CHAPTER 3

EFFICIENCY, PROPERTY RIGHTS, MARKET FAILURE AND THE ENVIRONMENT

3.1. Efficiency

An ‘allocation of resources’ describes;

- √ What goods are produced and in what quantities they are produced
- √ Which combinations of resource inputs are used in producing those goods, and
- √ How the outputs of those goods are distributed between persons.

The definition of efficiency in welfare economics owes much to the economist Vilfredo Pareto.

Definition of efficiency or Pareto optimality:

“*An allocation of resources is said to be efficient or Pareto optimal if it is impossible to make one person better-off except by making someone else worse-off”.*

Conversely, an allocation is inefficient if it is possible to make at least one person better off without worsening the position of anyone else. A gain by one or more persons without anyone else suffering is known as a Pareto improvement or a Pareto superior move. When all such gains have been made, the resulting allocation becomes Pareto optimal. Pareto optimal is a state in which there is no possibility of Pareto improvements.

There should be efficient allocation of resources in general and of natural and environmental resources in particular. Two important facts make efficiency a point of concern in natural resource and environmental economics.

i. The natural environment is a complex system of resource stock, which provides a variety of valuable services to a society.
ii. Natural and environmental resources are available in limited quantity; but human wants are unlimited.

Economic efficiency is classified in to two types:

a. Static efficiency: concerned with efficient allocation of resources in specific point of time. It ignores time factor.
b. Dynamic efficiency: concerned with efficient allocation of resources over a period of time.

Conditions for Static Efficiency and Optimality

To understand the concept of static efficiency, we use the following assumptions:

i) The economy consists of two persons (A and B).
ii) The economy produces two goods (X and Y).
iii) The economy uses two inputs [capital (K) and labour (L)].

iv) The productive resources are available in a fixed quantity.

v) No externalities exist in either consumption or production of both goods; this means that consumption and production activities do not have unintended and uncompensated effects upon others.

vi) Both goods are private (not public) goods.

Utility functions

Each person's total utility depends on the quantity of goods that he/she consumes in a particular period of time. Thus, utility functions for A and B are given by:

$U^A = U^A(X^A, Y^A)$

$U^B = U^B(X^B, Y^B)$

The marginal utility that A derives from the consumption of good X is denoted by $MU_X^A = \frac{\partial U^A}{\partial X^A}$. Equivalent notation applies for the other marginal utilities.

The marginal rate of utility substitution for A is the rate at which X can be substituted for Y at the margin, or vice versa, while holding the level of A's utility constant. It varies with the levels of consumption of X and Y and is given by the slope of the indifference curve. We denote A's marginal rate of substitution as $MRUS_{XY}^A$, and similarly for B.

$$MRUS_{XY}^A = [\frac{MU_X}{MU_Y}]^A$$

$$MRUS_{XY}^B = [\frac{MU_X}{MU_Y}]^B$$

Production functions

The production functions for the two goods are given by:

$X = X(L^X, K^X)$

$Y = Y(L^Y, K^Y)$

Each production function specifies how the output level varies as the amounts of the two inputs are varied.

The marginal product of the input L in the production of good X is denoted as $MP_L^X = \frac{\partial X}{\partial L^X}$. Equivalent notation applies for the other three marginal products.

The marginal rate of technical substitution as between L and K in the production of X is the rate at which L can be substituted for K at the margin, or vice versa, while holding the level output of X constant. It varies with the input levels for L and K and is given by the slope of the isoquant. We denote the marginal rate of substitution in the production of X as $MRTS_{LK}^X$, and similarly for Y.

$MRTS_{LK}^{X} = [\frac{MP_L}{MP_K}]^X$

$MRTS_{LK}^{Y} = [\frac{MP_L}{MP_K}]^Y$

The marginal rates of transformation for the commodities X and Yare the rates at which the output of one can be transformed into the other by marginally shifting labour or capital from one line of production to the other.

Thus, MRT_L^X refers the effect on the output of X when labour is, at the margin, shifted from use in the production of Y to the production of X. Similarly, MRT_K^X refers the effect on the output of X when capital is, at the margin, shifted from use in the production of Y to the production of X.

$MRT_L^X = \frac{dY}{dX}$ [When labour is shifted from use in the production of Y to the production of X and there is no reallocation of capital]

$$\Rightarrow MRT_L^X = \frac{dY}{dL} \Big/ \frac{dX}{dL} = \frac{MP_L^Y}{MP_L^X}$$

Therefore, the marginal rate of transformation for labour is the ratio of the marginal products of labour in each line of production.

Similarly, $MRT_K^X = \frac{dY}{dX}$ [When capital is shifted from use in the production of Y to the production of X and there is no reallocation of labour].

$$\Rightarrow MRT_K^X = \frac{dY}{dK} \Big/ \frac{dX}{dK} = \frac{MP_K^Y}{MP_K^X}$$

Therefore, the marginal rate of transformation for capital is the ratio of the marginal products of capital in each line of production.

In two-persons, two-goods and two-input economy or (2x2x2) model, static efficiency in allocation is achieved if the following three efficiency conditions are fulfilled:

i) efficiency in consumption

ii) efficiency in production, and

iii) product-mix efficiency

Efficiency in consumption

Consumption efficiency requires that the marginal rates of utility substitution for the two individuals are equal:

$MRUS_{XY}^{A} = MRUS_{XY}^{B}$

$\Rightarrow [\frac{MU_X}{MU_Y}]^A = [\frac{MU_X}{MU_Y}]^B$

If this condition is not satisfied, it is possible to re-arrange allocation of the goods between A and B so as to make one better off without making the other worse off. Graphically, efficiency in consumption is described by the tangency between indifference curves of the two persons in Edgeworth Box.

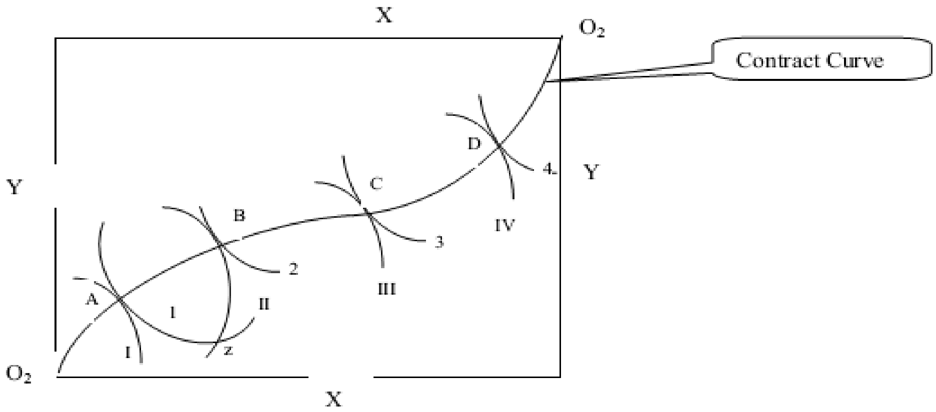


Figure 3.1.: Efficiency in consumption

Starting from O_A moving horizontally to the right measures A's consumption of X, and moving vertically upwards measures A's consumption of Y. Starting from O_B moving horizontally to the left measures B's consumption of X, and moving vertically downwards measures B's consumption of Y. As A's consumption of a commodity increases, B's must decrease. Note that efficiency in consumption occurs on the contract curve. Movement from Z to A or Z to B is Pareto improvement. But movement from A to B (or B to C or C to D) is not Pareto improvement.

Efficiency in Production

Efficiency in production requires that the marginal rate of technical substitution be the same in the production of both commodities. That is,

$$MRTS_{LK}^{X} = MRTS_{LK}^{Y}$$

$$\Rightarrow [\frac{MP_L}{MP_K}]^X = [\frac{MP_L}{MP_K}]^Y$$

If this condition is not satisfied, it is possible to re-allocate inputs to production so as to produce more of one of the commodities without producing less of the other. Graphically, production efficiency is described by the tangency between isoquants of the two commodities in the Edgeworth Box.

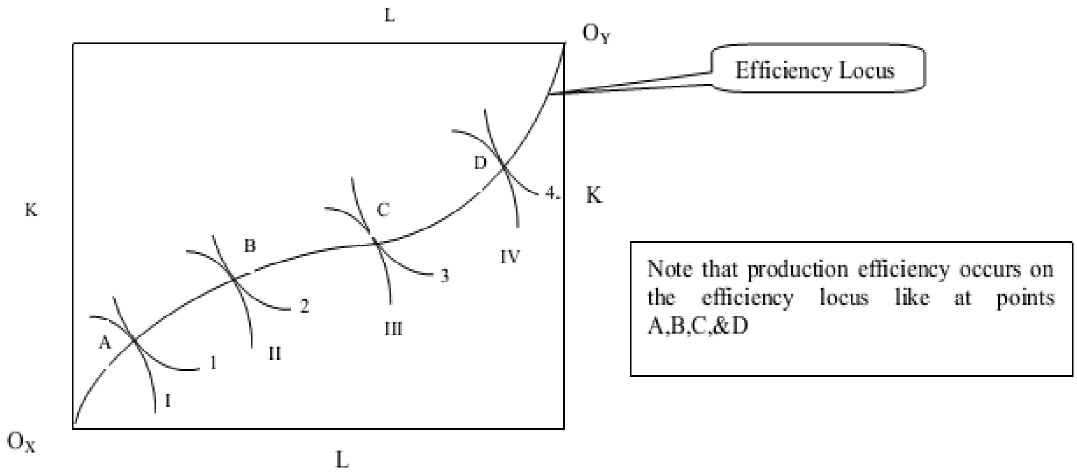


Figure 3.2: Efficiency in production

Starting from O_X moving horizontally to the right measures increasing use of labour in the production of X, and moving vertically upward measures increasing use of capital in the production of X. Starting from O_Y moving horizontally to the left measures increasing use of labour in the production of Y, and moving vertically downward measures increasing use of capital in the production of Y. Any increase/decrease in use of labour/capital for X production must involve a decrease/ increase in use for Y production.

Product-mix efficiency

The final condition necessary for static economic efficiency is product-mix efficiency. This requires that $MRT_L^X = MRT_K^X = MRUS_{XY}^A = MRUS_{XY}^B$

$$\Rightarrow \frac{MP_L^Y}{MP_L^X} = \frac{MP_K^Y}{MP_K^X} = [\frac{MU_X}{MU_Y}]^A = [\frac{MU_X}{MU_Y}]^B$$

Product-mix efficiency requires that the subjective value of X in terms of Y should be equal to its opportunity cost of producing X. Graphically, product-mix efficiency is described by tangency between production possibility frontier and indifference curve that satisfies efficiency in consumption condition.

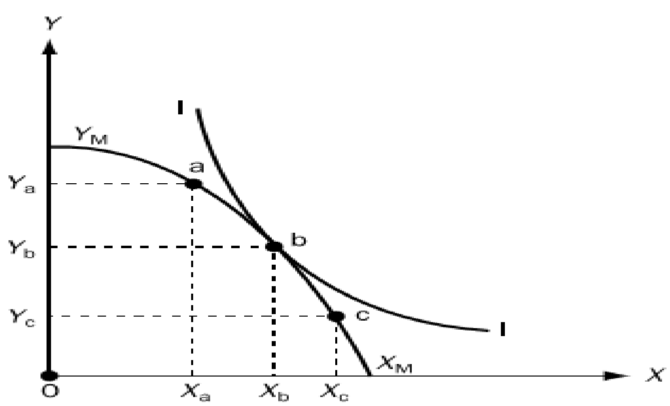


Figure 3.3: Product-mix efficiency

Conclusion: an economy attains a fully static efficient allocation of resources if the conditions required for consumption efficiency, production efficiency and product- mix efficiency are satisfied simultaneously.

An efficient allocation of resources is not unique.

For an economy with given quantities of available resources, production functions and utility functions, there will be many efficient allocations of resources. That is, the criterion of efficiency in allocation does not serve to identify a particular allocation which is best from the point of view of society.

There are *many combinations of X and Y* output levels that are consistent with allocative efficiency, and for any particular combination there are *many allocations as between A and B* that are consistent with allocative efficiency.

The social welfare function and static optimality

Consider a particular allocation of capital and labour as between X and Y production which implies particular output levels for X and Y, and take a particular allocation of these output levels as between A and B which give a particular level of utility for A and for B.

If all available resources were used to produce commodities only for consumption by A, A would obtain $U^A_{max.}$ On the other hand, if all available resources were used to produce commodities only for consumption by B, B would obtain U^B_{max}. The line $U^A_{max}U^B_{max}$ is the utility possibility frontier – the economy cannot deliver combinations of U^A and U^B lying outside that line. Given its resources, production technologies and preferences, the economy can deliver all combinations of U^A and U^B lying in that area.

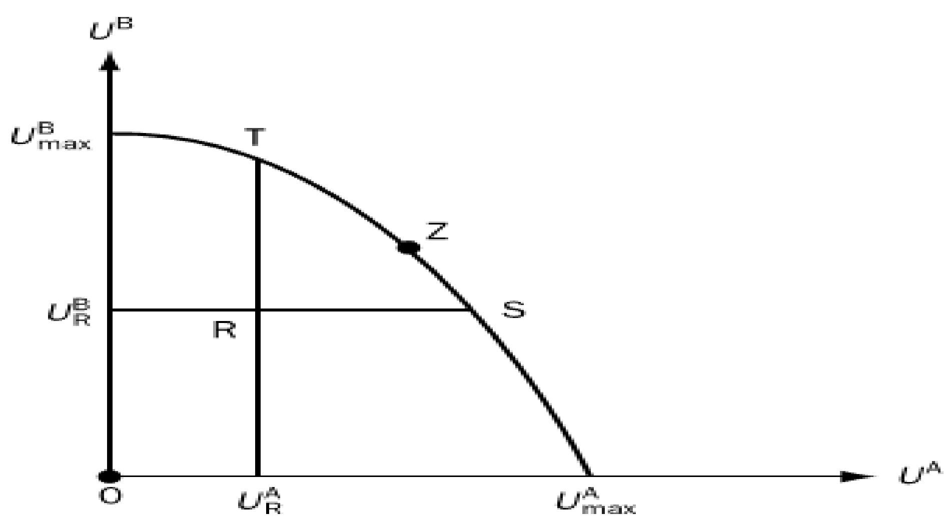


Figure 3.4: The utility possibility frontier

The *utility possibility frontier* is the locus of all possible combinations of U^A and U^B that correspond to efficiency in allocation -- situations where there is no scope for a Pareto improvement. There are many such combinations. Is it possible, using the information available, to say which of the points on the frontier is best from the point of view of society? It is not possible, for the simple reason that the criterion of economic efficiency does not provide any basis for making interpersonal comparisons. Put another way, efficiency does not give us a criterion for judging which allocation is best from a social point of view.

In order to choose a particular allocation which is best from a social point of view, we need the concept of a social welfare function (SWF). A SWF can be used to rank alternative allocations. For the two-person economy, a SWF will be of the general form:

$W = W(U^A, U^B)$

The only assumption that we make here regarding the form of the SWF is that welfare is non-decreasing in U^A and U^B. In other words, we assume that $W_A = \partial W/\partial U^A$ and $W_B = \partial W/\partial U^B$ are both positive. Given this, the SWF is formally of the same nature as a utility function. Whereas the latter associates numbers for utility with combinations of consumption levels X and Y, a SWF associates numbers for social welfare with combinations of utility levels U^A and U^B. Just as we can show a utility function in terms of indifference curves, we can also show a SWF in terms of social welfare indifference curves. Figure 3.5 shows a social welfare indifference curve WW that has the same slope as the utility possibility frontier at ***b***, which point identifies the combination of U^A and U^B that maximizes the SWF.

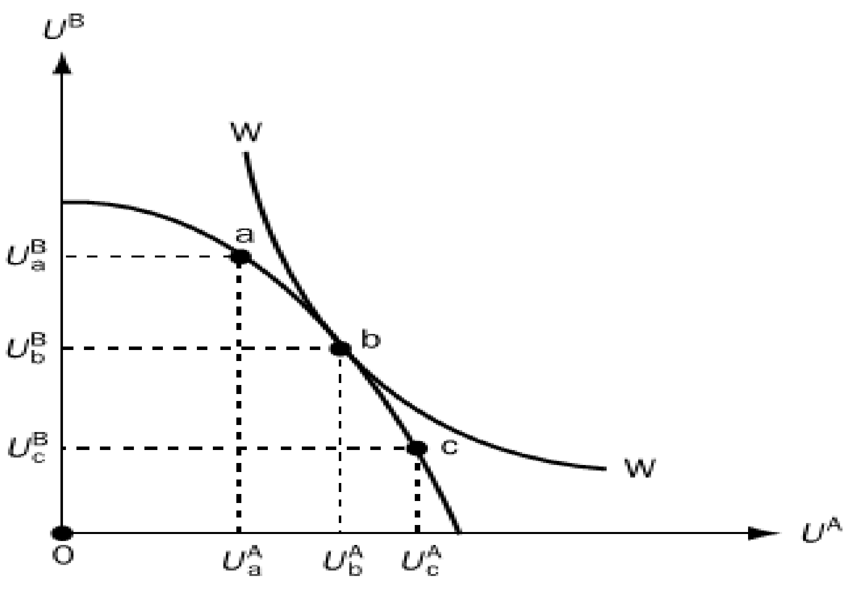


Figure 3.5: Maximized social welfare

The fact that the optimum lies on the utility possibility frontier means that all of the necessary conditions for efficiency must hold at the optimum. Conditions for efficiency in consumption, efficiency in production and product-mix efficiency must be satisfied for the maximization of social welfare. Also, an additional condition, the equality of the slopes of a social welfare indifference curve and the utility possibility frontier, must be satisfied. This condition can be stated as;

$$\frac{W_A}{W_B} = \frac{\mathrm{MU_X^B}}{\mathrm{MU_X^A}} = \frac{\mathrm{MU_Y^B}}{\mathrm{MU_Y^A}}$$

At the maximum of social welfare, the slopes of the social welfare indifference curve and the utility possibility frontier must be equal, so that it is not possible to increase social welfare by transferring goods, and hence utility, between persons. While allocative efficiency is a necessary condition for optimality, it is not generally true that moving from an allocation that is not efficient to one that is efficient must represent a welfare improvement. Such a move might result in a lower level of social welfare. In figure 3.6, we observe that at C, the allocation is not efficient, at D it is. However, the allocation at C gives a higher level of social welfare than does that at D. Moving from C to D replaces an inefficient allocation with an efficient one, but the change is not a Pareto improvement – B gains, but A suffers – and involves a reduction in social welfare.

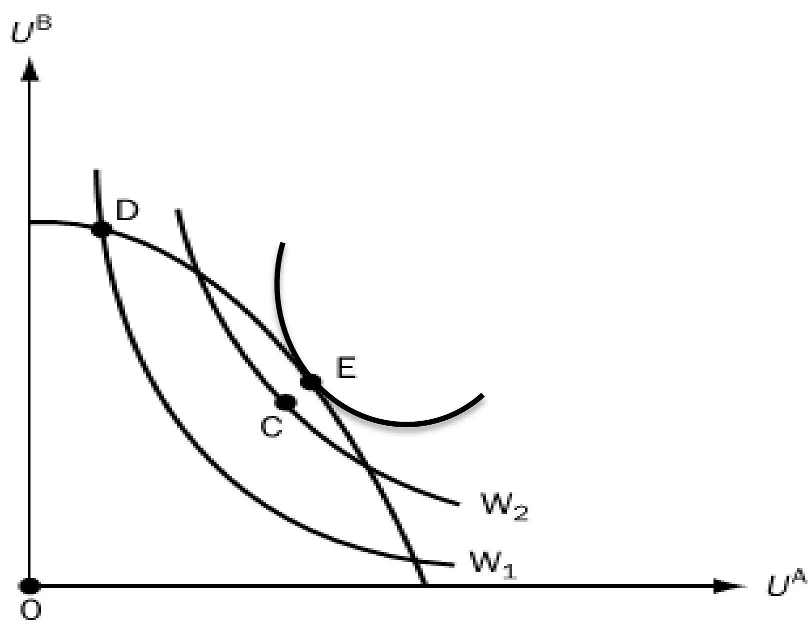


Figure 3.6: Welfare and efficiency

Nevertheless, whenever there is an inefficient allocation, there is always some other allocation which is both efficient and superior in welfare terms. For example, compare points C and E. E is allocatively efficient while C is not, and E is on a higher social welfare indifference curve. The move from C to E is a Pareto improvement where both A and B gain, and hence involves higher social welfare.

Clearly, any change which is a Pareto improvement must increase social welfare as defined here. Given that the SWF is non-decreasing in U^A and U^B, increasing U^A/U^B without reducing U^B/U^A must increase social welfare.

Static efficiency in a market economy

Does a system of free markets achieve an efficient allocation of resources? Welfare economics theory points to a set of conditions such that a system of free markets would achieve an efficient allocation of resources. These conditions, which are ideal, include the following:

1. Markets exist for all goods and services produced and consumed.
2. All markets are perfectly competitive.
3. All transactors (agents) have perfect information.
4. Private property rights are fully assigned in all resources and commodities.[;
5. No externalities exist.
6. All goods and services are private goods. That is, there are no public goods.
7. All utility and production functions are 'well behaved'.
8. All agents are maximisers. Firms are assumed to maximize profits, individuals to maximize utility.

These conditions do not accurately describe any actual market economy. The economy that they describe is an ideal type, to be used in the welfare analysis of actual economies as a benchmark to assess performance, and to be used to devise policies to improve the performance, in regard to efficiency criteria, of such actual economies. Actual market economies depart from the ideal circumstances in a variety of ways, and the allocations that they produce are not efficient

- An efficient allocation of resources in a market economy is an outcome of maximizers behavior where all of the institutional arrangements (1-7 conditions) were in place.

Consider, first, individuals and their consumption of produced commodities. Any one individual seeks to maximize utility given income and the fixed prices of commodities. An individual maximizes his/her utility when the budget line is tangent to the indifference curve. In the following figure, this occurs at point b. At b, the slope of the indifference curve is equal to the price ratio. Given that the slope of the indifference curve is the MRUS, at b we have:

$MRUS_{x,y} = Px/Py$

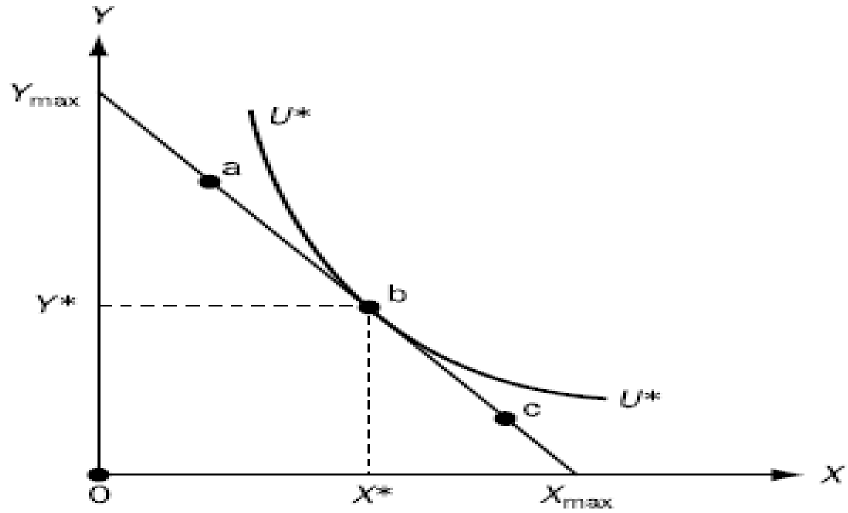


Figure 3.7: Utility maximization

In the ideal conditions under consideration, all individuals face the same prices. So, for the two-individuals, two-commodities market economy, we have

$MRUS_{x,y}^{A}$ = $MRUS_{x,y}^{B}$ = Px/Py ----------------------------- (1)

☞ Consumption efficiency condition is satisfied in the ideal market system.

Now consider firms. To begin, we will assume that firms minimize the costs of producing a given level of output. The cost minimization assumption is in no way in conflict with the assumption of profit maximization. For given prices for inputs, P_K and P_L, an isocost line shows the combinations of input levels for K and L that can be purchased for a given total expenditure on inputs. The slope of an isocost line is the ratio of input prices, P_K/P_L. Given production of X*, the cost minimizing firm will choose the input combination given by the point b in figure below.

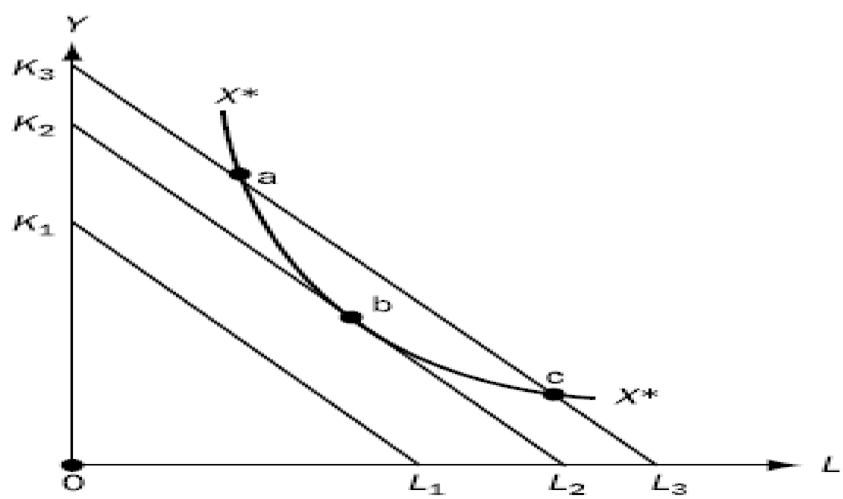


Figure 3.8: Cost minimization

The essential characteristic of point b is that an isocost line is tangential to, has the same slope as, an isoquant. The slope of an isoquant is the MRTS so that cost minimizing choices of input levels must be characterized by:

$MRTS_{L,K} = P_L/P_K$

In the ideal circumstances under consideration, all firms, in all lines of production, face the same P_K and P_L, which means that $\mathbf{MRTS_{L,K}^{X} = MRTS_{L,K}^{Y} = P_L/P_K}$ ---------------------------(2)

☞ Cost-minimizing firms satisfy the production efficiency condition for allocative efficiency.

The remaining condition that needs to be satisfied for allocative efficiency to exist is the product-mix condition, which involves both individuals and firms. In explaining how this condition is satisfied in an ideal market system, we will see how the profit-maximizing levels of production and utility maximizing levels of consumption are determined. The utility maximizing condition is given by equation (1) above. Rather than look directly at the profit maximizing output choice, we look at the choice of input levels that gives maximum profit. Once the input levels are chosen, the output level follows from the production function. Consider the input of labour and capital to the production of X, with marginal products, MP_L^X and MP_K^X, respectively. Similarly, consider input of labour and capital to the production of Y, with marginal products, MP_L^Y and MP_K^Y, respectively. Given fixed prices of the commodities, Px and Py and prices of the inputs, PL and PK, profit maximization will be characterized by the following:

$Px\ MP_L^X = PL$

$Px\ MP_K^X = PK$

$Py\ MP_L^Y = PL$

$Py\ MP_K^Y = PK$

which imply

$Px\ MP_L^X = Py\ MP_L^Y = PL$

and

$Px\ MP_K^X = Py\ MP_K^Y = PK$

Using the left-hand equalities here, and rearranging, this is

$Px/Py = MP_L^Y / MP_L^X$

and

$Px/Py = MP_K^Y / MP_K^X$

$MRT_L^X = MRT_K^X = Px/Py$

From equation (1), $\mathbf{MRT_L^X = MRT_K^X = MRUSx,y^{A} = MRUSx,y^{B} = Px/Py}$ --------------------(3)

☞ The profit maximizing output levels and utility maximizing consumption levels in the ideal market economy satisfy the product-mix condition for allocative efficiency.

Static efficiency as net benefit maximization

The chief normative economic criterion for choosing among various allocations occurring at a point in a time is called static efficiency or merely efficiency. An allocation of a resource is said to be satisfy the static efficiency criterion if net benefit from the use of the resource is maximized by that allocation.

$$Net\ Benefit = total\ benefit - total\ cost$$

NB = TB - TC

Efficiency = Max NB

$\frac{dNB}{dQ} = \frac{dTB}{dQ} - \frac{dTC}{dQ} = 0$, because at maximum of NB, the derivative is zero.

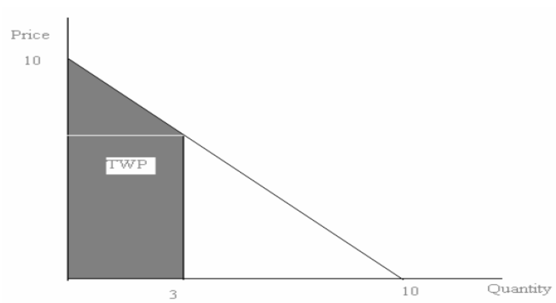
MB-MC=0

MB=MC

But how do we measure benefits and costs of allocation of the resource? All benefits and costs are valued in terms of their effects on human kind.

Total benefits can be derived from the market demand curve for a good or service provided by the resource.

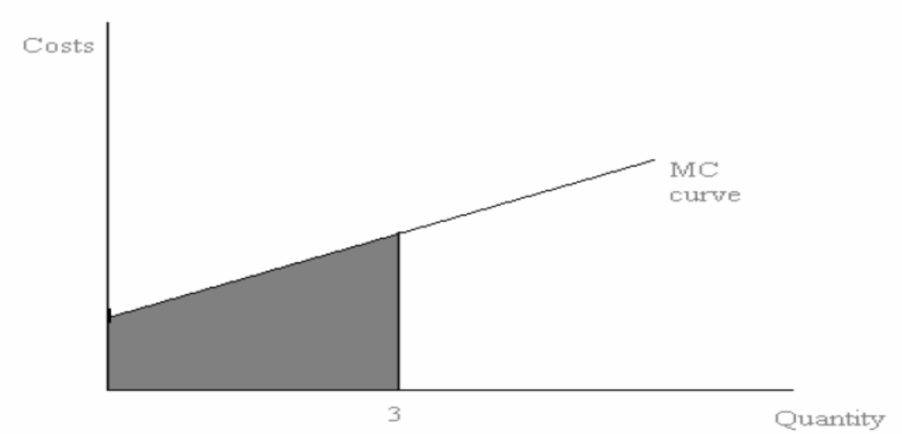
Market demand curve measures quantities of a particular good or service that consumers would be willing to purchase at various prices. For each quantity purchased, the corresponding point on the inverse market demand curve represents the amount of money consumers are willing to pay for the last unit of the good. The total willingness to pay for some quantity of the good-say 3 units-is the sum of the willingness to pay for each of the three units. That is, total willingness to pay for 3 units is the sum of WTP for the 1^{st}, 2^{nd} and 3^{rd} units=the area of the shaded region below. Hence, the total willingness to pay is the area under the continuous inverse market demand curve to the left of the allocation in question.



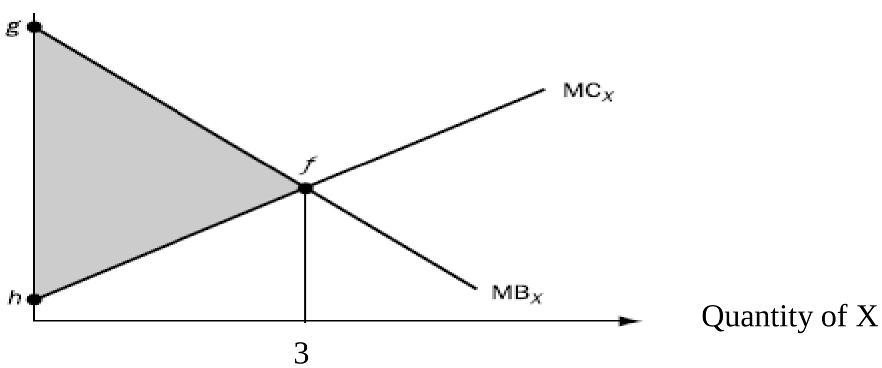
Note that total willingness to pay is the concept we shall use to define total benefits. Thus, total benefits are equal to the area under the market demand curve from the origin to the allocation of interest.

Costs should be measured as opportunity costs. For environmental services, their opportunity cost is the net benefit forgone because the resources providing the service can no longer be used in the next most beneficial use. Resources are not free if they can be put in alternative uses. In graphing costs, we shall use the marginal opportunity cost curve. The marginal opportunity cost curve defines the additional cost of producing the last unit. In purely competitive markets, the marginal opportunity cost curve is identical to the supply curve.

Total cost is simply the sum of the marginal cost. The total cost of producing 3 units is equal to the cost of producing the first unit plus the cost of producing the second units plus the cost of producing the third unit. As with total willingness to pay, the geometric representation of the sum of the individual elements of a continuous marginal cost curve is the area under the marginal cost curve.



Since net benefit is defined as the excess of benefits over costs, it follows that net benefit is equal to that portion of the area under the demand curve which lies above the supply curve.



Having defined the measurements of costs & benefits, we can now make an inference as to whether a certain allocation is efficient or not. An allocation is said to be efficient if it maximizes the net benefit. One implication of the above analysis is what we call the "first equimarginal principle":

First equimarginal principle (the "*efficiency equimarginal principle"*): *Social net benefits are maximized when the social marginal benefits from an allocation equal the social marginal costs.*

Example: The demand curve for the good produced by a resource is given by P=10-Q and the marginal cost curve of producing the good is given by MC=Q.

a) Determine function for total benefits, total costs and net benefit.
b) Calculate the efficient output level and
c) Check that maximum net benefit is equal to the sum of consumer surplus and producer surplus.

Dynamic Efficiency

The static efficiency criterion is very useful for comparing resource allocations when time is not an important factor. Yet, many of the decisions made now have consequences, which persist well in to the future time. Examples:

√ Exhaustible energy resources, once used, are gone;

√ Biological renewable resources (such as fisheries or forests) can be over harvested, leaving smaller and possibly weaker populations for future generations;

√ Persistent pollutants can accumulate over time.

Since many of the decisions made now affect the value of assets for the future generation, we should take the future generation into account while taking some actions. How can we make choices when the benefits and costs occur at different points in time?

Incorporating time into the analysis requires an extension of the concepts we have already developed, i.e., we have to extend the static efficiency concept. This extension provides a way for thinking not only about the magnitude of benefits and costs, but also about their timing. In order to incorporate timing, the decision rule must provide a way to compare the net benefits received in different time periods. The concept that allows this comparison is called ***present value***. Present value explicitly incorporates the time value of money.

The present value of a *one – time* net benefit received at t is

$$PV\ (NBt) = \frac{NB_t}{(1+r)^{t-1}}\ \ , t =\ 1, 2, - - - -$$

The present value of a stream of net benefits (NB_1, NB_2, ----, NB_n) received over a period of n years is computed as

$$PV\ (NB1, NB2, ----, NBn,) = \sum_{t=1}^{n} \left[\frac{NB_t}{(1+r)^{t-1}}\right] = NB_1 + \frac{NB_2}{(1+r)^1} + --- + \frac{NB_n}{(1+r)^{n-1}}$$

Where r is the appropriate interest rate and NB_1 is the amount of net benefits received immediately (NB of the current period). The process of calculating the present value is called *discounting*, and the rate r is referred to as the *discount rate*.

Note that the issue of discounting and intergenerational equity will come up with the discussion of dynamic efficiency.

Dynamic efficiency as the maximization of present value of net benefits over time

The traditional criterion used to find an optimal allocation when time is involved is called dynamic efficiency, a generalization of the static efficiency concept already developed. In this generalization, the present-value criterion provides a way for comparing the net benefits received in one period with the net benefits received in another. Dynamic efficiency can simply be defined as the maximization of present value of net benefits over time.

- An allocation of resources across *n* time periods satisfies the dynamic efficiency criterion if it maximizes the present value of net benefits that could be received from all the possible ways of allocating those resources over the *n* periods.

The Simple Mathematics of Dynamic Efficiency

Assume that the demand curve for a depletable resource is linear and stable over time. Thus, the inverse demand curve in year t can be written as

$$p_t = a - bq_t \text{ --- } 1$$

The total benefits from extracting an amount q_t in year t are then the integral of this function (the area under the inverse demand curve).

$$(\text{Total Benefits})_t = \int_o^{q_t} (a - bq)dq \text{ --- } 2$$

$$= aq_t - \frac{b}{2}q_t^2 \text{ --- } 3$$

Further assume that the marginal cost of extracting that resource is a constant c and therefore the total cost of extracting any amount q_t in year t can be given by

$(\text{Total Cost})_t = cq_t$ -- 4

$$NB_t = aq_t - \frac{b}{2}{q_t}^2 - cq_t \text{ ----------------------------- } 5$$

$$\text{PV } (NB_t) = \frac{aq_t - \frac{b}{2}{q_t}^2 - cq_t}{(1+r)^{t-1}} \text{ --------------------------- } 6$$

If the total available amount of this resource is $\overline{Q}$, then the dynamic allocation of the resource over n years is the one which satisfies the maximization problem:

$$Max \sum_{t=1}^{n} \left[\frac{aq_t - \frac{b}{2}{q_t}^2 - cq_t}{(1+r)^{t-1}} \right]$$

$$subject\ to\ \overline{Q} = \sum_{t=1}^{n} q_t$$

From the objective and the constraint functions we form the Lagrangean function:

$$L = \sum_{t=1}^{n} \left[\frac{aq_t - \frac{b}{2}{q_t}^2 - cq_t}{(1+r)^{t-1}} \right] + \lambda \left[\overline{Q} - \sum_{t=1}^{n} q_t \right] \text{ ------------------- } 7$$

At the maximum the first order conditions must be satisfied. That is, the partial derivatives of the Lagrangean function with respect to q_t and λ must be equal to zero.

Assuming that Q is less than would normally be demanded, the dynamic efficient allocation must satisfy necessary conditions;

$$\frac{\partial L}{\partial q_t} = 0 \Rightarrow \frac{a - bq_t - c}{(1+r)^{t-1}} - \lambda = 0 \text{ ------------------------- } 8$$

$$\frac{\partial L}{\partial \lambda} = \overline{Q} - \sum_{t=1}^{n} q_t = 0 \text{ ---------------------------- } 9$$

From equation (8), we have $\frac{(\boldsymbol{Pt - c})}{(\boldsymbol{1+r})^{\boldsymbol{t-1}}} = \boldsymbol{\lambda}$. The difference in the numerator, which is known as the ***marginal user cost*** **(MUC_t)** or ***marginal net benefit*** **(MNB_t)**, plays a key role in our thinking about allocating depletable resources over time.

What does the marginal user cost measures? Marginal user cost measures the opportunity cost of allocating an extra unit of the resource against the future generation, i.e., every unit of the resource used in one period is a loss to generation in the future period and this loss is referred to as the marginal user cost. The value of λ measures the present value of marginal user cost.

An implication of equation (8) is that an allocation of the resource satisfies the dynamic efficiency criterion when PV of marginal net benefits of each period is equal to λ.

PV (MNB_1) = PV (MNB_2) = ----- = PV (MNB_n) = λ

$$MNB_1 = \frac{MNB_2}{(1+r)} = ----= \frac{MNB_n}{(1+r)^{n-1}} = \lambda$$

In addition, equation (8) implies that the MUC_t (=$Pt - c$) increases over time at rate r.

Numerical Example:

Let the inverse demand function for the depletable resource is $\boldsymbol{Pt = 8 - 0.4qt}$ and the marginal cost of extracting it is **$2**. The total available amount of the resource is **20** units.

a) If 20 units are to be allocated between two periods, in a dynamic efficient allocation how much would be allocated to the first period and how much to the second period when the discount rate is 0.1?
b) What would the efficient price be in each period?
c) Calculate marginal user cost in each period?
d) Check that the social marginal cost (MC_T) is equal to social marginal benefit (MB) in dynamic efficient allocation of the resource.

Solution:

$$TB_t = \int_0^{q_t}(8 - 0.4q_t)d\,q_t$$

$$TB_t = 8q_t - 0.2{q_t}^2$$

$$TC_t = 2q_t$$

$$NB_t = TB_t - TC_t = 6q_t - 0.2{q_t}^2$$

$$PV(NB_1, NB_2) = \sum_{t=1}^{2}\left[\frac{6q_t - 0.2{q_t}^2}{(1+0.1)^{t-1}}\right] = 6q_1 - 0.2{q_1}^2 + \frac{6q_2 - 0.2{q_2}^2}{1.1}$$

$$Max\sum_{t=1}^{2}\left[\frac{6q_t - 0.2{q_t}^2}{(1+0.1)^{t-1}}\right]$$

Subject to $q_1 + q_2 = 20$

$$L(q_1, q_2, \lambda) = 6q_1 - 0.2{q_1}^2 + \frac{6q_2 - 0.2{q_2}^2}{1.1} + \lambda[20 - q_1 - q_2]$$

The necessary conditions are;

$$\frac{\partial L}{\partial q_1} = 0 \Rightarrow 6 - 0.4q_1 - \lambda = 0 ----------------------------1$$

$$\frac{\partial L}{\partial q_2} = 0 \Rightarrow \frac{6 - 0.4q_2}{1.1} - \lambda = 0 ----------------------------2$$

$$\frac{\partial L}{\partial \lambda} = 0 \Rightarrow 20 - q_1 - q_2 = 0 -3$$

From equations 1, 2, and 3, we obtain

$q_1 = 10.238$

$q_2 = 9.762$

λ= 1.905

Note that equation (1) implies that in a dynamic efficient allocation the PV of the marginal net benefit in period 1 should be equal to λ. Similarly, equation (2) implies that the PV of the marginal net benefit in period 2 should also be equal to λ. Therefore, they must be equal to each other.

$\Rightarrow PV(MNB1) = PV(MNB2)$

$$6 - 0.4q_1 = \frac{6 - 0.4q_2}{1 + r}$$

$$6 - 0.4(10.238) = \frac{6 - 0.4(9.762)}{1.1}$$

$$\underline{\underline{1.905 = 1.905 = \lambda}}$$

b) $P_1 = 8 - 0.4q_1 = 8 - 0.4(10.238) = 3.9048$ &

$P_2 = 8 - 0.4q_2 = 8 - 0.4(9.762) = 4.0952$

c) $MUCt = Pt - c$

$MUC_1 = P1 - c = 3.9048 - 2 = 1.9048 = \lambda$

$MUC_2 = P2 - c = 4.9052 - 2 = 2.9052 = \lambda(1 + r) = 1.905(1.1) = 2.0955$

d) Check that MC_T= MB

Social marginal cost (MC_T) is the sum of marginal extraction cost and marginal user cost.

MC_T=MEC + MUC

Recall that we obtain P_1=3.905 and P_2= 4.095 (from question b).

Furthermore, we know that P_1= $MB_1$and P_2=MB_2

Thus, at equilibrium,

$$\begin{cases} MB = MC_T \\ MB = MEC + MUC \end{cases}$$

Period I: $MEC_1 + MUC_1 = MB_1$

$$2+1.905 = 3.905$$

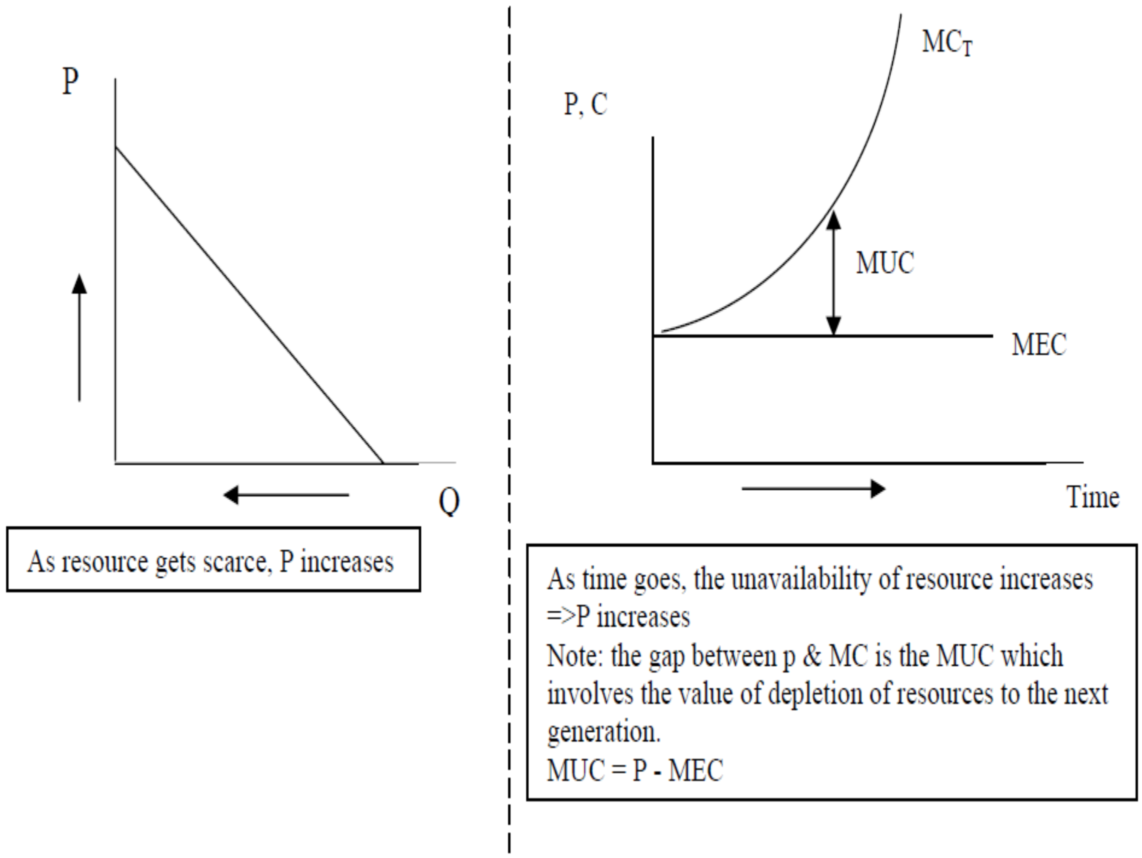
$$\underline{\underline{3.905 = 3.905.}}$$

Period II: $MEC_2 + MUC_2 = MB_2$

$$2+2.095 = 4.095$$

$$\underline{\underline{4.095 = 4.095.}}$$

Efficiency is achieved!!



Do dynamic efficient allocations satisfy the sustainable criterion?

In the above numerical example, more resources are allocated to the first period than to the second. Therefore, net benefits in the second period are lower than in the first period. Sustainability does not allow earlier generations to be profited at the expense of later generations. This example demonstrates that dynamic efficient allocations do not automatically satisfy sustainability criteria. However, they could be compatible with sustainability if generation in the first period saves some of their net benefits for those in the second period.

3.2. Property Rights and Efficient Market Allocations

Purely competitive markets automatically achieve efficient resource use through the independent profit-maximizing behavior of firms and the independent utility-maximizing behavior of households, provided there exists an efficient set of property rights.

In economics, *property right refers to a bundle of entitlements defining the owner's rights, privileges, and limitations for use of the resource*. Property rights are institutional rules that govern and facilitate the use and exchange of resources and commodities. Efficient property rights are a pre-requisite for market transactions and to achieve efficient resource use.

These property rights can be vested either with individuals, as in a capitalist economy, or with the state, as in a centrally planned socialist economy.

Note that the manner in which producers and consumers use environmental resources depends on the property rights governing those resources.

The four main characteristics of property rights that could produce efficient allocations in a well-functioning market economy include;

- ☞ *Exclusivity*: All benefits and costs accrued as a result of owning and using the resources should accrue to the owner, and only to the owner, either directly or indirectly by sale to others.
- ☞ *Specificity*: There should be property rights for a particular property, and they should determine what can and cannot be done with that property.
- ☞ *Transferability*: Property rights should be transferable from one owner to another in a voluntary exchange.
- ☞ *Enforceability*: Property rights should be enforceable and enforced when there is a violation. Exclusivity, specificity and transferability of property rights are of limited value in achieving efficient resource use without enforceability.

An owner of a resource with a well-defined property right (one exhibiting these four characteristics) has a powerful incentive to use that resource efficiently because a decline in the value of that resource represents a personal loss. For instance, farmers who own the land have an incentive to fertilize and irrigate it because the resulting increased production raises income.

Transferability (exchangeability) of property rights facilitates efficiency. The price level which producers & consumers face will adjust until supply equals demand. Given that price, consumers and producers maximize their surplus and market clears.

Is this allocation efficient? According to our definition of static efficiency it is clear that the answer is yes! The net benefit is maximized by the market allocation and it is equal to the sum of the consumer and producer surplus.

Improperly designed property rights systems

Private property is, of course, not the only possible way of defining entitlements to resource use. Other possibilities include;

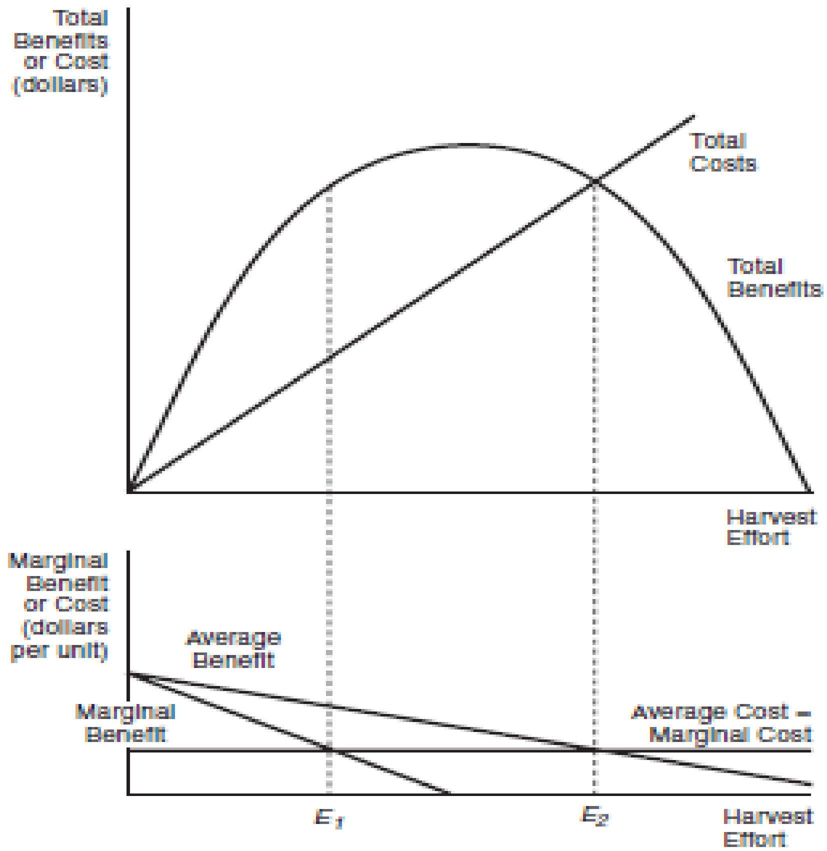
a. ***State-property regimes***: where the government owns and controls the property. State-property regimes exist not only in former communist countries, but also to varying degrees in virtually all countries of the world. Parks and forests, for example, are frequently owned and managed by the government in capitalist as well as in socialist nations. Problems with both efficiency and sustainability can arise in state-property regimes when the incentives of bureaucrats, who implement and/or make the rules for resource use, diverge from collective interests.

b. ***Common-property (res communis) regimes***: where the property is jointly owned and managed by a specified group of co-owners. Common-property resources are those shared resources that are managed in common rather than privately. E.g. Grazing land in rural area. Entitlements to use common-property resources may be *formal* (protected by specific legal rules) or they may be *informal* (protected by tradition or custom). Common-property regimes exhibit varying degrees of efficiency and sustainability, depending on the rules that emerge from collective decision making. While some very successful examples of common-property regimes exist, unsuccessful examples are even more common.

c. ***Open-access (res nullius) regimes***: The property belongs to no one. Here resources are exploited on a first-come, first-served basis because no individual or group has the legal power to restrict access. Thus, res nullius property resources are those resources in which no one owns or exercises control over them. Open-access resources have given rise to what has become known popularly as the "***tragedy of the commons***" which signifies that 'the unregulated behavior of self – interested utility maximizing individuals will result in overexploitation of resources (such as over-grazing, over-harvesting, over hunting, over-fishing, etc.).

Note that common property resource can be changed to open access resource if there are no well – defined systems of rules governing the use and ownership of the resource; and if the number of owners is large and every member has the incentive to break the rule so that the rules become unenforceable.

Let's consider resource allocation under private property and open access regimes.



Private-property allocation occurs where Marginal benefit equals marginal cost of harvesting (which is point E_1). With unrestricted access, the resulting allocation becomes inefficient, which occurs at E2 where total benefits equal total costs of harvesting. Two characteristics of this formulation of the open-access allocation are worth noting: (1) In the presence of sufficient demand, unrestricted access will cause resources to be overexploited; (2) the net benefit is lost.

3.3. Environmental Externalities

An externality occurs when the production or consumption activities of an acting party influence the welfare of an affected party in an unintended way, and when no compensation/payment is made by/for the acting party.

The acting party is the party engaged in the activity responsible for the externality, and the affected party is the party whose welfare is influenced by the externality. The acting and affected party can be a household or a firm. Hence, externalities can take place between firms, between households, and between households and firms. If the acting party engages in an activity for the sole purpose of harming or benefiting the affected party, then the activity does not constitute a true externality.

When an externality is present, the welfare of the affected party is influenced not only by its own activities, but also by the activities of the acting party.

Distinction between private and social values

In the presence of real externalities, there will be a divergence between private and social evaluations of costs and benefits .

- *Private costs*: costs that are born to undertake an activity by the economic agent undertaking the activity.
- *Social costs*: costs that are born to undertake an activity by the economic agent undertaking the activity plus costs imposed on all other economic agents.

  $Social\ costs = Private\ costs + External\ costs$

  And $External\ costs > 0$

  Therefore, $social\ costs\ >\ private\ costs$
- *Private benefits*: benefits obtained from the realization of an activity by the economic agent undertaking the activity.
- *Social benefits*: benefits obtained from the realization of an activity by the economic agent undertaking the activity plus benefits obtained by all other economic agents.

  $Social\ benefits = Private\ benefits\ +\ External\ benefits$

  And External benefits>0

  Therefore, $social\ benefits\ >\ private\ benefits$

Types of externalities

- According what sort of economic activity externalities originate in and what sort of economic activity they impact on, we have the following classifications:

Arising in	Affecting	Utility/production function
Consumption	Consumption	$U^A(X^A, Y^A, X^B)$
Consumption	Production	$X(K^X, L^X, Y^A)$
Consumption	Consumption and production	$U^A(X^A, Y^A, X^B)$ and $Y(K^Y, L^Y, X^B)$
Production	Consumption	$U^A(X^A, Y^A, X)$
Production	Production	$X(K^X, L^X, Y)$
Production	Consumption and production	$U^A(X^A, Y^A, Y)$ and $X(K^X, L^X, Y)$

- According to the unintended impact of externalities;

i) Positive externality: It is a benefit not reflected in price of a product.

- √ It causes additional benefit to other members of the society that consumers or producers of the product will not take into account.
- √ It results in excess of social benefits over private benefits. i.e., SB > PB by EB ⇒MSB > MPB by MEB.

For example, when beekeepers produce honey, honeybees create honey to beekeepers, but they also pollinate flowers for the cultivators. On the other hand, flower cultivation benefits the beekeepers since honeybees produce honey using input from flowers. However, the beekeepers may not consider the external benefit of their hives to the cultivators when they decide the price of honey. Similarly, the cultivators do no incorporate the external benefit of their flowers in whey they decide the price of full-grown flowers.

ii) Negative externality**:** It is a cost not reflected in the price of a product.

- √ It causes additional cost to the other members of the society that consumers and producers of the product will not take into account.
- √ It results in excess of social costs over private costs. i.e., SC > PC by EC ⇒MSC > MPC by MEC.

For example, steel factory dumps wastes into a river which a downstream resort hotel uses it to attract customers seeking water recreation. However, the steel factory does not consider the cost of water pollution which reduces business of resort hotel when it decides the price of the steel.

- According to direction of impact;

i) Unidirectional externalities: occur when externalities are in one directional, or unidirectional.

A→B

ii) Bi-directional externalities: occur when externalities are reciprocal or bilateral.

A↔B

Externalities and Economic Efficiency

Here, we are going to analyse the impact of externality on the market system and demonstrate the conditions for efficiency. Recall that in the presence of externalities social costs are different form private costs and /or social benefits are different from private benefits

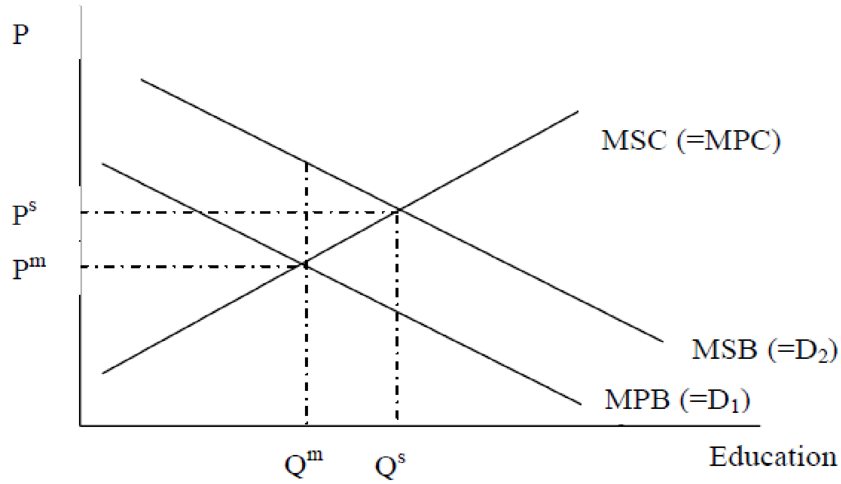
=> MSC≠MPC and /or MSB≠MPB

Hence, in the existence of externalities the traditional condition of MC=MB has to be revised so as to incorporate the external costs & benefits.

i) Positive externality and economic efficiency

In this case, an unregulated market system would under produce (desired) quantity of a given product.

⇒ $Q_s > Q_m$, where Q_s= social optimum and Q_m = private (market) optimum



MPB= marginal private benefit

MSB = marginal social benefit

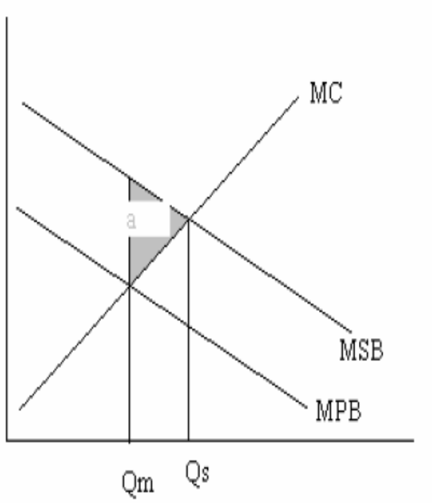
MEB = marginal external benefit

Q^m = out put produced by the market system

Q^s = socially optimum out put level

- Social optimum occurs when MSB= MSC
- Private optimum occurs when MPB = MPC

Alternative method of depicting positive externality

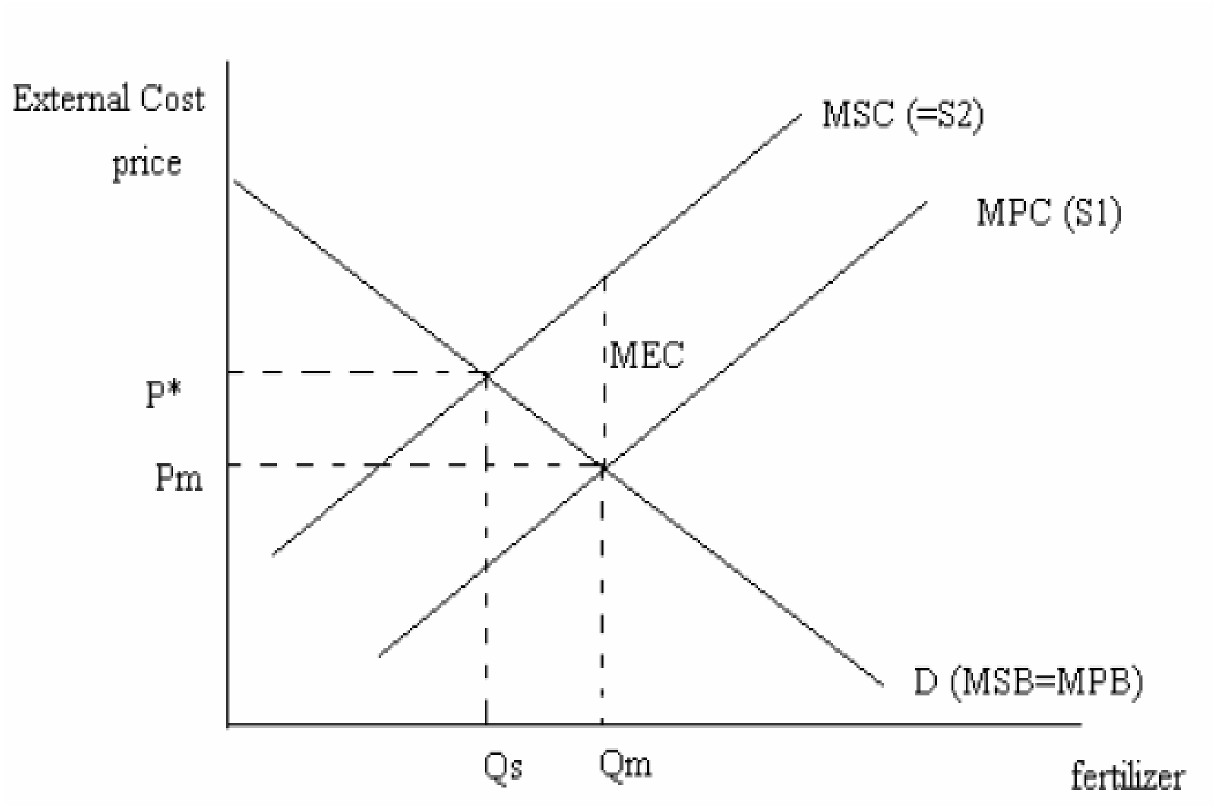


a = social inefficiency or dead weight loss due to the externality.

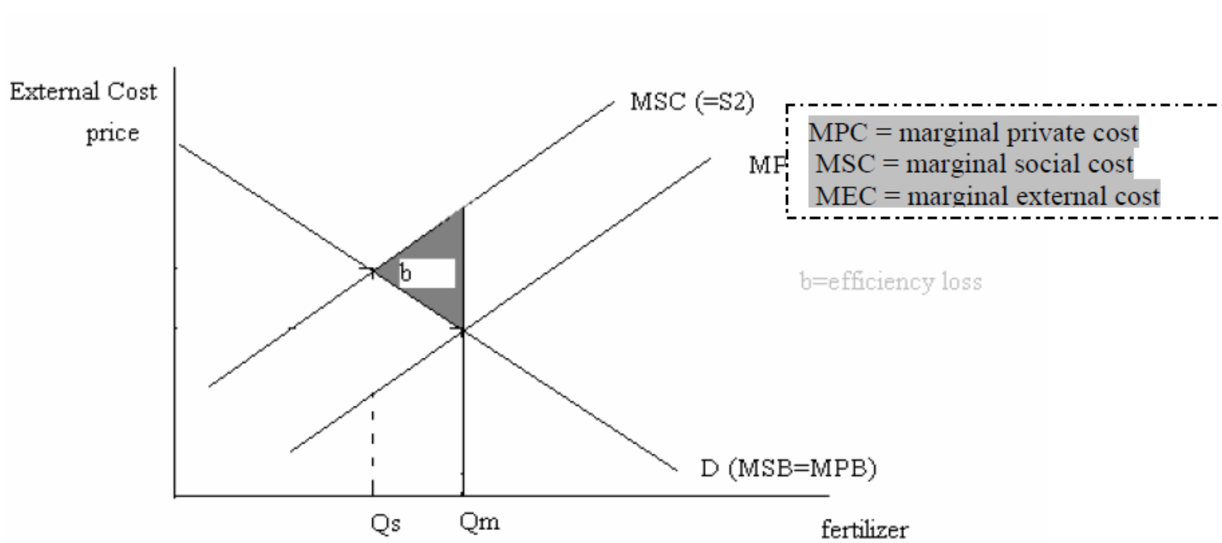
☛ When there are positive externalities less of the activity is undertaken by the market system.

ii) Negative externality and economic efficiency

In this case, an unregulated market system would over produce [undesired] quantity of a given product. $\Rightarrow Q_s < Q_m$



Alternative method of depicting a negative externality



- ☞ When there are negative externalities more of the activity is undertaken by the market system.

Summary of the impact of externalities on the market system

	Negative externality	*Positive externality*
Quantity produced	Too much	Too little
Costs/ Benefits	Costs greater than socially optimal	Benefits less than socially optimal
Stimulus to innovation	Disincentives to reduce social costs	Incentives to increase social benefits

3.4. Public goods

Public goods are goods that either cannot be supplied by the market or if supplied, are not supplied in sufficient quantity. E.g. clean air, clean water, biological diversity, national defence, police, public education, street light, etc.

A pure public good has two characteristics:

- √ Non-rival in consumption (=> indivisibility) : The use of the good by one person does not diminish the benefits that the good provides to other person.
- √ Non-exclusive in consumption (=> non-excludability): Property rights to the good are not exclusive.

- ✍ Consumption is said to be *indivisible* when one person's consumption of a good does not diminish the amount available for other (or does not reduce the supply available for others). This implies that it costs nothing for additional individual to enjoy the benefits of the public good. => The marginal cost of producing public good to additional consumer is zero. Hence, according to the efficiency rule price should be zero. Thus, it is inefficient to put positive price on public goods.

  E.g. let's take national defence service

  70 million people = costs X Br

  70 million +1 person =?

  => Cost X Br!!

  => Admitting one user does not increase the cost of defence service because MC=0

- ✍ *Non-excludability* refers to circumstance where, once the resource is provided, even those who fail to pay for it cannot be excluded from enjoying the benefit it confers. It is not possible or at least very costly to exclude or to protect non-payers from getting benefit from this type of goods.

Can we rely on the private sector to produce the efficient amount of public goods, such as biological diversity? Unfortunately, the answer is no! Why? Consider the following case.

In the following figure, individual demand curves for preserving biodiversity have been presented for two consumers A & B.

The market demand curve is represented by the vertical summation of two individual – demand curves. A vertical summation is necessary because everyone can simultaneously consume the same amount of biological diversity. We are therefore able to determine the market demand by finding the sum of the amounts of money they would be willing to pay for that level of diversity.

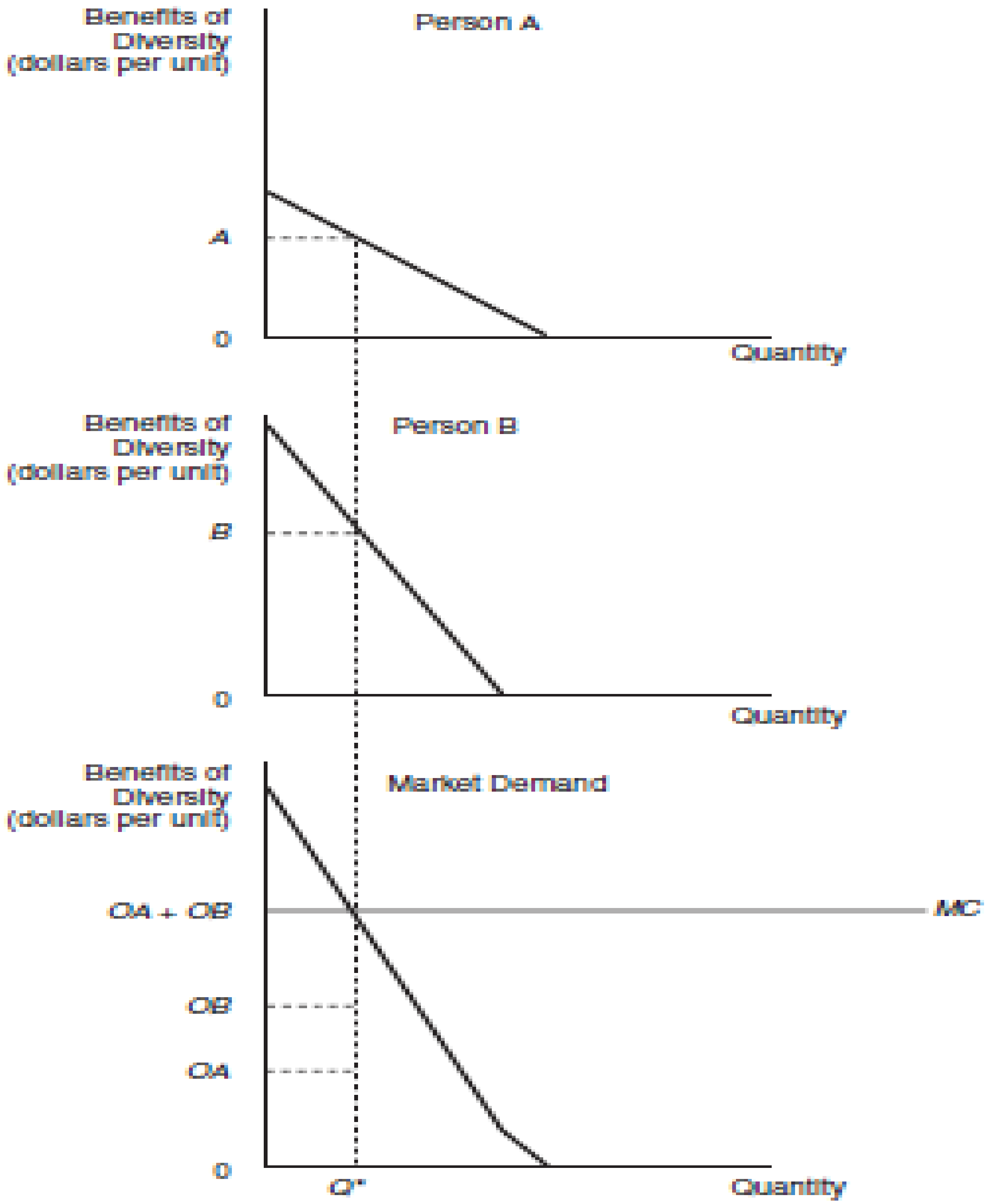
What is the efficient level of biodiversity? => The amount that maximize net benefit (= area under the market demand cure that lies above MC).

Consider the following graphical representation of efficient provision of public goods. Q* is the allocation that maximizes net benefit because it is the allocation where the demand curve crosses the marginal cost curve.

Note that both consumers consume this amount. At this level of availability, the marginal benefit to person B is OB; to person A is OA, and the sum of this (OA+OB) is society's marginal cost curve.

Would a competitive market supply this efficient level of this good? Since the two consumers have different marginal willingness to pay from the efficient allocation of this good (OA versus OB), the efficient market equilibrium for a public good requires different price for each consumer. In this case, if A were charged OA and B were charged OB, then both consumers would be satisfied with the efficient allocation.

Furthermore, the revenue collected should be sufficient to finance the supply of the public good (because OAQ* + OBQ* = MC.Q*). Thus although an efficient pricing system exists, it is very difficult to implement.



The efficient pricing system requires charging a different price to each consumer. However, consumers do not likely choose to reveal the strength of their preference for this commodity in the absence of excludability. All consumers have an incentive to understate the strength of their preferences to try to shift more of the cost burden to the other consumers.

Therefore, inefficiency results because each person is able to become a free rider on the other's contribution. *A free rider is someone who derives the value from a commodity without paying an efficient amount for its supply*. Because of the consumption indivisibility and non-excludability properties of the public good, consumers receive the value of any diversity purchased by other people. When this happens it tends to diminish incentives to contribute, and the contributions are not sufficiently large to finance the efficient amount of the public good; it would be undersupplied.

Summary: The fundamental problem associated with public good are

- √ *Free rider problem*: individuals want to consume public good freely.
- √ *Pricing problem*: efficiency in public good requires different pricing for different individuals which is difficult to implement.
- √ *Information problem*: the problem of revealing the demand for public goods.

Distinguishing characteristics of private goods, public goods, congestible resources and open-access resources

	Excludable	Non-excludable
Rivalrous	**Pure Private Good** Ice cream	**Open Access Resource** Ocean fishery (outside territorial waters)
Non-rivalrous	**Congestible Resource** Wilderness area	**Pure Public Good** Defence

3.5. Market Failure

Market failure is the failure of the free market to allocate resources efficiently. It is a situation that occurs when market prices fail to reflect the true social cost and benefits of resource use. Market failure can result from

- √ Imperfect competition
- √ Imperfect information
- √ Existence of externalities
- √ Existence of public goods

Here it is necessary to distinguish market failure from policy failures and institutional failures.

Policy failures occur when government intervention in the market system lead to economic inefficiency. Examples are subsidies taxes, tariffs, quotas, etc.

Institutional failures occur when government does not establish and enforce property rights even when it is technically possible to do so. Example; in natural resource management are inefficient taxation of economic rent from natural resources, low or zero stumpage fees etc.

Correcting Market Failure

The major causes of market failure are public good & externalities. But is there any solution to these problems? Basically two solutions are proposed.

a. Redefining property rights

One reason for inefficiency is improper definition of property rights. Hence, we need to assign exclusive property right to the individuals. The individual will get a fee for the use of resource. The fee should be equal to the MC (= SMC) of using the resource. However, it should be noted that most common property resources are vast (or large) and single ownership may not be practical. Therefore, government ownership may be needed.

When assigning property right is not possible a government or community can invest on resource maintenance or it can restrict harvesting. E.g. by giving quotas, issuing license or imposing taxes.

b. Internalizing externalities

When there is an externality, for firm which causes the externality, the profit maximization conditions are not the same as the Pareto efficiency conditions.

Therefore, the society must find a way of inducing their firm to accounting for the externality.

Internalizing externalities may be defined as the process by which an externality is absorbed by the market system. This can be done by:

i. private transactions
ii. government instruments

i. Conditions required for internalizing externalities by private transactions

- ✓ there must be technically feasible gains from internalizing externalities
- ✓ there must be net gains from internalizing the externalities
  - ➢ Transactions costs must be less than gains from internalizing externalities.

Transaction costs are the costs of identifying and contacting the relevant parties, assessing costs and benefits, and creating and enforcing contracts.

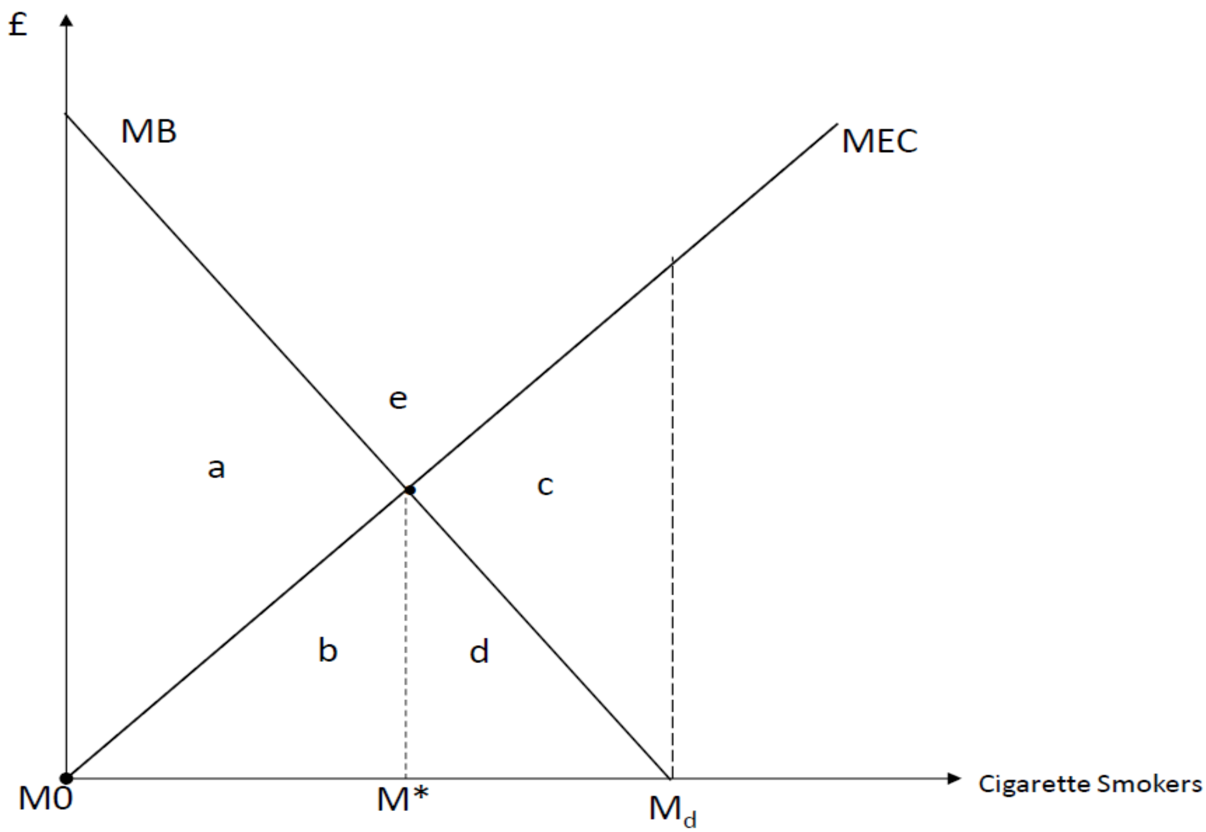
- ✓ There must be well defined property right.
  - ➢ There should be no institutional barriers in internalizing.

But the conditions are hardly achieved!

Coase Theorem- private solution to the problem of externality

The Coase Theorem says that if property rights are clearly defined and transaction costs are zero, parties involved in an externality situation reach an efficient solution by bargaining among themselves regardless of the property right is to the polluter or the victim and the method of enforcing the property right.

- If property right is to the polluter,
  - The victim can bribe the polluter to reduce the consumption of public bad towards M* since MB < MEC.
- If property right is to the victim,
  - The polluter can bribe the victim to smoke higher.
  - There is room for bargaining b/n M0 and M*.
- Through bargaining efficient outcome M* could be reached as shown below.



ii. Government instruments

There are two main types of government instruments for internalizing externalities, namely *a) Regulatory instruments*

E.g. air and water quality standards, permits and licenses, land water controls.

They are also called command-and-control measures.

b) Economic instruments

E.g. Pigovian subsidies and taxes, tradable pollution rights, etc.

- ✓ Pigouvian tax: taxing the polluter equivalent its to its marginal external cost
- ✓ Pigouvian subsidy: subsiding the beekeper equivalent to its marginal external benefit

- Regulatory instruments are also called the market based instruments.

Merging

- What other policies generate efficiency? One clever method is known as *merging*.
- This involves merging the two firms and maximizing the joint profit πj, where $\pi j=\pi 1+\pi 2$.