ENVIRONMENTAL ECONOMICS

LECTURE NOTES

Course Outline

1. What is environmental economics? (Harris C.1)
   - Economic analysis
   - Incentives for household and industry
   - Design of environmental policy
   - Environment and growth
   - Economy-Environment interactions (Field, C.2)
2. Market failure (Field, C.4; Perman, C.4 part 2; Bowers, C.3)
   - Imperfect markets
   - Externalities
   - Public goods
   - Property rights, common property resources and environmental resources
   - Imperfect information, risk and uncertainty and irreversibilities
   - Government policy, government failure and market failure
3. The theory of Environmental externalities (Harris C.3)
   - Accounting for environmental costs and benefits
   - Welfare analysis of externalities
   - Pigovian tax and Coase theorem
   - Limitations of Coase theorem
4. Choice of instruments for pollution policy. (Bowers, C.6)
   - Command and control
   - Pollution taxes
   - Marketable permits
   - Pollution subsidies
5. The Economics of Sustainable Development (Perman, C.3; Bowers, C.15; Pearce, C.3)
   - Reasons for concern about sustainability
   - Definitions and meanings of sustainability
   - Attaining sustainable economic behavior
   - Irreversibility and sustainability
6. Theory and methods of environmental valuation (Bowers, C.11)
   - Cost-Benefit analysis
   - Contingent valuation
   - Other methods

Table of Contents

CHAPTER ONE

INTRODUCTION

Defining Environmental Economics

Environmental Economics is the application of the principles of economics to the study how environmental resources are managed and developed. It is also concerned with how economic institutions and policies can be changed to bring environmental impacts more into balance with human desires and the needs of the ecosystem itself (Field, 1997).

Environmental economics is "That part of economics which deals with the inter-relationship between environment and economic development and studies ways and means by which neither is the former impaired, nor is the latter impeded" – Eugine, 2007 pg.1

Scope of Environmental economics

1. Economic growth and environmental balance – economic growth implies increased production which means increased waste/by-products generation. The waste adversely affects the environment – environmental imbalance.
2. Pollution control and environment – waste is also majorly a pollutant that affects the environment and must therefore be controlled.
3. Conservation of resources – resources are vital for production activities and life of humans. To have continued/sustained production the resources must be conserved
4. Limits to growth – scarcity of resources means growth is constrained and hence limits may exist as to what extent an economy can grow

The environment can be divided into four segments

a) Lithosphere – the earth's crust including soils and rocks found on the surface of the earth
b) Hydrosphere – all the water resources found on earth. Rivers, lakes, seas, dams, oceans etc.
c) Atmosphere – the 'life blanket' of the earth that is composed of gases extending up to 500km above the surface of the earth. Nitrogen, oxygen, CO_2, ozone, rare gases
d) Biosphere – the region where life exists and consist of the Lithosphere, hydrosphere and part of the atmospheres covering 6,000 meters below sea level and 10,000 meters above sea level

Functions of the Environment

1. Resource function – supplies material resources with economic value to mankind. The environment is also known as land in economics – or natural resources. Land is therefore one factor (input) of production.
2. Sink function – assimilates wastes and residues produced in the consumption and production processes. Waste gases (CO, CO2, SO2), solid waste and liquid waste generated from production and consumption activities are assimilated by the environment and converted to non-toxic or harmless substances (often converted to useful substances that can be used for further production – when recycled). Enabling the natural functioning of the food-chain cycle/system.
3. Life support and amenity function – support life and provides amenity services to mankind. Makes life of humans, flora and fauna possible on earth – hence life support. Amenity function refers to direct satisfaction from consumption of goods and services provided directly by the environment – includes mainly recreation.

- Soil – agriculture - kiptim
- Mining – coal - Maureen
- Fisheries – solo
- Pollution – francis

CHAPTER TWO

MARKET FAILURE

PUBLIC BADS AND EXTERNALITIES

Two fundamental characteristic of a good dealt in the market are:

1. Excludability – "A good is excludable if it is feasible and practical to selectively allow consumers to consume the good. A bad is excludable if it is feasible and practical to selectively allow consumers to avoid the consumption of the bad" – Kolstad (2000)

Examples of excludable goods are; bread, pen. Excludable bad includes; car battery waste, worn out cloth

Non-excludable goods or services are; loud music system, road, football match in an open field – allocation of such god or service may not be efficiently allocated by the market. Non-excludable bads include; sewage waste, gaseous pungent emissions, noise

2. Rivalry – "a bad (good) is rival if one person's consumption of a unit of the bad (good) diminishes the amount of the bad (good) available for others to consume, i.e. there is a negative (positive) social opportunity cost to others associated with consumption. A bad (good) is rival otherwise" – Kolstad (2000)

Examples of rival good are: bread, pen, banana. Examples of rival bads include; waste paper, scrap metal, sewage waste, garbage waste.

Examples of non-rival good are: public cinema, radio waves, rugby match in a field. Non-rival bad includes; noise from a generator, noise from an PA System

The first fundamental theorem of welfare economics states that a competitive equilibrium is always Pareto efficient if

i) A complete set of markets with well defined property rights exist so buyers and sellers can exchange assets freely for all potential transactions and contingencies
   - Often in the market property rights may not be well defined for some products and resources hence this assumption may lead to failure of the market to enable (Pareto) efficiency

ii) Consumers and producers behave competitively by maximizing benefits and minimizing costs

- However, not all consumers and producers behave competitively

iii) Market prices are known by consumers and firms, and;

- Perfect information/knowledge is however often lacking in the real market

iv) Transaction costs are zero so changing prices does not consume resources

- Transaction costs can be very high at times especially for goods or bads that have externalities

PROPERTY RIGHTS

Property rights are considered well defined if they have the following characteristics

a) Comprehensively assigned – either privately or collectively owned with all entitlements known and enforced effectively
   - Orange fruit vs. fresh air; plot in a municipality vs plot in a communally owned land

b) Exclusive – all benefits and costs from use of the resources accrue to the owner and only to the owner either directly or by sale to others
   - Water well vs river

c) Transferable – all property rights must be transferable from one owner to another in a voluntary exchange
   - Car/shares of a company and land

d) Secure – secure from involuntary seizure or encroachment by other people, firms or government
   - Bread and land

Market fails in as far as environmental because of the following.

1. Externalities
2. Non-exclusion and the commons – common property
3. Non-rivalry and public goods – public goods
4. Nonconvexities – marginal cost and marginal benefit functions may be non-convex
5. Asymmetric information – in the case of for example moral hazard (when regulators cannot monitor actions or when market cannot monitor actions) and adverse selection (when a person cannot identify the type or character of another person)

CHAPTER THREE

THE THEORY OF ENVIRONMENTAL EXTERNALITIES

External costs and benefits

"An externality exists when the consumption or production choices of one person or firm enters the utility or production function of another entity without that entity's permission or compensation" – Kolstad (2000). It is also known as a third–party cost or benefit.

Examples

a) Automobiles emissions – carbon (CO) and lead (Pb)
b) Gold-mining – use of mercury (Mg)
c) Pollution of rivers and lake – estuaries (lead and mercury)
d) (Chloro)Hydro-fluorocarbons (CFCs)
e) Panpaper mills
f) Chemical intensive farmer
g) Battery manufacturer
h) Soil erosion – non-terracing, gabion
i) Timber factory

Accounting for Environmental Costs

To account for environmental costs or externality costs (since they are excluded in the producer's cost schedule) we seek for ways to internalize them. In this we accommodate them in our market analysis.

First most difficult task is to estimate money value of the externality or environmental damage.

- Water treatment costs (among others) in the case of water pollution (though only caters part of the costs)
- Medical expenditure for treatment of health problem (among others) resulting from air pollution only accounts for a fraction of the externality cost

Since the methods of assigning money value to externalities is very involving and yet to be fully comprehensive, it will be dealt with later. We for now assume that the externality costs are given and use graphical or simple algebraic models to conduct analysis for purpose of building our understanding of theory.

Let us assume the emissions by Webuye panpaper mills in the process of producing paper causes external costs in form of air pollution (SO) which results in an environmental damage of the town, destruction of forests as raw materials, damage to roads in the process of transporting the timber and effluents into rivers of waste from the factory. The costs and benefits of the production activity by the firm can be represented graphically using private cost, social cost and demand functions as in figure 3.1 below

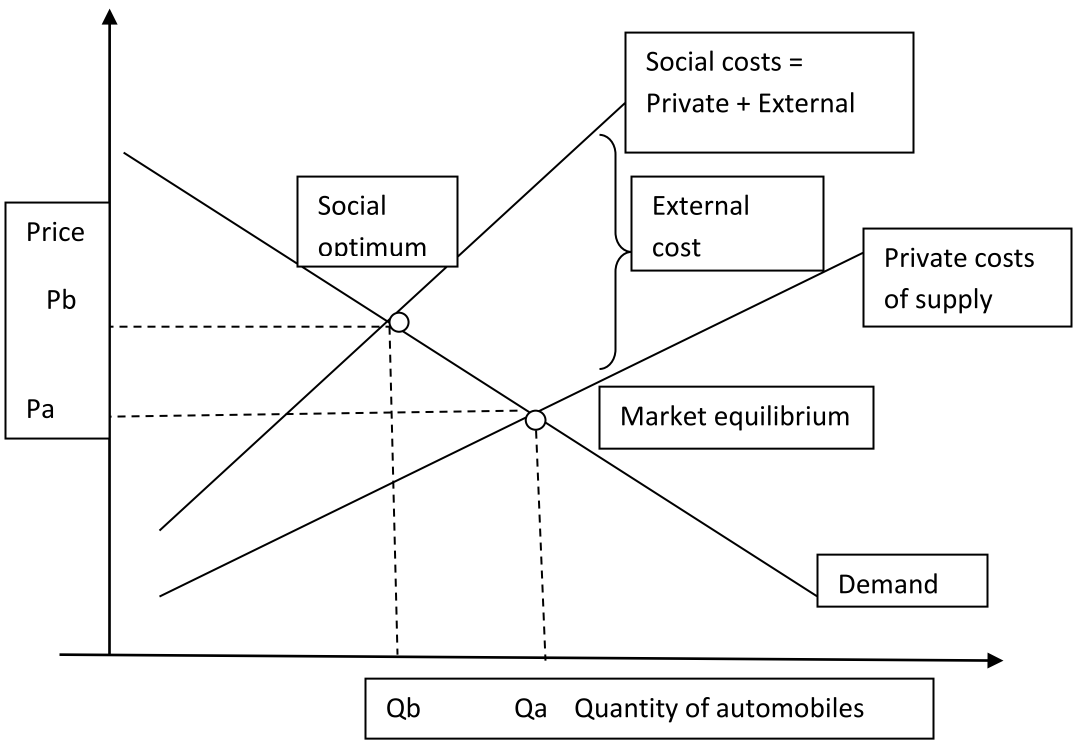


Fig.3.1 Paper market with externality costs

Social costs are the real costs to the society being the sum of market costs and external costs. The social cost can include all other externalities apart from environmental costs if they exist (some industries such as tourism have moral costs to the society whose members indulge in illegal or wayward/indecent practices – drug abuse, prostitution, drug trafficking etc.).

The introduction of externalities into the market model results in efficiency gain with new equilibrium which a social optimum at a higher price and lower quantity than before. It is similar to a pollution tax on purchasers/users of automobiles. This also can be interpreted to mean that users of automobiles will make less use of the automobiles hence less traffic and higher prices for operating the automobiles.

Internalizing Environmental Costs

The environmental cost (if significant) can be internalized through a pollution tax to achieve the social optimum and hence correct for inefficiency in the market.

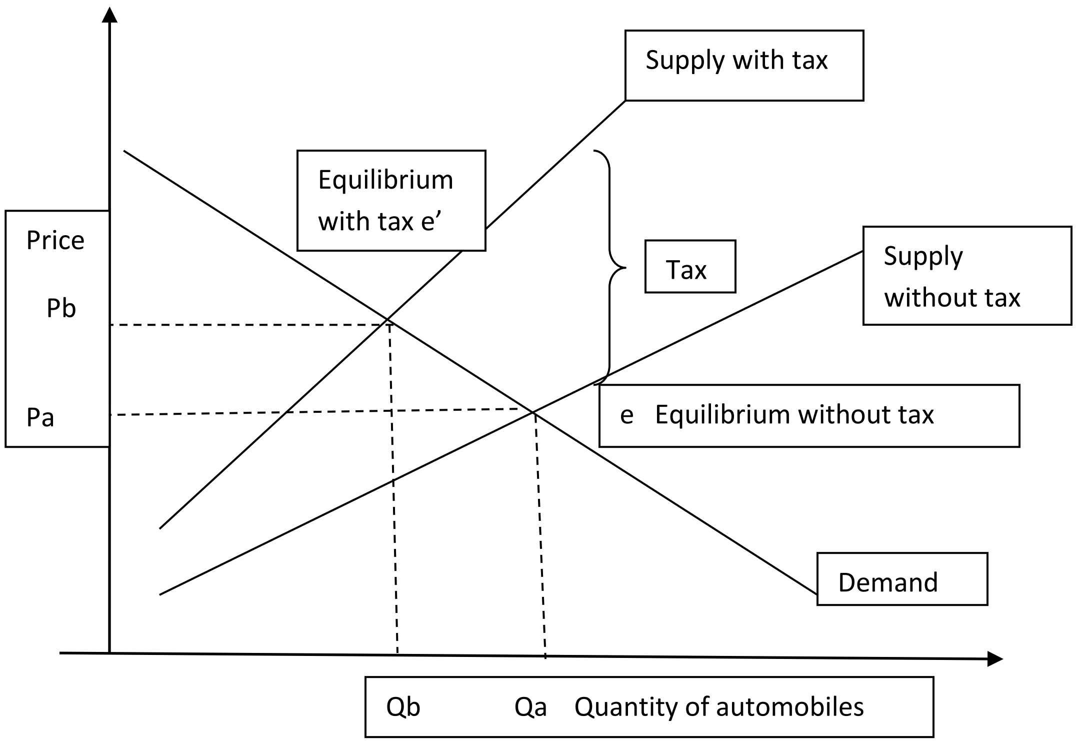


Fig.3.2 Equilibrium production with pollution tax

What may remain debatable is how to charge the tax? Do we charge a lump sum tax, tax per output of the product or per value of sales? And what amount of tax or tax rate? In an example of automobile pollution tax how much tax to charge, what commodity to charge (automobile or gasoline or toll tax) and what type of tax should be used. Irrespective of the mechanism used to internalize the environmental costs through tax, the idea is supported by economic theory.

Welfare analysis of externalities

The explanation why the social optimum is ensures efficiency in the market can be given through use of consumer and producer surplus in a graphical market model as in fig3.4 below.

In ignoring the social optimum, and only considering private (market) optimum the society incurs (both producers and consumers) a net welfare loss from overproduction as represented by area LOS.

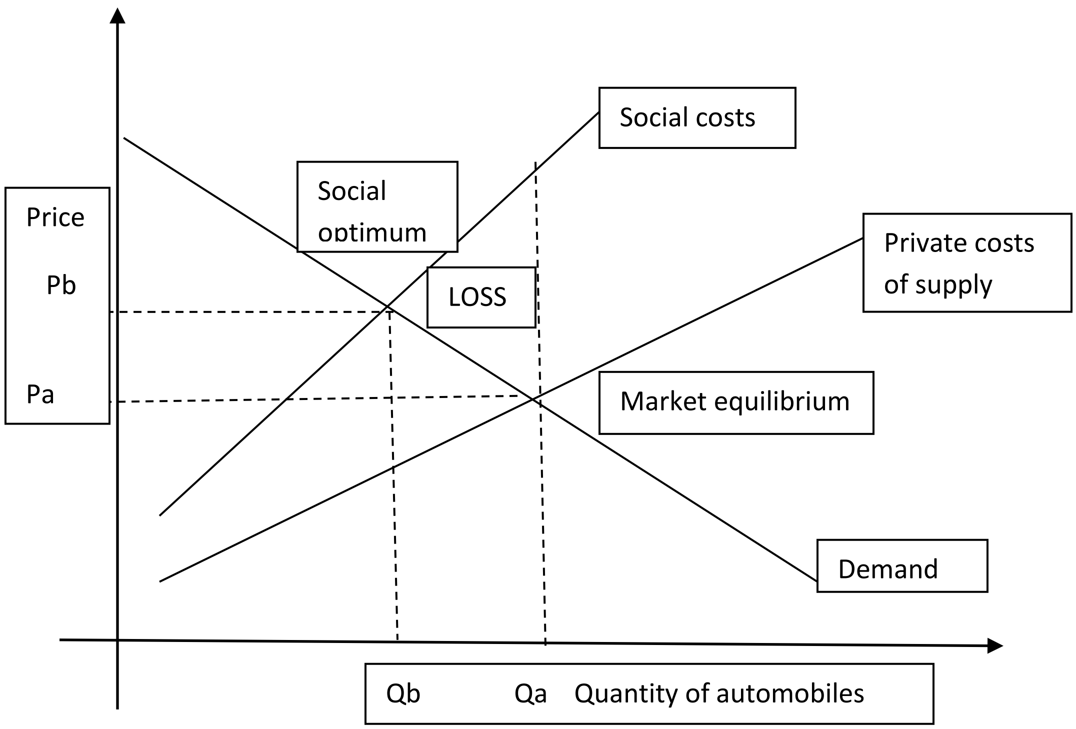


Fig.3.1 Net social loss from overproduction

Example

A firm engaged in the production of batteries is faced with the following demand and supply functions

$P_d = 1500 - 0.0025Q$ and $P_s = 500 + 0.0025Q$

The pollution costs per unit resulting from its production is $C = 0.0015Q$

a) By use of a graph distinguish the social optimum allocation from the market equilibrium.
b) Using algebra, solve for the output and price at market equilibrium and the social optimum allocation.

Market equilibrium

$P_d = 1500 - 0.0025Q$ and private cost is $P_s = 500 + 0.0025Q$

$P_d = 150 - 0.0025Q = P_s = 50 + 0.0025Q$

$1000 = 0.005Q$, $Q = 200{,}000$, $P = 50 + 0.0025(20000) = 1000$

At social optimum, $P_d = 1500 – 0.0025Q = P_{soc} = 500 + 0.0035Q$

$P_d = 150 – 0.0025Q$ and Social cost is $P_{soc} = 50 + 0.0035Q$

$150 – 0.0025Q = 50 + 0.0035Q$

$100 = 0.006Q$, $Q = 16{,}666.70$, $Psoc = 108.30$

c) What amount of tax rate will be necessary to enable an achievement of the social optimum?
d) Discuss three ways in which the government can intervene in the market to control pollution.

POSITIVE EXTERNALITIES

Just as there are activities that generate negative externalities so are there some which generate positive externalities. Even the same activity that generates negative externality also generates positive externalities. Positive externalities are externality benefits to third-parties. Such social benefits need to also be internalized.

Internalizing Environmental benefits

Let us assume that a land owner's effort of keeping indigenous (natural) vegetation in his/her piece of land generates some external benefits to the society – a beautiful scenery, a park or playground for children.

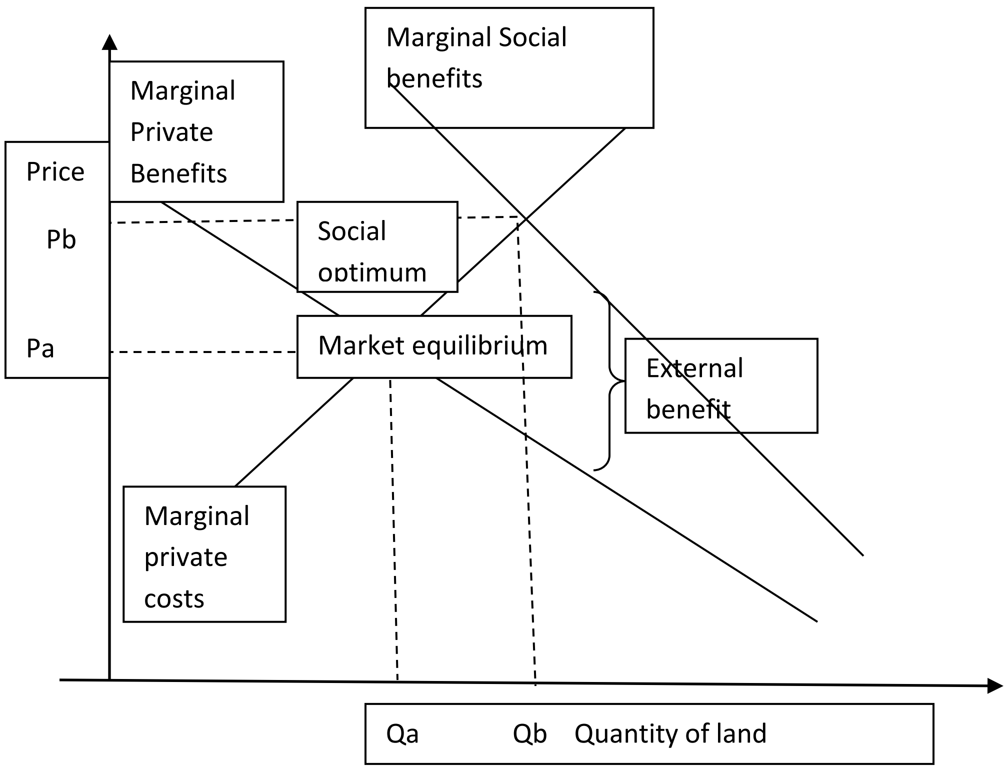


Fig.3.3 Private and social equilibrium for positive externality

The Marginal Net Benefit (MNB) is also better known as the Marginal Net Private Benefit (MNPB). It is the difference between the marginal benefit (DD) for a given quantity and its marginal cost (SS). Hence sum of the MNB is total of the consumers' and producers' surplus.

The introduction of externality benefit into the market model results in efficiency gain with new equilibrium which a social optimum at a higher price and greater quantity than before. This can be empirically internalized through a subsidy that will ensure the social optimum quantity is achieved as in the diagram below.

Example

A firm engaged in the production forest for timber is faced with the following demand and supply functions

$P_d = 10{,}000 - 0.4Q$ and $P_s = 2{,}000 + 0.2Q$

The externality benefit resulting from its production of the forest is $C = 500 + 0.05Q$

a) By use of a graph distinguish the social optimum allocation from the market equilibrium.
b) Using algebra, solve for the output and price at market equilibrium and the social optimum allocation.

Market equilibrium

$P_d = 1500 - 0.0025Q$ and private cost is $P_s = 500 + 0.0025Q$

$P_d = 150 - 0.0025Q = P_s = 50 + 0.0025Q$

$1000 = 0.005Q$, $Q = 200{,}000$, $P = 50 + 0.0025(20000) = 1000$

At social optimum, $P_d = 1500 - 0.0025Q = P_{soc} = 500 + 0.0035Q$

$P_d = 150 - 0.0025Q$ and Social cost is $P_{soc} = 50 + 0.0035Q$

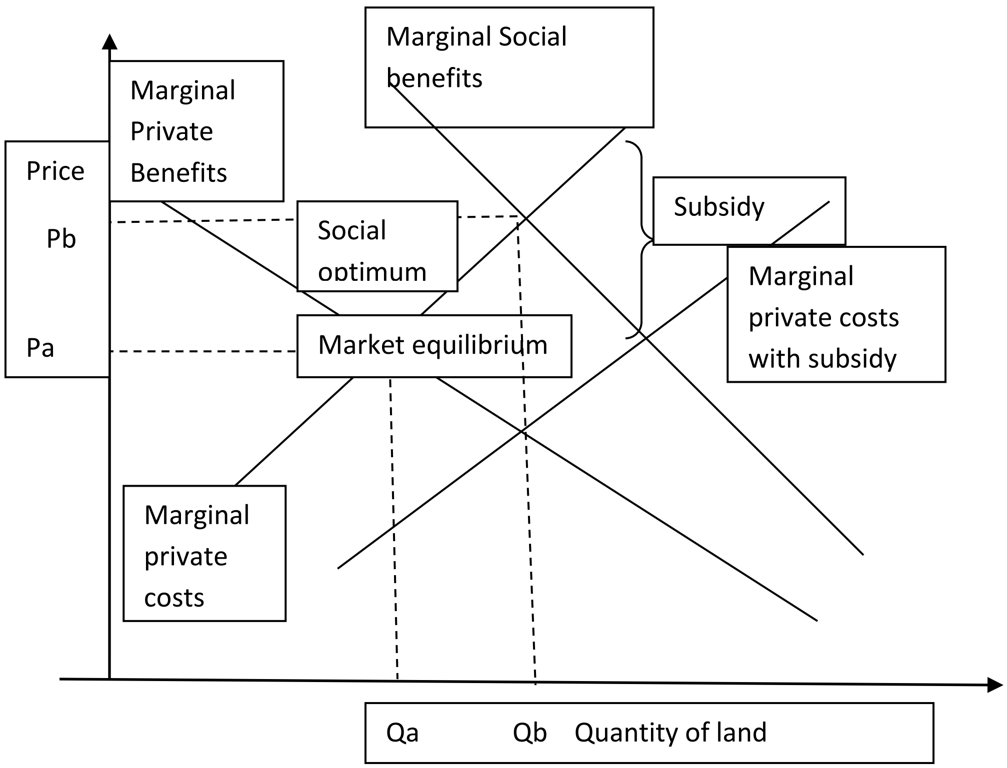
$150 - 0.0025Q = 50 + 0.0035Q$

$100 = 0.006Q$, $Q = 16{,}666.70$, $Psoc = 108.30$

c) What amount of tax rate will be necessary to enable an achievement of the social optimum?
d) Discuss three ways in which the government can intervene in the market to control pollution.

Internalizing Environmental Social Benefits

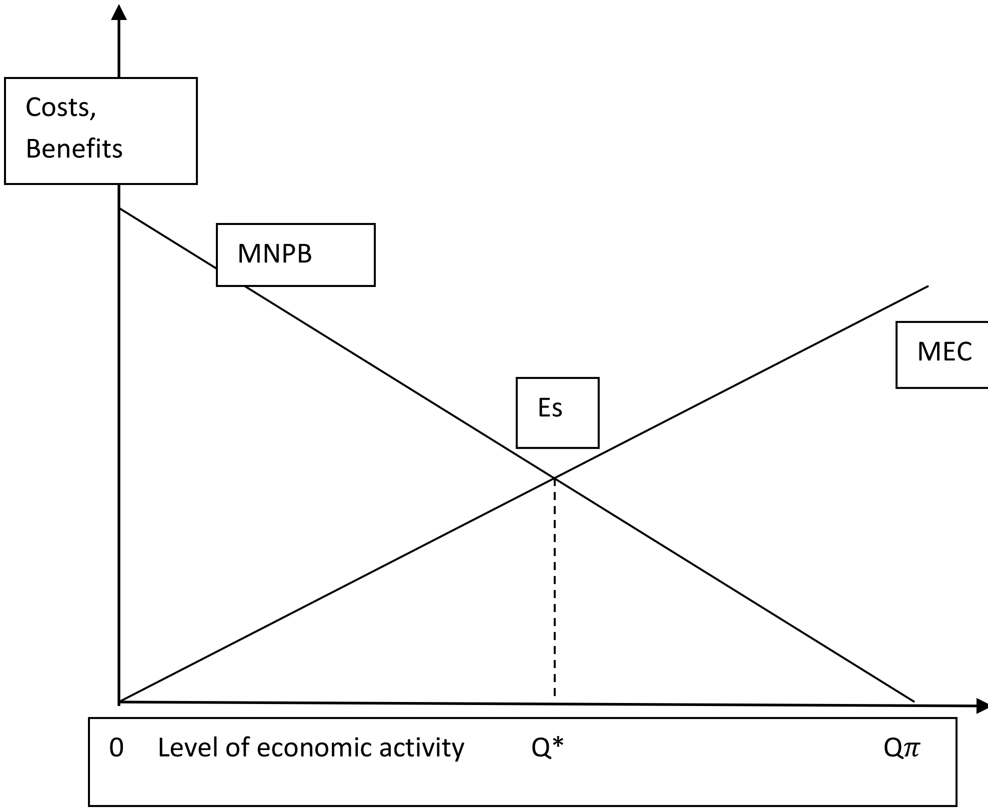
The environmental externality benefit can be internalized through a subsidy given to the landowner to achieve the social optimum.



Optimal pollution levels will therefore be identified with emission levels where MNPB is equated to marginal externality costs (MEC).

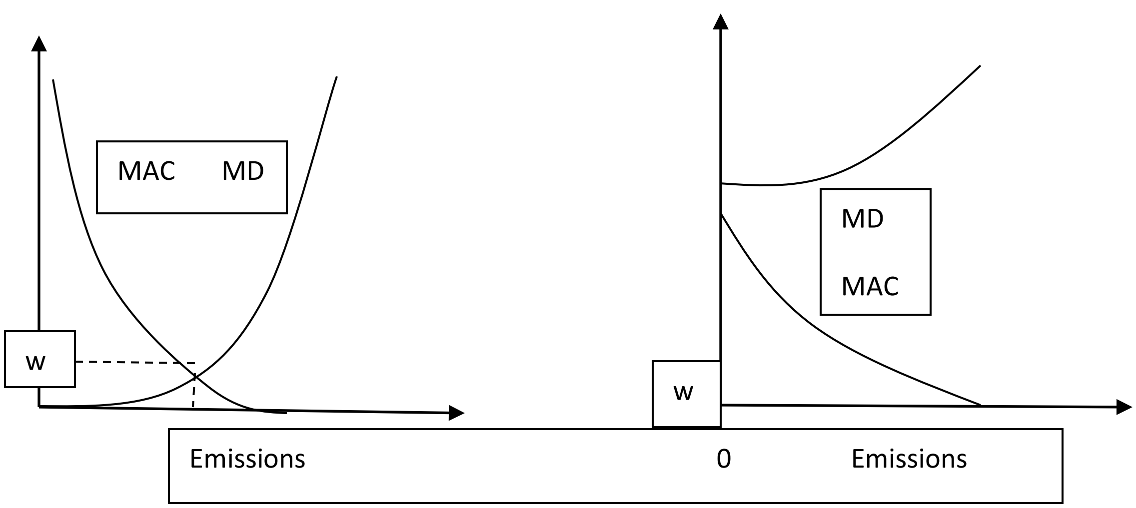
MNPB = MEC

Graphically it is shown in the figure below.



Market optimal without consideration of externality cost is Qπ while after internalizing the externality cost it will be Q*. The optimal level of externality will therefore be the area 0Q*Es.

Effectiveness of the determination of optimal emissions for different pollutants under the equimarginal principle can be shown in the figures below.



MAC = marginal abatement costs

MD = marginal damages

PROPERTY RIGHTS AND THE COASE THEOREM

The theory of externalities raises a fundamental issue of rights. Does the polluter have a right to carry out the activity that causes pollution or does the polluted have a right to be protected from the pollution?

Pigovian Tax

A Pigovian tax is a negative externality tax that is equal to the marginal external cost (t* = MEC) which ensures an optimal level of pollution. Pigovian tax is a method of responding to externalities through taxing the polluter amount equal to the value of the environmental damage. The Pigouvian tax internalizes (makes private) the externality cost. It is also known as polluter pays principle as first given by Arthur Pigou a British economist (*Economics of Welfare* – 1920).

Tp = MSC – MPC (Marginal social cost less Marginal private cost)

However, the Pigovian approach has been criticized as assuming that the producer has no right of engaging in any activity that will have an externality. The right to produce has an implied right to produce some externality by-product. A farmer who drains his/her farm has no less rights than another farmer downstream who suffers flooding that results from the drainage activity.

Should a Pigouvian Tax be Applied to the Activity or the Externality?

- In general (and ideally), applying the tax to the externality itself (e.g., emissions of sulfur dioxide or particulates) is preferable to applying the tax to the output (e.g., steel)
- Exceptions: cases where the only way of reducing the externality is to reduce the output
- In some cases, there is a close 1:1 relationship between the activity and the externality. In such cases, a tax on the activity may be preferable

- May discourage technological innovation.
- But: in some cases, there is a close 1:1 relationship between the activity and the externality. In such cases, a tax on the activity (or a key input to the activity) may be preferable.
- And: the activity (or related input) is generally easier to measure than the externality. It can be very difficult to monitor emissions!!
- Examples: automobile emissions; agricultural chemicals.

COASE THEOREM

Coase theorem – There is a tendency for a market to automatically approach the social optimum regardless of who holds the property rights. The theorem suggests that the market will generate the optimal level of an externality, regardless of how property rights are assigned. It assumes that economic agents are free to negotiate.

The Coase theorem fails because of various reasons

Major Deficiencies of the Coase Theorem

- It assumes no or small transactions costs, whereas in many cases they are high, even with small numbers of negotiators. Example?
- It assumes a small number of negotiators, when in fact many of our most pressing problems have many participants. Example?

- Property rights DO affect the market and the externality itself, when we move beyond the one polluter/one victim example.
- Income effects do influence the ability to pay and willingness to be compensated.

CHAPTER FOUR

CHOICE OF INSTRUMENTS FOR POLLUTION POLICY

TYPES OF INSTRUMENTS ARE:

1. Command and control
2. Pollution taxes
3. Marketable permits
4. Pollution subsidies

Factors determining instrument choice (Bowers pg.63)

1. The nature of discharge
2. The receiving medium
3. Substitutability between receiving media
4. Toxicity of the polluting substances and its persistence
5. Detection technology
6. Sensitivity of pollution to location of entry into the environment
7. Existence of identifiable discharge locations
8. Socio-legal factors – acceptability and enforceability of the instruments

Economic Incentives

- taxes
- subsidies
- Marketable emissions permits
- Deposit-refund systems
- Liability frameworks

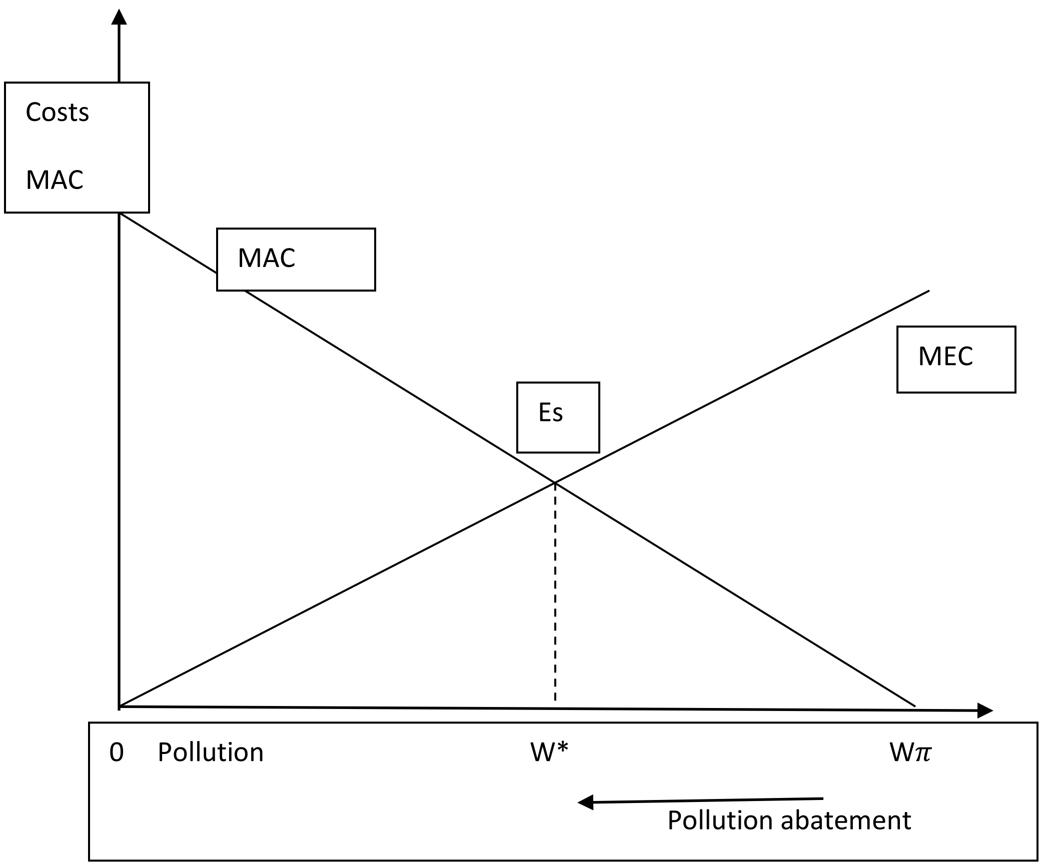
Efficiency enhancing policy intervention

For a pigouvian tax to fully resolve inefficiency problem, the following must hold:

- Ability to accurately measure marginal external cost
- Ability of the political system to produce an efficient environmental policy
- Ability to monitor emissions, charge appropriate tax, and enforce this system

POLLUTION CHARGES AND ABATEMENT COSTS

Pollution charges do encourage use of pollution abatement (or control) equipment. The incorporation of abatement equipment will still lead to social optimum at levels where Marginal abatement cost (MAC) equals the Marginal externality costs (MEC).



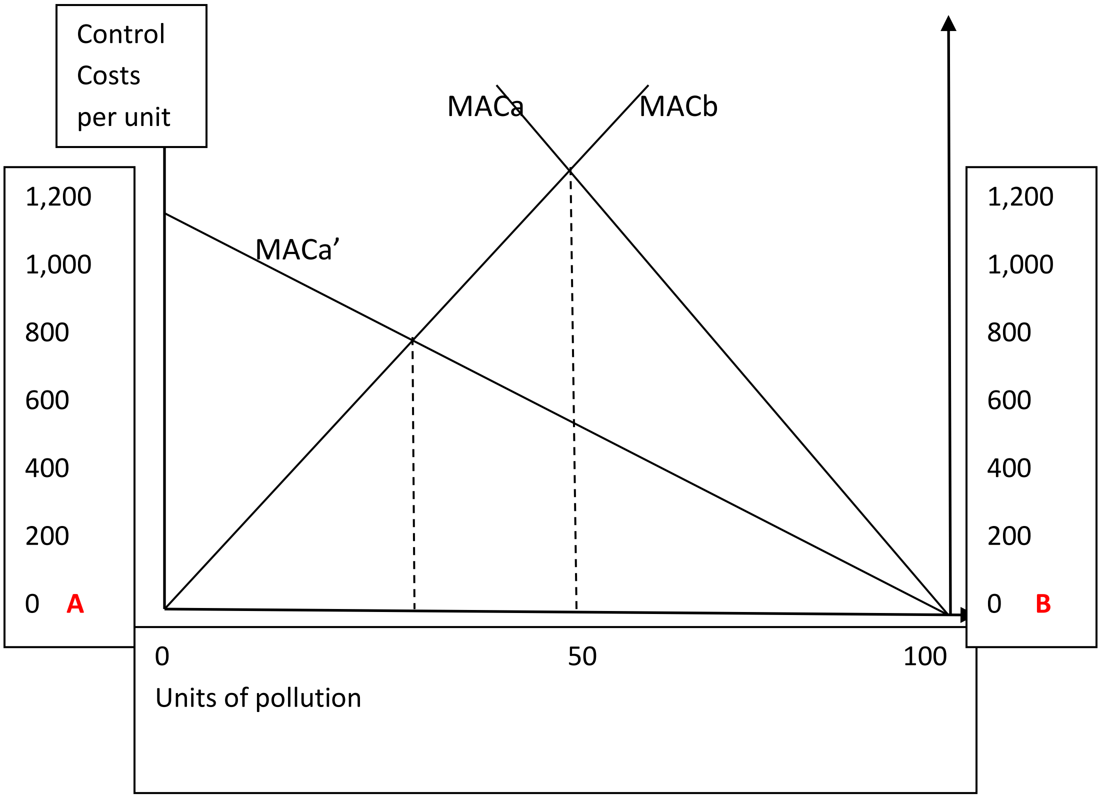
Market optimal without consideration of externality cost is Qπ while after internalizing the externality cost it will be Q*. The optimal level of externality will therefore be the area 0Q*Es.

Transferable (Marketable) Emissions Permits

A marketable permit scheme involves,

1. A decision as to the total quantity of pollution that is to be allowed. The total quantity of emission permits issued should equal the efficient level of pollution.
2. A rule which ensures that any firm is allowed to produce pollution (of a certain designated type) only to the quantity of emission permits it possesses.
3. A choice by the control authority over how the total quantity of emission permits is to be initially allocated between procedures.
4. A guarantee that emission permits can be freely traded between firms at whichever price is agreed for that trade.

The total number of permits should equal the desired target level of pollution and can be allocated to existing firms or sold at an auction. Once allocated, they are fully transferable, or tradable, among firms or other interested parties. Firms can choose to reduce pollution and sell the permits or increase pollution and purchase the permits for the pollution they emit. The total pollution by all firms cannot exceed the maximum set by the total number of permits. The marginal cost of control by the firms will finally be equated for efficient allocation.



Advantages of marketable permits

1. Minimization of costs
2. New entrants are easily accommodated
3. Opportunities to participate are open to non-polluters and the polluted
4. Inflation and adjustment costs are in-built
5. Spatial dimension of interested parties are catered for – many emission sources and receptor points
6. Has some technological ‘lock-in’ – encouraging use of abatement equipment and environmentally friendly technologies

CHAPTER FIVE

RESOURCE ALLOCATION

5.1 NONRENEWABLE RESOURCES

Resources can either be renewable or non-renewable. **Renewable resources** are those resources which if well managed, can last indefinitely. They are resources which can be regenerated. **Nonrenewable** resources are those which cannot last indefinitely or are depleted through use or extraction. Nonrenewable resources are also called exhaustible resources.

The Allocation of Nonrenewable Resources

A resource is an economic resource if it is scarce. When a resource is scarce over one time period efficient allocation is possible through use of the invisible hand assuming market conditions are met. However in the case of nonrenewable resources allocation must be over several time periods or generations. In such a situation market mechanism may fail to efficiently allocate the resource. The problem of allocation becomes complex because other future generations must be accommodated in the pricing of the resource if efficiency is to be achieved. The following illustration will explain the point.

Example 1 - Assume the market demand and supply function of an exhaustible resource is given as,

$P_d = 200 - 0.01Q$ and

$P_s = 40 + 0.015Q$

The allocation in the current time period (e.g. 10 years) will be determined through solving for the market equilibrium quantity.

$0.025Q = 160$ =» $Q = 6400$

$P = 136$

Suppose the total stock of the resource available for the two time periods (assuming whole life-time of the community is 20 years) is 8,000 units. We observe that only 1,600 units will be available for the next time period with price being,

$P_d = 184$

The allocation of the resource will not be equitable since the period 2 (2^{nd} decade) consumers will not only consume less than period 1 (1^{st} decade) consumers but will also pay a higher price for the same resource. The period 2 consumers will bear some third-party costs as a result of being ignored by period 1 generation.

The problem can be better explained through the concept of marginal net benefit function. The **marginal net benefit** is a measure of the net benefit or total surplus enjoyed by both consumers and producers. It is the benefits to the community net of the costs and is estimated as the difference between the demand and supply function. In other words it is the sum of the producers' and consumers' surplus.

$MNB_1 = P_d - P_s = 160 - 0.025Q$

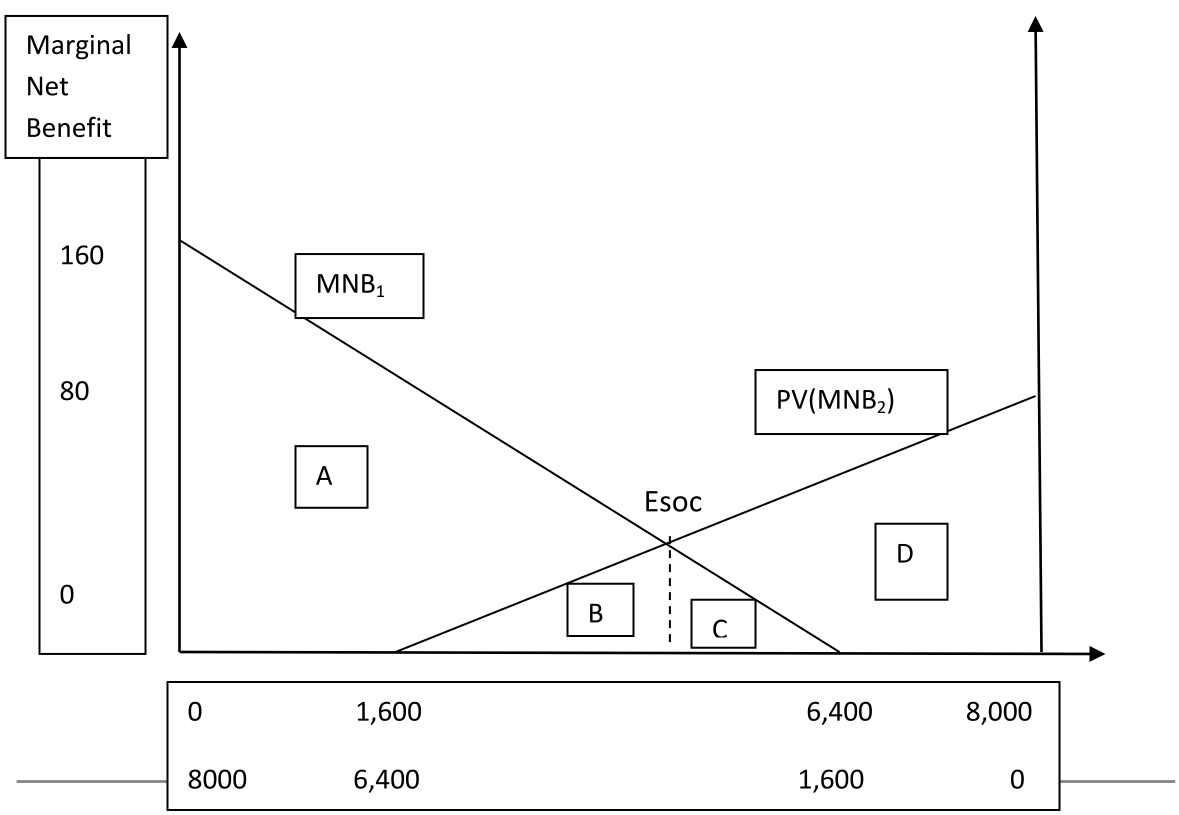
Assume that the discount rate is 7.25% and that one period is 10 years (the number of years between one period and another is 10 years). Further assuming that the demand and supply conditions for the two periods are the same, the present value of MNB for period 2 will be

$PV(MNB_2) = (MNB_2)/(1+r)^t$

$PV(MNB_2) = (160 - 0.025Q)/(1+0.0725)^{10} = (160 - 0.025Q)/2 = 80 - 0.0125Q$

Efficient intertemporal (dynamic) resource allocation will be solved graphically as given in the figure below.

Fig.5.1 Optimal Intertemporal Resource Allocation



Mathematically, the equation for the PV(MNB2) will be

$\Delta MNB / \Delta Q =$

$MNB_1 = 160 - 0.025Q_1$ (Eq.1)

$PV(MNB_2) = 80 - 0.0125Q_2$ (Eq.2)

constraint, $Q_1 + Q_2 = 8000$ (Eq.3)

At social inter-temporal optimal allocation: $MNB_1 = PV(MBN_2)$ (Eq.4)

Therefore from eq.3, $Q_1 = 8000 - Q_2$,

Max social welfare $\int(MNB_1 + MNB_2) = \int (160 - 0.025Q_1)dQ_1 + \int(80 - 0.0125Q_2)dQ_2$

Subject to: $Q_2 + Q_2 = 8000$

Lagragean function

$\text{Max } W = 160Q_1 - 0.0125Q_1^2 + k_1 + 80Q_2 - 0.00625Q_2^2 + k_2 + \lambda(8000 - Q_1 - Q_2)$

FOC $\partial W/\partial Q_1 = 0$, $\partial W/\partial Q_1 = 0$, $\partial W/\partial \lambda = 0$

Therefore, $\partial W/\partial Q_1 = 160 - 0.025Q_1 - \lambda = 0$

$\partial W/\partial Q_1 = 80 - 0.0125Q_2 - \lambda = 0$

$\partial W/\partial \lambda = 8000 - Q_1 - Q_2 = 0$

Solving by substitution, $Q_2 = 8000 - Q_1$

$160 - 0.025Q_1 = \lambda = 80 - 0.0125Q_2$

$80 - 0.025Q_1 = -0.0125Q_2$ => $0.025Q_1 = 80 + 0.0125Q_2$

$Q_1 = 3200 + 0.5Q_2$,

By substitution, $8000 = 3200 + 0.5Q_2 + Q_2$

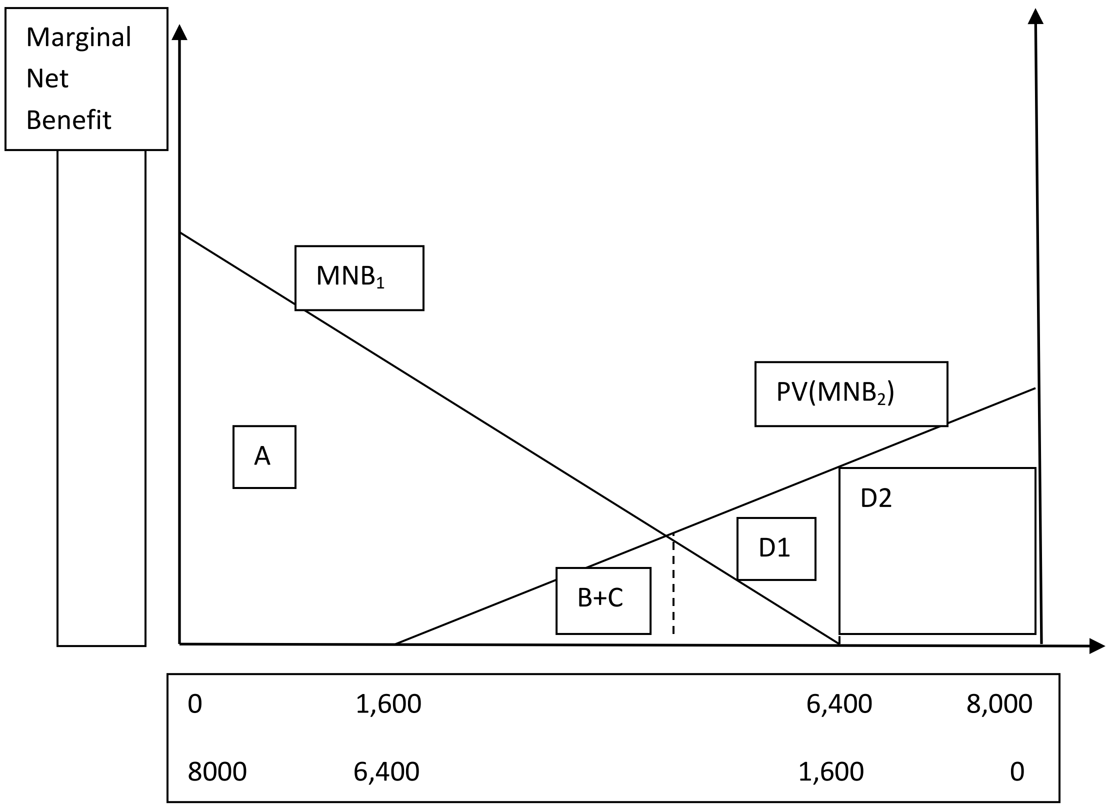
$1.5Q_2 = 4800$

$Q_2 = 3200$ (precisely 3168) and $Q_1 = 8000 - 3200 = 4800$ (precisely 4832)

Under the above optimal inter-temporal allocation, period 1 generation consumes and produces 4,800 units while period 2 consumes and produces the residual 3,200 units. Period 1 generation get total Net Benefit equal to A+B+C while period 2 generation get total net benefit equal to D2 only which is less than the earlier intertemporal optimal allocation.

This can be compared to the intertemporal optimal allocation as given in the figure 5.2 below

Fig.5.2 Sub-optimal Intertemporal Resource Allocation



Period 1 generation consumes and produces 4,800 units while period 2 consumes and produces the residual 3,200 units. Period 1 generation get total Net Benefit equal to A+B+C while period 2 generation get total net benefit equal to D2 only which is less than the earlier intertemporal optimal allocation.

Example 2 - Assume the market demand and supply function of an exhaustible resource is given as,

$P_d = 87{,}000 - 0.1Q$ and

$P_s = 3{,}000 + 0.1Q$

The allocation in the current time period (e.g. 10 years) will be determined through solving for the market equilibrium quantity.

$0.2Q = 84{,}000$ =» $Q_1 = 420{,}000$, $Q_2 = 180{,}000$

$P_1 = 45{,}000$, $P_2 = 69{,}000$

Suppose the total stock of the resource available for the two time periods (assuming whole life-time of the community is 20 years) is 600,000 units. We observe that only 180,000 units will be available for the next time period with price being,

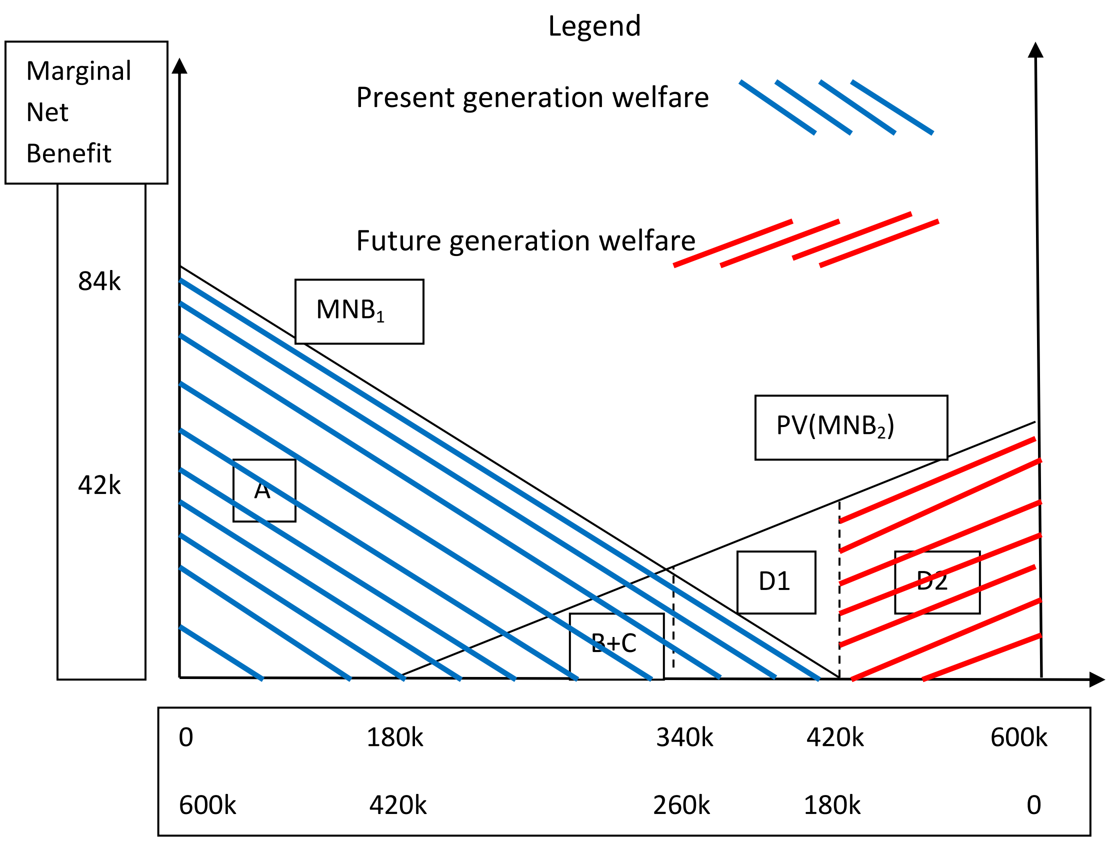
$P_d = 69{,}000$

The allocation of the resource will not be equitable since the period 2 (2nd decade) consumers will not only consume less than period 1 (1st decade) consumers but will also pay a higher price for the same resource. The period 2 consumers will bear some third-party costs as a result of being ignored by period 1 generation.

The problem can be explained through the concept of marginal net benefit function. The **marginal net benefit**.

$MNB_1 = P_d - P_s = 84{,}000 - 0.2Q$

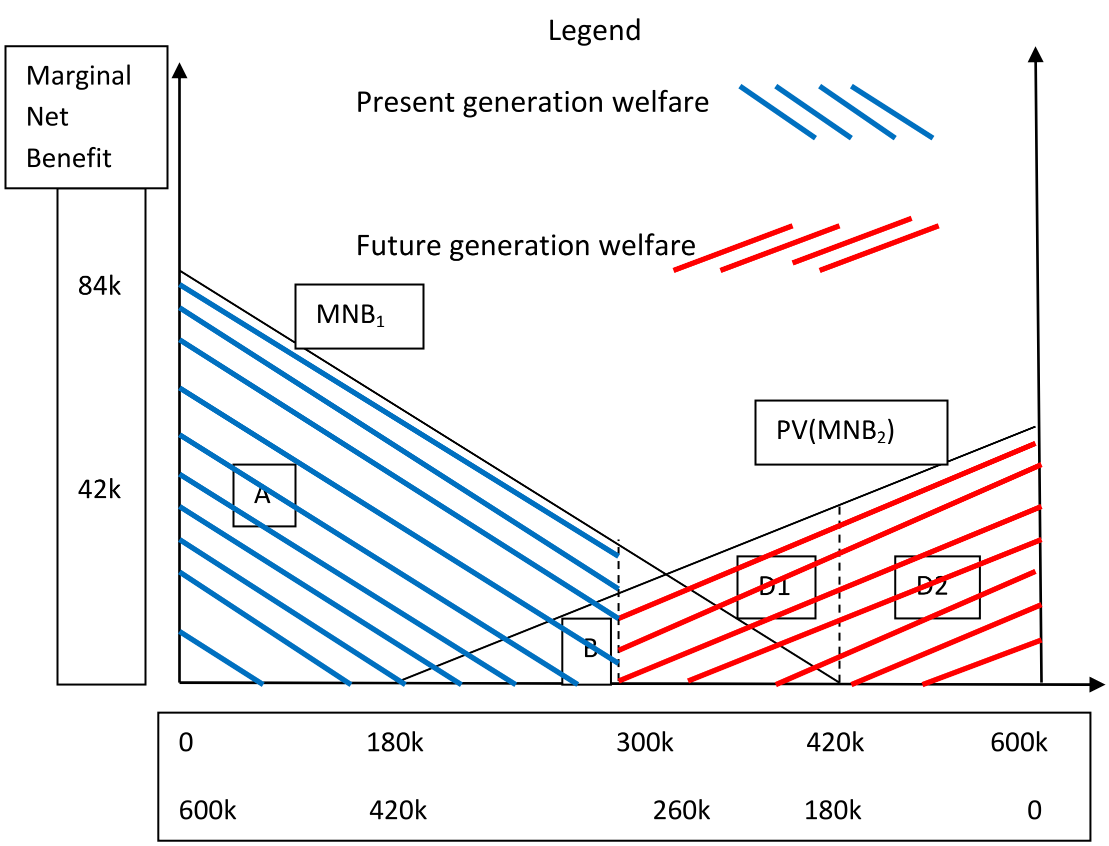
Fig.5.3 Market allocation of exhaustible Resource



Under market allocation, the present generation will enjoy welfare as represented by area shaded in blue lines while future generation will enjoy welfare as represented by area shaded in red lines. The surplus represented by (triangle) area D1 will not accrue to any of the generations since the quantity (80,000 units) due to this surplus will go to the present generation as the lower part triangle shaded blue.

If we were to contrast this with equity allocation, where each generation gets 300,000 units, the welfare analysis would graphically be given as below,

Fig.5.4 Equity allocation of exhaustible Resource



From the figure above, equity allocation ensures a greater welfare to both generations combined than market allocation hence, equity is more efficient than market allocation. Though, equity is not most efficient (Pareto optimal) as can be seen in the optimal inter-temporal allocation given in the figure below.

Assuming a discount rate of 7.25% and that one period is 10 years (the number of years between one period and another is 10 years) and that the demand and supply conditions for the two periods are the same, the present value of MNB for period 2 will be

$PV(MNB_2) = (MNB_2)/(1+r)^t$

$PV(MNB_2) = (84{,}000 - 0.2Q_2)/(1+0.0725)^{10} = (84{,}000 - 0.2Q_2)/2 = 42{,}000 - 0.1Q_2$

Since therefore,

$MNB_1 = 84{,}000 - 0.2Q_1$ (Eq.1)

$PV(MNB_2) = 42{,}000 – 0.1Q_2$ (Eq.2)

And the constraint is, $Q_1 + Q_2 = 600{,}000$ (Eq.3)

At social inter-temporal optimal allocation: $MNB_1 = PV(MBN_2)$ (Eq.4)

Therefore from eq.3, $Q_2 = 600{,}000 – Q_1$,

By substitution,

$84{,}000 – 0.2Q_1 = 42{,}000 – 0.1Q_2 = 42{,}000 – 0.1(600{,}000 – Q_1)$

Hence, $42{,}000 + 60{,}000 = 0.3Q_1$ and $Q_1 = 102{,}000/0.3 = 340{,}000$

With $Q_2 = 260{,}000$

Or alternatively in a better working of welfare maximization,

Max social welfare $\int(MNB_1 + MNB_2) = \int (84{,}000 – 0.2Q_1)dQ_1 + \int(42{,}000 – 0.1Q_2)dQ_2$

Subject to: $Q_1 + Q_2 = 600{,}000$

Lagragean function

Max $W = 84{,}000Q_1 – 0.1Q_1^2 + k_1 + 42{,}000Q_2 – 0.05Q_2^2 + k_2 + \lambda(600{,}000 – Q_1 – Q_2)$

FOC $\partial W/\partial Q_1 = 0$, $\partial W/\partial Q_1 = 0$, $\partial W/\partial \lambda = 0$

Therefore, $\partial W/\partial Q_1 = 84{,}000 – 0.2Q_1 – \lambda = 0$ eq.1

$\partial W/\partial Q_1 = 42{,}000 – 0.1Q_2 – \lambda = 0$ eq.2

$\partial W/\partial \lambda = 600{,}000 – Q_1 – Q_2 = 0$ eq.3

From equation 1&2, $84{,}000 – 0.2Q_1 = \lambda = 42{,}000 – 0.1Q_2$

$42{,}000 – 0.2Q_1 = -0.1Q_2$ => $0.2Q_1 + 0.1Q_2 = 42{,}000$

Solving from equation 3, $Q_2 = 600{,}000 – Q_1$

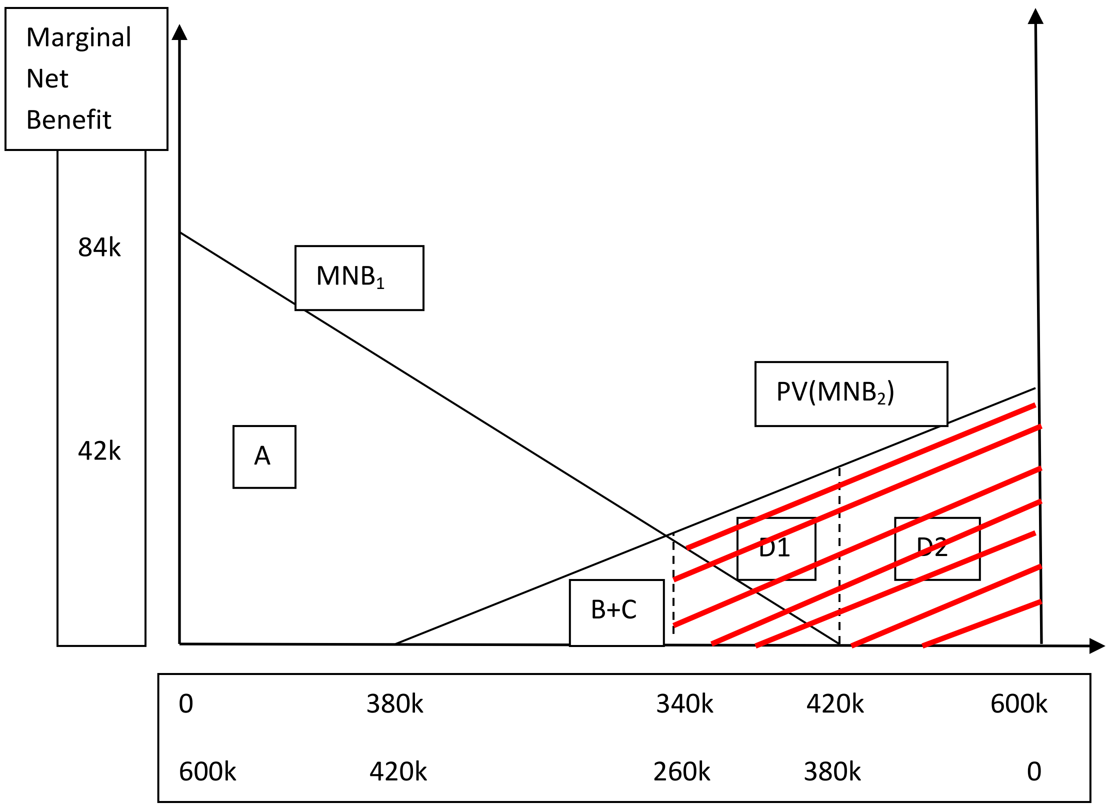
By substitution, $0.2Q_1 - 0.1(600{,}000 – Q_1) = 42{,}000$

$0.3Q_1 = 102{,}000$ hence, $Q_1 = 340{,}000$ and $Q_2 = 260{,}000$

$Q_2 = 340{,}000$ (precisely 341,595) and$Q_1 = 600{,}000 – 340{,}000 = 260{,}000$ (precisely 258,405)

Under the above optimal inter-temporal allocation, period 1 generation consumes and produces 340,000 units while period 2 consumes and produces the residual 260,000 units. Period 1 generation get total Net Benefit equal to A+B+C while period 2 generation get total net benefit equal to D2 only which is less than the earlier intertemporal optimal allocation.

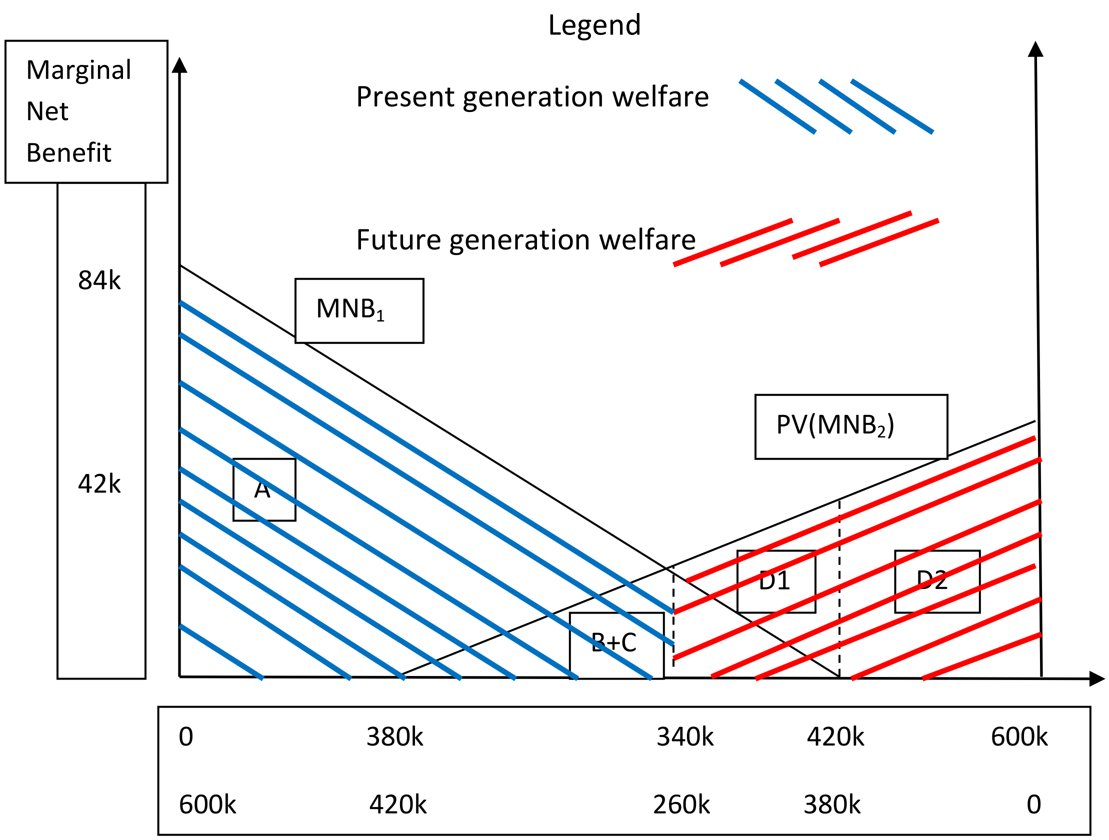
Fig.5.5 Optimal Intertemporal Resource Allocation



Period 1 generation consumes and produces 420,000 units while period 2 consumes and produces the residual 380,000 units. Period 1 generation get total Net Benefit equal to A+B+C while period 2 generation get total net benefit equal to D2 only which is less than the earlier intertemporal optimal allocation.

Welfare analysis can be shown graphically below,

Fig.5.6 Welfare under optimal Intertemporal Resource Allocation



Efficient intertemporal (dynamic) resource allocation will be solved thru Hotelling's rule.

User costs and Hotelling's rule

Hotelling's rule is summarized in the following fundamental equation

$$\frac{\dot{P}}{P} = s$$

Resource should be depleted in such a way that the rate of growth of price of the extracted resource is equal to the discount rate. Alternatively it can be stated

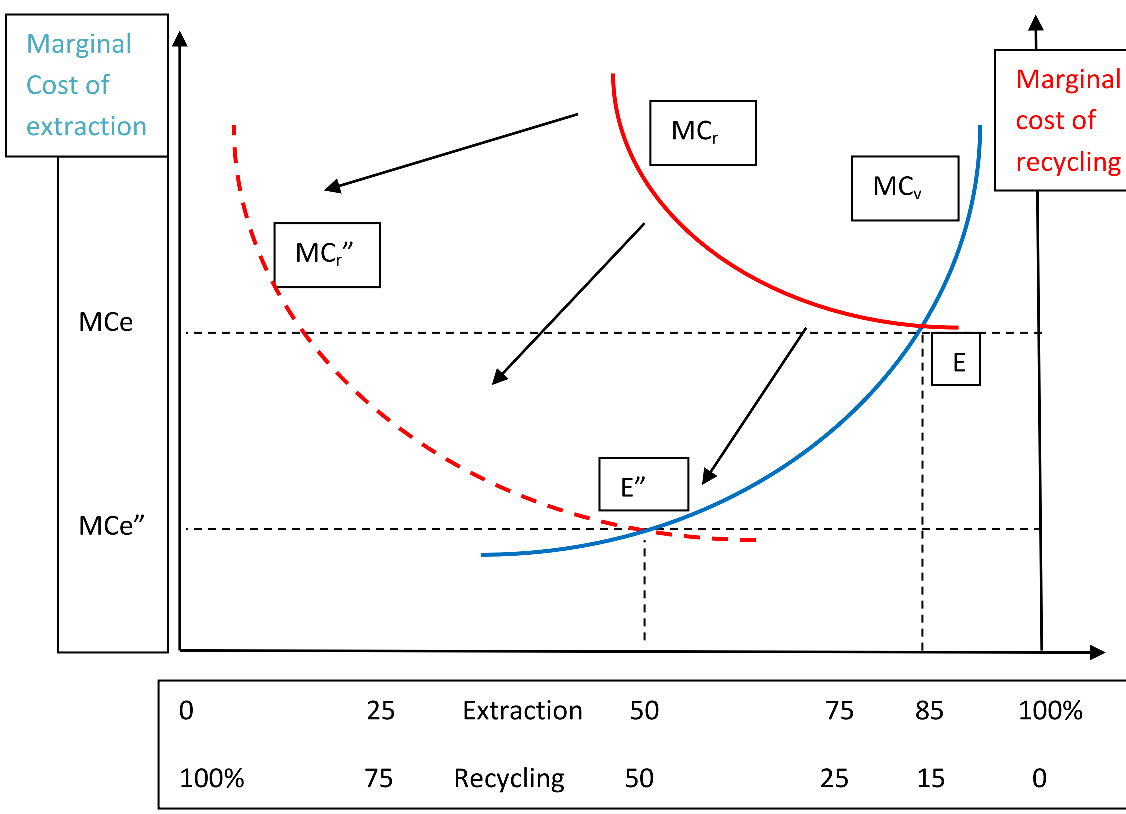
$$P_t = P_0 e^{st}$$

The owner of the resource should be indifferent between a unit of resource at P_0 now and the same unit at $P_0 e^{st}$ in t years of time. By leaving resources in the ground (preserving them) the resource owner can expect capital gains as the resource price rises through time. The owner will be indifferent between holding the resource in the ground and extracting it if the rate of capital gain ($\dot{P}/P$) equals the rate of interest (s) on alternative assets.

5.2 RECYLING OF RESOURCES

The economics of recycling is basically centered on costs of recycling versus cost of using or extracting virgin resource which implies a consideration of opportunity cost of recycling versus the alternative/s. We will build a model with the assumption that units of both recycled and virgin resource are homogeneous and that the demand for the resource is given. We will further assume that all costs associated with supply of virgin resource and recycling are fully accounted for, and can get the marginal costs of recycling and extracted virgin resource represented as a function of the quantity of the resource supplied. The costs associated with extraction and recycling represent the supply of extracted/mined (virgin) and recycled resource respectively. Hence graphically, the marginal cost of recycling (with origin down at the right hand side – 0%) and that of extraction (with origin down at the left hand side – 0%) can be represented as in figure 5.7.

Fig.5.7 Optimal allocation in recycling versus extraction of virgin resource



Under the marginalist principle, the equilibrium will be established at quantities where marginal cost of extraction is equal to the marginal cost of recycling. Assuming that the initial cost of recycling is very high (MC_r) and the cost of extraction/mining is MC_v, the equilibrium will be established at E, and the amount of virgin resource extracted/mined will be 85% while the amount recycled will be 15% of the total quantity sold and bought in the market. But if the cost of recycling fall to MC_r" (shift of the MC curve inwards), the new equilibrium will be established at E" and the amount extracted/mined will be 50% while the amount recycled will make up 50% of the amount traded in the market.

Whenever the marginal cost of recycling is less than that of extracting virgin resource the industry shall opt for recycling. In other words more recycling will take place with greater proportion of the resource in the market being recycled.

$MC_r < MC_v$ => decision would be to increase recycling

In the converse, whenever the cost of recycling is greater than cost of extraction, extraction is preferred and hence increased extraction. This will imply that there will be an increase in proportion of extracted resource in the market relative to recycled.

The trend over time is that costs of recycling are bound to decline as improved technologies through research and innovations increase. Increase in research and development (R&D) activities have led to better quality of recycled resource and hence created new demand for the recycled resource. Furthermore, the processes of disposing used (waste) resource may improve over time and hence lead to reduced costs associated with recycling. This is augmented by the fact that for exhaustible resources the stock of virgin resource is bound to diminish and hence cost of extraction, prospecting and exploration is going to increase unless new discoveries of big deposits are found. New emerging or alternative/competing uses of the resource can lead to increased derived demand for the resource and hence increased profitability of recycling and hence increased recycling of the resource. There are new inventions, products, processes or improved technologies that utilize used/waste resources and hence increased demand for recycled resources. However, new alternative resources that can substitute the demand for the resource may ease the pressure of market demand and possibly the need for recycling.

Therefore, whenever the cost of recycling increases (rarely the case),

$MC_r > MC_v$

Less of recycling is done and more extraction of virgin resource will take place.

Out of the above arguments, increase recycling and re-use has been observed in:

1. Metals – iron, steel, copper, gold, mercury, lead, titanium – in metal based industries and products
2. Plastics – packaging, storage, handling, conveyance

3. Paper – newspapers, magazines, cartons, office stationeries,
4. Glass & ceramics – panes (for windows etc), mirrors, bottles, pots and jars
5. Water – e.g. from sewer systems, clean fresh water, drinking, irrigation – industrial, farming and domestic use

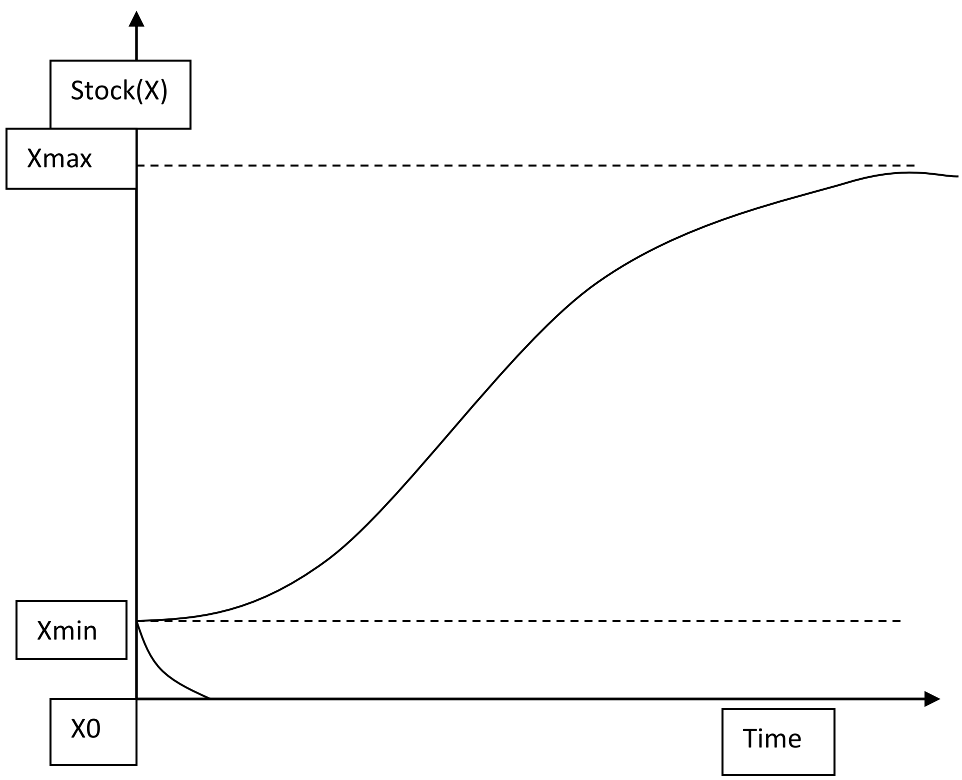
5.3 RENEWABLE RESOURCES

Renewable resources were earlier defined as those resources which if well managed, can last indefinitely. They are resources which can be regenerated.

Growth curves

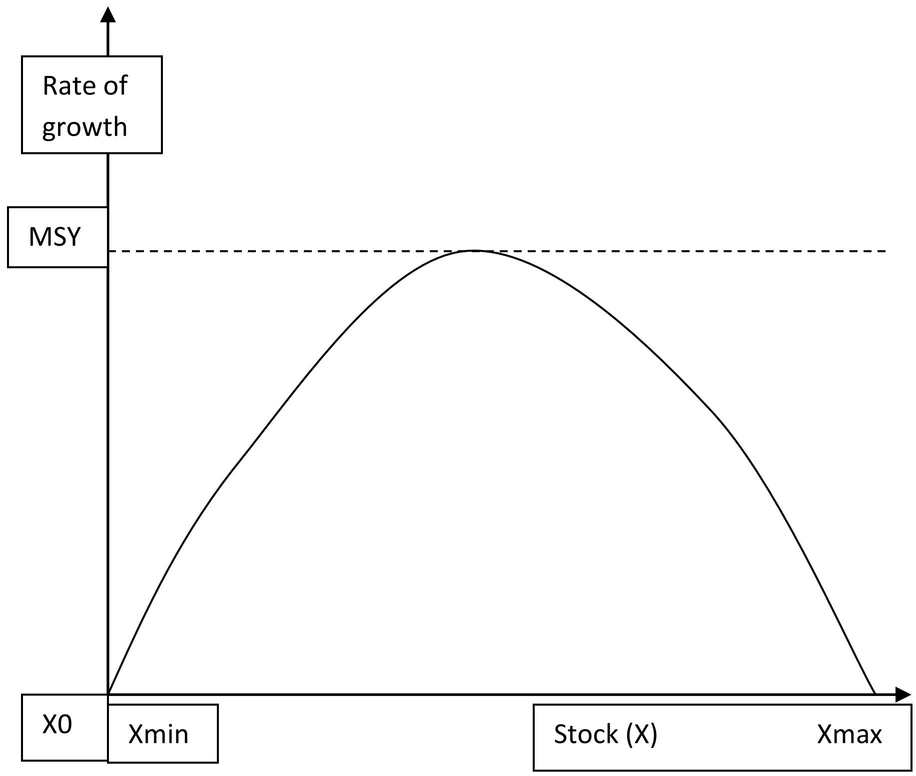
A stock (biomass) of a single fish species may exhibit a growth curve as shown by the logistic function below. The growth will finally converge to some maximum level (Xmax).

Fig.5.6 Stock function of Biomass



We can plot the same information in a different way as a growth rate function in the figure below

Fig.5.7 Growth function of Biomass

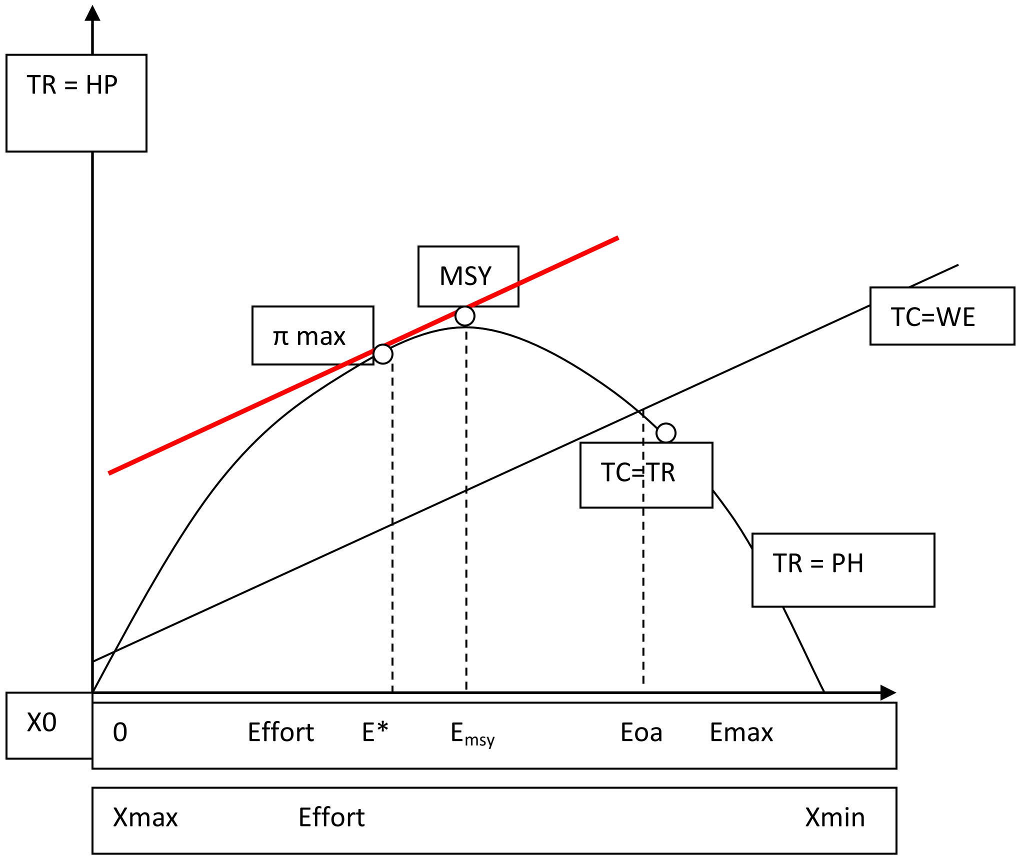


MSY = maximum sustainable yield

MSY is the amount of maximum yield rate (regenerative capacity) of the renewable resource that can be harvested continuously without reducing the stock in the long run. If we are to harvest an amount equal to the MSY every period, the stock will remain the same indefinitely while the harvest we get is the maximum rate possible. However this is if no consideration of effort, costs and revenues are made in the harvesting.

If maximization of profits is considered, we will end up with the following model.

Fig.5.8 Revenue and cost functions of renewable resource



Profit-maximizing solution is at π max as shown in the figure above. This is if the resource is privately owned. At this equilibrium the following observations can be made; Max TR-TC

a) If new entrants cannot be kept out profit will be dissipated. This happens if ownership rights are not well defined
b) Profit-maximizing equilibrium does not coincide with MSY.
c) Price of effort (W) can be so high that a profit-maximizing solution is nearer to maximum stock (nearer to origin in the figure) or so high that no exploitation takes place at all.
d) On the other hand effort can be so costless (W=0) that TC will coincide with the horizontal axis with profit-maximizing solution will coincide with MSY.
e) Profit maximization does not lead to species extinction
f) The above case is a static model with no allowance for time.

The break even solution point is also known as **open-access** solution. It can be observed that at open-access solution;

a) The stock is less than that associated with profit maximization
b) Open access does not coincide with MSY, unless by chance, TC cuts TR at the latter's maximum
c) Open access does not lead to extinction of species – the flatter the TC function the less costless the effort.

Common-property solution lies between profit-maximizing solution and open-access solution. Common-property-solutions can break down if the defined group increases in size. It may be rewarding to an individual to 'break ranks' and maximize individual utility at the expense of community's overall interest. This may lead to species extinction.

SPECIES EXTINCTION

Extinction is possible if,

1) Resource is harvested under conditions of open access than when enforceable property rights exist – common-property and open-access conditions increase the probability of extinction
2) Market price of the commodity is high
3) Cost of harvesting is very low – many species can be harvested at extremely low cost, example of poachers of elephants, rhinos etc
   $P > C(X)$
4) Prices are endogeneous – the more market prices rise as harvesting costs increase or harvest quantities decline
5) Natural growth rate of the stock is very low
6) Extent to which marginal extraction costs rise as stock size diminish is low
7) Discount rate is high – discount rates of poachers tend to be very high, or when discount rate is higher than the growth rate of the stock
   $[s > F'(X)]$
8) In the process of ‘harvesting’ of one species can lead to the extinction of a separate species that happen to be the incidental victim of the deliberate harvesting policy (joint production). As some species are eliminated so are the preditors which require these prey as food.
9) For a very large number of species, market, or ‘perceived’ price is zero or near zero. However the habitat of such species has positive value. The destruction of the habitat can drive the species to extinction
10) Problem of externality – price received by the exploiter deos not reflect the externality (good) – conflict of values

CHAPTER SIX

ECONOMICS OF SUSTAINABLE DEVELOPMENT

ECONOMIC GROWTH AND SUSTAINABLE DEVELOPMENT

All governments are concerned with economic growth as a measure of economic performance of a country. But, is GNP a good measure of well-being? Criticisms of use of GNP as good measure of welfare of a nation include:

a) Effects of economy on the environment are not well measured in GNP accounts
b) Changes in natural resource stocks (e.g. soil erosion, depletion of mines) are not reflected in the NDP
c) GNP does not tell how distributed of the national income is
d) Changes in factors such as health and literacy have impacts on a communities sense of well-being yet they are not reflected in the GNP

It has been recognized that GNP is very limited as an indicator of development and a more broader definition of development (as per *UN Human Development* Report) includes the following indicators:

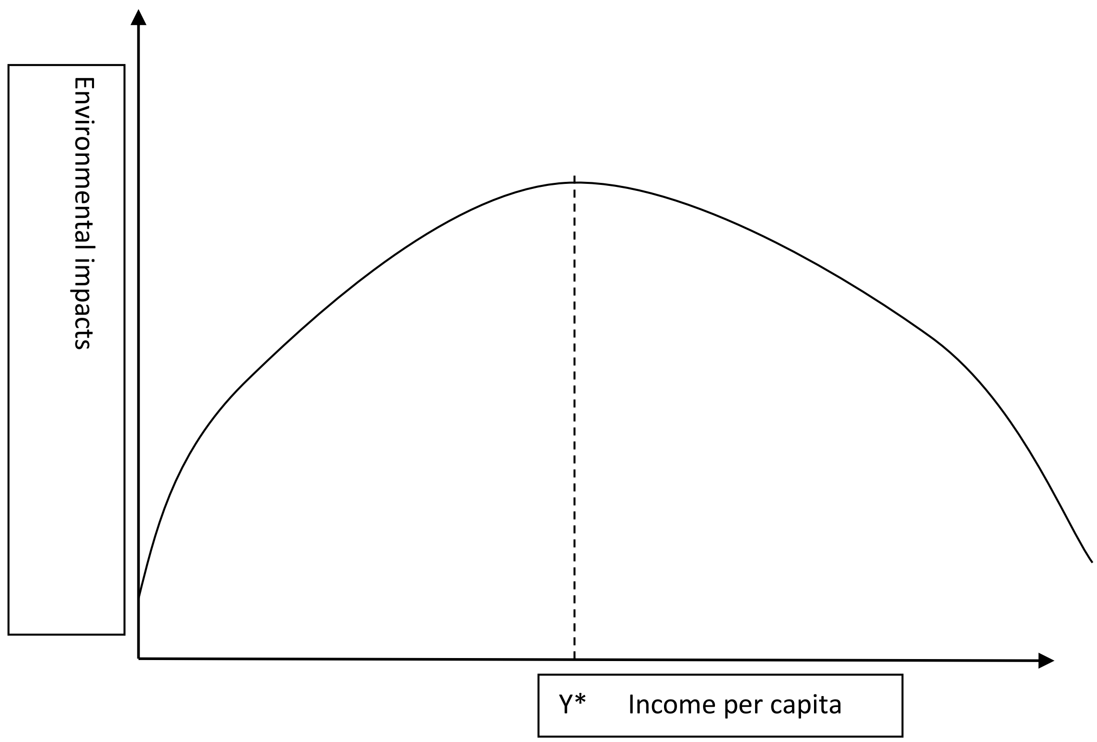
1) GNP per capita (still important)
2) Measure of income inequality
3) Improvement in adult literacy rates
4) A reduction in infant mortality
5) Reduction in morbidity (illness) and mortality (death) rates amongst adults.

It is observed that these indicators are both monetary and non-monetary.

Over-time of new concern is whether growth has limits and whether economic growth is perpetual. Hence the concept of sustainable development.

THE ENVIRONMENTAL KUZNETS CURVE

The Environmental Kuznets Curve (EKC) theory is a view supported by international institutions such as World Bank (World Development Report, 1992). Named after Simon Kuznets (who in 1955 hypothesized an inverted-U-shaped relationship between the equality of income distribution and income levels) the theory hypothesizes that the relationship between environmental quality and growth is also an inverted-U-shaped. As per capita incomes grow, environmental impacts rise, hit a maximum, and then decline.



Explanations for the EKC theory,

Fall in environmental quality is due to

- Increased use of resources and land clearance gives rise to waste
- Early development stage as an agricultural country then industrialization leads to increases in emissions

Emmisions decrease and environmental quality rises as a result of;

- Demand for environmental quality rises as income increases – increase in government protection of environment and green consumerism
- Technological development make production to be cleaner
- Changes in the structure of the economy from manufacturing to service and high-tech industries
- Increasing scarcity of environmental quality drives up its relative price – less is consumed and more is preserved

Definition of sustainable development

Sustainable development is “development that meets the needs of present generations without compromising the ability of future generations to meet their own needs” – Bruntland Commission in 1987

SD is “a requirement to our generation to manage the resource base such that the average quality of life we ensure ourselves can potentially be shared by all future generations” – Ger Asheim (Norwegian economist).

Common features of the definitions are fairness across generations and fairness within generations. It more of equity and not efficiency issue.

In SD capital can be split into

- Man-made capital – this is the familiar capital in elementary economic theory
- Human capital – this is labor that includes all skills and knowledge embodied within people
- Natural capital – all gifts of nature

$$K_n + K_h + K_m = K$$

SUSTAINABILITY RULES

Weak sustainability rule is that there should be no decline in K,

$$K_n + K_h + K_m = K$$

Strong sustainability is that there should be no decline in natural capital

$$K_n$$

Or in critical natural capital

To achieve sustainable development the government can go for any of the following methods

1. **Value all environmental goods and services at their correct prices**

As said before, the overuse of environmental resources arises from lack of correct prices being attached to their use. Attaching correct prices to resources will cause a movement towards SD. Reason why it will not fully enable SD is that it only ensures efficiency but not equity or fairness.

2. **The 'Hartwick rule'**

Hartwick rule (John Hartwick, 1997) is closely related to idea of weak sustainability though historically preceding it. An economy dependent on non-renewable resource as one input to production could have constant consumption levels over time, provided that it reinvest all rents (the difference between price and marginal cost per unit extracted) from exploiting the resource in man-made capital. This is also called the 'zero net investment' rule and allows the total capital stock to be constant. This is the basis for genuine savings measure.

3. **Daly's 'operational principles'**

Herman Daly gave the following set of 'operational principles' for SD:

a) In the case of renewable resources – Harvest rates should be kept at less than or equal to the growth rate.
b) For non-renewable resources – Invest sufficient part of the income from resource extraction each time period in renewable substitutes and only use the residual on current consumption
c) For pollutants – ensure that emissions in any time period do not exceed the assimilative capacity of the receiving environment
d) Controls should be placed on the scale of the world economy – tighter quantity controls of the total matter-energy throughput of the economy must be put in place. According to Daly this includes maximum limits to total pollution emissions, energy use, resource use, and, most controversially population.

4. Rules set in terms of natural capital itself

'Strong sustainability' view requires a non-declining stock of natural capital. This is a very restrictive rule. This implies that if a non-renewable resource is depleted re-investment is required in a renewable resource. This is discussed in other texts.

CHAPTER SEVEN

THEORY AND METHODS OF ENVIRONMENTAL VALUATION

THEORY OF ENVIRONMENTAL VALUATION

(FIELD, chapter 7)

Willingness to Pay (WTP) concept gives a monetary indicator of the total benefit an entity derives from a good or service

Gross WTP = Market price + Consumer surplus.

WTP is slightly different from (Willingness to Accept) WTA though intended theoretically to be the same.

TOTAL ECONOMIC VALUE

User values or user benefits are benefits derived from the actual use of the environment. More complex values are expressed through option value. Option value is the value of the environment as a potential benefit as opposed to actual present use value.

Total economic value = total user value = Actual use value + option value

Another value is the existence value or intrinsic value. Existence values are values not related to use of environment, or future use either by the valuer or some future person related to the valuer.

Total economic value = Actual use value + option value + existence value

Where,

Option value = Value (potential) in use (by the individual) + value in use by future individuals (decendant and future generations) + value in use by others (vicarious value to the individual)

Three **important features** are present in our economic valuation of the environment/resource,

1) <u>Irreversibility</u> – if the asset is not preserved, it is likely to be obliterated such that little or no chance of reinstating is possible

2) Uncertainty – the future is not known hence potential costs exist if the asset is eliminated and future choice can be foregone
3) Uniqueness – existence value relate to endangered species and unique scenic views

OPTIONS VALUE

Total WTP is also known as option price (OP) which is the sum of expected consumer surplus plus option value. Options value refers to the value that arises from retaining an option to a good or service for which future demand is uncertain. In other word it is the additional value to any utility that may arise if and when the good is actually consumed.

Option price = Expected consumer surplus + option value

EXISTENCE VALUE

Existence value (EV) is value placed on an environmental good and is unrelated to any actual or potential use of the good. EV bridges economists and environmentalists and includes.

1. Bequest motives to heirs or future generations in general.
2. Gift motive to current relations or friend
3. Sympathy motive for people or animals

Direct measurement

Damages from externalities can be measured directly in the following steps if its emissions

I. Measure emissions
II. Determine the resulting ambient quality
III. Estimate human exposure
IV. Measure impacts (health, aesthetic, recreation, etc.)
V. Estimate the values of associated with different impacts

The first three are largely done by physical scientists. Step 4 is done partially by economists. Step 5 is purely by economists.

Past approaches used to directly measure damages include

i) Health damages – related to human health such as treatment of diseases resulting from exposure to pollution (SO_2 and other toxic pollutants)
ii) Effect of pollution on production costs – reducing yield of plants and animals or even workers
iii) Materials damage – to exposed surfaces, metal surfaces of machinery, stone surfaces of buildings and painted surfaces of all types of items.

Direct damage approaches are **however limited** with most estimates being incomplete.

- They often exclude non-market values.
- There are other numerous monetary benefits received by relatives and friends not accounted for.
- Does not account for pain and suffering of illness
- People and markets do adjust or change to environmental pollution hence full accounting for the cost is not possible

It is for these reasons that we resort to the concepts of willingness to pay. There are three ways of finding out WTP

i) Indirectly through getting amount of expenditure incurred to control the pollution
ii) Indirectly through measuring variation in prices paid for properties around the environment compared to other identical properties in environments that don't have the said characteristic.
iii) Directly through a survey by estimating the WTP of people for closely associated environmental characteristics.

Examples of indirect methods

- Value of human health as expressed in 'averting' costs
- Value of human life as expressed in wage rates
- Value of environmental quality as expressed in house prices
- Value of environmental quality and intercity wage differentials
- Value of environmental amenities as expressed in travel costs

CONTINGENT VALUATION METHOD

Direct method

This is also known as Contingent Valuation (CV) method. It basically asks respondents what they are willing to pay (WTP) for a benefit.

Willingness to pay

There are basically three ways of finding out the willingness to pay by a polluted individual.

a) Through expenditures incurred to control for the pollution
b) Through changes in pricing of commodities in the vicinity e.g. house rent and
c) Direct method of conducting a survey on what they are willing to pay for reduction in the pollution

Steps in a CV analysis are;

1. Identification and description of the environmental quality characteristic to be evaluated.
2. Identification of the respondents to be approached, including sampling procedures used to select respondents
3. Design and application of a survey questionnaire.
4. Analysis of results and aggregation of individual responses to estimate values for the group affected by the environmental change.

CVM has several biases that a researcher/valuer need to be aware of

a) Strategic bias – incentive to free ride

The respondent is likely not to tell the truth so as to secure a benefit in excess of the actual costs. This is also referred to as a free rider problem.

b) Design bias – which can be divided into three

- Starting point bias – interviewer suggest the first bid which may elicit different responses depending on the respondent
- Vehicle bias – instrument of payment used in the approach has some influence on the respondent, some being too sensitive than others
- Informational bias – initial information provided by the interviewer can distort the perceived benefits by the respondents hence the valuation

c) Hypothetical bias – are bids in hypothetical markets different from the actual market bids

CVM is meant to elicit hypothetical bids that conform to actual bids if only actual markets exist. One has actual losses in case of wrong decisions while the other has none hence response may be actually different

d) Operational bias – how are hypothetical markets consistent with markets in which actual choices are made

Limitations of benefit cost analysis

Value of Human Lives: Some of the benefits of environmental improvements include the reduced loss of human life. What are the policy implications of placing an infinite value on a life? Of measuring the value of a life based on earnings capacity?

Future vs. Current Generations: What discount rate is appropriate when bringing future impacts into present discounted value? Will future generations value things the same way we do? If not, then how can we bring their values and preferences into policy debates today that will affect them?

Marginal Utility of Money: When we monetize benefits and costs without regard to who receives them, we are implicitly assuming that a dollar generates the same incremental gain in pleasure or marginal utility to all people. Is this usually true?

While it is clear that monetization and benefit/cost analysis capture at best only parts of the total impact of a policy, and so should not be considered a sole guide to policy, data on benefits and costs can be informative and valuable.

If economic benefits aren't estimated, will policy makers assume they do not exist?

Efficiency criterion

The Pareto criterion is considered to be nearly impossible to satisfy in actual policy analysis, and so Kaldor-Hicks is the usual efficiency criterion used.

While the usual method of performing benefit/cost analysis is to maximize the present discounted value (PV) of net monetary benefits (as described below), an alternative method is to select policies that generate the greatest amount of monetary benefit for each dollar of cost, called the benefit/cost ratio.

The ratio method tends to favor smaller projects, while the net monetary benefit method tends to favor larger projects. In the presentation that follows, we will assume that the Kaldor-Hicks efficiency criterion is applied to the PV of net benefits.

Maximizing NPV criterion

To calculate the PV of total net benefits, we must first estimate the flow of benefits and costs from various project alternatives for each year into the future (usually with a finite project time horizon). Then we choose an appropriate discount rate (the rate of interest charged if you loan money for a year rather than use that money yourself) and compute the PV of the net benefits for each year into the future.

$PV_{TNB} = (B_0 - C_0)/(1 + r)^0 + (B_1 - C_1)/(1 + r)^1 + \ldots$

$+ (B_n - C_n)/(1 + r)^n.$

Note that C = total cost in a given time period, B = total benefit in a given time period, r = discount rate, and n = the end period of the project in years from the present. $(B_1 - C_1)$, for example, refers to total net benefits received one year from the present. The expression $(1 + r)^n$ means that the sum $(1 + r)$ is taken to the n th power.

1. CONTINGENT VALUATION

A) Demand-side Methods
   - Hedonic pricing – attempts to value environmental services as they relate to value of marketed goods e.g. value of house situated next to a recreation site
   - Travel cost method – used to value the recreational attributes of environmental resources such as parks and scenic areas

B) Supply-side Methods
   - Production function and engineering cost methods – estimates of costs of facilities required to clean or treat the pollution
   - Economic value – approximation of pure economic value
   - Ecological value

2. THE DISCOUNT RATE – BALANCING PRESENT AND FUTURE

   Discount rate plays an important role in weighting of costs and benefits over time. We use it to estimate a present value of some future cost or benefit.

Social discount rate is often used and is also known as social rate of time preference (SRTP)

COST BENEFIT ANALYSIS

The CBA involves measuring, summing up and comparing all benefits and costs of a specific public project or program.

Stages of a CBA (Folmer, 2000)

1) Definition of project/policy – in terms of the reallocation of resources being proposed and the population of gainers and losers to be considered
2) Identification of project impacts
3) Which impacts are economically relevant?
4) Physical quantification of relevant impacts
5) Monetary valuation of relevant effects
   In estimating the money value of the relevant impacts, the bigger task is to;
   a) Predict prices for value flows extending into the future
   b) Correct market prices where necessary; and
   c) Calculate prices where none exist
6) Discounting of cost and benefit flows
7) Applying the net present value test – do the sum of discounted gains exceed the sum of discounted losses?
8) Sensitivity analysis
   This involves recalculation of NPV when values of certain key parameters are changed. The parameters include
   a) Discount rate
   b) Physical quantities and qualities of inputs
   c) Shadow prices of these inputs
   d) Physical quantities and qualities of outputs
   e) Shadow prices of these outputs, and
   f) Project life-span

Optimum level of environmental quality can be obtained when two conditions are met;

- Total benefit must be greater than total cost
- Marginal benefit must equal marginal control cost

Merits

a) CBA may be applicable to both new as well as old projects
b) CBA is based on accepted social principle that is on individual preference
c) It encourages development of new techniques for evaluation of social benefits

Demerits

a) The authorities may not be aware of all costs and benefits associated with the project
b) CBA does not state who should bear the costs
c) Method of collecting data is generally biased
d) Normally value systems vary from entity to entity hence it is likely that there will be losers in the process

TRAVEL COST METHOD

(TCM)

TCM is the earliest method used by environmental economists to study demand for and value of natural resources used for outdoor recreation and related amenities such as national parks, nature reserves and other tourist sites. Individuals must travel to the site with the observed travel behavior sufficiently revealing valuation of the resource (Folmer, 2000).

REFERENCES

1. Bowers, John (1997) *Sustainability and Environmental Economics: An Alternative Text.* London, Pearson Prentice Hall.
2. Eugine, T. (2007) *Environmental Economics*. Vrinda Publications (P) Ltd. Delhi.
3. Hanley, Nick; Shogren, Jason F. and Ben White (2007) *Environmental Economics in Theory and Practice.* 2nd Ed. New York, Palgrave Macmillan.
4. Harris, Jonathan M. (2002) *Environmental and Natural Resource Economics: A Contemporary Approach.* New York, Houghton Mifflin Co.
5. Field, Barry C. (1994) *Environmental Economics: An Introduction.* 2nd Ed. New York, The McGraw-Hill Co. Inc.
6. Field, Barry C. and M. Field (2007) *Environmental Economics: An Introduction.* 7nd Ed. New York, The McGraw-Hill Co. Inc.
7. Folmer, Henk and h. Landis Gabel (Ed.) (2000) *Principles of Environmental and Resource Economics.* Edward Elgar, Northampton.
8. Kolstad, Charles D. (2000) *Environmental Economics*. Oxford University Press, New York.
9. Pearce, David W. and R. Kerry Turner (1990) *Economics of Natural Resources and the Environment.* New York, Harvester Wheatsheaf.
10. Perman, Roger; Yue Ma and James McGilvray (1996) *Natural Resource and Environmental Economics.* London, Longman.