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1. Learning Outcomes

After studying this module, you would

- To know about externalities and their types
- To know the methods of correcting externalities
- To know about the instruments such as taxes and subsidies
- To evaluate the difference between taxes and subsidies

2. Introduction

An externality is present whenever some individual's utility or production relationships include real variables whose values are chosen by others without particular attention to the effects on that person's welfare. Alternatively: Actions of individual *A* affect utility or production function of individual *B*, but the effects are not expressed in terms of prices. The real variables could be in the form of shift in production or consumption possibilities of individual A due to externalities generated by actions of say Individual B. The decision taken by individual B does not consider the interests of Individual A and that generates externalities. As the result of which, there exist a difference private and social costs.

3. Types of Externalities

Externalities cause private and social costs to differ from each other. Externalities can be expressed in terms of a utility function in the following way. Consider a production function given by

$U = f(X_1, \ldots, X_n, Z)$ where $X_1, \ldots, X_n$ are market-valued goods and services and Z is some measure of environmental quality. Z is attributed to a condition in an individual's utility function which can be affected by the actions of (other firms, other consumers).

A similar concept can be viewed in the production function as well. Consider a production function where

$Q = f(L, K, Z)$ is L is labour, K is capital and Z is some environmental input which the firm uses. Here again the state of Z,(though a part of the production function of individual's firm) depends upon the actions of others. A few examples of Z could be waste-disposal capacity of the various resources (air, water, land) for a factory, clean water for a whisky distiller etc.

The effect of the externality can both be positive and negative. Some of the examples of positive externalities are benefits from education and telephone connection. The negative external effects includes costs of environmental pollution, traffic jams etc. Individuals take into consideration only their private benefits/costs. Thus with the presence of negative (positive) external effects, it is not possible to account for all marginal social costs (benefits) . This generates inefficiency. We will focus on negative external effects, in particular environmental pollution. Production generates pollution and it can be seen as a linear function of output. Thus pollution increases as output rises. In the analysis that follows, we assume increase in pollution is proportional to increase in production. However, the damages from pollution rise at an increasing rate. We also assume that output sells at a constant price and marginal *private* costs are continuously increasing.

4. Graphical Analysis

a) <u>Gross Domestic Product(GDP)</u>

Figure 1 depicts marginal private production cost (MCp) and marginal social production cost (MCs). Production costs rises with the output(Q). The difference between these two curves is the negative external effect of pollution which causes irreversible environmental damage.

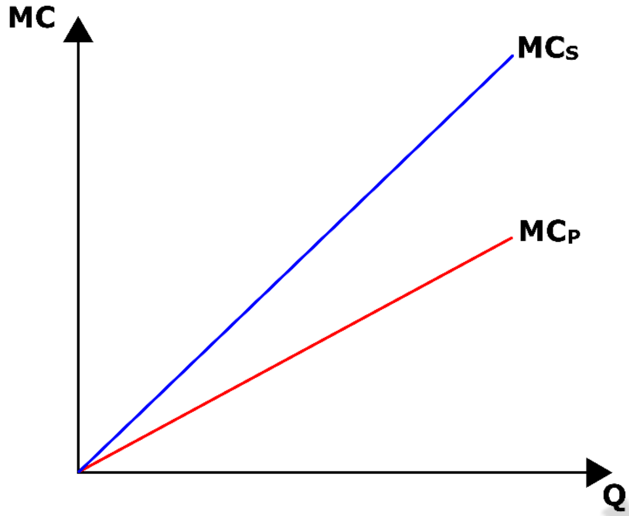

Figure 1: Social and Private Marginal Cost

Suppose MD is marginal damage due to the external effect then MCs= $MC_P + MD$.

However, production also generates benefits which can be viewed in the form of MB (marginal benefits from production) . Consider figure 2, where MB is a downward sloping curve. It is because as the output increases the benefit accruing from each successive unit of output tends to be lower. The socially optimum level of output is (Qs) where marginal benefit is equal to the marginal social production cost. The social optimum Q_S generates economic surplus (welfare) *abc.*

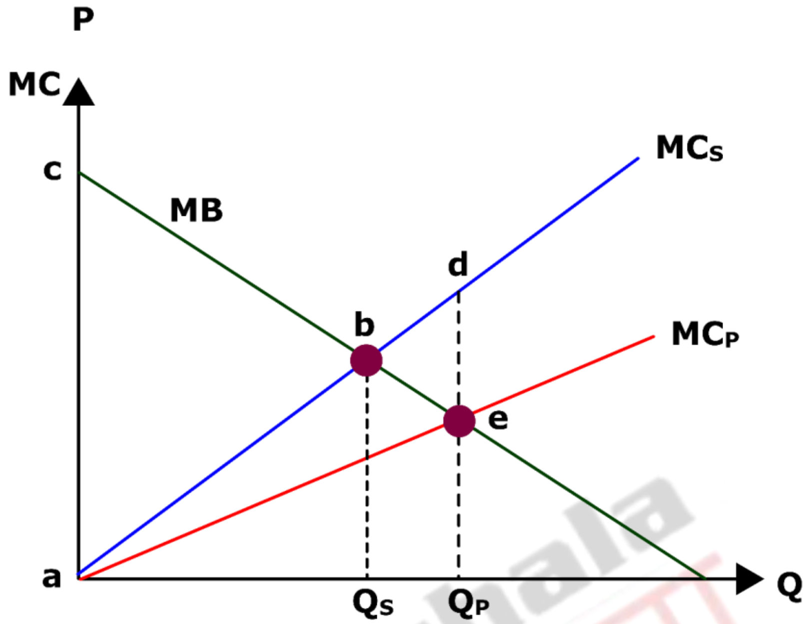

Figure 2: Efficiency loss due to negative externality

The private optimal level of output is (Qp) where marginal benefit is equal to the marginal private production cost. At Q_P welfare is given by the region **aec** – ***aed***. It is interesting to observe that there is an additional loss of welfare given by region ***bde*** in this case. Thus, we can infer that welfare with output level Qp is smaller than socially optimal level of output Qs [***abc*** – ***bde*** < ***abc***]. Efficiency loss at Q_P equals to the region ***bde.***

It is important to note that optimal pollution cannot be zero as this would mean that output has to be driven down to zero. However, in this scenario optimal pollution is less than that generated by the market.

The social optimum condition is $MB = MC_S = MC_P + MD$. The socially optimal output is Qs but seldom free market forces result in this level. The reason could be that the firm only takes account of its own private costs and does not consider the marginal damage from pollution. However, if the government can intervene and restrict output upto Qs, we might have a plausible solution to the problem of environmental pollution.

Negative externalities can be internalized using the following policy alternatives

- *Taxation*
- *Subsidies*

5. Emission Fees

An emission fee is a price or fee paid by a polluter to a regulatory entity for every unit of emissions a polluter emit. A tax rate equal to the marginal damage will help the economy reach socially optimum level of production. Consider Figure 3. A tax equal to the size of (*br*) may prompt the firm to reduce production from Qp to Q_S .

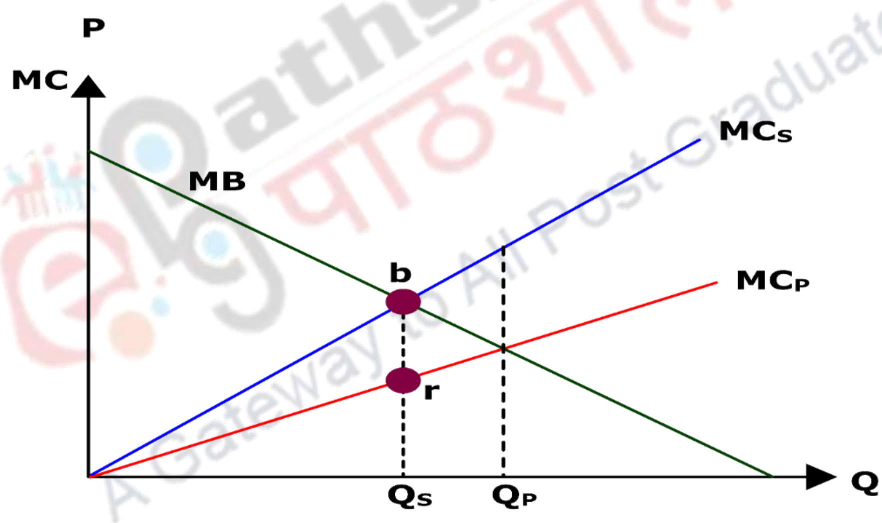

Figure 3: Emission fees

At the output level of Qs the marginal social cost of production **(**MC_S) is equal to marginal private cost of production (MC_P) plus the tax size of (*br).* If Q is less than the social optimum level of output (Qs), the marginal benefit is greater than the marginal private cost of production plus the size of tax (br).

$Q < Q_S \rightarrow MB > MC_P + br$

However if Q is more than Qs but less than Qp, marginal benefit will be less than the than marginal private cost of production plus the size of tax (br).

If $Q_S < Q < Q_P \rightarrow MB < MC_P + br$

At the Ievel Q_S, the marginal benefit equals the marginal social cost of production such that

$MB = MC_P + br = MC_S$

Thus if the government sets the tax rate equal to marginal damage calculated at the socially optimal level of output, Q_S, the firm may be forced to produce at the socially optimal level of output. Production at this level of output also ensures that the firm's private costs come into line with social costs of output.

For an alternate explanation consider a firm producing some good along with pollution, call it x. If the emission fee is p and the polluter emits x units of pollution, the payment from the polluter to regulator is px. To determine how much the polluter emits, let C(x) be the production costs associated with emitting x units of pollution, holding goods output fixed. Costs will decline as the pollution increases thereby implying that the polluter saves money by emitting pollution. Total costs for the firm can be given as

$TC(x) = C(x) + px$

The total cost is minimized with respect to x, we obtain

$p = - MC(x) = MS(x)$

The equation states that the firm operates until a point where the marginal cost of reducing pollution by one unit (which is same as marginal savings from emitting one more unit of pollution) is equal to the price of pollution. In other words, in the case of emission fees the firms will reduce pollution upto a point where firm's marginal cost of abatement is equal to the emission fee.

In the case of multiple firms, each firm abates till the point where marginal cost of abatement is equal to the emission fee. As all the firms equate their MACs to the same fees, they satisfy the equimarginal principle and hence maintain efficiency. The equimarginal principle states that in controlling emissions from several polluters, all emitting the same pollutant, effectively requires that the marginal cost of emission control be the same for all polluters.

6. Pigovian Fees

A pigovian fee is an emission fee exactly equal to the aggregate marginal damage caused by the emissions when evaluated at the efficient level of pollution. It is a special kind of emissions fee- an emission fee that is set at the marginal damage of pollution in an attempt to restore pareto optimality to a situation of market failure.

Two cases have been discussed in the module

Single Polluter

Suppose there is a factory generating pollution of the amount x at a cost C(x), with marginal costs MC(x). Since cost declines as x increases, marginal costs are actually negative.

Suppose there are N people surrounding the factory and that pollution causes damage to who cannot use the locational choice to change the amount of pollution they face. For any person, the damage from pollution is $D_i(x)$ which is positive and increases in x. The aggregate damage for pollution can be written as

$D(x) = \sum_i D_i(x)$

The efficient amount of pollution that minimizes total costs and damages

x* minimizes [C(x) +D(x)]

thus

MC(x*) + MD(x*) =0

As the marginal savings is the negative of marginal costs , we obtain

$MS(x^*) = \sum_i MD_i(x^*)$

In other words, we target at a level of pollution such that marginal savings to the firm is equal to the marginal damage from pollution over the entire pollution. The aggregate marginal damage ($\sum_i MD$) is the vertical sum of individual marginal damages (MD_i)

Figure 4 illustrates this situation in the case of one polluter and two victims. The marginal damage increases with emissions whereas the marginal savings (negative of marginal cost) decreases with emissions.

The marginal damage functions of two victims of pollution are vertically summated to obtain the aggregate marginal damage. The optimal amount of pollution is the level at which the aggregate marginal damage curve intersects the marginal savings curve. The optimal level of pollution is x* and the corresponding pigovian fees is given by p*.

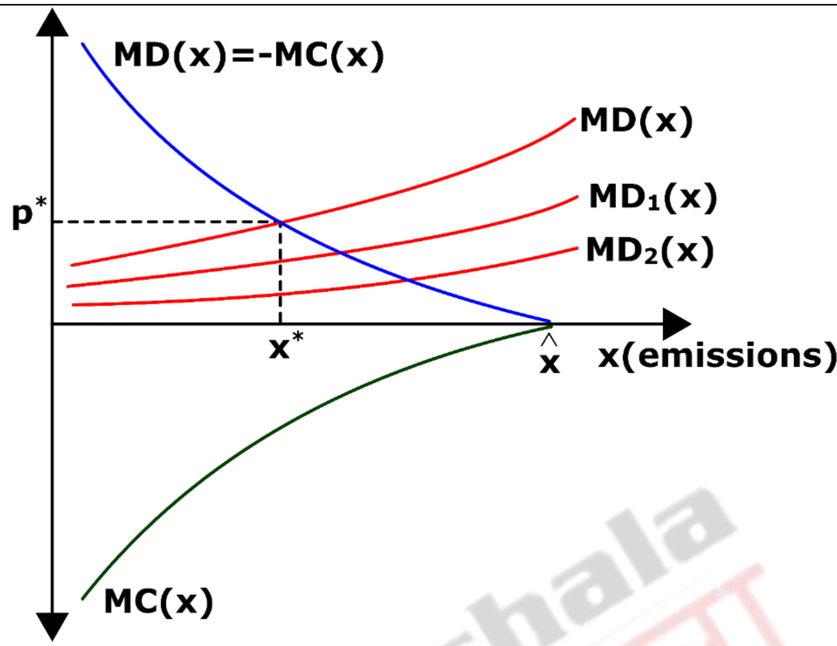

Figure 4 Pigovian fee with single polluter

A Pigovian fee is defined as the marginal savings from pollution generation at the optimal level of pollution. It is different from emission fees. It can be used to generate the efficient amount of public bad.

Multiple Polluters

Now consider the case of two polluters. Figure 5 shows the aggregate marginal damage function of all victims. Also shown is the marginal savings to each polluter (two in this case). Aggregate marginal savings is calculated by horizontal summation of marginal savings function of polluting firms. An aggregate marginal savings function indicates the change in marginal savings with the change in one unit of pollution. For any level of fee, MS(x) tells us how much pollution (x) in total will be emitted and each $MS_i(x)$ tells us how much each firm will contribute to the total.

The efficient amount of pollution is where the marginal savings curve (MS) intersects the marginal damage curve (MD). The optimal amount of pollution is (x*) and the marginal savings to polluters is (p*). Thus, the pigovian fees is (p*). At this fee level firm 1 will emit (x_1^*) level of emissions, whereas firm 2 will generate (x_2^*). Each firm's marginal savings from polluting is set equal to the pigovian fee.

$MS_i(x_i^*) = p^*$

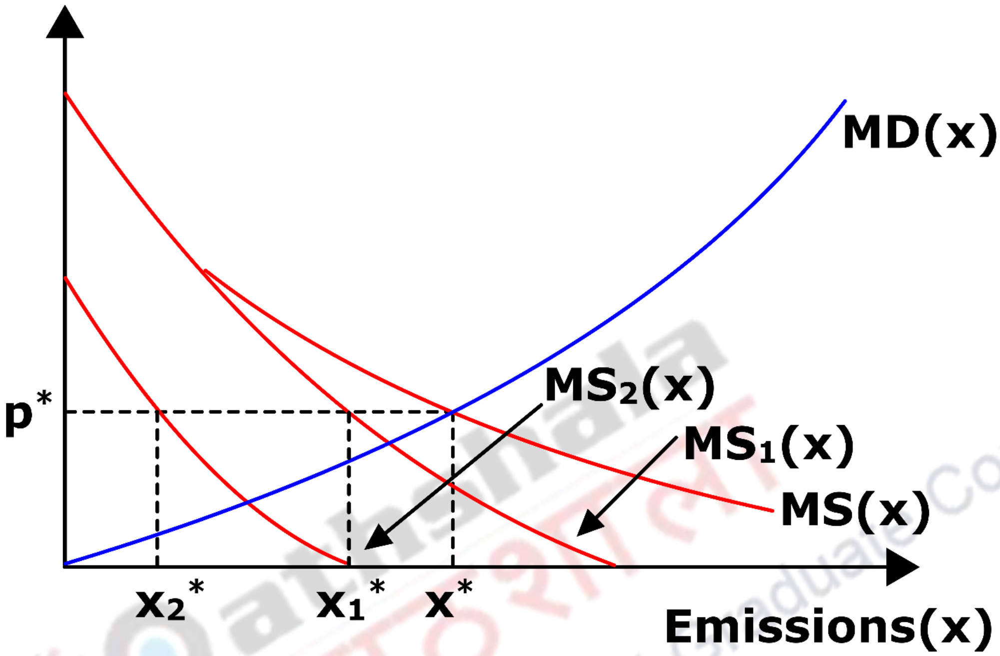

Figure 5 Pigovian fee will multiple polluter.

Furthermore it may be clear that

$MS(x^*)= p^*$

The above property ensures that all the firms will control pollution at the same level of marginal costs. As marginal costs of pollution is equated across all polluters. The cost minimizing way of appropriating the abatement responsibility is to equate marginal cost of abatement or in other words marginal savings (from polluting) among firms.

7. Pigovian Subsidies

Payments made to the individuals or firms by the government are called subsidies. They are generally used to correct externalities / problems associated with natural resources and their use. Market failures lead to externalities. Pollution is a negative externality generated during production of goods and services.

Arthur Pigou proposed that if externalities can be internalized and the producers of the externality are made to face the true price, the problems arising out of externalities may be solved. A producer generating negative externalities (pollution) may face tax per unit on emissions (as discussed above). Similarly, producers generating positive externalities (for example using green technologies) can be given subsidy to reach the social optimum. For negative externalities (e.g. pollution), the subsidy is levied per unit of abatement of emissions. It can be shown that if the subsidy rate and tax rate are equal, it will result in same amount of pollution. However, the distribution of the costs and revenue in each case differs. Taxes generate revenues for the government whereas the subsidies involve costs. Issues regarding the distribution of costs or revenues concern the policy maker, however, the choice of the instrument does not affect the efficiency and overall level of the pollution. But in certain cases where the firms can enter or exit the industry in response of such policy actions, the equivalence between taxes and subsidies might not hold. It is worth noting that in the short run when there is no time for new firms to enter the industry, pigovian fees and subsidies might yield the same outcome.

Let us consider a competitive industry, where all firms in industry are identical. Under a pollution tax(t) , the production cost of a typical firm would be

$C(y,e) = V(y,e) + t\,e + FC$ (1)

where y = the amount of the good being produced,

e = emissions

C(y,e) = costs of production

V(y,e) = variable costs

t = tax rate

FC = fixed cost of production

Suppose emissions are relayed to output such that e=ay where is a is the constant

$C(y,ay) = V(y,ay) + t\,ay + FC$ (2)

We may rewrite the above equation as

TC(y) = VC(y) +t ay+FC (3)

The marginal production costs would be

MC(y) = MVC(y) + ta (4)

Under subsidy e, with no regulation the firm will produce emissions at the level say e*. With the subsidy the firm will paid to reduce emissions. So if the firm reduces emissions to e, the subsidy payment will be s(e*- e). This means that cost will be

TC(y) = VC(y) +FC - s(e*- e) (5)

TC(y) = VC(y) + say + [FC - se*] (6)

The term in the bracket is a figure consisting of standard fixed cost plus a lumpsum transfer of se* which is independent of y or e.

Consequently

MC(y) = MVC(y) + ta (7)

The above equation is same as equation 4 with the difference of t and s

Thus in case of identical firm in short run , pigovian fees and subsidies give the same result.

In the long run, there will be more firms in the industry with a subsidy than a tax. Subsidy, hence might result in the overuse of certain environmental resources which are used as inputs. Also subsidy might be undesirable because it does not allow the market to communicate the true costs of the product.

8. Summary

An externality is present whenever some individual's utility or production relationships include real variables whose values are chosen by others without particular attention to the effects on that person's welfare. The effect of the externality can both be positive and negative. Arthur Pigou proposed that if externalities can be internalized and the producers of the externality are made to face the true price, the problems arising out of externalities may be solved. Externalities can be internalized either to imposition of tax or grant of subsidies. A Pigovian fee is defined as the marginal savings from pollution generation at the optimal level of pollution. It is different from emission fees as it a price or fee paid (fixed by the regulatory body) by a polluter to a regulatory entity for every unit of emissions a polluter emit. Payments made to the individuals or firms by the government are called subsidies. A subsidy for pollution control and a tax on pollutant emissions both result in the same marginal conditions for pollution emissions. However, the subsidy in both short run and long run results in excess production in polluting industry.