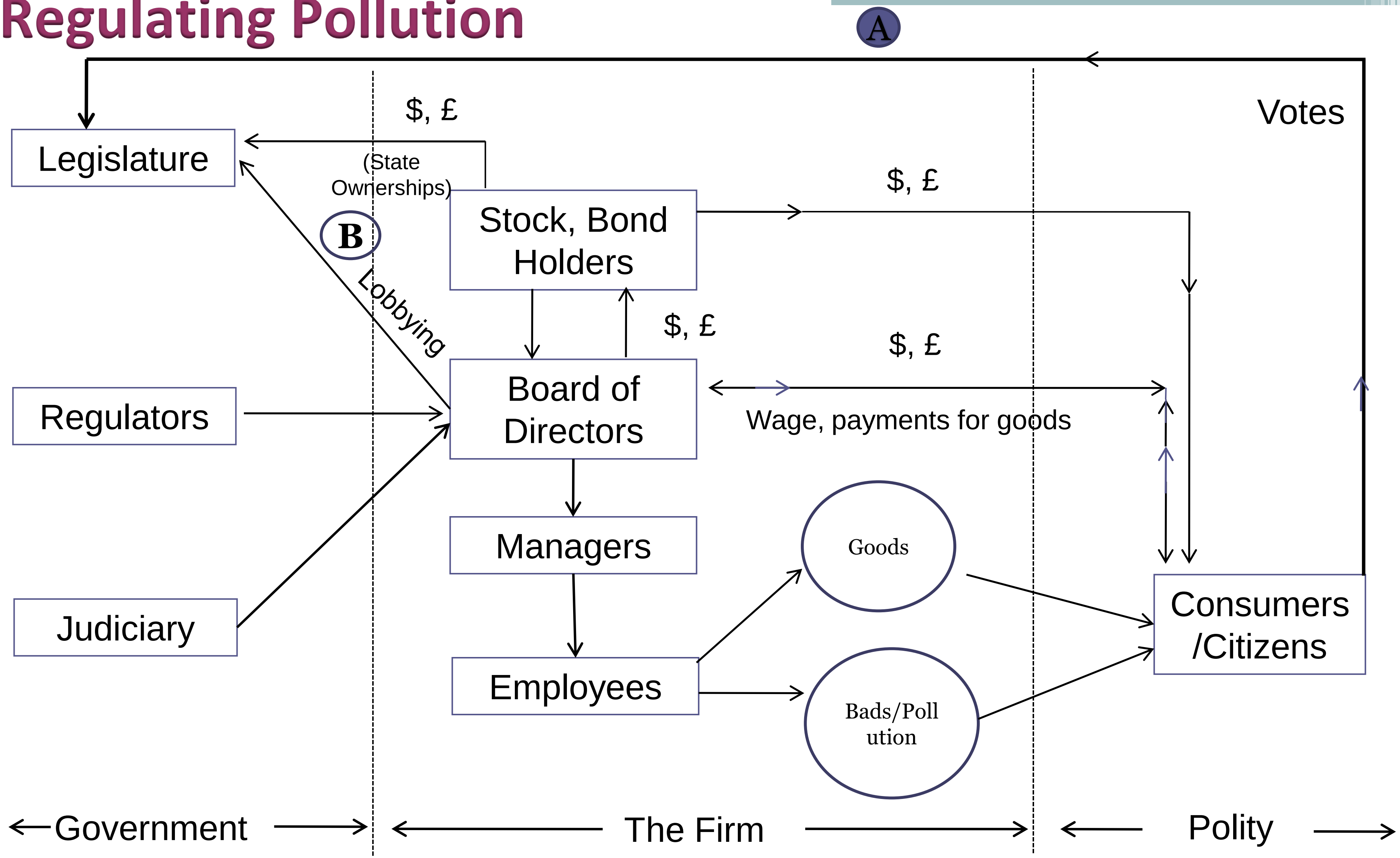


Figure 1

Regulating Pollution

The Government as shown in figure 1, consists of three branches: the Legislature, the Judiciary and the Regulators

Legislature passes laws defining what the regulators are to do in controlling pollution.

Regulators are charged with the responsibility of implementing the legislature's laws

Judiciary: the actions of the regulators are tempered by the judiciary.

Regulating Pollution

The firm consists of several pieces:

the Board of Directors, Managers, Employees, Stock and Bond Holders.

The Board issues directives to the managers; the managers issue directives to employees who produce the product of the firm as well as pollution.

The key point is that regulators direct the Board to take certain actions, but the Board is removed, by several steps, from the employees who actually generate the pollution.

Regulating Pollution

There arises Principal-agent problem due to inability of the regulator (the principal) to completely control the polluter (the agent).

The firm may not be a passive entity but may in fact influence legislation, through lobbying or financial incentives (shown by the line B)

The third component of the figure, the consumers direct votes and other influence to the legislature (line A) while at the same time sending money to the firm in exchange for the goods consumed.

Regulating Pollution

Two important lessons can be drawn from the figure:

1. There are many imperfect links between the legislature and the pollution generating process.

2. The legislation does not necessarily act as an efficient benevolent maximizer of social well being.

Regulating Pollution

- Inclusion of Line B: indicates regulation with endogenous politics.
- Omission of Line B indicates regulation with exogenous politics.
- Positive interest group theory is consistent with endogenous politics model of regulation
- Environmental regulation is susceptible to interest group theory

Basic Regulatory Framework: Command and Control

A. **Command and Control**:

Under this method the regulator specifies the steps that individual polluters must take to solve a pollution problem.

The essence of this method is:

1. The regulator collects the information necessary to decide the physical actions to control pollution

2. The regulator then commands the polluter to take specific physical steps to control the pollution.

Basic Regulatory Framework: Command and Control

Command and Control can take several forms.

1. The specific pollution control equipments requirement can be specified or alternatively the regulation may specify an emission limit for particular types of plants and particular pollutants.

2. Command and Control may be combined with significant fines and penalties associated with non-compliance. This, however, differs from the economic incentives to abate pollution on two salient points.

Basic Regulatory Framework: Command and Control

2.a. Restricted choice for the polluters as to what means will be used to achieve an appropriate environmental target

2.b. A lack of mechanism for equalizing marginal control costs among several different polluters.

3. The best analogy for Command and Control is the system of central planning (existed in the former Soviet Union).

However major problem of this is the enormous requirement of information.

Basic Regulatory Framework: Command and Control

Advantages:

a. More flexibility in regulating complex environmental process and much greater certainty in how much pollution will result from regulations.

b. It simplifies monitoring of compliance with a regulation.

Basic Regulatory Framework: Command and Control

Disadvantages:

a. The regulatory system may be very costly to administer as informational costs are high.

b. It may reduce incentives to find better ways to control pollution

c. Difficulty in satisfying the equi-marginal principle, i.e. it is almost impossible for command and control regulations to ensure that the marginal costs of pollution are equalized among different polluters generating the same pollution.

d. Finally, the greatest problem with the Command and Control principle is that the polluter pays only for pollution control, not residual damage form the pollution that is still emitted even after controls are in place

Basic Regulatory Framework: Economic Incentives

Economic incentives provide rewards for polluters to do what is perceived to be in the public interest.

Three basic types of economic incentives include: fees, marketable permits and liability.

Fees:

Fees involve the payment of charge per unit of pollution emitted. When a polluter must pay for every unit of pollution emitted, it becomes in the polluter’s interest to reduce emission.

Basic Regulatory Framework: Economic Incentives

Marketable Permit:

A marketable permit allows polluter to buy and sell the right to pollute.

Trading induces a price or value on a permit to pollute, thus, causing firms to see polluting as an expensive activity.

Less pollution means fewer permits need be bought. Similarly, there is an opportunity cost of emitting, i.e. by not emitting the firm can sell more permits.

A graphical illustration of the marketable permit is shown in figure 2.

Basic Regulatory Framework: Economic Incentives

Marketable Permit:

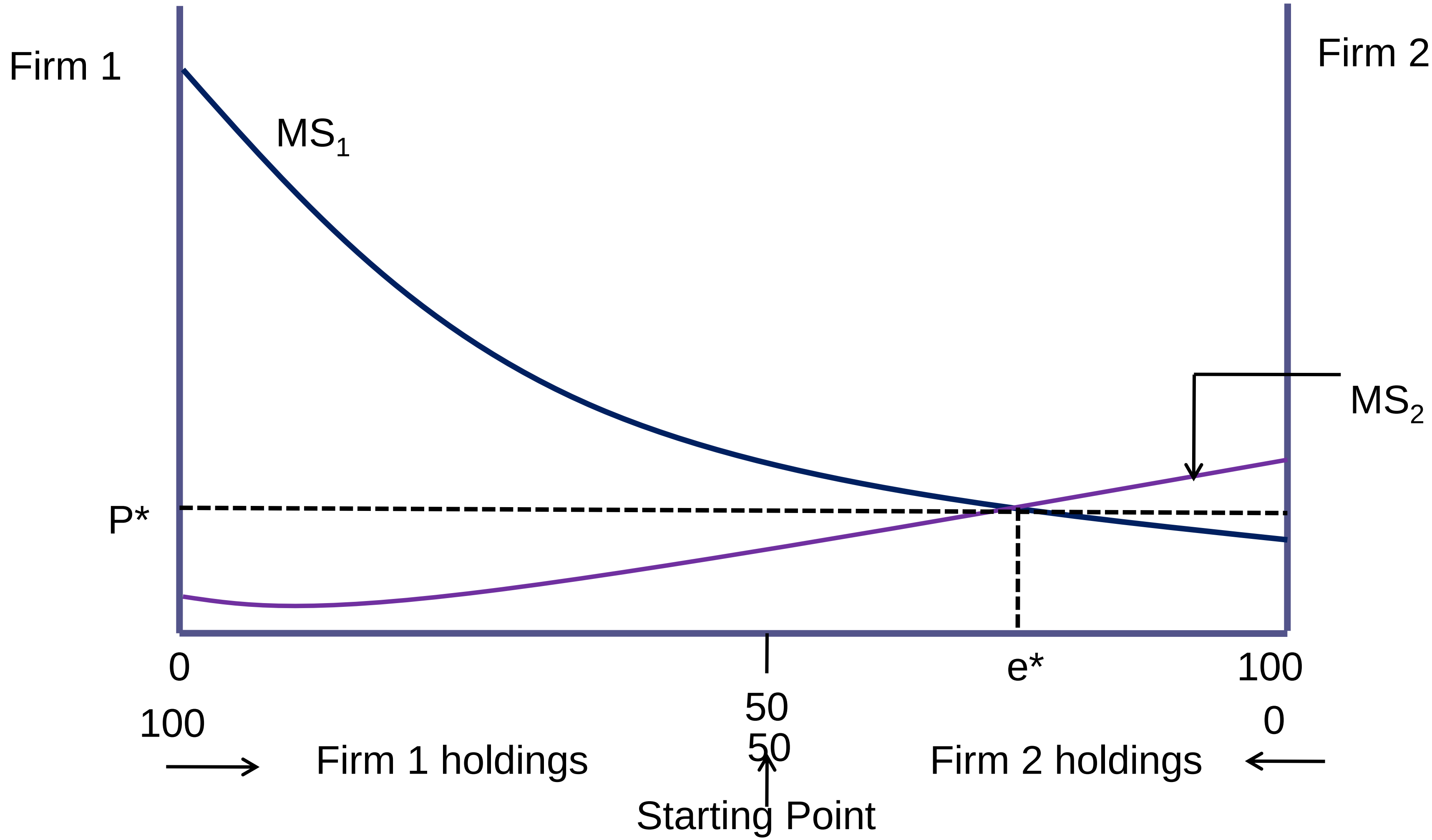
Assume a situation where two polluters exist and we are interested in allowing 100 units of pollution in total.

Let’s start by giving each firm 50 permits.

The equilibrium price of permit is p*.

Basic Regulatory Framework: Economic Incentives

Figure 2: Marginal savings from polluting functions for two firms. MS1, Marginal savings from emitting, firm 1; MS2 Marginal savings from emitting, firm 2; e*, equilibrium holding of permits; p*, equilibrium price of permits.



Basic Regulatory Framework: Economic Incentives

Liability: The basic idea is that if you harm someone, you must compensate that person for damage.

Let us take an example of Hazardous waste storage facility (‘dump’). The dump can do things to minimize the risk of hazardous wastes leaking in to the environment through ‘Precaution’. (i.e. if the dump takes a great deal of precaution the risk of a leak will be low).

But precaution is expensive and *ceteris paribus*, the dump would prefer to take little precaution. Damage to society also depends upon the level of precaution. (this is illustrated in Figure 2).

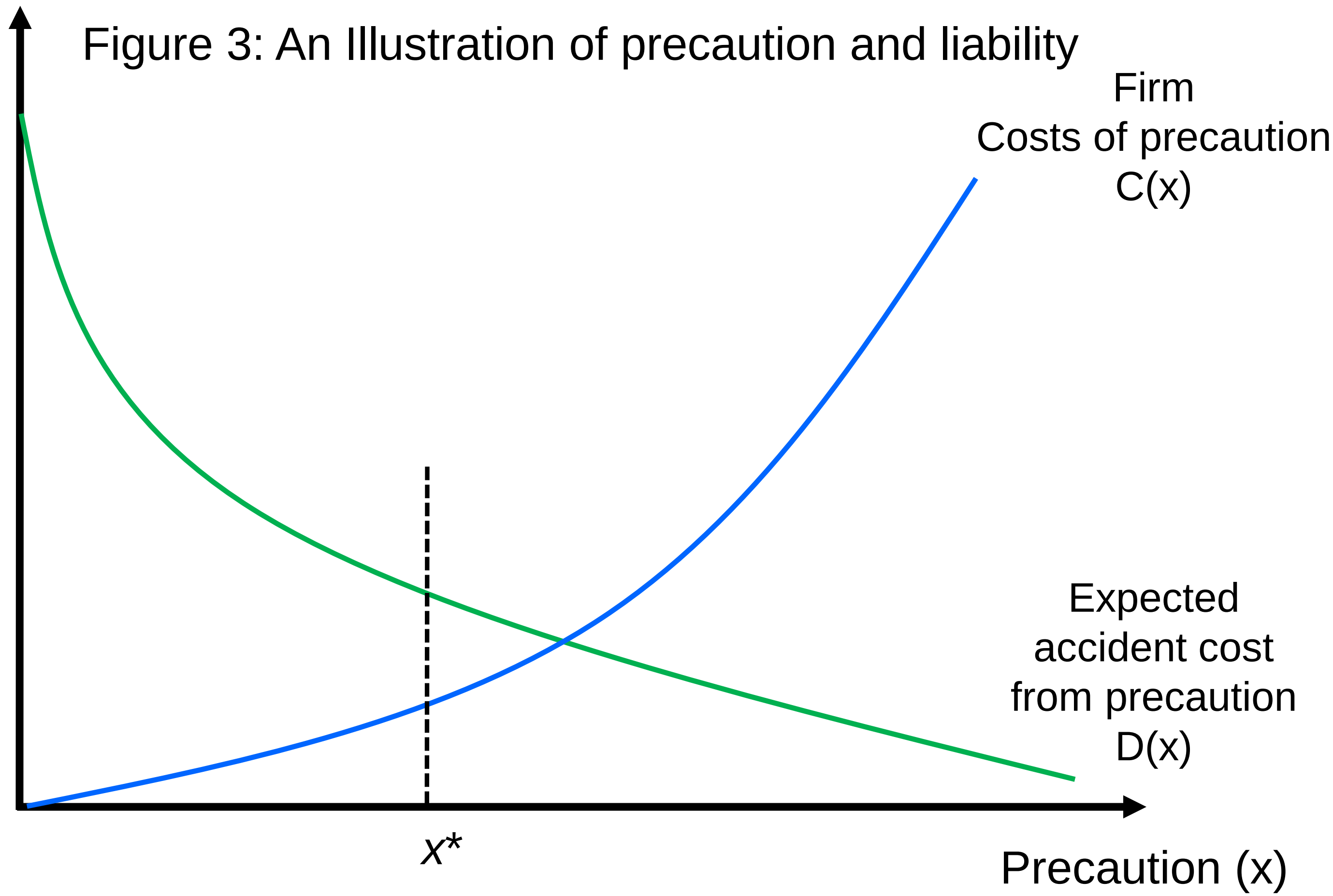
Basic Regulatory Framework: Economic Incentives

Liability:

In figure 2, both costs to dump and damage to society are shown as functions of the level of precaution. The socially desirable level of precaution is x^*, at which the marginal costs of taking more precaution are just offset by the reduction in marginal damage from taking more precaution.

Here, negligence liability works in the sense that the threat of being held responsible from accident damages is often a sufficient incentives for firms to take the socially desirable amount of precaution.

Basic Regulatory Framework: Economic Incentives



MC (x^*) = - MD (x^*)

Basic Regulatory Framework: Economic Incentives

Advantages:

- Informational requirements are less significant
- Economic incentives provide an incentive for a polluter to innovate, finding cheaper ways of controlling pollution.
- Economic incentives involve the polluter paying for control costs as well as pollution damage. Therefore, there is no implicit subsidy to the industry.
- For many economic incentives the equi-marginal principle holds true.

Disadvantages of EI

- ✓Developing an economic incentive that efficiently and perfectly takes complexities in environmental transformation into account can be very difficult. (air pollution)
- ✓Given the political conditions, it is very difficult to adjust the level of incentives (level of fee, no. of marketable permits) when there is great deal of uncertainty associated with the environmental problem.
- ✓Instituting tax (on emission) may be very difficult (it involves transfer of massive amount of wealth from firms to the government).

Complication for Environmental Regulation

A.Space and Time

Pollution regulation is complicated by the physical environment that interposes itself between polluters and consumers (illustrated in figure).

There are differences between pollution and ambient concentration of the pollution.

Generally, it is the ambient concentration that causes damages not the pollution.

However, ambient concentration are imperfectly connected with the emission, which need to be regulated.

Complication for Environmental Regulation

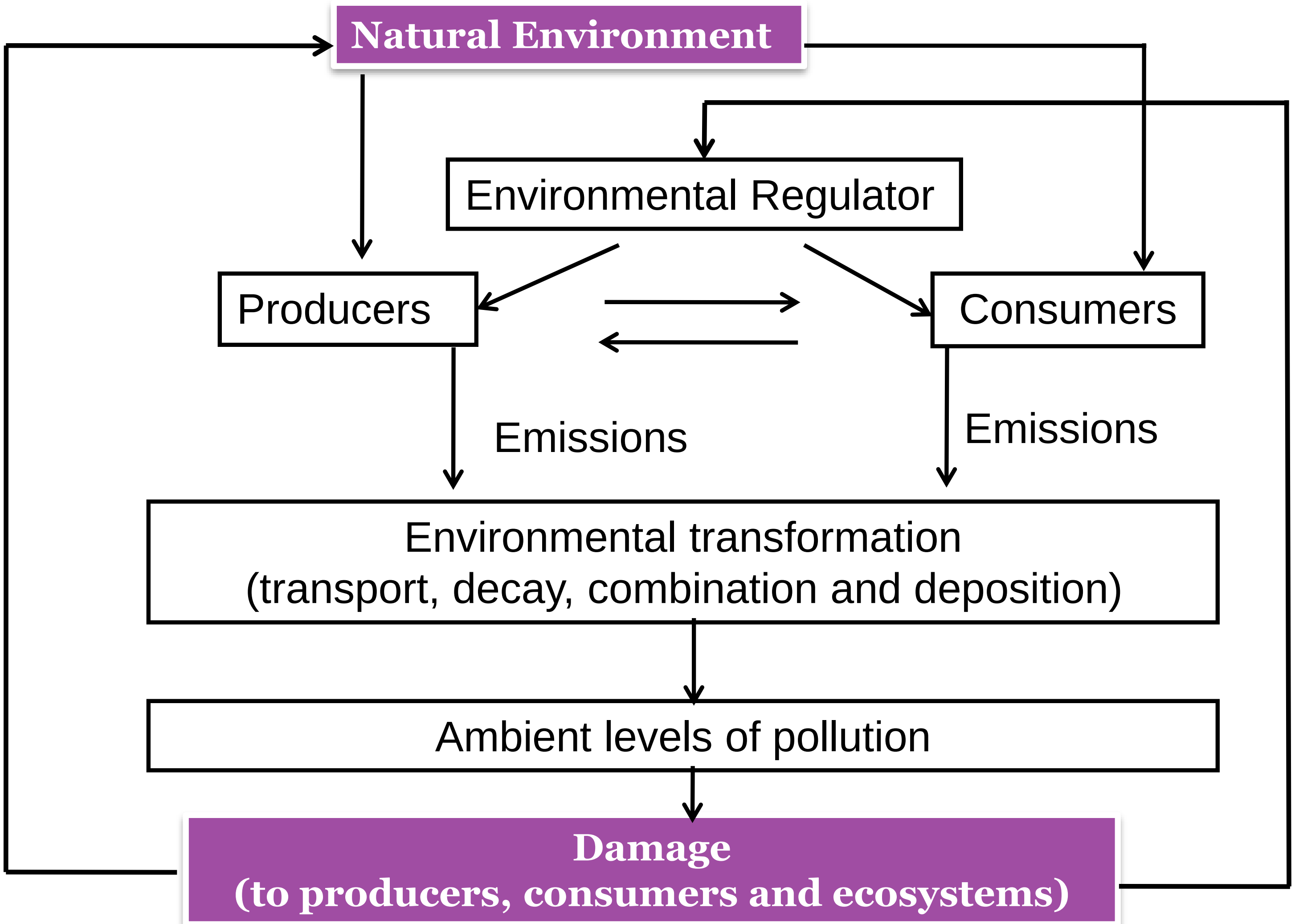
A.Space and Time

This brings space and time into concern of the regulators. Generally, sources of pollution nearby will generate more damage than sources located in distant suburbs.

Time, though less important than space, also exert significant influence in environmental transformation. There is hour-to-hour, day-to-day and season-to-season variation in pollution.

Capturing these time and space factors in to decision making is a bit difficult.

Complication for Environmental Regulation



Figure

Basic Issues in Environmental Regulation

1. Debate over whether command and control or economic incentives
2. Public sources of pollution and controlling them
3. Information, particularly private information polluters may have that regulator needs
4. Risk and how to deal with the problems of risk. What sort of regulations are appropriate?
5. Growing competition between jurisdiction vis-à-vis environmental regulations
6. Incidence of regulations: who bears the burden (either in cost or pollution damage)? Who reaps the benefits?
7. Innovations and technical change

Basic Regulatory Framework: Emission Fees and Marketable Permits

Several issues complicate using incentives to control pollution: Space, Time and Imperfect competition

I. Space :

A. Sources, Receptors and Transfer Coefficients:

Let us take an example of a river.

Two factories discharge organic waste (sewage) in to the river

A municipal water supply takes water from the river

Factories are in the upstream of the municipal waste supply

Further one goes downstream the smaller the effects from pollution.

Basic Regulatory Framework: Emission Fees and Marketable Permits

A. Sources, Receptors and Transfer Coefficients:

Now to correctly regulate the two factories their individual effects on the municipality have to be taken into account. At this point, to take space in to account, let's consider two points: sources and receptors. A source is a point of discharge of pollution (e.g. a factory). A receptor is a point at which people care about the level of ambient pollution.

Although there are several receptors, in practice, we will identify a small set of receptors where pollution levels will be measured. Receptors are scattered over space and serve as a good proxies for overall level of pollution.

Basic Regulatory Framework: Emission Fees and Marketable Permits

In general, there is some relationship between emission at various sources, e_1, e_2 . . . e_i and concentration of pollution at any receptor j.

$$p_j = f_j(e_1, e_2, \ldots, e_i) + B_j \qquad (1)$$

where, B_j background level of pollution at j (perhaps zero).

In many environmental problems, the physical environment is linear,

$$pj = \textstyle\sum_i a_{ij}\, e_i + B_i \qquad (2)$$

The coefficient a_{ij} is called the transfer coefficient. We assume $B_j = 0$. In equation (2), if we change emission at some source i by a little amount (Δe_i), pollution will change by $a_{ij}\Delta e_i$

Basic Regulatory Framework: Emission Fees and Marketable Permits

The transfer coefficient between the source *i* and the receptor *j* is defined as the ratio of the change in pollution at *j* to the change in emission at *i* .

$$a_{ij} = \Delta p_j / \Delta e_i \qquad (3)$$

Equation (3) gives the conversion rate for emission to ambient concentration.

Basic Regulatory Framework: Emission Fees and Marketable Permits

B. How much Pollution do we want?

Let’s start with what is the efficient level of pollution?

Efficiency involves equating marginal damage with marginal savings to the firm from pollution generation.

To link these we express marginal damage of a firm as marginal damage per unit of emissions.

Basic Regulatory Framework: Emission Fees and Marketable Permits

B. How much Pollution do we want?

Let us term marginal damage per unit of emissions from source I as the function $MDE_i\ (e_i)$ which is in contrast to marginal damages per unit of ambient pollution, MD(p)

MDE_i is the ratio of the change in damage {D(p)} to the change in emission at source *i*.

$$\begin{aligned} MDEi\ (ei) &= \{D\ (p + \Delta p) – D\ (p)\}/\ \Delta e_i \\ &= MD\ (p).\ \Delta p/\ \Delta e_i \qquad (4) \\ &= a_i\ MD\ (p) \end{aligned}$$

Basic Regulatory Framework: Emission Fees and Marketable Permits

As stated above, efficient amount of pollution requires equating marginal savings from emission with marginal damage. If there are $i = 1, 2, \ldots I$ sources of pollution, then following must hold:

$-MC_i\ (e_i) = MDE_i\ (e_i) = a_i\ MD\ (p)$, for all $i = 1, \ldots, I$ (5)

Now for any two sources m and n

$$MCm(e_m)/a_m = MC_n(e_n)/a_n = MD\ (p) \qquad (6)$$

Basic Regulatory Framework: Emission Fees and Marketable Permits

MC/a is marginal cost per unit of ambient pollution.
i.e. marginal cost in terms of ambient pollution must be equal to the negative of marginal damage.

Thus efficiency calls for all sources to have the same marginal costs of emissions, normalized by the source's transfer coefficients.

If 'a' is high, MC of emissions should be larger.

Two conditions for efficiency:

1. Marginal cost of emission, normalized by the transfer coefficient must be equalized for all sources
2. Normalized marginal cost must equal the negative of marginal damage.

Basic Regulatory Framework: Emission Fees and Marketable Permits

C. Emission Fees:

We seek emission fees, t_i, one for each firm i that yields efficiency.

These are ambient differentiated fees. Whatever fee is used, the firms will respond by minimizing direct costs plus fee payments. This is equivalent to setting marginal cost equal to negative of the fee:

$$MC_i\,(e_i) = -\,t_i, \text{ for all sources } i \qquad (7)$$

Thus the condition for efficiency can be re-written as,

$$t_n/a_n = tm/a_m \text{ for all firms } n \text{ and } m \qquad (8)$$

And, $t_n = a_n\, MD\,(p)$ for any firm n (9)

Basic Regulatory Framework: Emission Fees and Marketable Permits

C. Emission Fees:

Equation (8) implies that emission fees levied on the firms must be equal after normalizing by the transfer co-efficient or control costs across firms are equal.

Equation (9), the second condition, implies that for any firm marginal damage in emission units (MDE) must be equal to the emission fee (t), or marginal pollution damage and control costs are equalized.

Alternatively all firms face same emission fee per unit of ambient pollution but to convert it to emission units, it must be multiplied by appropriate transfer coefficient.

Basic Regulatory Framework: Emission Fees and Marketable Permits

Thus, it can be concluded that, ambient differentiated emission fees can achieve efficiency.

However, it is too complicated to let emission fee vary from location to location.

Normally most emission fees do not depend upon location even though damages do.

Thus, is applying uniform emission fee inefficient when damages depend on location?

Let us consider the following illustration (with the help of figure – 5).

Basic Regulatory Framework: Emission Fees and Marketable Permits

In figure 5, marginal savings curve is assumed same for every firm. As well as marginal damages, normalized by the transfer coefficient.

t^*_1, t^*_2 are efficient taxes

e^*_1, e^*_2 are emissions from the two firms (which are efficient)

$\hat{t}$ uniform emission fee

$\hat{e}$ emissions from firm 1 or firm 2

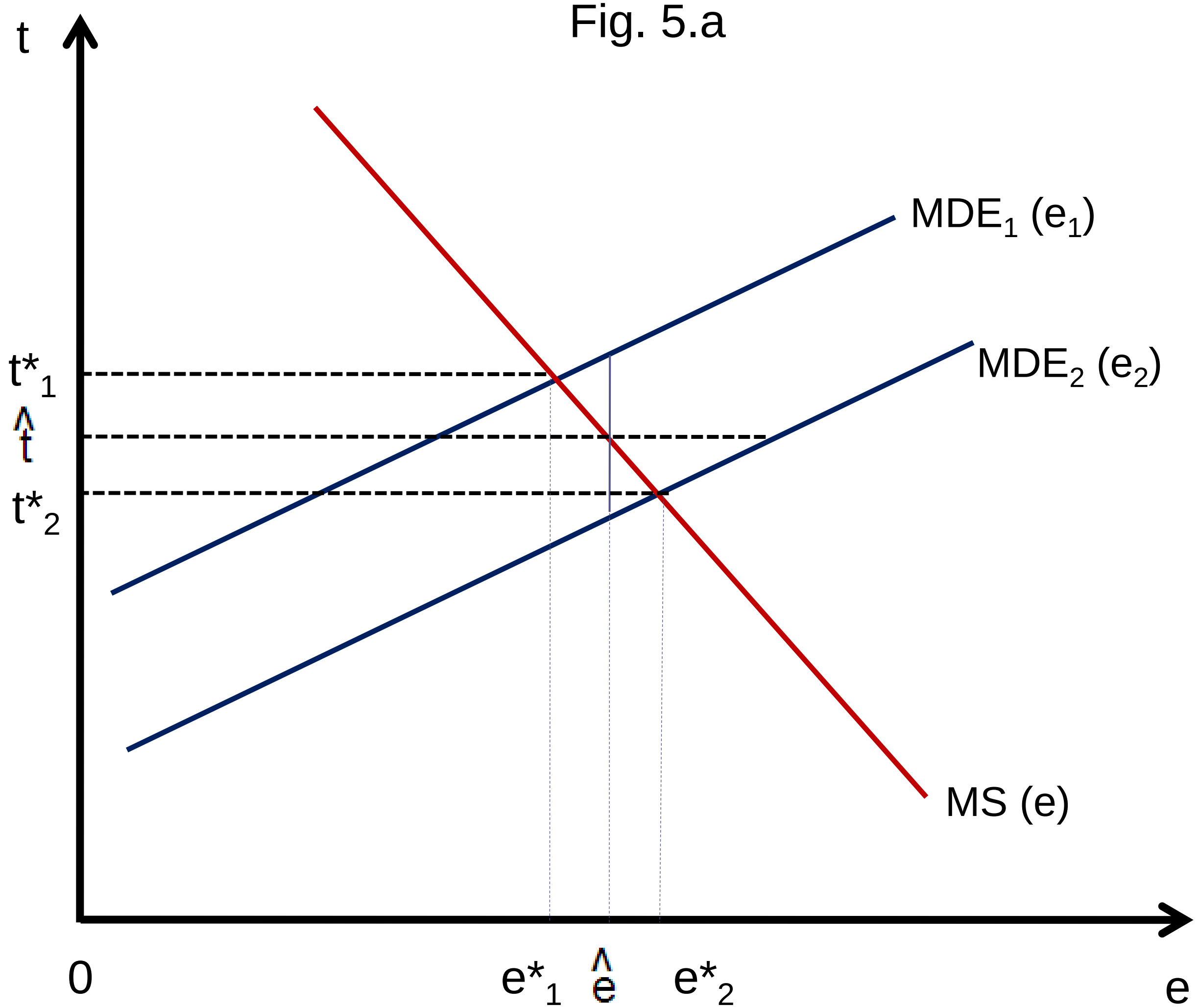
the shaded area are deadweight loss.

The optimal uniform tax is one that minimizes the total area of the two triangles.

The loss from a uniform fee depends on the nature of the marginal cost and damage functions.

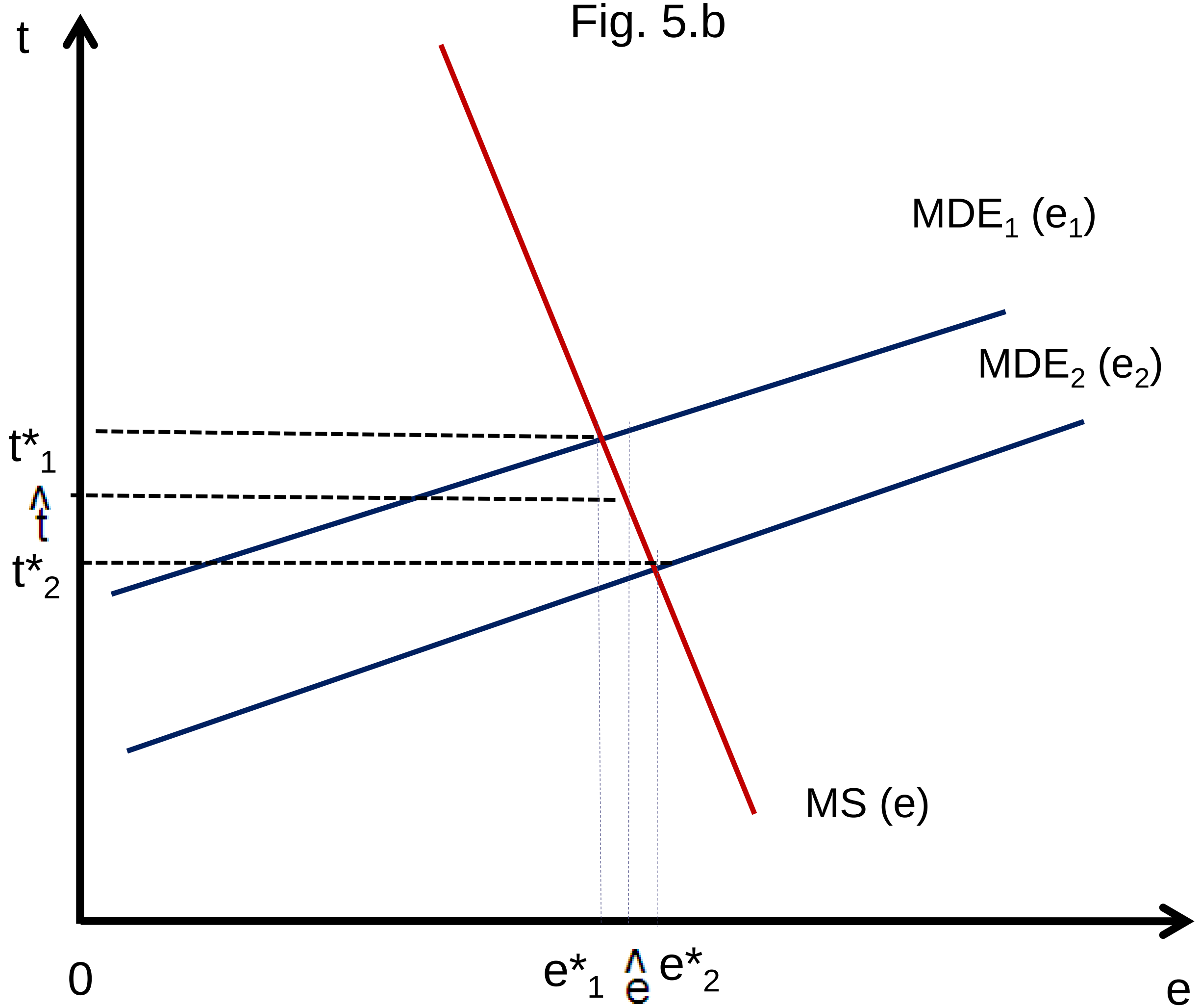
Basic Regulatory Framework: Emission Fees and Marketable Permits

Fig. 5.a



Basic Regulatory Framework: Emission Fees and Marketable Permits

Fig. 5.b



Basic Regulatory Framework: Emission Fees and Marketable Permits

D. Marketable Ambient Permit:

An ambient pollution permit for a receptor “j” gives the holder the right to emit at any location, provided the incremental pollution at receptor ‘j’ does not exceed the permitted amount.

Thus an ambient pollution permit system is a set of permits, distributed to sources in a well-defined way of computing the effects of emissions on ambient pollution at receptors along with a right to buy and sell these permits.

Two Firms: Let’s consider the case of two firms and one receptor. Suppose EPA issues L_1 amount of permits to firm 1 and L_2 ambient permits to firm 2 for a total of $L = L_1 + L_2$ permits.

Basic Regulatory Framework: Emission Fees and Marketable Permits

D. Marketable Ambient Permit:

Now after trading of permits, let l_1 and l_2 be the number of permits eventually held by the firms.

i.e. $L_1 + L_2 = l_1 + l_2$ (1)

Equation (1) raises many questions:

a. What will the price of permits be?

b. How much will each firm emit?

Answering the second question first - a firm can emit whatever is allowed by its permit holdings.

Basic Regulatory Framework: Emission Fees and Marketable Permits

Emission and ambient pollution levels are connected by transfer coefficient.

i.e. $a_1 e_1 = l_1$ (2)
and $a_2 e_2 = l_2$ (3), provided all permits are used.

Suppose, the price of permits is π (an unknown). Then how much pollution will be emitted?

However many permits a firm may hold, if the price of permits is greater than the marginal savings from emitting the firm will want to sell some permits and emit less.

Basic Regulatory Framework: Emission Fees and Marketable Permits

If the price of permit is less than the firms' marginal savings form polluting, buying permits is easier than controlling emissions.

We try to find the price for which the desired emission levels for each of the two firms corresponds to the number of permits issued.

Total costs for each firm are:

$$TC_1(e_1) = C_1(e_1) + \pi(l_1 - L_1)$$, where $C_i(e_i)$ is the direct cost to firm i,

$$= C_1(e_1) + \pi(a_1 e_1 - L_1) \quad (4)$$

And,

$$TC_2(e_2) = C_2(e_2) + \pi(l_2 - L_2)$$

$$= C_2(e_2) + \pi(a_2 e_2 - L_2) \quad (5)$$

Basic Regulatory Framework: Emission Fees and Marketable Permits

In order to Minimize total costs each firm sets the marginal total costs (MTC) to Zero, i.e.

$$MTC_1(e_1) = MC_1\,(e_1) + a_1\pi = 0 \qquad (6)$$

$$MTC_2(e_2) = MC_2(e_2) \;+ a_2\pi = 0 \qquad (7)$$

Which implies: $MC_1(e_1)/a_1 = MC_2\,(e_2)/a_2 = -\,\pi$

Or, $MS_1(e_1)/a_1 = MS_2(e_2)/a_2 = \pi$ (8)

Equation (8) says that marginal savings normalized by the transfer coefficient should equal to the permit price. This is analogous to the working of ambient emission fee which states that marginal savings normalized by the transfer coefficient equals the same number for all firms.

Basic Regulatory Framework: Emission Fees and Marketable Permits

There is one additional equation that gives us information.

Combining equations (1), (2) and (3) we get,

$$a_1e_1+a_2e_2=L \qquad (9)$$

Equations (8) and (9) constitute three separate equations in three unknowns (e_1, e_2 and π) and thus can be solved.