4) State the condition under which the government intervention to provide a public good is economically viable and desired.

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5) What is meant by the term 'free riding'? In what situation, the decision to provide a good for public usage is not affected by free riding?

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3.4 EXTERNALITIES

Externalities occur when the actions of one agent have an impact on the utility (or profit) of another agent in unintended ways, without any compensation/payment made to the affected party. It is important to note that externality occurs when one *economic agent* indirectly affects another *economic agent.* By this definition, 'external' forces such as Nature or weather are not the sources of externalities as they are not caused by another economic agent. Externalities can exist either in production, wherein the unintended effect originates in a production activity, or consumption, where the external effect originates through a consumption activity of an agent. The various kinds of externalities are summarised in Table 3.3.

Table 3.3: Externalities by Consumption/Production

Sl. No.	Source of Externality	Affecting in Consumption/ Production	Specification of Utility or Consumption or Production Function (for two Agents A and B)
1	Consumption	Consumption	The consumption made by agent B enters the utility function of agent A as: $U^A(X^A, Y^A, X^B)$
2	Consumption	Production	The consumption of agent B enters the production function of agent A as $F(K^F, L^F, Y^B)$ or the cost function of agent A such as: $C_A(F, Y^B)$
3	Production	Consumption	The output G of agent B affects the utility of agent A as: $U^A(X^A, Y^A, G)$

4	Production	Production	The output G of agent B affects the production process of agent A through the production function $F(K^F, L^F, G)$ or the cost function $C_A(F, G)$

Note: A and B are two agents with utility functions $U^A(.) and\ U^B(.)$ respectively. The quantities X^A and Y^A denote the consumption of goods X and Y by A and quantities X^B and Y^B denote the consumption of goods X and Y by agent B. The agents A and B also produce goods F and G using inputs K and L. The cost functions of each agent $i \in \{A, B\}$ are represented by $C_i(.)$. The inputs used by good F are denoted by K^F and L^F. Similar notation is used for the inputs denoted by good G.

Further, externalities can be positive or negative. In case of positive externalities, an agent bestows some benefits to another agent in unintended ways, without receiving income or compensation for providing the benefit. In case of negative externalities, an agent adversely affects another agent without providing any compensation for the adversity caused. Positive and negative externalities originating in production and consumption can be listed as in Table 3.4. With this background, we can now discuss a formal model of economic interactions involving externalities. Our aim is to identify how externalities result in market failure i.e. why do externalities lead to an inefficient outcome? Since the problem of environmental pollution is essentially a case of negative externality, we restrict ourselves to a discussion of two situations viz. (i) negative externality in consumption and (ii) negative externality in production.

Table 3.4: Positive/Negative Externality Originating in Consumption/Production

Positive Externalities Originating in Consumption	**Positive Externalities Originating in Production**	**Negative Externalities Originating in Consumption**	**Negative Externalities Originating in Production**
Using a jute/cloth bag instead of plastic bag reduces generation of waste and releases pressure on public amenities for all	An apiary (where bees are reared) helping with pollination in a nearby orchard	Using a car instead of public transport increases congestion and pollution for others	A chemical factory releasing effluents in a river hurting a downstream fishery
Getting vaccinated against an infectious disease reducing the probability of spreading infection	An orchard improving the quality of honey produced in a nearby apiary	Noise pollution from a neighbour playing loud music	Noise generated at an airport affecting the residents of a residential colony

3.4.1 Negative Externality Originating in Consumption

Consider the case where the consumption of an agent (A) adversely impacts the utility of another agent (B) in a situation like where agents A and B are roommates staying together with A liking to smoke cigarettes but B a non-smoker having to suffer the smoke. Their utility functions can be expressed as:

$$U^A = U^A(M^A, C^A) \; and \; U^B = U^B(M^B, C^A) \qquad (3.14)$$

Here, M^i is the wealth of agent i $(i \in A, B)$ and C^A is the number of cigarettes consumed by A. Note that A's consumption of cigarettes enters the utility function of B due to the negative externality imposed on him by A. Further, we can specify that A's utility increases in M and C, while B's utility may increase in M but decreases in C. This means, we can place the following restrictions on the partial derivatives, namely their marginal utilities:

$$\frac{\partial U^A}{\partial M^A} \geq 0 \qquad (3.15)$$

$$\frac{\partial U^A}{\partial C^A} \geq 0 \qquad (3.16)$$

$$\frac{\partial U^B}{\partial M^B} \geq 0 \qquad (3.17)$$

$$\frac{\partial U^B}{\partial C^A} \leq 0 \qquad (3.18)$$

Assuming well-behaved utility functions, as more cigarettes are consumed by A, the marginal utility (or marginal benefit) of consuming cigarettes decreases for A and the marginal disutility by inhaling the smoke from cigarettes increases for B. This can be graphically represented as in Fig. 3.1.

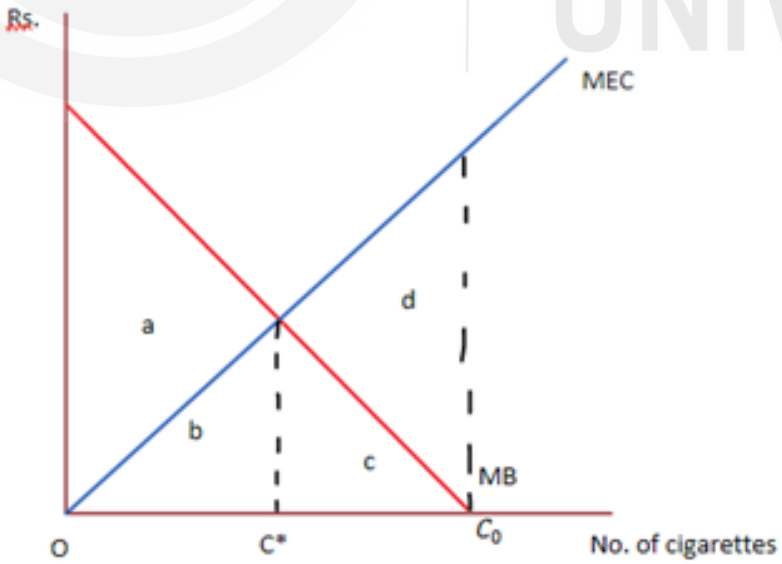

Fig. 3.1: Compensation for Negative Externality

The downward sloping line represents the 'marginal benefit' of cigarettes to agent A. This can be interpreted as the 'demand' for smoking cigarettes. To smoke an additional cigarette, agent A would be interested in paying an amount to B as compensation not exceeding his marginal benefit. The upward sloping line is the marginal external cost of cigarettes (and hence measures the negative externality) imposed by A on B. Each point on the MEC curve represents the maximum amount B would be willing to pay to A [a 'compensation' or an incentive or 'bribe' that B (the non-smoker) is willing to pay A (smoker) to reduce smoking] so as to decrease his own disutility (i.e. avoid his costs) by reducing the latter's consumption of cigarettes by one unit. If there are no restrictions on smoking and there is no arrangement of compensation, agent A will continue to smoke until the marginal benefit of the last cigarette is zero i.e. he will smoke C_0 cigarettes. The total 'surplus' in this allocation is the total benefit accruing to A minus the total costs imposed on B i.e. $a+b+c-(d+c+b)=a-d$. However, this allocation is not efficient, since at this point, the marginal external cost of cigarettes is higher than the marginal benefit from the cigarettes. The efficient outcome is at the intersection of the two curves i.e. where the number of cigarettes smoked is C*. The surplus at this allocation is $a+b+c-(b+c)=a$, which is higher than $a-d$. While the 'solution' seems straightforward, ensuring that no more than C* cigarettes are smoked needs the enforcement of individual rights. The details of how to correct such externality will be discussed in Unit 4.

3.4.2 Negative Externality Originating in Production

Let us consider a case where the output is produced by an agent, a firm S located upstream and producing steel, and due to the sludge released by S and dumped into the nearby river, another firm F located downstream and engaged in fishery is adversely affected in lowering the quality of the output produced by the firm F. Let '*S*', denote the quantity of steel produced, *x* the amount of sludge released and '*f*' the number of fishes caught by the firm F. The steel firm's cost function can be written as $c_s(s,x)$, where we assume with higher sludge permitted (i.e. till a mechanism is instituted where producing higher sludge or not disposing it off properly is made punitive), the cost of production for the firm S is reduced. In other words, more pollution reduces the costs of the steel firm which means for the steel producing firm: $\frac{\partial c_s}{\partial s} \geq 0$ and $\frac{\partial c_s}{\partial x} \leq 0$. Likewise, let the cost function of the fishery be represented by $c_f(f,x)$. Note that pollution generated by the steel firm enters the cost function of fishery due to external effect and that the cost function for the fishery firm behaves in a manner that with increase in the fish catch, there is also an increase in the pollution effect on its output i.e. $\frac{\partial c_f}{\partial f} \geq 0$ and $\frac{\partial c_f}{\partial x} \geq 0$ respectively.

To identify the source of inefficiency we set up the two firm's maximisation problem as: the steel firm maximises profits by choosing s, while the fishery maximises its profits by choosing f. Note that the choice of 's' increases x (pollution) affecting the fishery adversely and hence it is a negative external effect. We can write this as:

$$\max_{s,x} p_s s - c_{s(s,x)} \quad (3.19)$$

and

$$\max_f p_f f - c_f(f,x) \quad (3.20)$$

The first order optimality conditions give us s*,x* and f* satisfying:

$$ps = MC_s^s(s^*, x^*) \quad (3.21)$$

$$0 = MC_s^x(s^*, x^*) \quad (3.22)$$

and

$$p_f = MC_f^f(f^*, x^*) \quad (3.23)$$

Equation (3.21) says that the price of steel should be equated to the marginal cost of steel i.e. the standard profit maximising condition for a perfectly competitive firm. Similarly, Equation (3.23) gives us the profit maximising condition for the fishery i.e. at the optimum, price of fishery's output should be equated to the marginal cost of fish production. Equation (3.22) indicates the source of the market failure problem and states that the marginal cost of pollution should be zero! In simpler terms, this means that the steel firm does not face any price for pollution and hence can pollute till the cost of the last pollution unit is zero. Using a diagram similar to the previous one, we can observe that this condition will not yield efficiency (Fig. 3.2). Fig. 3.2 indicates the private and social optimal allocations.

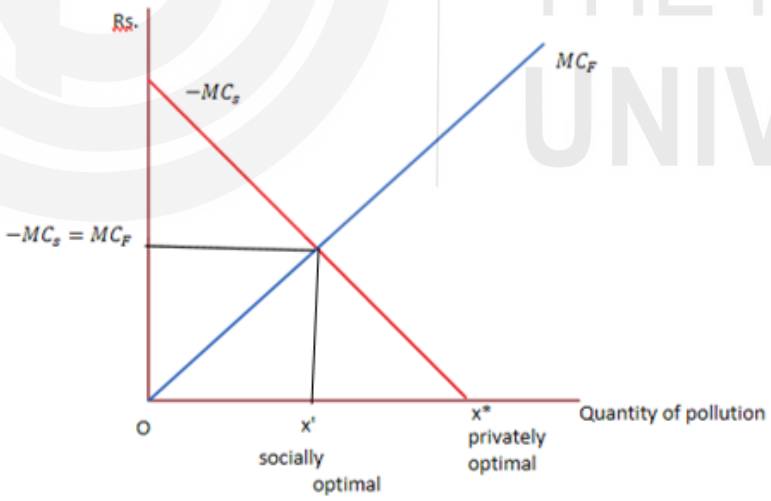

Fig. 3.2: Socially Efficient Optimisation

The downward sloping line represents the 'negative' marginal cost or the marginal benefit of pollution to the steel firm, while the upward sloping line is the external cost imposed by the steel firm on the fishery. At the private optimal, where the marginal cost curve intersects the X axis, MC equals zero [as in Equation (3.22)]. The marginal cost to fishery (or society) is larger than the marginal benefit and hence the allocation is socially inefficient. On the other hand, the total surplus is maximised at the socially optimal, x', where

the two curves intersect. At this point, the marginal benefit to the polluter (S) and the marginal cost to the victim (F) are the same.

Check Your Progress 2 [answer within the space given in about 50-100 words]

1) Define externality. Distinguish between positive and negative externality.

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2) Give two examples of positive externality in consumption.

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3) Give two examples of positive externality in production.

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4) In a two agent case, where B is negatively affected by the consumption habits of A, write down the utility functions for A and B with an explanation of how their marginal benefits would behave.

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3.5 LET US SUM UP

Markets fail to allocate resources efficiently due to the violation of certain assumptions. Economists explain environmental degradation using the theory of market failure by primarily identifying (negative) externalities and public goods as the two sources of inefficiency. In light of this the unit has discussed the conditions to be satisfied if the government has to provision a facility as a public good. In this context, the concept of free riding and how it affects efficiency is illustrated. The unit has then discussed the issue of externalities presenting conditions under which societal inefficiencies in situations of negative externalities in production or consumption can be minimised.

3.6 KEY WORDS

Market Failure : Refers to the inability of the market to achieve allocative efficiency, due to the violation of certain 'ideal' conditions.

Non-rivalry in Consumption : Refers to a situation where the consumption by one agent doesn't reduce the units of consumption available to another agent.

Non-excludability : Refers to a situation where no agent is denied access to a good or service.

Congestible Goods : Goods that are excludable but non-rival up to a point.

Open-access Resources : Goods that are non-excludable but rival.

Private Goods : Goods that are both rival and excludable.

Public Goods : Goods that are non-rival and non-excludable. Such goods are typically not provided at the efficient level by private markets.

Externalities : Externalities arise when the consumption or production of one agent affects (positively or negatively) the consumption and/or production of another agent with no compensation mechanism existing.

3.7 SOME USEFUL BOOKS AND REFERENCES

1) Kolstad C (2006). *Environmental Economics*. New Delhi: Oxford University Press.

2) Perman R, Y Ma, J MacGilvray and M Common (2003). *Natural Resource and Environmental Economics,* Harlow, England: Addison-Wesley.

3) Stevens M, Bowles S, and Sethi R (2017). *Markets, Efficiency and Public Policy*, Unit 12 in The CORE Team, The Economy. Available at: http://www.core-econ.org. [Accessed on January 13, 2018].

4) Varian, H. R. (2010). *Intermediate Microeconomics: A Modern Approach,* New York, W.W. Norton & Co.

3.8 ANSWERS/HINTS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) Markets work efficiently when certain assumptions made on their functioning are fulfilled. In reality, the assumptions are often violated resulting in markets to function in a less than efficient manner. This is termed as 'market failure'. The term connotes the inefficiency of systems or institutions (to govern the establishment of prices solely by the interplay of forces of demand and supply) in place which allows factors favourable to violation of assumptions to take effect.

2) The set of assumptions made for the efficient working of markets are classifiable under three heads viz. market characteristics, economic agents and nature of commodities. Market failure in the case of environmental goods arise when the assumptions made on 'nature of commodities' are violated. In particular, these assumptions require that: (i) there are no externalities; (ii) all goods are non-public are private goods; and (iii) following assumption (ii), there are well defined property rights.

3) Common pool resources are goods which carry the property of non-excludable but are rival. Example is ocean fishery. All those with the necessary equipment can access but subsequent catches would be less in number than those done before. Opposite of a common pool resource is called as club good (also called as congestible good). An example of the congestible good is a toll road which can be excluded for those who cannot pay the toll (hence excludable) but all those who can pay can access without hindrance (i.e. non rival). However, it can get congested with more users; hence the name congestible good whereupon its availability/access might become reduced.

4) The cost of establishing the good must be at least equal to the combined WTP of all users of the facility or the reservation price of all the potential users.

5) It refers to a situation where the articulated WTP is less than the actual WTP. Free riding will not affect the decision to provide a good for public usage when the number of users are so large that the total cost of provisioning would still be less than the aggregate articulated WTP.

Check Your Progress 2

1) Externality refers to the unintended consequences on one agent by the action of another agent. The action could be related either with the

consumption or production aspects of the two. If the resulting externality is a positive benefit (like A gets inoculated due to which B cannot contract a disease at least from A), then such an externality is called as positive externality. On the other hand, if it is negative (like A is a smoker but B is a non smoker, and when the two of them are staying together, B is adversely effected by A's smoking), then the effect is termed as negative externality.

2) Keeping ones' surroundings clean; using organically disposable material.

3) Pollution caused by burning plastics in public parks; pollution of rivers by dumping wastes.

4) See Equations (3.14) to (3.18) and answer.

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