SPATIAL AND TEMPORAL DIMENSIONS OF REGULATION

⇒ There are several issues which complicate use of incentives to control pollution.

(1) Space :- Pollution transport is often highly dependent on location.

(2) Time :- Primarily accumulation over time, such as multidecades accumulation of greenhouse gases (but also including daily & seasonal variation).

[1] SPACE:-

[A] Sources, Receptors, and Transfer coefficients:-

→ The problem of dealing with spatial effects is very real for pollution control.

— Figure 1 shows a river with two factories discharging organic waste (such as sewage) into the river and a municipal water supply taking water out of river.

→ To take space into account, we will introduce two terms: sources and receptors.

⇒ A source is a point of discharge of pollution. Each factory in our example is a source.

⇒ A receptor is a point at which we care about the level of ambient pollution.

→ Ambient pollution :- It refers to the level of pollution in the surrounding environment.

· In our example, a logical receptor is the intake point for the municipal water supply.

If we are concerened about the health of the river at other points, we might have several receptors located at different points along the river.

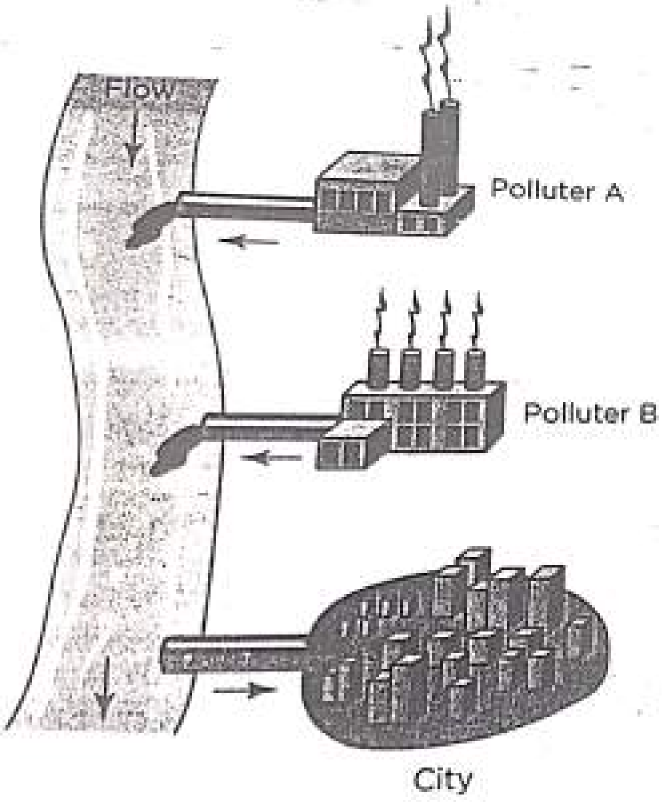

FIGURE 15.1 River with two factories discharging organic waste into it and a municipal water supply taking water out of it.

or Receptors :- where pollution level is measured.

⇒ Generally speaking, there is some relationship b/w emissions at the various sources, $e_1, e_2 \cdots e_I$ (I is the No. of sources) and concentrations of pollution at any receptor j:

$$\Rightarrow \boxed{P_j = f_j(e_1, e_2 \cdots e_I) + B_j} \text{ — } (1)$$

where B_j is background pollution at j [Perhaps zero]

For reading { In our example

P_j = pollution level at receptor [i.e. Point of Municipal water supply]

e_1, e_2 = sources of emission [i.e. firms]

$\Rightarrow P_1 = f(e_1, e_2)$

⇒ fortunately, in many environmental problems the physical environment is linear. i.e. eqn (1) can be written as

$$P_j = \Sigma_i \, a_{ij} e_i + B_j \text{ — } (2)$$

Read { In our example [$P_1 = a_{11} e_1 + a_{21} e_2$] since $B_j = 0$]

The coefficient a_{ij} in eqn (2) is called the transfer coefficient.

⇒ Transfer coefficient :- suppose a change in emissions from source i "(Δe_i)" [or firm 1/2] result in a change in pollution at receptor j (i.e. M.W.supply) ΔP_j.

The transfer coefficient b/w 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."

$$\boxed{a_{ij} = \frac{\Delta P_j}{\Delta e_i}} \text{ — } (3)$$

→ Eqⁿ ③ is essence gives the conversion rate for emissions to ambient concentrations.
For instance, if a_{ij} is equal to 2, then every unit of emission at i yields two units of ambient pollution at j.

[B] <u>How much Pollution Do We Want?</u>

→ What is the efficient amount of pollution?
→ As we know, efficiency involves equating marginal damage with the marginal savings to the firm from pollution generation.
→ Marginal savings is in terms of emissions.
Marginal Damage is in terms of ambient pollution.

→ To link these, we must either convert a firm's marginal saving function to marginal savings per unit of ambient pollution. i.e. [MDA(P)]
or
Express marginal damages as marginal damage per unit of emissions. i.e. [$MDE_i(e_i)$]

→ We know that MDE_i is the ratio of change in Damages [D(P)] to the change in emissions at source i.

i.e. $$MDE_i = \{D(P+\Delta P) - D(P)\} / \Delta e_i$$
$$= MDA(P)\, \Delta P / \Delta e_i \quad \text{— ④}$$
$$= a_i\, MDA(P) \qquad \left\{ \begin{array}{l} \text{From eq}^n\ ③ \\ \because a_i = \frac{\Delta P_i}{\Delta e_i} \end{array} \right\}$$

→ Efficient amount of pollution :-
Efficiency calls for equating the marginal savings from emissions with the marginal damage and this must apply to all sources (from equimarginal principal)
i.e. MS (Marginal supply) which is equal to $-MC$ for firms must equal to MDE_i

or

$$\boxed{-MC_i(e_i) = MDE_i = a_i\, MDA(P)\,;\ \text{for all } i = 1 \cdot I} \quad \text{— (5)}$$

eqn (5) is really a set of I equations, one for each source.
Dividing each of equation (5) by a_i implies that for any two sources, m & n or firm(1) & firm(2),

$$\boxed{\frac{MC_1(e_1)}{a_1} = \frac{MC_2(e_2)}{a_2} = -MDA(P)} \quad \text{— (6)}$$

$\frac{MC}{a}$ = Marginal cost per unit of ambient pollution.

→ Thus, if a source has a larger impact on ambient pollution [a is larger], ∴ its MC of pollution control [MC of emissions] must be larger.

⇒ Two Conditions are necessary for efficiency :-

(1st) MC of emissions, normalized by a_{ij} (Transfer coefficient), must be equalized for all sources.

(2nd) Normalized MC must equal the -ve of marginal damage.

Date

Ex:- Suppose, in our problem with the river & the municipality in fig (1)

$a_1 = 2$, $a_2 = 3$

$MC_i(e_i) = -14 + 7e_i \quad i = 1, 2$

$MDA(P) = P \quad , B_j = 0$

Q. How much should each source efficiently emit?

Ans:- Since both source share the same MC function. & MC is −ve, i.e. cost of firms decrease as emissions increase, yielding −ve MC.

Applying necessary condition of efficiency:-

[1] $$\frac{MC(e_1)}{a_1} = \frac{(-14+7e_1)}{2} = \frac{MC(e_2)}{a_2} = \frac{(-14+7e_2)}{3} \quad \text{— [a]}$$

[2] either $$\frac{MC(e_1)}{(a_1)} = \frac{(-14+7e_1)}{2} = -MDA(P) = -MDA(2e_1+3e_2)$$

explanation

$$\Rightarrow \left[\frac{-14+7e_1}{2} = -(2e_1+3e_2)\right] \rightarrow [B]$$

∵ from eqⁿ (2) from page 3

$P_{ij} = \Sigma a_{ij} e_j + B_j$

$P = a_1 e_1 + a_2 e_2 \quad ∵ B_j = 0$

∴ $MDA(P) = MDA(a_1 e_1 + a_2 e_2)$

or $$\frac{MC(e_2)}{a_2} = \frac{(-14+7e_2)}{3} = -MDA(P) = -MDA(2e_1+3e_2)$$

$$\Rightarrow \left[\frac{-14+7e_2}{3} = -(2e_1+3e_2)\right] \text{— (B)}$$

We can use any of eqⁿ of (B) for 2nd condition.

→ By solving eqⁿ (A) & (B) for e_1 & e_2

$-42 + 21e_1 = -28 + 14e_2 \quad \text{— (C)}$

$-14 + 7e_1 = -4e_1 - 6e_2 \quad \text{— (D)}$

⇒ which can be solved for $\boxed{e_1 = 1}$ & $\boxed{e_2 = 0.5}$.

⇒ $MC_1 = -14 + 7(1) = \underline{7}$ & $MC_2 = -14 + 7(0.5) = \underline{-10.5}$

⇒ Total ambient pollution is $= [2\times(1) + 3(0.5)] = 3.5$ which yields Marginal Damage of $\underline{3.5}$