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MAECO-504

Environment and Population Economics

MA ECONOMICS

3rd Semester

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SYLLABI-BOOK MAPPING TABLE

PAPER NO: MAECO504
ENVIRONMENT AND POPULATION

SYLLABI	Mapping in Book
UNIT-I: THE ECONOMY AND THE ENVIRONMENT Components of Environment - Interlinkage between Economy and Environment - Environmental Economics vs Natural Resources Economics - Common Property Resources - Open Access - Tragedy of Common - Environmental Degradation as market failure – Externality - Coase theorem: Market efficiency through negotiation - Critical evaluation	
UNIT - II: ENVIRONMENTAL VALUATION Use value and non-use value - Contingent Valuation method - Hedonic Pricing - Travel Cost Method (TCM)	
UNIT - III: ENVIRONEMNT AND DEVELOPMENT Environment and Development trade-off - Population, Poverty and Environment - Trade and Environment - Concept of Sustainable Development - Indicators of sustainable Development - Rules to sustainability - Concept of Green Accounting	
UNIT IV - POPULATION GROWTH AND FERTILITY Trends of population growth since the beginning of 20^{th} Century - Basic measures and concepts in Demography - Basic Demographic Equation - Demographic Data Sources - Censuses: Definition given by the United Nations handbook of the Census (1958) - Vital Statistics - Basic Measures of Fertility - Types of Analysis: Period and Cohort measures - Child-Women Ratio (CWR) - Crude Birth Rate (CBR) -General Fertility Rate (GFR) – Age-specific Fertility Rates (ASFR) - Total Fertility Rate (TFR) - Gross Reproductive Rate (GRR) - Net Reproductive Rate (NRR) -Economic Theories of fertility	
UNIT- V: MORTALITY Measures of Mortality-Life Table- Trends of Mortality in Developed and Developing Countries - Mortality trends country wise -Determinants of Mortality	

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UNIT IV - POPULATION GROWTH AND FERTILITY

UNIT- V: MORTALITY

Introduction of the book

The book consists of ten units about the environment, population and agriculture.

In the first unit of this book, we have discussed the economy and the environment. In this unit, the students will learn about the components of an environment, inter-linkages between the economy and the environment, environmental economics vs. natural resource economics, the tragedy of commons, environmental degradation as market failure, externality, Coase theorem and market efficiency.

Environmental degradation is concern for every society and nations of the world. Therefore, many measures have been taken up in society level to improve the quality of the environment or to reduce environmental degradation. Hence, the types and methods of environmental valuation are discussed in unit two of this book.

Unit three deals with the relationship between environment and development. One of the main reasons for the degradation of an environment is economic development. Therefore, in this unit, we have discussed the causes of environmental degradation due to economic development and their corrective measures.

Population growth is often said to be one of the main factors behind India's backwardness. For any student of demography, it is important to have a clear understanding of the size and growth of population, the reasons for the changes in growth rates of population and the factors which determines its growth. Therefore, we have discussed the population growth and fertility in unit four of this book.

Mortality analysis is one of the most important branches of demographic studies. This branch deals with the measurement of mortality. Thus, the techniques for analyzing mortality have a long history and are more developed than those for analyzing fertility. In this regards, different measures and determinants are discussed in unit five of this book.

In unit six of this book, we have elaborately discussed the nature of agricultural economics, interdependence and complementarities between agriculture and industry.

The nature of agricultural production function, risk and uncertainty in agricultural production and its prices have been examined in unit seven of this book. Further, decision theoryis comprehensively explained.

In unit eight of the book, we have discussed various theories of agricultural development which are applicable to underdeveloped countries.

The unit nine elaborately discussed about the rural credit market, understand the various theories, model of rural credit and impact of share tenancy system.

Finally, in unit ten of this book, we have discussed about the agricultural system in India, Problems, Green Revolution, Food Security, WTO and Indian Agriculture.

UNIT-I
THE ECONOMY AND THE ENVIRONMENT

Structure

1.0 Introduction

Environmental Economics is concerned with the importance of environment in economy and impact of various economic activities on the environment. The environment, in-turn, have but limited carrying capacity, beyond which it becomes not only unsustainable but also may have perverse implications upon economy itself. It is in this context that the significance of environment is raised with respect to economy. In this unit the focus is upon several dimensions of environmental economics which may relates to the necessity of formulating basis of environmental policies.

1.1. Objectives

The following are the learning objectives of this unit-

- Components of environment
- Inter-linkages between the economy and the environment

- Environmental economics vs. natural resource economics; Common Property Resources
- Open Access, tragedy of Commons
- Environmental degradation as market failure
- Externality
- Coase theorem, market efficiency through negotiations, critical evaluation.

1.2. Components of Environment

Generally, environment refers to all conditions and their effects which influence the life of a man at any place and at any time. Or, it refers to all those things which are surrounding by the earth. According to the Environment Act 1986, "Environment includes water, air and land and the inter-relationship which exists among and between water, air, land and human beings and other creatures, plants, micro-organism and property".

There are mainly two components of environment:

a. Biotic or living.

b. Abiotic or non-living.

Both these elements are interdependent and they influence each other. With change in Abiotic element, there is also a change in living element of environment. Likewise, a change in living element brings about a change in physical element of environment. Abiotic component includes all physical, non-living elements that provide sustenance to the living organisms.

The Abiotic component of our planet consists of the following categories:

i. The solid matter of the earth starting with top soil or dust and all its solid components.

ii. The water in the ocean and in the rivers, lakes ponds, including marshes and wetland.

iii. The gaseous components around us including nitrogen, oxygen and water vapour called the atmosphere.

The biotic component that includes all living organisms, that is all life forms that follow the process of birth and death.

i. Plants, that depends primarily upon soil nutrients, water and sunlight.

ii. Animals including reptiles, rodents, insects, birds and fishes.

iii. Man, though strictly speaking, a part of the animal category is being considered a separate group here for his capacity to adapt and modify nature with the use of technology.

iv. Micro-organisms including parasitic and saprophytic bacteria and fungi, which are very small and may often be invisible to the eye, but feed primarily upon other living or dead organisms also some non-biotic elements.

1.3. Interlinkage between Economy and Environment

Environmental economics attempts to study the inter relationship between economic agents and environment. Economic as a subject cannot exist in isolation, it cannot even be a mere study of how good and services are produced, but at the same time it has to take into consideration the impacts of the use of resources on the environment. The impact may be in the form of externality, pollution, exhaustion, etc. Any study on the economic content of production, distribution, development, etc., cannot be completed without touching upon the environmental aspects like externality, pollution, damage, exhaustion, depletion etc. environmental economics can therefore be defined as that part of economics which deals with interrelationship between environment and economic development and studies the ways and means by which the former is not impaired nor the letter impeded. Environmental economics teaches us how to promote economic growth of nations with least environmental damage. When the environmental goods get transferred into economic goods, the problems of environmental damage crop up and therefore the need to interact with economic principles.

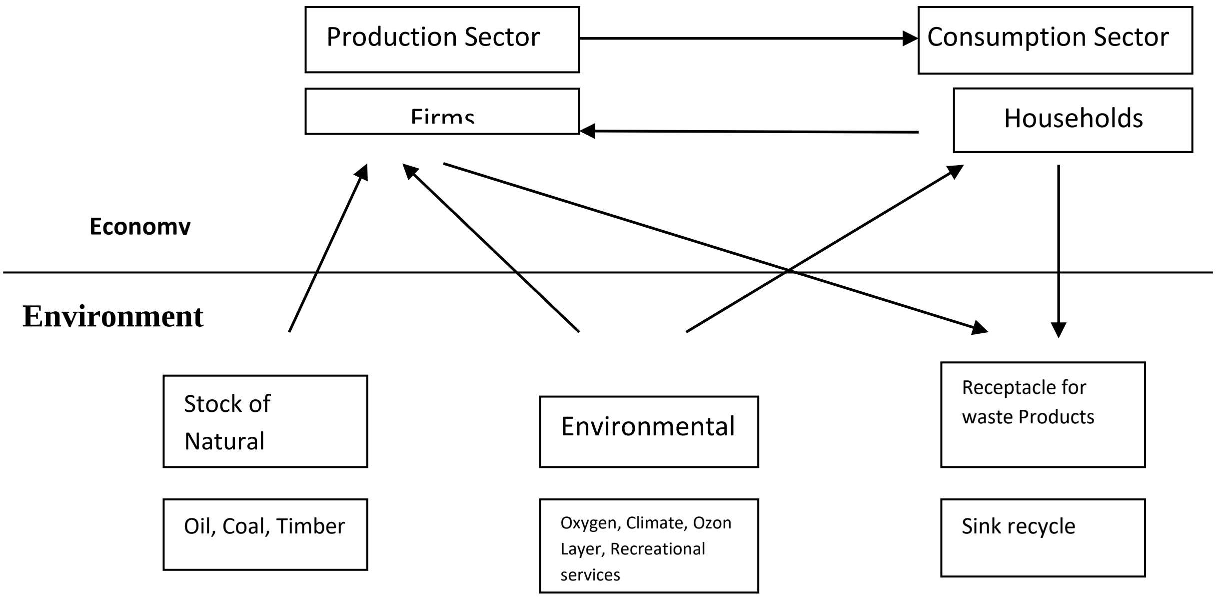
One must begin by recognizing the threefold connection between the environment, human society and its economy.

First, the environment provides the economy with raw materials which are transformed into consumer products through the production process. These raw materials include energy, which is itself a consumer product as well as an intermediate that drives this transformation.

Second, the environment provides services which are used directly by consumers. These may be critical life-support services such as the oxygen in the air that we breath or the water that we drink. They may be aesthetic or recreational services that we may derive pleasure from, such as rambling in the forest or boating on the river.

Finally, there is a less recognized but vital service that the environment provides to the economy. It act as a receptacle or a sink for all the waste products that are the result of the process of production and consumption. The environment is not a passive sink, it act upon the waste products to clean up the environment and recycle the waste intp material that can be used again.

These inter linkages are given in the following diagram:



All problems relating to the degradation of the environment relates somehow to an interference that occurs in this relationship, that hinders the delivery of these good and services that are provided directly or indirectly by the environment to the economy. It may involve the slowing down or a complete break down of the natural clean up process. It is this interference or obstacle that lies at the root of all environmental problems.

Let us take a simple example, if a factory produces some good, it also produces smoke. The amount of good it produces is decided by the economy. This in turn decides the amount of smoke that will be belched out and the damage to human health it will cause. If your neighbor plays his music system too loudly, your mental peace is disturbed.

Thus all problems of environmental pollution or degradation occure as a by product of our activities related to production or consumption. It is therefore, important to understand the economic forces that derive production and consumption such as the formation of market prices and the optimal allocation of inputs.

1.4. Environmental Economics vs Natural Resource Economics

Prior to 1980's little attention was paid to the study of environmental economics. Instead, the theory that was being popularized among the social scientists was known as resources economics. Until the early 1950's natural resource supply and conversation had been neglected by modern economists. Orris C. Herfindhal was the first to go beyond descriptive survey and to view mineral resources as economic goods. Therefore resources economics was concerned with the production and use of natural and mineral resources of both renewable and non-renewable character. The pollution aspect of resource use was not a concern of resource economists. They traced resource economics as flows with dynamic factors.

Environmental economics is concerned with the impact of economic activities on the environment, the significance of ecosystem to the economy and suggest the appropriate ways of regulating economic activity, so that cosmic balance is achieved in the society. Resource economics does not bother about the environmental impact of production and consumption, but environmental economics deals with these aspects. Environmental economics point out the "right volume of pollution" which the society can bear. In order to attain this 'balanced' level of production and pollution, economists recommended economic tools like market mechanism principles. This is so because, in the case of environment, market fails to bring equilibrium. Market fails because environment is a public good. But by assigning true values to the environmental goods it is possible to apply market mechanism principles. These aspects are covered in environmental economics which distinguishes it from resources economics.

1.5. Common Property Resources

Common property resource means a good or service shared by a well-defined community. The community controls the use of such resource by individuals. However, enforcement is weak due to difficulties in monitoring. For example, water in a village pond, which is a common property resource, is used by the villagers only. The village as a community decides upon the manner and the purpose for which the pond water can be used, which results in a set of norms, evolved over time, and largely unwritten. In case of a breach of the norms, however, imposition of penalty is poorly enforced due to poor monitoring, subjectivity in the norms and ambiguities in property rights. The common property regime for managing natural resources is frequently misunderstood. It is often observed as a situation in which there is no management regime in place; as a situation of open access, which is free for all. Accordingly, resource degradation in the developing countries is incorrectly attributed to 'common property systems', whereas it actually originates in the dissolution of local , level institutional arrangements. Therefore, there is a need to properly understand the common property resources and its management systems as these have direct bearing on the sustainable development of natural resources.

We can list a large number of CPRs, which can be brought under the broad headings like land resources, forest resources, water resources, and fishery resources. These resources are being degraded overtime due to overuse or lack of proper management. We shall discuss briefly about these common property resources.

Land Resources

Common property land resource refers to lands identified with a specific type of property rights. The common lands covered in the National Sample Survey (NSS) enquiry are panchayat lands, government revenue lands, village common lands, village thrashing lands, unclassified forest lands, woodlands and wastelands, river banks, and lands belonging to other households used as commons.

Forest Resources

Another category of land for which common property rights may exist is land under forests. Unclassified forests, with very low productivity, are always open to use by local communities: Accordingly, both protected and unclassified forests are treated as forming a part of common property forest resources. It is, therefore, the subset of total forest area minus reserve forests to which common property rights are assumed to exist.

Water Resources

There are a variety of resources of water, which are in the public domain, and a significant part of these are included in the category of commons. Examples are flows of rivers, tanks and natural lakes, groundwater, wetland and mangrove areas, and such other water bodies. Man-made water resources such as dams and canals, tube wells, other wells, and supply of all types of potable water also fall in the category of CPRs depending upon their property rights. Unfortunately, even after many debates about property rights (such as traditional rights, community rights, and basic need human rights), water has not yet been declared as CPR in India, though references are made in the water policy document indirectly. By and large, water resources in India are in common property regimes only. Irrigation canals are managed jointly by the government and communities. Traditionally, tanks, village ponds, and lakes - all of which are treated as CPRs -are sources of water for drinking, livestock rearing, washing, fishing and bathing, and several sanitary-related activities.

1.6. Open Access

Basically, it is a situation where there are no enforceable property rights over the use of the resource. Here, a right of inclusion is granted to anyone who wants to use the resource. Examples of open access resources are fishing in the open sea, river, lake, or ponds, ill-managed village common grazing lands, buffer areas of forests, groundwater, etc. Open access results from the absence - or breakdown - of a management and authority system whose very purpose was to introduce and enforce a set of norms of behaviour among participants with respect to the natural resource.

1.7. Tragedy of Common

People have always a tendency to use (misuse) public property according to their whims and fancies. As the public property is not owned by any individual, no one can claim for an exclusive ownership. The net result being misuse of public properties. Perhaps this is the main reason for garbage appearing in the public road, discharging effluents into the river, public parks being misused, public buildings being disfigured etc.

Prof. Garrett Hardin examined the reasons why public properties are either being misutilised or over utilized by the people. The answer that he identified has been published in the article titled "The Tragedy of commons" (1968). He had studied the character of herdsmen in England. Hardin anxiously watched out the peculiar behavior of herdsmen that they are always prepared to add additional cattle into the pasture land in England. The logic prevailed that the farmer who grazed the most cattle stood to benefit most from the commons. But the tragedy of this kind of action is that the land was overgrazed and destroyed. This came to be known as " Tragedy of Commons" . Though the tragedy of commons is an observation based on the real experience example, it finds its applicability in most of the situation in which the resources are owned by the public. There is a tendency to over exploit public resources resulting in total destruction or non-availability of further resources'.

1.8. Environmental Degradation as market failure

1.9. Externality

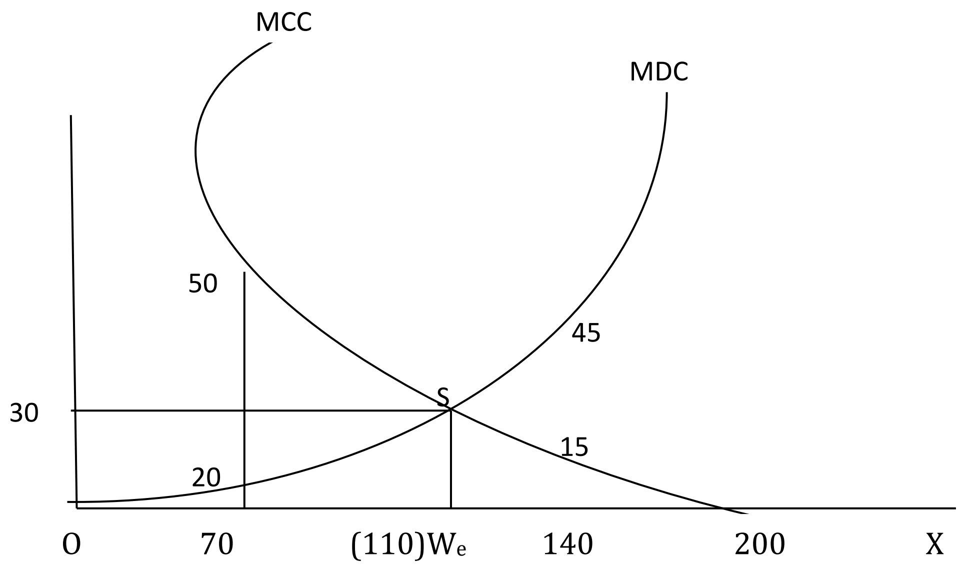
Externality is defined as conditions arising when the actions of some individuals have direct (Positive or Negative) effects on the welfare or utility of other individuals none of whom have direct control over that activity. In other words, externalities are incidental benefits or costs to others for whom they are not specifically intended.

Two classic example of externality are explained below. One is represented by the action of a gardener who invests in the beautification of his or her own property and in doing so raises the property value of neighboring houses. A second example is represented by a fish hatchery plants that has to bear the cleaning up costs for the wastes discharged by a paper mill near to it. In the first example, the neighbours are gaining real external benefit (Positive Externalities) without sharing the cost that yield beneficial results. In the second case the cleaning up costs of the hatchery is external (Negative externality) since it is the result of an action imposed by a third party i.e., the paper mill.

1.10. Coase theorem: Market efficiency through negotiation

According to Coase, any effort to internalize environmental externalities requires an effective scheme for assigning property rights. Coase also believed that by assigning property rights to at least one of the parties involved (either polluter or the pollutee) there would be no effect on the final outcome of the environmental problem. The Coase theorem developed by economist Ronald Coase in 1960. The advantages of this theory is that the pollution problem can be solved by an arbitrary assignment of property rights. Optimal level of pollution can be attained through voluntary negotiations of private parties (polluter and pollutee). If the state is acting as a regulator, enforceable ownership rights have to be assigned so that it can act as private enterprise.

To illustrate the essence of this theory, let us follow the example given below. The two familiar firms to be taken to explain this theory are the paper mill and the fish hatchery. River flowing nearby these firm are a common good. The fish hatchery believes that and as per the legal rights, the river can be used for its activities. The paper mill is not permitted to discharge the effluents into this river. In the figure, this situation is represented by the origin O, where the amount of waste released into this river from the paper mill is zero.



The figure explains that if the paper mill is not permitted to dispose of the wastes, it has to find an alternative method of disposal of 200 units of waste. But this system cannot sustain for a long period. When the waste discharged by the firm is less than W_e (110 units). The Marginal Cost of Cleaning (MCC) of the Mill is higher than the Marginal Damage Cost (MDC) to the hatchery. As shown in the figure, for the 70^{th} unit of waste emitted into the river, the MDC to hatchery is Rs. 20. The MCC of mill is Rs. 50. The Rs. 50 is for cleaning up of 130 units (200-70=130) of wastes. To discharge 70 units of wastes, the mill is prepared to pay Rs. 20 to compensate for the damage caused to hatchery, because the alternative cost for waste disposal of 70 units is Rs. 50. This proposal is advantageous to the paper mill. Though both the parties, the paper mill and the fish hatchery, enjoy some advantages, they can think of a better bargain. These two firms will be in a position to engage in a mutually beneficial transaction provided that it is at the point where the MCC>MDC. Further the negotiation ends when the MCC=MDC. This is the condition for the optimum level of pollution. In figure this is attained at W_e or 110 units of waste emission.

Coase theorem goes beyond the mere attainment of optimally. It also states that this optimal outcome is completely independent of the two parties who have the rights to the river. To illustrate this, let us imagine that the paper mill has exclusive legal rights to the use of the river. Under this circumstance, the mill can dispose of the entire wastes to the river. The figure shows that the paper mill can discharge a total of 200 units. But for each units between 110 and 200 units of wastes discharged, the MDC is greater than MCC. It means that the mill's MCC for abating pollution is lower than MDC which the mill needs to meet. This situation will call for the two firms. The paper mill and the hatchery to engage in a mutually beneficial transaction. When the waste is 140 units, the control cost which the mill needs to pay to the hatchery is Rs. 15 per unit, whereas the mill itself needs to spend Rs. 45 to avoid the 1 unit of waste emission. Thus when the emission level is at 140 units, the MDC is greater than MCC. The hatchery will take initiative to offer any amount higher than Rs. 15 to avoid higher levels of pollution emission to the river. Thus, the hatchery moves on the MCC curve and finally, it settles at S where MDC=MCC. Thus the optional level of pollution is again reached at W_e or 110 units where MDC=MCC.

The theory based on several assumptions:

a. Every firm has perfect information

b. Consumer and producers are price takers

c. Producers maximize the profit and consumers maximize the utility

d. There are no income or wealth effects

e. There are no transaction costs.

1.11. Critical evaluation

The following major limitations of this theory are:

1. Wealth effect is assumed to be non-existent. But in reality we all of us know that there are wealth effects which are subject to environmental factors.

2. Complete set of property rights is necessary to obtain optimum allocation of resources. Coase says that for achieving efficiency it does not matter how these rights are distributed. The question who will assign property rights to public goods is still a hard nut to crack. Arbitrary valuation cannot be considered as the relatively better option.

3. The transaction costs will be much higher when the parties involved in the negotiation process are many.

4. Coase theorem appears to be indifferent from the polluter pay principal which states that it is the polluter who has to meet the environmental damage cost. The extent of optimality in the polluter pay principle is analysed in the Pigovian fee.

1.12. Questions

1. What are the various components of Environments? Also, discuss the various inter-linkages between economy and environment.
2. What do you mean by common property resources?
3. Discuss the concept of Tragedy of Common in the context of environmental economics.
4. State and illustrate the Coase Theorem.

1.13. Key Words

Components	:	Individual parts comprising the total
Inter-linkage	:	Inter-relationship between various individual sectors/parts
Tragedy	:	Misfortune
Utility	:	Amount of satisfaction derived from good

1.14. Suggested Readings

1. Hanley N, J.F. Shogern and Ben White, *Environmental Economics in Theory and Practice*, Macmillan, 1997.
2. Kolstad,C.D., *Environmental Economics*, Oxford University Press, New Delhi, 1999.
3. Sankar,U. (Ed), *Environmental Economics*, Oxford University Press, New Delhi, 2001.

Bhattacharya, R.N. (Ed), *Environmental Economics – An Indian Perspective*, Oxford University Press, New Delhi, 2001.

UNIT II
ENVIRONMENTAL VALUATION

Structure

2.0 Introduction

These days, environmental degradation is a great concerned for every nation in the world. Subsequently, many measures have been taken up in society level to improve the quality of the environment or to reduce environmental degradation.

2.1 Objectives

The following are the learning objectives of this unit-

- Types of environmental valuation
- Methods of Environmental valuation

2.2. Use value and non-use value

Economic value expresses the degree to which a good or services satisfies individual preferences. These preferences can be expressed in terms of utility but more practical in monetary terms. Thus, economic value can be measured by the amount of money an individual is willing to pay for a service or good or the amount of money an individual is willing to accept as a compensation for foregoing the good or service. The environmental goods have two types of value viz., use value and non-use value.

The environment has direct user value. User values are derived from the actual use of the environment. For example, the benefit that one derives from the provision of safe drinking water, pollution free air and so on. This is sometimes referred to as the instrumental/operational/ functional value which arises out of both actual current use and future potential use. When we value the environment for present personal use is the actual present value.

Non-use value is the value that people assign to economic goods (including public goods) even if they never have and never will use it. The non-use value is categorized into four parts. These are as follows-

Option Value: it is defined as the willingness to pay by the potential user for the possible use of natural environment in future.

Bequest value: it refers to an individual willingness to pay to preserved resource for future generation.

Existence value: it refers that the value which is individual is willing to pay for an environmental amenity even though individual received no direct benefit.

Aesthetic Value: it represents the value of scenic beauty even though no market transaction may occur to capture that value.

2.3. Contingent Valuation method

The direct method seeks to infer individual preferences for environmental quality directly, by asking them to state their preferences in terms of the environment. That means, they are asked to make a trade-off between environmental and other goods in a constructed market. There are two basic types of constructed markets i.e., hypothetical and experimental. The most commonly used, popular as well as debated method of hypothetical valuation is the contingent valuation method (CVM). In this section we discussed only about contingent valuation method.

The CVM was formulated by Davis in 1936 in his paper “Recreational Planning as an Economic Problem”. CVM is the oldest and most widely used but the controversial method of environmental valuation techniques. The contingent valuation method consists of asking the people to express either their maximum willingness to pay for an increase in environmental quality or minimum willingness to accept compensation for a decrease in environmental quality.

CVM attempts to quantify the amount of income compensation required to leave the individuals level of utility unchanged that is, observations are generated around the surface of the total value curve to estimate this relationship empirically. In CVM we go for direct estimation of the marginal willingness to pay and then by aggregating these responses the total value curve is estimated.

Any CVM exercise can be broadly divided into five stages:

i. Formulation of the hypothetical market

ii. Obtaining the bids

iii. Average bids

iv. Estimating the bid curve

v. Aggregating data to estimate society's WTP/WTA.

Formulation of the hypothetical market

In any regular market for a commodity, the participation decision depends on (a) the exact knowledge about the quality of the goods, (b) the utility to be derived from the consumption of the goods and (c) the price to be paid to consume these goods. But, in the real world no market for environmental goods. But this good have demand and supply, so, here we talking about a hypothetical market. In order to construct a hypothetical market for 'α', information needs to be supplied on these three aspects. Here one has to show the respondent pictures of the existing state, pictures of the proposed state and the expected impact of this improvement. Finally, respondents should be convinced that the project cannot be undertaken unless some funds can be raised though nothing exactly is being changed at present. If proper awareness cannot be built up here, respondents will not have enough motivation to make payment commitments. The response is expected to be sensitive not only with respect to the magnitude of the required funds, but also the mode of payment vehicle. Suppose, the issue in question is up gradation of a recreational site. If general taxes are proposal to be imposed instead of charging entry fees, the respondents may state lower WTP because of the non-specific nature of the bid vehicle.

Obtaining the Bids:

At this stage the survey is administered. A face to face interview by well trained interviewers has turns out to be the most effective method of data collection. Individuals are asked to state their maximum WTP or minimum WTA for a proposed change in α. To quantify the precise amount truthfully, a number of alternative strategies can be applied. Generally, there are two types of obtaining bids-

i. Close ended bids (CEB)

ii. Open ended bids (OEB)

Close Ended Bids: a single payment P is suggested to which respondents either agrees or disagree. Such responses are known as dichotomous choice (DC) responses. If the response is Yes, then the investigator knows P≤ Max WTP, if No, then P≥ Max WTP, but no concrete information is available here to pin down the exact maximum WTP. In spite of this limitation this method is adopted quite often to avoid strategic bias in response.

Open Ended Bids: here the interviewer attempts to find out the exact maximum WTP. He adopts any of the three methods.

Bidding Gap: it start from a very low P and ask the interviewer whether he would pay this amount or not. If Yes, increase the bid and repeat this process until the first no comes. If No is the initial response then keep on lowering the bid until the first Yes comes.

Payment Card: Try to assess the average expenditure of a household with a similar socio-economic background on other publicly supplied goods and services.

Open Ended Question: Ask the respondent directly the maximum amount that he will be willing to pay for α, with no value being suggested to him. Respondent generally find it difficult to organize their reply.

Estimating average WTP/WTAC:

If open ended biding game or payment card approaches have been used, then the calculation of sample mean or median WTP or WTAC is straightforward. It is usual in CVM to find that mean WTP exceeds median WTP, since the former is influenced by a relatively small number of relatively high bids. If a dichotomous choice (DC) method has been used, then the calculation of average WTP/WTAC is more difficult, as we now explain.

In the DC framework, the researcher makes use of random utility theory. In particular, it is assumed that whilst the representative individual knows their own preferences, these are not completely observable by the researcher. In particular, it is assumed that the utility function of individual has

$U=U(Q_i, Y, X)$

Where, Q is the level of environmental quality

Y is income

X is socioeconomic characteristics, is only partly observable by the researcher. Suppose environmental quality improves from j=0 to j=1. The researcher acts as though the utility function is:

$V = (Q_i, Y, X) + \varepsilon_j$ ....(1)

Where, ε_j is an identically and randomly distributed error with zero mean. Suppose now that the individual is asked if they would pay an amount A for the environmental improvement . The probability that they will accept this offer is :

$P(Yes) = P[V(Q_1, Y-A, X) + \varepsilon_1) \geq V(Q_0, Y, X) + \varepsilon_0]$..............................(2)

And the probability of saying 'No' is {1 – P (Yes)}. Equation (2) can be estimated statistically by first rewriting it as:

$P[\varepsilon_{0-}\varepsilon_1] \leq [V(Q_1, Y-A, X)] - V(Q_1, Y-A, X)]$..(3)

Define $\triangle V$ as the change in the observable part of the utility function and n as $(\varepsilon_{1-}\varepsilon_0)$ and f_n as the cumulative distribution function of the error. We can then write that:

$P[n \leq \triangle V] = f_n(\triangle V)$

Which , if $f_n(\triangle V)$ is assumed to have a logistic cumulative density function is equal to $(1 + e^{-\triangle V})^{-1}$. In order to proceed , a specific functional form for V must be adopted; V may be simplified into the form $V = (\alpha+\beta Y)$ with the change in utility determind by the change in this over the two states and the offer price A. suppressing X in this case we have:

$\triangle V = (\alpha_1 - \alpha_0) - \beta A$

Where the α and β terms will depend on X and the probability of a Yes response is

$P(Yes) = F_n[(\alpha_1 - \alpha_0) - \beta A]$

Alternatively, if $V = \alpha + \beta \log Y$; then the $\triangle V$ is roughly equal to $(\alpha_1 - \alpha_0) - \beta(A/Y)$.

Utility theoretically, WTP measure are calculated by Hanemann from these models. Let W be the true willingness to pay (WTP). W is distributed according to the function G_w, mean WTP is given by the integral:

Mean WTP $= \int_o^T [1 - G_w]\, dA$ ....(4)

Where, T is some upper limit, infinit for a true mean or some upper value for a truncated mean. Median WTP is given by:

$P[u(Q_1, Y-W, X) \geq u(Q_0, Y, X)] = 0.5$............(5)

In other words, the WTP value at which exactly half of the population would say 'no' which is that value of A to which exactly half the population would say Yes; since it is equal to or less than their true WTP. Hanemann gives formula for the calculation of these values from the models for V. as Duffield and Patterson point out, many CVM researchers use an alternative form for V. which, although does not give exact utility theoretic measures of compensating or equivalent. Surplus is thought to provide reasonable approximations. This involves specifying the probability that a respondent will say 'Yes' to the offer price A as:

$P\,[Yes] = [1 + e^{-\alpha-\beta \log A}]^{-1}$ ………………………….(6)

Where, α term is the $(\alpha_1\text{-}\alpha_0)$ term above. This is the model that Bishop and Herberlin used and implies that WTP has a log-logistic distribution, which is everywhere positive and positively skewed. Median WTP can be calculated as Expected – (α/β): mean WTP must be evaluated by numerically integrating under the logistic function between specified upper and lower bounds.

Estimating Bid Curve:

Investigating the determinants of WTP/WTAC bids is useful is aggreagating results and for assessing the validity of the CVM exercise. A bid curve can be estimated for open-ended CVM formats using WTP/WTAC amounts as the dependent variable and a range of independent variables. For instance, in an open ended CVM survey, WTP bids might be regressed against income (Y), education (E) and age (A), as well as against some variable measuring the quantity of environmental quality being bid for (Q), if this varies across respondents:

$WTP_i = f\,(Y_i, E_i, A_i, Q_i)$

Aggregate Data

At the final stage the total WTP for the population as a whole is to be estimated. From our estimators of average WTP for the sample we have to infer about the average population WTP. If Y_i, E_i, A_i, and Q_i are replaced by their respective average population value, then the corresponding WTP_i would be the average population WTP (W_p). then (W_p * N) would give the total WTP for the society as a whole, where N is the population size.

There are many problems that have been identified with CVM:

1. Strategic bias: if the respondent presumes that the amount of money would actually be collected from him at some future date then with the intention of free riding he would

understate that this question is totally unrelated to his ability to pay then to enjoy higher moral satisfaction he would overstate his preference.

2. Hypothetical bias: another criticism of CVM is that the value is obtained in CVM surveys are not based on real income decisions- they are hypothetical. There is no budget constraint in a hypothetical survey and without a budget constraint choices are meaningless. This bias is identified as hypothetical bias.

3. Embedding Bias: Another problem with CVM is called embedding. The response is sensitive with respect to quality and not quality. People may place the same value on cleaning up one lake or ten lakes.

2.4. Hedonic Pricing

The hedonic price method starts with the assumption that as the environmental quality changes property prices would also change indicating the scope for estimating and implicit demand function for the environmental good by observing the property price variations. Hedonic price method depends on quality of changes and quality of environment. This approach is generally applied to the housing market, where the demand for housing is dependent on a number of characteristics that a particular site possesses. The price of a house is the written as:

$P_n = f(S_n, L_n, \alpha_n)$

Where, P_n = Price of the house

S_n = Space related factor

L_n = Location specific factor

α_n = Environmental factor

like any other market the transaction decisions in the housing market are also governed by the demand-supply interactions. Now, an attempt is made to present the theoretical framework in order to show how demand and supply function emerged in the market:

The consumer

Suppose a typical consumer has a utility function U and income is Y. The consumer purchases one house and the choice is only regarding the environmental attributes (α), as the available alternatives are identical with respect to all other characteristics. The consumer allocates income between the consumption of an ordinary good X and the housing, whose price P depend on α, i.e., $P = P(\alpha)$. The consumers problem is :

$\text{Max } U(X, \alpha)$; subject to $X + P(\alpha) = Y$

Given the level of $U=U_0$, the question is what would be required amount to be spent on X consumption attain U_0 corresponding to alternative values of α ? let us define $(Y-X)=\Theta$, where Θ is the amount of income left to be spent on α. Obviously $\Theta= \Theta(Y,\alpha,U_0)$ which is called the bid function, as it represent the amount of money the consumer may bid for the house with characteristics α, to keep utility fixed at U_0, given his income level Y.

Since α is an exogenous variable, in order to enjoy better quality of α, one has to bid higher Θ. Thus, the bid function is upward rising. As more and more α would be available, for successive increases in α. The marginal willingness to pay will go down, which makes the bid curve concave shape. The bid function represents the total willingness to pay. This is shown in the following diagram:

The Producer

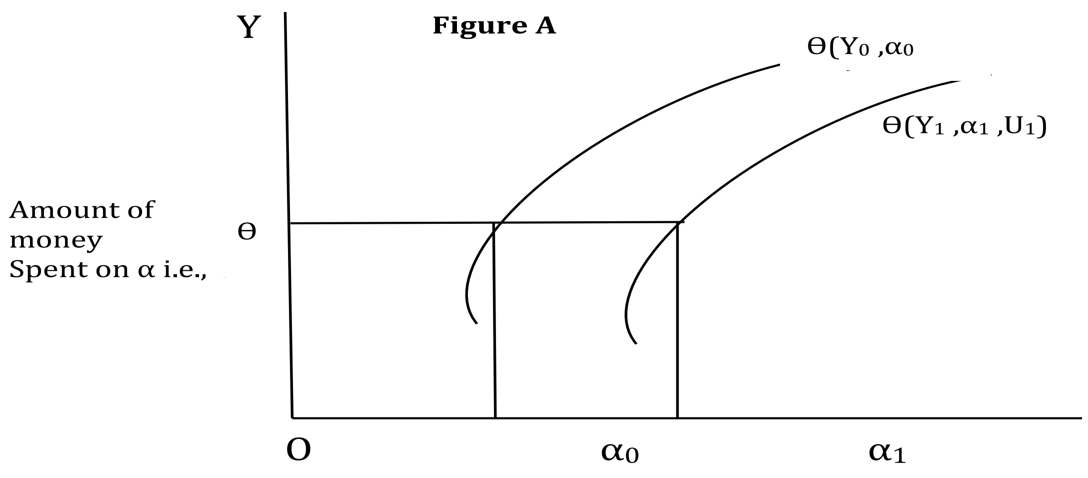
The supply side basically for the producer and supplier. The supply side of the housing market can be summarized in terms of offer curve. For the house with environmental quality α, the total production cost is a function of non land input prices (γ) and the land price is a function of α. Hence, the total cost is $C=C(\gamma, \alpha)$. If the price offered by the producer is denoted by ϕ, then his profit from this sale would be vanish:

$\Pi \neq \phi - C(\gamma, \alpha)$. This ϕ will be represent by $\phi = \phi(\gamma, \alpha, \Pi)$,

Where, γ = Non land inputs price

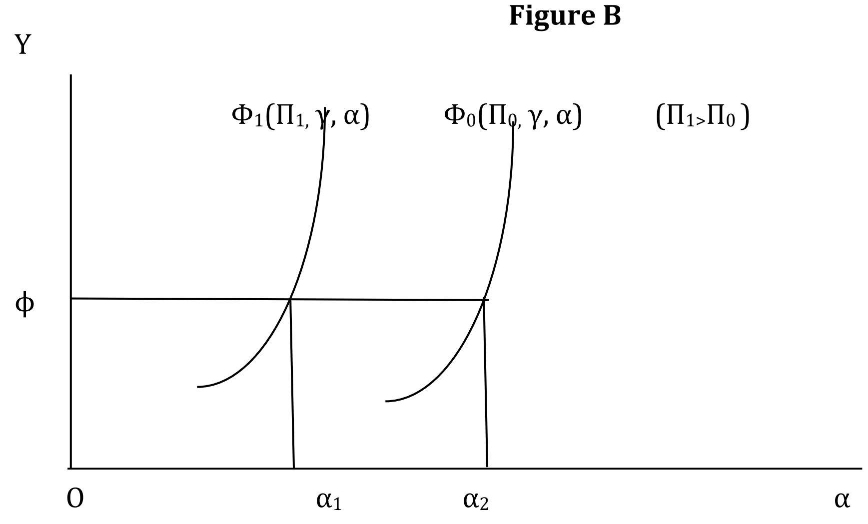
α = Environmental quality

Π = Profit



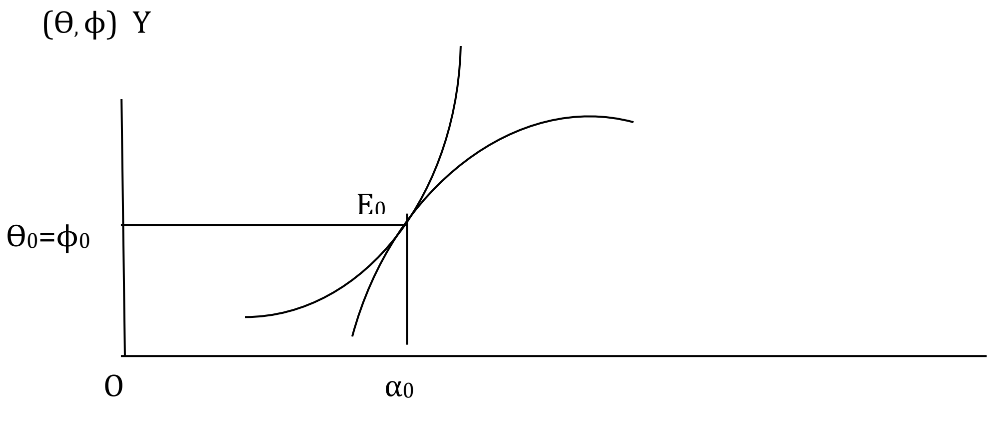
As more and more better quality of α can be purchased due to non-reproducible nature of environment, its relative scarcity would go up. Hence, the offer cup will be upward rising and will have a concave shape. We have shown in the following diagram:

Figure B



Now for any particular transaction to take place, the bid curve has to match the offer curve, where the bid curve has to match the offer curve, where the bid curve shows the consumer's willingness to pay (WTP) and the offer curve represent the producer's willingness to accept (WTA). For the transaction to take place the maximum WTP has to be greater than or equal to the minimum WTA. By superimposing Figure A and Figure B, we can show that the acceptable bid-offer match takes place at E_0 in Figure C, where the maximum WTP equals the minimum WTA in the margin , making the two relevant curves tangent to each other. So the house would be transacted at price $\Theta_0=\phi_0$ with environmental quality α_0.

Figure C



2.5. Travel Cost Method (TCM)

This method involves using travel cost as a proxy for the value of visiting outdoor recreational sites. A statistical relationship between observed visits and the cost of visiting is derived and used as a surrogate demand curve. The travel cost method assumes complementarities between the environmental assets and consumption expenditure.

The simplest version of TCM involves collecting data on the total number of visits to a site from zone i, that is V_i and the total visitors population P_i of zone i. then (V_i/P_i) is proposed to be a function of the average travel cost C_i and other socio-economic characteristics S_i. This C_i is the total travel cost which includes both direct expenditure during the trip and the imputed value of the time cost.

$$(V_i/P_i)= f(C_i ,S_i) = a_0 + a_1 C_i + a_2 S_i + W_i$$

Where , W_i is the random error term and i= 1,2,3,….k

K being the number of zones.

The estimated a_1 coefficient would quantify the change in the visitation rate following a change in the travel cost. So, a_1 is the estimated slope of the intercept of this demand function one needs data upto that level of C_i where visitors stop visiting the site altogether due to exorbitantly high cost. A few implications of TCM are interesting to note.

i. the representative visitors utility function is assumed to be seperable, at least in the recreational activity being modeled. If the activity of interest is visiting a national park , the willingness to pay (WTP) for the trip can be estimated independent of his WTP for everything else.

ii. when the representatives visitors decides not to undertake the trip because of the high expenditure involved in the decision then the marginal social cost of future environmental degradation will not have any influence on the implicit demand function. The negative WTP is not observable. This features makes travel cost method inappropriate to capture non-user values. It can only quantify the user-value of the environmental amenity.

iii. for a proper estimation of the amenity demand function one needs to collect information from households that have made a visit as well as those who did not take up a trip to this particular site. If the information on the second group is not collected, the empirical estimates would be subjected to a truncation bias. Because of this partial observability one has to run a Tobit regression instead of a regular one.

iv. in demand estimation through travel cost method, problems arise with multipurpose trips. It may be necessary to make a distinction between meanders and purposeful visitors. For those who are visiting different sites on a single trip. Only a part of their total travel cost is to be attributed to a particular site visit. The proper specification of the apportionment rule for this common cost is a methodological challenge.

v. on many occasions, environmentalist and policy makers are more interested in the value of changing the characteristics of a site rather than in the value of the site in toto. Here the demand equations for different sites have to be estimated and the sensitivity of the regression coefficients with respect to the site characteristics is to be studied. This sensitivity analysis would quantify the marginal WTP. Two alternative techniques applied for this purpose are the varying parameter models and the dummy variable technique.

vi. when the visitors selects a particular site from a number of alternatives then one can suggest a modified version of travel cost method to incorporate this discrete choice. Here, the Random utility model is generally applied where the utility from the visit to a recreational site is assumed to be composed of an observable deterministic component and the random error term. Here the sole purpose of the quantitative analysis is to find out the probability of visiting a particular site, given the relevant information. If we assume the probability to be totally explained in terms of relative site characteristics, we apply conditional logit. When besides relative site attributes, these probabilities are made contingent upon the personal characteristics of the individual taking the decision and then the relevant quantitative technique would be the multinomial logit.

2.6. Questions

i. Discuss the use and non-use value.

ii. Discuss the various steps of contingent valuation method.

iii. Explain the Hedoric pricing of environmental goods.

iv. Discuss the travel cost method.

UNIT III
ENVIRONEMNT AND DEVELOPMENT

Structure

3.1. Introduction

This unit deals with the relationship between environments and development. The environment is very important to economy. However, there has been rapid degradation of environment with the passage of time. There are various reasons for environmental degradation. One of the main reasons for degradation of environment is the economic development. The increase in the level of economic development requires extraction of more and more resources from the environment. At the same time, the increase in economic activities of production and consumption due to economic development increases the amount of waste and pollutants which are ultimately disposed-off in the environment. In this background this unit attempts to examine the trade-off between environment and development, impact of trade on environment, substainable development and green accounting.

3.2. Objective

The objective of this unit is to impart the knowledge about the importance of environments to the economy and to understand the relationship between environment and development. The rapid economic growth over the last decades coupled with population growth has put huge pressure on environment. As a result, there has been significant degradation of the environment throughout the world. Hence, the need for promoting sustainable development has assumed greater importance.

3.3. Environment and Development trade-off

The environment and economy are closely interlinked. The environment provides raw materials and other resources to the economy. The economy transforms those raw materials derived from the nature into consumable goods. However, along with production of goods, the producers also generate wastes and pollutants which are ultimately disposed into the environment. The environment also acts as a sink of wastes pollutants. But it has a limited capacity of waste assimilation as there are some wastes or pollutants which cannot be degraded easily. The environment also provides amenity and global life support services.

In the pre-industrial period, there was a very little or no environmental problem. However, after the industrial revolution, there has been rapid economic development and at the same time the environmental quality started to deteriorate. Hence, the question of environment and development came to occupy an important place. This question relate to relationship between environment and development. Since economy derives resources from the environment and disposes waste into the environment, the economic development is likely to put pressure on environment and cause its degradation. However, the recycling of waste can reduce the flow of resources from the environment into economy reduce pressure on environment. At the same time, the development of new technology can ensure higher efficiency of use of energy like fossil fuel and reduce pressure. The progress in science and technology can optimize resource use and ensure sustainable development.

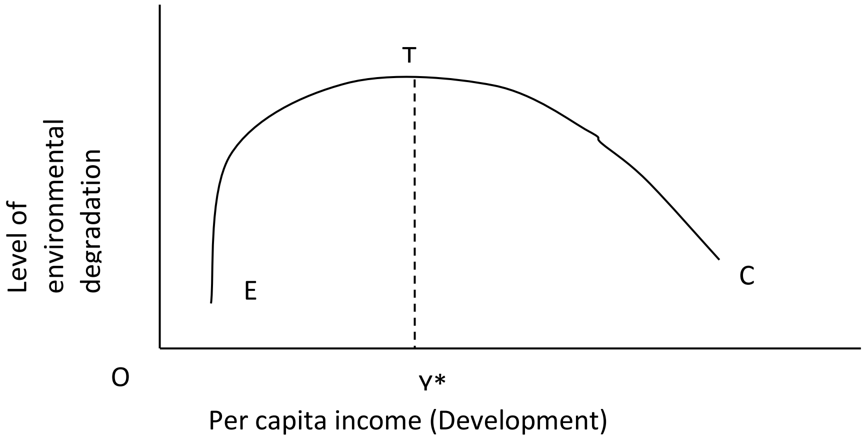
Thus, the nexus between environment and development is quite complex. The question of how are they related to each other is similar to the one posed by Simon Kuznets in 1955, regarding the level of income and inequality along the state of economic development. Kuznets hypothesized that there is an inverted U-shaped relationship between inequality and development. That is due to the income inequality increases initially along the path of development but it reduces at the higher stage of development.

The environment and development trade-off can also be explained in terms of Environment Kuzets curve. This discussed as follows;

3.3.1. Environmental Kuznets Curve (EKC)

The Environmental Kuznets curve relationship between environment and development takes its inspirations from the income distribution theory developed by Simon Kuznets in 1955. In his study, Kuznets found an inverted U-shaped relationship between the indicators of income inequality and the level development as measured by per capita income. The income inequality increases along the path of economic development in the early phase, declares in the later phase.

Gene Grossman and Alan Krueger in their studies of the relationship between the environment degradation and economic development found a similar inverted U-shaped relationship. This inverted U-shaped relationship between the environmental degradation and economic development is known as Environmental Kuznets Curve (EKC). The EKC hypothesis expresses the most likely relationship between the environment and economic development. It states that the environmental degradation is low when the level of economic development is low. The environmental degradation increases with economic development in the early phase but it comes down at the later stage of development. That is, in the initial stage of development, environmental degradation increases but eventually declines at certain threshold level of income.



In the figure EC is the environmental Kuznets curve which is inverted U-shaped. The level of environmental degradation is measured along the vertical axis and the level of per capita income (a measure of development) is measured along the horizontal axis. The curve shows that as the level of income increases, the environmental degradation also increases but up to point T. T is the turning point and Y* is the threshold level of income at which the turning point occurs. As the level of income increase further the level of environmental degradation starts to decline as indicated by the downward sloping portion of the EC curve beyond the point T.

The explanation for the invested U-shaped relationship between the environmental degradation and the level of development are as follows:

The increase in environmental degradation in the initial phase can be attributed to the heavy emphasis on economic growth and capital formation to enhance production and consumption. It is due to heavy emphasis on industrial development and movement of the economy from the clean agrarian economy to polluting industrial economy. For the early phase of development, people tend to neglect environmental matters due to high level of poverty, lack of awareness, income inequality and lack of community level institutions etc. These result in increase in environmental degradation in the early phase of development.

The decline in environmental degradation after the certain threshold level of income is attributable to technological change and efficiency in use of energy and other resources. The technical innovation enables the economy to produce more level of output with the same resources. At the same time, it encourages the recycle of materials and reduces the pressure on the environment. Further, the institutions of natural resources by resources not linked to environment, increase in education and awareness among the people about the ill effects of environmental degradation and better implementation of environmental regulations contribute to reduce environmental degradation. In fact the person to with higher income has a tendency to prefer better environmental quality and spend more to consume the environment. The economic structure also changes from polluting industrial to clean services economy.

3.3.2 Criticisms

The EKC relationship between the environmental degradation and the level of development has been criticized under the following grounds:

(1) The Environmental Kuznets curve has been found only for some air quality indicators especially local pollutants. There is no evidence of the EKC in case of global pollutant like carbon dioxide (CO_2).

(2) The EKC hypothesis states that at certain threshold level of per capital income the turning point will occur and increase in income beyond that level heads decline in environmental degradation. However, it does not say the exact level of income at which the turning will occur. There is no agreement in literature on the income level at which the environmental degradation starts declining.

(3) The shape of the curve may be N-shaped instead of invented U-Shaped if the level of environmental degradation after declining for some time again starts increasing as nations incomes continue to increase. Arrow argues that the inverted U-shaped relationship would appear to be false, if pollution increases again at the end due to higher levels of income and mass consumption.

(4) Suri and Chapman urged that met reduction in pollution may not be occurring. On a global scale because the wealthy nations have a tendency of exporting the pollution intensive activities like, manufacturing of clothing, furniture etc. to poorer countries. Thus, the level of pollution may be declining in the developed countries but it is compensated by the increase in pollution in developing countries. So, the pollution level at the global scale may remain unchanged with economic development.

Thus, it can be concluded that the relationship between the environment and economic development is quite complex and unpredictable. The environmental Kuznets curve has tried to explain the possible relationship between the level of environmental degradation and economic development. The hypothesis populated that in the early phase of development, environmental degradation increases. But as the level of development reaches certain threshold the people become aware about the environment and invest more in environmental protection. This leads to decline in environmental degradation.

3.4. Population, Poverty and Environment

Human population has grown at an accelerated rate in the two centuries – at the advent of industrial revolution. During the same period development in medicine and health care as a result of advances in science and technology contributed to substantive reduction in death rate – leading to high growth of population was around 0.5 billion and was growing at the rate of 0.3% per annum. By 1970 world population became 3.6 billion and with a growth rate of 2.1% per annum world population rose to 5.4 billion in 1991 and fall in growth rate to 1.7% per annum. This was done to fall in global birth rate which were falling since the middle of 20^{th} century, but it was falling shown than the death rate. The world population has reached 7 billion in 2010. The current (2019) world population is 7.7 billion.

Thus there has been increasing pressure of population growth and human activities on the limited resources of the biosphere.

With growth of population –density, the natural resources to human population ratio goes down, straining the life support system of humans and resource supply to their economy.

Human population creates demand on environment in two ways –

First, like all other species, human population depends on nature for life support services – like oxygen, water, and some natural foods. Second, unlike other species, human beings transform through production process, materials and energy drawn from nature into consumable goods and services. The size of an economy where growth would cause strain and pressure on the nature has two aspects returning consideration:

a) Size in terms of population
b) Size in terms of GDP.

These two factors have interactive relationship.

Capital accumulation and development of an economy influences the process of demographic transition and the growth of population.

On the other hand, the growth of population in an economy would have scale, composition and technology of the economy depending among others on the local natural resources base.

Every society and economy adapt to the population pressure. The institutions evolve arrangements to accommodate the needs of the growing population while attempting at the same time to control population growth through policies. The ecological and economic effects of population growth would have a feed back on population growth itself. The demographic, technological, economic, ecological and cultural factors of a society influence each other in a web-like manner. The mechanism of their interaction is quite complex and it is difficult, if not impossible, to strictly separate the partial effects of variation of population and that of GDP as pure scale factors on the nature and environmental quality. However, the interaction of the complex factors is likely to exert a regulating influence on population growth so that it does not violate the carrying capacity.

There is no definite law of behavior of the socio-economic system which would guarantee that carrying capacity limits are not violated by human population growth. The success of the society in regulating population growth and not violating sustainable use of resource use would depend on the extent of success in revolving the distribution problem which is attend and with growing population.

The extent of success has often been far less than the sustainability mark in countries of high population density in Afro-Asian region. If the economy can absorb the growing labour force in effective employment, it can mitigate the problem of poverty an environmental degradation. But if the population growth leads to growing unemployment than poverty will size in number of poor without income and property rights to well defined resource endowment. The availability of land per capita falls within increase in population, leading to fragmentation of land holdings leading to less productivity and dispossession of land due to cash need of families to meet basic necessities. The landless people would join landless labour and class in the rural system or migrate to urban area to join urban labour force. In other case, the poor in developing countries resorts to forest burning or forcible occupation of open access common property land and its conversion into cropland, leading to ecological balance in land use. This causes deforestation and farming on hill areas cause soil erosion and flooding.

However, even if the rural poor farmers are able to practice agriculture, they often over use the land for cultivation by unsustainable agriculture practices such as mono-cropping and shifting cultivation. Over population and poverty do not pursuit investment in land and results in its degradation and unsustainable agriculture practices in many Afro-Asian countries.

Besides, the fuel need of the poor has been met from trees or plants from forests causing deforestation.

The rural-urban migration of the poor in over populated economic system has led to unauthorized occupation and use of land. The density of population in such unauthorized settlements of urban areas is very high with inadequate access to water and almost no access to sanitation. This heads to serious problem of water population and health problem. Urban slaves with high population density and paved surface poses serious problems of an collected unabsorbed wastes. Thus, urban system forces problems of serious population due to lack of adequate water supply, sanitation and waste disposal.

Thus, population growth with growing poverty, leads to appropriation of natural resources of land, water and forest which are open access. Such resources are inevitably overused leading to either depletion or degradation.

The poor would operate outside market system and consume natural resources directly for survival by over harvesting natural resources. Thus, the growth of population with observing of the distribution problem has reduces further. The resource to mass ratio through not only rises in denominator but also fall in the value of numerator. This decline in ratio reduces carrying capacity of nature and biological limits to growth and aggregates the problem of sustainable development.

Since the population grows in and poverty adversely affects the environment, the policy should be designed to check population growth and reduce poverty.

3.5. Trade and Environment

The relationship between trade and the environment is quite complex and has been a matter of concern for economists. The concern relates to how expansion of trade impacts on the local as well as global environmental conditions. The issue has gained greater importance in the context of liberalisation of trade and shift in trade policy across the world from inward looking to an outward looking approach based on export promotion driven by the market forces. In the changing situation, the volume of trade among the countries is expected increase significantly. The increase volume of trade is likely to increase the demand for environmental goods and increase in waste and pollutants due to increase in production and consumption. Hence, the question of trade and the environment has come to occupy the fore front seat as to how the expansion of trade affects the environment. Therefore, the need to study the implication of the new world order on the environment is increasingly being felt.

Before going to the discussion on the effect of trade on environment, let us consider the basis for international trade. The basis for international trade is the existence of a price differential. Two countries can engage ina mutually beneficial trade if the price of a commodity differs in them under autarchy. The reasons for prime difference are the comparative advantage. According to Ricardo, trade between the two countries occurs due to comparative advantage. A country is said to have comparative advantage in production of a good if the relative price of that good is lower under autarchy compared to other country. A lower relative price of good 1 means a lower relative cost of producing good 1. The relative cost is the cost of producing good 1 in terms of goods 2. Thus, a country is said to have comparative advantage in good 1, if it can produce good 1 at lower relative costs. According to trade theories the causes of a difference in relative costs between two countries are (i) labour productivity and (ii) The relative availability of factor endowment.

The Ricardian model locates the source of comparative advantage in labour productivity. A country has comparative advantage in some goods because its labour is relatively more productive in that line of production compared to other country. This makes the relative cost of producing that good lower.

Given two goods, 1 and 2 which are produced with the help of a single factor labour. Hence country has a comparative advantage in good 1, if

$AL_1/AL_2 < AL^*_1/AL^*_2$

Where $AL_1$and AL_2 are the amount of labour needed to produce good 1 and good 2 in home country and AL^*_1 and AL^*_2 are the amount of labour needed to produce good 1 and good 2 in foreign country. The ratio shows that relative of cost of producing good 1 is lower in home country. Thus, if trade opens up, home country will export good 1 and import good 2.

When the trade opens up, the home country will specialize in production of good 1 and foreign country will specialize in production of good 2. The volume of trade as well as production of two goods expands and both the countries obtain higher output and higher level of welfare. Thus, both the countries gain from trade due to comparative advantage arising out of differences in labour productivity.

However, in the context of trade and the environment, this comparative advantage can be artificially created. This is particularly in the case of the North-south trade relation. Here the North refers to developed countries and the south to underdeveloped countries. The

North-south trade relations have traditionally been characterized in terms of asymmetry with the pre-industrial south exporting primary products and the North exporting industrial products. However, in the last four decades the nature of the North-South trade has changed significantly with several countries in the south having considerable degree of industrialization, industrial products now constitute a good share in the exports of south. This does not imply that the Souths have achieved true comparative advantage in industrial products. Its comparative advantage may be artificially created by the North so as to shift the polluting industry to the south with a motive to protect their environment.

The impact of trade on environment in the context of the North-south trade relations can be explained with the help of externality, market failure and the environment.

3.5.1 Externality, market failure and the environment

Sometimes there are cost associated with an economic activities that are borne by the population at large but do not appear in the calculations of the producer. Similarly, there might be benefits according to the society that the producer's fails to capture these are the cases of externality. In the presence of externality there is a divergence between private and social costs and benefits.

It is this divergence between private and social costs that provides entry point to the question of environment and allow us to analyze its relationship with international trade. The Environment is just like open access/common property resources – water, air, forests, plants, biodiversity etc.

All waster products of economic activities are dumped in the environment. The damage does cause to environment in the form of air pollution, water and destruction of plants and biological species are important costs in society as a whole has to bear.

These costs do not appear in the cost calculation of the producer (external cost) and thus remains unconvinced. This is a case of market failure which has implications of international trade.

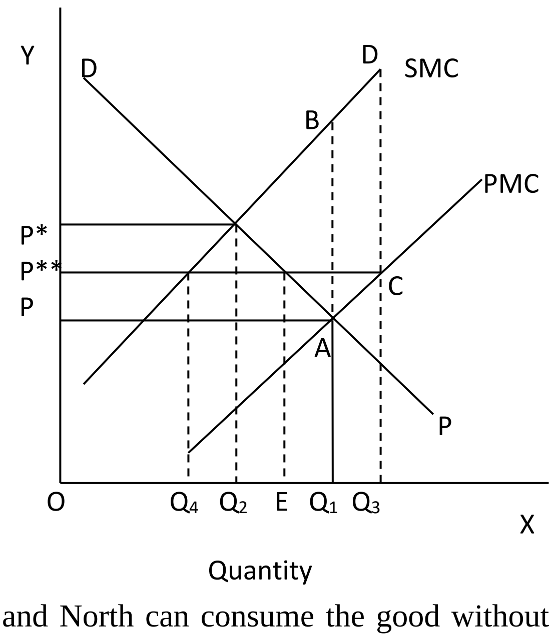
The negative impact of trade on environment might be local as well as global. Increase in economic activities due to trade may pollute and degrade the environment of a particular country or may have global impact. Population of good causes pollution, marking the social cost and marginal private cost.

We locate the difference between North and South in terms of presence or absence of environment regulations stringent regulation forces producers to set prices at level equal to social costs. But such regulations are absent in the South. This is because people in North are more aware about the ill effects of environmental degradation. The North have higher hence of income and so preference for better quality of environment fresh air, clean water and green surroundings.

Assuming the same technology in the two region autarchy prices will be different P price in South and P* price in North. Note that absence of environmental regulations result in the production of larger quantity of the polluting good in the South.

The South enjoys a comparative advantage although the advantage is at the expenses of the environment.

As trade opens ups, arbitrage begins and the South exports the goods to North. The final free trade equilibrium price settles somewhere in between the two autarchy prices and this price is P**. P**>P. This induces south to expand production up to Q_3. Thus, trade leads the South to specialize in the dirty good. The gap between social and private cast also increases as a result of trade from AB to CD. The flip side is that North produces less goods at home OQU but consumes more of them (OE instead of OQ_2) as they are cheaper in the trade situation P**<P*. Import QUE from the South. Thus, trade induces the South to expand production of the dirty goods and causes environmental damage to meet the Northern consumption needs and North can consume the good without having the damage its own environment.



The price of the North pays for the goods in the trade situation is less than its social cost of production. That is a part of the social cost that is not paid for by the North is borne by the South.

Thus, during the course of industrialization developing countries are inclined towards industrial activities that are pollution intensive in which they do not traditionally have comparative advantage. It is argued that increasing production costs of dirty goods in developed countries due to increased demand for clean environment from consumers and increased regulations, and loose regulation and less concern for environment in developing countries on the other hand, cause dirty industries to migrate from developed to developing countries. This is so called pollution haven hypothesis which argues that dirty industries flee from environmentally strict industrialized countries to less developed countries which provides pollution havens for those industries with their less environmental standards. The share of dirty industries is exported to increase while that of clean industries to decline over time in pollution heavens. Also, since, pollution havens becoming large producers of the dirty industries, the share of dirty industries is imported to increase in the exports of goods a pollution haven.

Thus, the difference in environmental regulations can serve as a basis of comparative advantage for the South and the expansion of trade based on such artificial comparative advantage can be detrimental to the environment in the South (developing countries).

3.6 Concept of Sustainable Development

Concept came into being in 1987, in view of environment degradation due to over exploitation of resources to achieve higher economic growth. So, development must take into account the interest not only of present but also of the future generation.

The concept of sustainable development concerns to fulfill the needs of the present generation without affecting the interest of the future generation. It aims at inter-generational equity.

One of the widely accepted definitions is from the report of the world commission on environment and development (WCED) in 1987.

Sustainable development is development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs. It is concerned with the welfare of the future as much as the present generation.

In essence sustainable development is a process of changes in which exploitation of resources. The direction of investments, the orientation of technological development and institutional changes are all in harmony and enhance both current and future potential to meet demand needs and aspirations. Thus, sustainable development is process of economic activities which leaves the environmental quality level intact with the policy directives corresponding to this notion being the maximization of net benefits of economic development for the present and future generation subject to maintaining the services and quality of natural resources over time.

It tries to combine efficiency with all other attributes to sustainability preserving opportunities for future generation is a common sense minimal notice of intergeneration justice. It says that the present generation does not have the right to deplete the opportunities offered by the current resource base since it does not own it.

Development = efficiency + equity

Sustainable Development = Development + proper valuation + resource stock recognition + resistance.

3.7 Indicators of sustainable Development

Sustainability refers to both ecological and economic attributes. Therefore, corresponding sustainability indictors will also have to account for both of them.

There are two types of sustainability

1. Strong sustainability and
2. Weak sustainability

The strong sustainability concept concentrates on the impact of development effort as ecology and environment. On the other hand, weak sustainability concentrates on green accounting which involves accounting of national income taking into account the ecological effect of development.

The main point of difference between the two is that former denies greater or lesser extent substitutability between natural assets and manmade assets and others.

3.7.1 Indictors of strong sustainability

The strong sustainability paradigm distortindicator that focus primarily on ecological aspects, functions and processes in them such indicators find to stress limits to the deterioration of ecological assets.

Indictors are –

1. **Carrying capacity –** The notion of carrying capacity is drawn from biology. It states that a given environment/area can sustain only a given population of a particular species and at this upper limit (carrying capacity) population would have reached

maximum sustainable level. In order to apply this concept of a saturation point to human population, we have to consider not only the level of population, but also the level of economic activities. For sustainability of the system, the carrying capacity should be extended.

2. **Resilience –** It refers to the ability of the system to absorb shocks and changes and still persist the degree of resistance of the system determines whether ecological process in largely unaffected, decrease, either temporary or permanently or in the extreme collapse all together. Because of risk and uncertainty in the production process. It was realized only recently due to development of thermodynamics theory that processes involving higher and higher levels of energy production and consumption also generates higher levels of waste.

   This is known as the entropy law in physics. Example, more electric production means more production of fly ash, SO_2 and CO_2 and NO_2 if fuel oil is the source (coal). Waste disposal is not cost free. Waste is on externality when no one wants to take the responsibility of disposing it. The biosphere has some capacity to assimilate waste however slow it may be out enhance waste assimilation requires additional investment on treatment plants on incineration plants. A measure of the degree of resistance could be interpreted as an indicator of the sustainability. For agriculture dependent system an indicator of field variability may also be relevant in measuring resistance.

3. **Distance to goal –** Under it the derivation of ambient assuming from some target are aggregated to derive an overall performance indicators.

3.7.2 Weak sustainability indicators

The weak sustainability on the other hand, emphasizes, the sustainability of manufactured and natural assets and hence focuses on aggregate measures like –

1. **Green GNP (green accounting of National Income)**

   The concept of green accounting of NNP arises from a concern that an economic indicator such as NNP doesn't reflect the depreciation and degradation of environment. This may lead to incorrect development divisibility. Green national income accounting takes into consideration the environmental and ecological loss arising out of the developmental effort while calculating the national income. Green national income is environmentally sustainable income of the economy.

A sustainable path has the characteristic that along it the overall productive capacity is not reduced, what we need to know is at each movement how much of this productive base we can use up. This is given by environmentally adjusted NNP. NNP is the total income earned by the economy less allowances for the depreciation of man-made capital.

ENP = GNP –Depreciation of man-made capital-depreciation of natural capital.

ENP is a good measure of sustainable development.

Environmentally adjusted NNP(ENP) is the annual pay-off from our total capital stock (Man-made and natural)

ENP will rise if the total capital rises or as technology improves. So the indicator of sustainable development is whether the ENP is rising or falling. The development to sustainable if the ENP is rising and vice-versa.

2. **Genuine savings**: Genuine savings is the national savings adjusted for the loss of assets to achieve sustainability. It is more promising offshoot of green accounting. For sustainability, genuine saving rate must not be persistently negative. Sustainable development requires the maintenance of total capital stock. Since the national savings are invested in physical capital, saving rate which is at least as great as the combined depreciation of natural and manmade capital help in maintaining the stock of total capital and ensure sustainable development.

3.8. Rules to sustainability

The following rules have been developed to achieve sustainability.

1. the Hartwick – Solow approach
2. Non-declining natural capital stock approach
3. The safe minimum standards approach
4. Daly’s operational principles

These rules to sustainability are discussed in details as follows:

3.8.1 The Hartwick-Solow approach

John Hartwick in 1977 proposed a rule for ensuring non-declining consumption through time in case where an economy made use of non-renewable resources like oil in its economic progress.

This rule is based on the assumption that manmade and natural capitals are perfect substitutes of each other. Further, it assumes that the aggregate production function is a Cobb-Douglas one.

Given these assumption, the rule states that as long as the stock of capital did not decline overtime, non-declining consumption was possible. According to Hartwick, the stock of capital can be held constant by reinvesting all the hotelling rents from the extraction of non-renewable resources in manmade capital. When the capital stock is held constant, then non-declining consumption is possible and such a development process is sustainable, according to Hartwick. Thus as the stock of natural capital goes down, the stock of manmade capital is built up in replacement. This result has been very important for achieving of sustainable development.

The Hartwick rule has been criticized on three points.

1. The non-declining consumption is not the same as non-declining welfare. This is because individuals derive utility directly from the environment. So, when the natural capital goes down. The utility also goes down and the people’s welfare will be lower even if the consumption remains the same.
2. The rule depends on the particular functional form chosen for the aggregate production function and does not hold good for other functional forms.
3. Natural and manmade capital are not perfect substitutes.

3.8.2 Non-declining natural capital stock approach

The deficiency in Hartwick rule is partially rectified by a rule designed by a group of economists from London School of Economics – (Pearce, Atkinton and Thorner). This rule states that many elements of National Capital K_n provide non-sustainable services to the economy. Examples of such critical natural capital are the processes responsible for regulation of atmospheric compositions the spiritual values provided by wildlife, and nutrients cycles. It is important to maintain these ecosystems in a functioning state. This rule states that the society should identify all such critical non-substitutable natural resources and must resolve to preserve them. This is commonly known as holding natural capital constant, as a concept, but as a rule to be applied for critical natural resources.

Thus, if it is necessary to maintain some amount of the natural capital stock constant in order to all future generations to reach the same level of utility as the average hold by this generation, this holding constant of the natural capital stock becomes a rule for sustainable development (SD).

This rule assumes that the value of K_n can be measured at any point of time; in other words, the different elements of K_n can be aggregated together in comparable units. In reality it is very difficult to aggregate the K_n. – Van Pelt (1993) identifies another problem with this rule. This is that the problem of spatial aggregation; within which geographic area should we hold K_n stocks and constant?

3.8.3. The safe minimum standard approach

This rule was proposed by Ciriacy-Wantrup and Bishop. It is closely linked to non-declining natural capital approach. The SMS approach originates from decision making under uncertainty. Society is deserved to be immense about the future costs of current environmental degradation.

The SMS rule is to prevent the reductions in the natural capital stock below the safe minimum standard identified for each component of this stock. Unless the social opportunity costs of saving so are unacceptably large. But it is a matter of moral and social obligation to define such standards.

The problem with this approach is how to identify these SMS levels. Another problem is with measuring of opportunity cost of conservation. It does not consider the economic benefits of conservation;

3.8.4 Daly's Operational Principles

Daly in 1990 developed operational principles for SD. He argued that a nation could move towards a SD position if these principles were followed. These principles are –

1. Renewable resources (like fish, forests) should be harvested at levels at less than or equal to the population size.

2. Pollution – For degradable establish assimilative capacities for receiving ecosystems and maintain waste discharges below this level. Daly proposes no rule for cumulative pollutants, but the implicit – is that their discharge should be set to zero.
3. Non – renewable resources –Receipts from non-renewable extraction should be divided into an income stream and an investment stream, the investment stream should be invested in renewable substitutes (For ex-biomass for oil) such that, by the time period when the non-renewable resources reaches the end of its economic extraction, an identical level of consumption is available from the renewable substitute.
4. Daly believes that it is vital to minimize throughout in the economy. This is a question levels and resources use.

3.9. Concept of Green Accounting

The Net National Product (NNP) is still the best welfare measure under standard national income accounting. But the present system of national accounting i.e. NNP fails as a measure of sustainable development as it does not take into account the use an abuse of natural resources. While considering the allowances for consumption of capital in calculating NNP, it gives consideration only to depreciation of men-made capital and ignores depreciation of natural resources – non-renewable, renewable resources, pollution etc.

The present SNA suffers from certain deficiencies. These are:

i. The SNA takes note of only such production and consumption processes where there is market price.
ii. It does not impute the values of environmental goods and services used in production process and
iii. It also does not consider any allowance for depreciation/degradation or depletion of natural resources.

The Green accounting of income is an attempt or method to correct the present measure of NNP for use and above of natural and ecological resources to arrive at sustainable income which can be a measure or indicator of sustainable development.

The improvement in the methods of SNA were debated in the 1992 United Nations conference on Environment and development (UNCED) held at Rio de Jenerio, which recommended all nations to develop a system of Integrated Environmental and Economic. Accounting (IEEA)- which came to be known as Green accounting.

The main objective of IEEA is to expand existing system of national economic accounts in order to integrate environment and social dimensions in the accounting framework. Alternatively, at least satellite systems of accounts for natural resources be developed to arrive at what is currently being coined as 'Green GNP.'

In practice, it is difficult to develop an accounting for natural resources.

Parikh and Parikh (1997) elaborated on the system of Environment and Economic accounting as developed by the United Nations and provided a definition of Green NNP as –

Green NNP = Value of consumption of natural goods and services + value of production of natural collected (such as fuelwood, biogas) + value of environmental amenities provided by environmental resources stocks (such as clean air, top soil) + value of leisure enjoyed (Say in enjoying aesthetic beauty of wildlife revenue) + value of net additions to production of capital + value of net addition to natural capital stock + value of addition to stocks of defensive capital (such) as water purifier).

Thus, NNP is the total income earned by the economy in any year, less an allowance for the depreciation of manmade capital.

Green NNP or environmentally adjusted NNP is a good measure of sustainable development as it induces – (i) all elements of NNP correctly valued in terms of current economic situation; (ii) when this is true in a forward looking sense too (prices reflect future scarcity) and (iii) when all depreciation of natural capital is similarly allowed for as well.

Thus, Green NNP is the annual pay-off from our total capital stock (manmade + natural). ENP can rise over time if this total capital stock rises and /or as technology improves. According, Hartwick rule, the total stock of capital can be maintained by reinvesting hotelling rents (price-MC) from optimal non-renewable resourcesinfraction planning new natural or manmade capita. So, the indictor of sustainability is non-declining ENP, or whether ENP is rising or falling. It ENP is falling, and then society's sustainable level of income is falling too. Development is unsustainable.

3.10 Let us Sum Up

This unit discussed about the relationship between the environment and development in the light of Kuznets curve hypothesis which argued that there is an inverted U-shaped relationship between the two. It also analysed and discussed how the expansion of trade can affect the environment, particularly of developing countries. Sustainable development has come to occupy an important place in literature and policy making process. The unit also discussed the concept and indicators of sustainable development and rules to sustainability. Finally, it also examined the measure of sustainable income i.e. green accounting.

3.11. Key terms

Environmental goods: These are those goods which are provided to the economy by the environment. They are non-excludable but rival in nature.

Environmental degradation: It refers to the deterioration in the quality of environmental amenities such as air, water, land etc. due to human activities.

Biosphere: It is the layer of the earth where life exists.

Carrying capacity: It is the capacity of a given environment to support the maximum number of population of a given species.

Sustainability: It is the ability of a system to maintain the resources and avoid depletion of natural resources in order to maintain ecological balance.

3.12. Questions

1. Analyse the relationship between the environment and development.
2. How does trade affect the environment? Discuss.
3. Explain the linkages between population poverty and environment.
4. What is sustainable development? What are its indicators?
5. Discuss the various rules to sustainability
6. Explain the concept of green accounting.

3.13 Further/Suggested Readings

Bhattacharya, R. N., *Environmental Economic: An Indian Perspective*, Oxford.

Hanley, N, J. Shogren and Ben White; *Environmental Economics: In Theory and Practice*, Macmillan Publication.

Unit IV
POPULATION GROWTH AND FERTILITY

Structure

4.0 Introduction

Population growth is often said to be one of the main factors behind India's backwardness. India is clearly one of the most densely populated countries in the world. India's population has trebled since independence. It seems to be heading towards 1.5 billion by the middle of the twenty-first century. For any student of demography, it is important to have a clear understanding of the size and growth of India's population, the reasons for the changes in growth rates of population and the factors determines its growth.

4.1 Objectives

After going through the chapter you should be in a position to answer the following questions:

- What has been the trend in population growth of India?
- What are the difference between Rates and Ratios.
- What are the various sources of data in Demography?
- Understanding the factors determining the fertility rate of a country. What are the reasons underlying the continuing high fertility rate in few States of India?
- Describe the economic theory of fertility as formulated by Garry S. Becker.
- Show how economic and non-economic factors are combined together to explain fertility behaviour by Richard Easterlin.

4.2 Trends of population growth since the beginning of 20th Century

The population of India is the second largest in the world next only to China. About 17 per cent of the world's population reside in India, where as it accounts for only 2.42 per cent of the total world area. If availability of demographic data is an indicator of development, then India is above many underdeveloped countries of the world where paucity of demographic data still poses a serious concern for systematic demographic analysis. The size of population of India presents a history of erratic growth. It was from 1881 onwards that Census was conducted every ten years in the country. Data from 1901 onwards are considered to be more reliable. The size of Indian population decreased between 300 B.C. and 1600 A.D and similar decreases could be seen during the decades of 1871-1881, 1891-1901 and 1911-1921. The decline of population during the interval 1911-1921 is mainly attributed to the influenza epidemic of 1918 in which according to one estimate more than 15 million persons were killed.

According to the 2011 Census, India's population of 1210 million shows 17.6 percent decennial growth between 2001-2011 resulting in absolute increase in population of 183 million over the 2001 census population. The total population consists of 623.7 million males and 586.5 million females indicating a sex ratio of 940 according to the 2011 census. Though, there has been a marginal decline in growth rate of population from 1.93 per cent during

1991-2001 to 1.51 per cent during the decade 2001-2011, yet the growth rate of population continues to be quite high in comparison to other countries of Europe and North America. The high rate of population growth in India with its large size of population has some advantages as well as disadvantage from the economic and social point of view. At the macro level it provides a large and growing labour force as well as a large market for goods and services. On the other hand, in an agrarian country with low savings and low capital formation, investment generation poses serious problems.

The population growth of India can be subdivided into four distinct periods. The first twenty years of the century from 1901 to 1921 witnessed a net addition of only 5.4 per cent, or 12.9 million persons to India's population, the next thirty years from 1921 to 1951 saw an increase of 43.7 per cent or an addition of 110 million people. It was from 1951- 1981 that India experienced an explosive population growth of 189.2 per cent or an addition of 322.2 million persons. The last three decades from 1981 to 2011 witnessed a high growth of population with some sign of slowing down. During this period the population increased by 526.7 millions.

Table: 1
Population of India: 1901-2011

Year	Population (million)	Decadal Growth rate %	Average Annual Exponential Growth Rate %	Density Sq. km.	Sex Ratio
1901	238.4	-	-	77	972
1911	252.1	5.75	0.56	82	964
1921	251.3	-0.31	-0.03	81	955
1931	279.0	11.00	1.04	90	950
1941	318.7	14.22	1.33	103	945
1951	361.1	13.31	1.25	117	946
1961	439.2	21.64	1.96	142	941
1971	548.2	24.80	2.20	177	930
1981	683.3	24.66	2.22	216	934
1991	846.3	23.85	2.14	267	927
2001	1027	21.34	1.93	324	933
2011	1210	17.6	1.51	382	940

Source: *Census of India various years*

Prior to 1921, population growth in India was sporadic and more or less stationary. Both birth rate and death rate were high during that period. The year of 1921, also known as the year of 'Great Divide', marks the difference in the growth pattern of population in India. The period between 1921-1951 saw rapid population growth, which was mainly because of decline in mortality and a large base population with little impact of family planning programmes, while the decade of 1951-1961 saw an explosive population growth, where 78 million persons were added to the Indian population. Between 1961-1971 about 109 million persons were added, while the next decade from 1971-1981 saw an addition of 135 million persons. Further, between 1981-1991 there was a net addition of 160 million persons and the last decade of the century from 1991-2001 saw an increase of 184 million persons. While in the latest decade from 2001-2011 it increased by 183 million persons. The significant point of the last decade was that India has entered a phase of Demographic transition characterized by declining fertility in some States and the increase in population has been primarily on account of a significant reduction in the death rate.

4.3 Basic measures and concepts in Demography

Demography is a branch of Social Science which studies population. Demography tries to cover different aspects in such a way that parts of this discipline belong to a number of subjects. There are economic demography, mathematical demography and statistical demography. Sociology and Anthropology also study demographic variables. It is an empirical science, it uses standard statistics in its empirical investigation. There are certain basic concepts of demography which are as follows:

4.3.1 Population or Universe

Any statistical investigation is concerned with one or more characteristics of a set of individuals or objects. This group of objects may be animate or inanimate, real or hypothetical, finite or infinite and is known as population or universe in a statistical sense. In short, population or universe is the totality of objects being investigated.

4.3.2 Sample

Most often the size of the population or universe is such that the entire things cannot be studied. Sometimes, the units of the population have the same characteristics. For example, a factory wants to test the glass plates manufactured by it. Since all glass plate have the same fragility, the factory can test only one glass plate. On the other extreme, when there is a huge variation in different units of the population, sample size must be large. In statistics, any representative part of a population or universe is called a sample.

4.3.3 Variable

In the study of demography, it is assumed that some underlying, unobservable process is occurring and this underlying process can be better understood by studying the characteristics of the population. Generally, the value representing a characteristic of a population may vary from individual to individual and over time and space. This type of characteristics is called a variable. For example, age of individuals in a population varies from individual to individual and is called a variable. There are two types of variables – discrete and continuous.

4.3.4 Scale of Measurement

All variables cannot be measured by the same scale. The nature of the scale to be used depends on the nature of the variable. Some variables can be measured by only values. Nominal scales others require the use of ordinal scales or class interval.

Nominal Scales **(NS)** – In the nominal scale the variables assume only a limited set of values without any hierarchical relationship with each other. For e.g. the variables like religion and sex of the individual comes under this category.

Ordinal Variables – These are positional values having cardinal effects. Variables which can be represented in an order of ascending or descending scale belong to the category of ordinal variables. For e.g. the socio-economic status which is normally represented by high, medium and low falls under this category.

Class Intervals – Variables whose values can be represented as falling within specified class intervals comprise the category of interval scales. For e.g. income and age are such types of variables. These values can be represented by cardinal numbers such as 1, 2, 3, or by fractions.

The main aim of demographic analysis is generally to identify and quantify as precisely as possible the various demographic phenomena through a variety of measures and indicators with a view to use them for making comparisons between populations and in a given population over time.

Measure: A Measure is a definitive quantitative value of the phenomenon being studied.
Indicator: An indicator is a proxy or an approximation to a measure. For example, while income is a measure of the economic status of an individual, the type of house he/she lives is an indicator of his/her income.

4.3.5 Ratios

A Ratio is the result of dividing the size of one of the two non-overlapping groups possessing some common characteristics by one or the other. An example is the number of males in a population divided by the number of females which is called sex ratio. A ratio is a helpful index in comparing the relative strength of each group in populations at different times and territories.

A ratio is a comparison between two variables or characteristics that belong to two different categories. That is, the objects being compared are disjointed. If in a class of 50 students, 20 have taken Biology and 30 have taken mathematics, the ratio between Biology - and mathematics taking students is 20: 30 or 2: 3. A very common example from demography is sex or gender ratio. This is the number of females per 1000 males. The gender ratio in Arunachal Pradesh is 938 and in India it is 940.

4.3.6 Proportions

A proportion is a relative number that expresses the size of one subgroup to the total of all subgroups which is equated to 1. When the sizes of all subgroups are expressed as percentages, the result is called a percentage distribution. In other words, a proportion is a special type of ratio in which the numerator is included in the denominator. If the characteristic under consideration is age, the distribution of persons at each age is called the 'age distribution' or the age composition of the population.

4.3.7 Rates

The most commonly used demographic measures are Rates. They express the number of events, say E, that occur in a population of size P in a given period of time, which is usually a year, as a fraction E/P. In a rate the numerator and denominator belong to the same categories: Their unit of measurement is the same that is dimensionally they are same. For example, in Crude Birth rate (CBR) which is defined as B/P x 1000, B is the number of live births in a year and P is the average population of that year.
Rate is a measure of the speed of occurrence of events in the population. Thus, the concept of rates is associated with dynamic phenomena such as growth, birth and death. A rate refers to the occurrence of events over a given interval of time. In demographic application, rates are normally considered as indicators of what is known in statistical parlance as 'occurrence/exposure', measures where the numerator is the number of events that have occurred in a population and the denominator is the duration of exposure of the population to such events. They contain a count of the number of events occurring within some defined time period in the numerator, and in the denominator, an estimate of the population during the middle of that time period.

4.4 Basic Demographic Equation:

The most basic equation that expresses the change in population over time in a single form is known as the Basic Demographic Equation or balancing equation. It is the decomposition of the population change into its component. It is expressed as follows:

$$P_2 = P_1 + B - D + I - E$$

Where, P_1 and P_2= Population at two different points of time; B = Number of Birth; D = Number of Death; I = Immigrants; E = Emigrants during the period.

$P_2 = P_1 + NI + NM$

Where, NI = Natural increase (B – D); NM = Net Migration (I – E)

4.5 Demographic Data Sources

The system of demographic data collection is the mechanism whereby information on some of the basic characteristics of the population such as its age, sex, marital structure and the various events that contribute to changes in this structure such as births, deaths, marriages, migration and other related topics is compiled and tabulated.

Demographic data can be categorized into two types: *Stock Data* and *Flow Data*.They are also called stock and flow. A stock is defined at a point in time, while a flow is defined over a period: at a point in time a flow is stock.

So, ***stock data*** denote the information pertaining to the situation of a population at a given point of time; these may be sex-distribution, marital structure, occupational structure, etc. It is a snap shot of the population at that point of time.
A ***flow data*** set pertains to events that occur over time. Example- deaths, births and migration. Deaths and out-migration reduce the size of population over time, while births and in-migration tend to expand the size of a population.

The most important sources of demographic data are Censuses, Vital Statistics and Sample Survey.

The most important and widely used demographic stock data at the national and sub-national level are from the population census.

The vital registration system or the system of compulsory registration of births, deaths and marriages is the major source of flow data.

An important source of demographic data that provide information on both the stock and the flow variables is the *sample surveys*. The analysts conduct a sample survey when they require detailed information on specific topics and the information available from the censuses and vital registration is not adequate in coverage and quality.

The fourth source of demographic information is the various administrative records and the service statistics, where data are compiled routinely -example, airport authorities on immigration and emigration.

4.6 Censuses: Definition given by the United Nations handbook of the Census (1958)

The Census is the total process of collecting, compiling and publishing of demographic, economic and social data pertaining to a specified time or times of all persons in a country or delimited territory. The Census refers to the population at a particular point of time.

In the Indian Census of 2011, this point of is the sunrise of 1^{st} March 2011. This is called the Census reference date and time. The tools used are the Questionnaires, enumerator and respondents.

Primary unit census enumeration includes two levels of data: individual and family. At the individual level information relating to name, age, sex, relationship with the head of the family, marital status, occupation and migration and at the family level housing conditions, amenities are collected. General questions, employment status – full time or part time, nature of work etc. are also collected.

4.7 Vital Statistics

Vital registration is a system for the registration of the demographic events occurring in a population – births, deaths and marriages, and is the basic source of information on population dynamics.

4.8 Basic Measures of Fertility

The three major demographic events which effect the population size of an area are births, deaths and migration.

Fertility refers to actual reproductive performance of a woman or the number of children a woman has or the average number of children for a group of women. Sometimes we also use the term Natality. Fertility is possible only when a woman attains menarche (adulthood) and ends with her menopause.

The term Fecundity is used to connote the physiological capacity to bear children and is the opposite of the term sterility. No direct measurement of fecundity is possible, whereas fertility is the actual performance in reproduction - measurable empirically.

4.9 Types of Analysis: Period and Cohort measures

The analysis of fertility is basically carried out in two ways - one is in a period perspective and the other in a cohort perspective.

In the period perspective, the events that occur in a given period of time, a year or a month are studied in relation to the durations of exposure of the population during that period. The period measures can look at fertility rates in a cross-sectional way, to get a comparative picture during the reference year or years.

In cohort perspective the events and duration of exposure are studied for well-defined cohorts as they move over time. The term ‘cohort’ indicates a group of people who have a similar experience at the same time.

Two types of cohorts are generally used in demography – birth cohorts i.e. those born in the same year or period and marriage cohort, those who are married in the same year or period. The fertility measures considered in a longitudinal way are called cohort measures.

4.10 Child-Women Ratio (CWR)

This is one of the simplest measures generally used in the fertility analysis and is defined as –

$$CWR = \frac{{}_{5}P_{0}}{{}_{35}W_{15}} \quad X \quad 1000$$

${}_{5}P_{0}$ = Number of children under 5 years of age in a particular time.

${}_{35}W_{15}$ = Number of women in the age group 15-49 (Reproductive span) in a particular time.

The subscript 15 on the right of W indicates the beginning of the age interval and the subscript 35 on the left of W indicates the duration of the interval beginning at age 15.The denominator may sometimes be 15-44. Basically, it is a crude measure and if fertility is high the ratio will be high and if fertility is low the ratio will be low.

4.11 Crude Birth Rate (CBR)

This is the most widely used measure of period fertility. It is defined as –

$$\text{CBR} = \frac{\text{Number of births during a year}}{\text{Population at mid} - \text{year}} \text{ X } 1000$$

This measure is the simplest and most available of all measures of fertility. This is the common measure of fertility, and it is simple in concept and measurement. The rate is called crude because it includes all ages and both sexes in the denominator.

4.12 General Fertility Rate (GFR)

The CBR uses the entire population in the denominator. A more meaningful measure is to use only women of the reproductive age group in the denominator.

$$\text{GFR} = \frac{\text{Number of births during a year}}{\text{Mid} - \text{year female population aged } 15 - 49} \text{ X } 1000$$

4.13 Age-specific Fertility Rates (ASFR)

The denominator of general fertility rate (GFR) uses all women in the reproductive ages and in the age- specific fertility rate (ASFR) both the numerator and the denominator pertain to births and number of women in a specific age or age group.

$$\text{ASFR at age X} \quad = \frac{\text{Births to women aged X in a year}}{\text{Mid} - \text{year female population aged X}} \text{ X } 1000$$

OR

$$\text{ASFR (in age group X, X + n)} = \frac{\text{Births to women aged X to (X + n) in a year}}{\text{Mid} - \text{year female population aged X to(X + n) in a year}} \text{ X } 1000$$

Generally, five-year age groups of women are used in calculating the rate. For e.g. 15-19, 20-24, 25-29, 30-34……….45-49.

4.14 Total Fertility Rate (TFR)

The Sum of the ASFRs over different ages 15 to 49 or 15-44 is known as total fertility rate. Thus,

TFR = Sum of ASFRs

It is the most widely used measure of fertility by demographers. The TFR is generally expressed as number per women. This measure can be thought of as the number of children a woman would have if she survived to age 50 and throughout her reproductive life span if she is subjected to a fertility schedule. The importance of TFR is that it is a single figure and is independent of age structure.

4.15 Gross Reproductive Rate (GRR)

Gross reproductive rate (GRR) is another summary measure of period fertility rate. This rate is essentially a TFR, with the modification that it is computed only for female births. Thus, GRR is the average number of daughters that would be born to a woman during her lifetime if she passed through the childbearing ages experiencing the average age-specific fertility pattern of a given period.

$$GRR = TFR \text{ X } (1/1+S)$$

Where, S = Sex ratio (We assume sex ratio at birth as 1.05)

4.16 Net Reproductive Rate (NRR)

The Net Reproductive Rate (NRR) is the rate at which the female population replaces itself. It is an index for the self-replacement potentiality of a population with given age-specific rates of fertility and mortality. It means that if we want to calculate the rate of population growth, we must ask, "what is the total number of daughters that would have been born to 1000 new born girl babies by the time the latter have all completed their life span". For example, if the total number of girls being born to 1000 women in child-bearing age (15-45 or 50 years) is 1000, then the NRR will be 1. This shows that the present generation of females would, on death have been fully replaced by the new born babies (girls) and the population will be constant. If only 800 (Girts) babies are born to such 100 women of child -bearing age, the NRR will be 0.8 and if in the long run, it continues, the population will definitely decrease. Thus, the rate at which the female population is replacing itself is the net reproduction rate. It indicates how rapidly the population would ultimately grow, if the risks of death and the fertility of each group remained unchanged and there were no migrations.

$$\text{Female net reproduction rate} = \frac{\text{Number of female children expected to be born to 1000}}{1000}$$

OR

$$NRR = \frac{\sum B_f \text{ x } S}{1000}$$

$\sum B_f$ =Total number of female birth expected to 1000 newly born female children

S = Survival rate

However, even the net reproduction rate as a measure of replacement of population cannot be much relied upon because of the following two reasons.

1. The population of the country may become depleted more by migration than by falling birth rate or the country may receive fresh stock of immigrants who might be more virile.
2. It assumes constant rates of fertility and mortality over a generation. In actual life both these rates go on changing.

4.17 Economic Theories of fertility:

Becker's Theory

There are several economic theories to explain how decisions on the number of children are made by couples. Economic theories of fertility are based on the assumption that decisions regarding family size are influenced mainly by economic considerations, and therefore these theories are built within the micro-economic framework.

In 1960 Becker in his famous article on 'An Economic Analysis of Fertility', put forward his economic theory of fertility. Becker applied the micro consumption theory of fertility. His theory was based on the argument that fertility behavior is the result of household choice.

In the economic theory of household behaviour, the choice of durable goods by a consumer with a given taste is considered to be made after a careful evaluation of the utility derived from the concerned goods and the costs to be incurred as well as his income.

Becker considered children to be the same as thecommodities consumed in the household and argued that the household choice of fertility is made in the same manner as in the case of the purchase of durable goods. A couple's decision to have an additional child according to Becker's point of view depends on the balance of its preference, the constraints of its income and the costs of the child.

Becker's argument rested on two assumptions: (1) the representative households behaves rationally on the basis of unchanging tastes, and (2) the prices of commodities desired by the representative household are unaffected by that household's consumption decisions.

According to Becker if knowledge of birth control methodsis widespread, and the price of children, the cost of child bearing and rearing remain unchanged, fertility would be directly related to the income of the parents. Becker attributed the inverse relationship between income and fertility to the rise in price of children because of rising time cost of child rearing and differential knowledge of birth control in various income groups. According to him, once such knowledge is evenly spread, a positive association would emerge between income and fertility.

Becker's theory was not free of criticism. Richard Easterlin, challenged Becker's theory and raised thepoint that tastes cannot be taken as immutable facts and insisted that tastes change systematically according to one's upbringing. He introduced the sociological concept of socialization into economic theory. According to Judith Blake, Becker ignored the sociological determinants of reproductive behaviour.

Richard Easterlin's Theory

Richard Easterlin challenged Becker's theory in 1966 and since then two rival schools of the economics of fertility have emerged. One headed by Gary Becker and the other by Richard Easterlin, who raised the point that tastes cannot be taken as immutable facts and insisted that tastes change systematically according to one's upbringing. He thus introduced the concept of socialization into economic theory. He however accepted Becker's second assumption that the prices of commodities desired by a representative household are unaffected by the household's consumption decisions.

According to Easterlin, a comprehensive economic framework incorporating the main concepts of demography, sociology and other sciences would be useful to analyses human fertility behavior in a systematic manner. Such a framework, it was thought should be relevant to present and past fertility behaviour in a large number of societies and it should also deal with the trends, fluctuations and differentials observed in fertility during the course of human history.

Easterlin proposed a framework in which an attempt has been made to combine sociology and Economics of human fertility. As parents are more concerned about the number of grown-up living children rather than the number of births, the principal dependent variables in Easterlin's theory is the total number of surviving children. It is also assumed that both spouses would live throughout the reproductive span of wife.

The determinants of fertility are as follows:

1. **The Demand for Children (Cd)**: The demand for children (Cd) is the number of surviving children the parents would want if fertility regulation were costless. The demand for children is ascertained by obtaining the information on the number of children desired by the couple. In keeping with the economic theory of the household choice, the immediate determinants of demand for children are income, price and taste.

   Thus, the factor demand for children deals with the individual choice about the number of surviving children and the social, economic and environmental factors or conditions that influence the choice.

2. **Potential output of children (Cn): Supply of children:** The production of children or child bearing in any society is a biological function shaped by various cultural practices. The number of surviving children a household would have if fertility is not deliberately controlled, is the potential output of children (Cn). The potential output of children is a product of a couple's natural fertility (N) and the survival rate i.e. probability of a new-born baby surviving upto adulthood. Natural fertility is determined by biological and cultural factors. Increase in couple's natural fertility and improvement in the chances of child survival would increase the potential supply of children.

Motivation for fertility regulation = Cn – Cd

The demand for surviving children and the supply of children together determine the motivation of fertility regulation.

If the potential output is smaller than demand i.e. Cn is less than Cd (Cn < Cd), there is no desire to limit fertility. Such a situation of ‘excess demand’ would call for way and means to increase fertility.

If the potential output of surviving children is larger than the demand for surviving children i.e. Cn is greater than cd 9 Cn > cd, this could be considered as a situation of ‘excess supply’.

In an ‘excess supply’ situation parents would be faced with the prospect of having unwanted children. If this excess is larger, the potential burden of unwanted children would be greater and hence as a consequence the households motivation to limit its family size is also greater.

3. **The costs of fertility regulation:** The adoption of means of regulating fertility depends upon cost of fertility, regulation, which includes subjective costs and objective costs such as money required to learn about and use a specific method. Motivation, attitude and access are the three important factors influencing adoption of fertility control.

It can be seen that in pre-modern society, demand (Cd) is greater than supply (Cn) and actual family size corresponds to supply. As Socio economic development advances an excess supply condition emerges which generates motivation for fertility control. In the beginning this motivation is low and does not offset regulation costs sufficiently to result in deliberate fertility control – hence actual family size continues to corresponds to supply. As socio-economic development progresses with motivation growing and fertility regulation costs going down, at some point deliberate restriction sets in. Eventually family size falls to a level where Cn is equal to Cd.

4.18 Key words:

Demography, Universe, Variable, Census, Vital Statistics, Crude Birth Rate, Total Fertility Rate, General Fertility Rate, Child Women Ratio, Gross and Net Reproduction Rate

Unit V
MORTALITY

Structure

5.0. Introduction

Mortality analysis is one of the most important branches of demographic studies and is the one with which demographers have been engaged from the very beginning of any systematic study of human populations. This branch deals with the demographic event of death. Measurement of mortality received much attention from actuaries during the 18th and 19th centuries. Thus, the techniques for analyzingmortality have a longer history and are more developed than those for analyzing fertility. Since death is a biological phenomenon that occurs just once to each individual, the analysis is simpler than, say, the study of fertility wherein the event of birth can occur with varying frequency among women. In this section we discuss the basic measures generally used in demographic analysis.

Mortality analysis is concerned with the study of the 'risk of dying' as it varies from one population to another and within a population from one subgroup to another. The study of mortality is of vital interest to researchers and planners involved in the public health programmes, to governmental and other agencies who are concerned with taking policy decision in relation to the levels and variations of mortality, to life insurance companies which study mortality to fix the premium and to medical professionals who need to understand the prevailing patterns of various causes of death with their varying importance. It is an instrument in the hands of demographers to measure the growth potential of a population to look into the probable changes in population composition, to assist in the study of demographic variables and to make population projections.

5.1. Learning Objectives

After going through the chapter, you should be in a position to answer the following questions:

What are the various measures of Mortality?

What is age specific mortality Rate? Show the relationship between age and mortality rate.

What is a Life table? Discuss the uses of Life table?

Derive the probability of dying from the age specific death rate in case of both abridged and complete Life tables?

Discuss the trends of mortality in developed and developing countries.

Distinguish between exogenous and endogenous factors determining the mortality in childhood.

5.2. Measures of Mortality

5.2.1 Crude Death Rate (CDR)

Crude Death rate is a simple and direct measure of occurrences of deaths in a population. This rate relates to the number of deaths during a year to the mid-year population of that year. The rate is expressed normally per thousand of population. It is a measure of totality, describing the total frequency of deaths occurring in a population during a specified period, which is normally taken to be a year. So,

$$\text{Crude Death Rate (CDR)} = \frac{\text{Deaths in a year}}{\text{population at mid year}} X\ 1000$$

The denominator in this case uses the total population with varying risks to death and hence CDR does not measure the risk of dying for a person in the population in the probabilistic sense. This measure is generally a poor indicator of mortality as it does not take age structure of the population into account. The number of deaths is a function of the size of the population, its age-sex structure and its overall health condition. The risk of dying, generally high in the infancy and childhood, declines drastically thereafter up to age 20 and then rises slowly but steadily increasing sharply at ages above 50. This type of curve, known as the reverse J-shaped curve is characteristic of age patterns of mortality in all populations. Many developing countries with high fertility show a lower CDR than developed countries because the former have a much larger proportion of their population at younger ages, while the latter have an old population. A crucial factor in the study of mortality is to take account of its variations by age.

5.2.2 Age-Specific Death Rates (ASDRs)

As the relative frequency of deaths varies with age, a better comparison can be made in terms of the death rates calculated separately for each age. It can separate the component of mortality from the inherent effect of age composition on the number of deaths and its ratio to the population.

The CDR is the weighted average of the age-specific rates, the weights being the population size at each age. The death rates may vary not only by age but differently for the two sexes. The age-specific rates (ASDR) for males and females separately, are the commonly used specific rates. The ASDR (${}_nM_x$) for the age group x to x + n is defined as:

$$ {}_nM_x = \frac{{}_nD_x}{{}_nP_x} \times 1000 $$

Where ,

${}_nD_x$= number of deaths between x and x + n in the year

${}_nP_x$= mid-year population aged between x and x + n

The curve of ASDRs is usually U-shaped in less developed countries with poor health status, the two sides of the ‘U’ representing the high mortality at infancy and old-age. The observation of the countries where mortality declined in the past is that the risk of mortality decreases first at the infancy and childhood, where it was previously extremely high and produces a nearly J-shaped curve. The base of 'U' also widens as the lowered mortality becomes a trait of increased life expectancy. Further in the developed countries with low mortality, ASDRs for females are generally found to be lower at all ages than for males. In underdeveloped countries, however there arise various typical differences in the ASDRs for the two sexes. One such typical pattern is of higher female mortality than that of males at infant and reproductive ages and the opposite trend is to be seen for other ages. The case of India confirms such a pattern of sex-differentials in mortality.

5.2.3 Infant Mortality Rate

Infant and child mortality rates reflect a country's level of socio-economic development and quality of life and are used for monitoring and evaluating population and health programmes and policies.

The segment of the population at greater risk of dying are the new borns, the early neonatal stage carrying the highest probability of dying. Once infancy is passed, the risk of dying declines first slowly and then rapidly after a year. Infant mortality Rate (IMR) is defined as the number of deaths under age one during a specified period divided by the number of live births in the same period and is usually expressed per thousand live births. Thus, the infant mortality rate is a measure of health status in the initial stage of life.

$$\text{IMR} = \frac{\text{Number of infant deaths under 1 age during a year}}{\text{Number of live births in the same year}} X\ 1000$$

The measure is not a proper rate but a ratio, as the denominator is not the population at risk of the events in the numerator. Some of the deaths under age 1 in the given year may be among the births which occurred during the previous year and some of the newborns during the year may die in the next year before reaching the first birthday. Also, the risk of dying during the first years of life is not uniform in the interval. The risk is maximum soon after birth and decreases slowly. During the early weeks, the causes of infant deaths tend to be different from those which occur later.

5.2.4 Early Neonatal Mortality

Infant Mortality Rate is often broken down into three parts, by dividing the first years of life into periods based on the intensity of risk of mortality. The first one week of life is found to have high risk and the number of infant deaths within one week of birth is termed as **early neonatal mortality**.

5.2.5 Neonatal Mortality

Further, the first four weeks or one month is also found to have a very high risk and the number of infant deaths during this period is termed as **Neonatal Mortality**. The Neonatal Mortality Rate (NMR) is defined as,

$$\text{Neonatal Mortality Rate (NMR)} = \frac{\text{Deaths of babies less than 4 weeks old (neonatal infants)}}{\text{number of live births during the same year}} \text{X1000}$$

5.2.6 Post Neonatal Mortality

The deaths of infants after four weeks but before the first birthday are termed as **Post-Neonatal Mortality (PNMR).** The rate (PNMR) is defined as:

$$\text{PNMR} = \frac{\text{deaths of babies ages } 4 - 52 \text{ weeks during a year}}{\text{number of live births during the same year}} \text{X1000}$$

5.2.7 Child mortality rate ($_4q_1$)is the probability of dying between the first and fifth birthday or deaths of children aged 1 to 4

Under-five mortality rate is the total number of deaths aged less than five divided by the total child population that is those aged less than five. This rate is usually experienced per thousand.

For both social and biological reasons infant and child mortality rates often exhibit a U-shaped pattern with respect to the mother's age at childbirth, with children of the younger and older mothers experiencing higher mortality rates than children whose mothers are in their prime reproductive ages. Children born to young mothers are more likely to be of low birth weight, which is probably an important factor contributing to their higher neonatal mortality rate. Similarly, children born to mothers above age 30 are at a relatively high risk of experiencing congenital problems. The expected U-shaped pattern of mortality by mother's age is observed for all indicators of infant and child mortality in India. Birth order also tends to have a U-shaped relationship to deaths of infants, with first births and high order births having elevated mortality rates. Antenatal, delivery and post-natal care is usually associated with lower child mortality.

5.2.8 Maternal mortality

Estimates say that 100,000 women in India die every year from causes related to pregnancy and child birth. These findings reinforce the urgency of ensuring that all pregnant women should receive adequate antenatal care during pregnancy and that deliveries should take place under hygienic conditions with assistance of trained medical practitioners.

5.2.9 Maternal Mortality ratio (MMR) is a widely used type of cause-specific mortality rate representing approximately the risk of dying as a result of complications of pregnancyand puerperium. This ratio is generally defined as the number of deaths due to puerperal causes per 100,000 live births

$$MMR = \frac{D_P}{B} \times 100,000$$

D_P = Number of deaths during a year due to puerperal causes (deaths that occur to mothers because of complicacy of pregnancy or delivery related problems.

B = Total number of live births in the same year.

5.2.10 Maternal Mortality Rates

Maternal mortality rate represents the risk of dying as a result of complications of pregnancy, and puerperium. This ratio is generally defined as the number of deaths due to puerperal causes per 100,000 married women aged 15-49. If the denominator uses the number of married women, then the measure is called Maternal Mortality Rate.

$$\text{Maternal Mortality Rate} = \frac{D_P}{\text{Number of married women aged 15-49}} \times 100{,}000$$

Thus, maternal mortality rate is defined per 100,000 married women and Maternal mortality ratio is defined per 100,000 live births.

5.3. Life Table

The statistical model which combines the mortality rates of a population at different ages into a single set-up is called a life table. Life table are principally used to estimate the level of mortality of a population at different ages. In actuarial science and demography, a life table which is also called a mortality table or actuarial table is a table which shows for each age, the probability that a person of that age will die before his or her next birthday. In other words, it represents the survivorship of people from a certain population. It was first developed by John Graunt in 1663. However, Halley in 1693 was the first to develop a life table which contained most of the columns of present day life table.

Uses

1. Life tables are principally used to estimate the level of mortality of a population at different ages.
2. The Life table is a powerful tool for the analysis of mortality and it provides the most complete way of comparing the mortality of different populations.

3. It is generally used by public health workers, demographers, actuaries and many others in studies of longevity and population growth, as well as in making projections of population size and also in studies of widowhood, orphanhood, length of married life, length of working life etc.

4. Life insurance companies use the life table age specific death rates (ASDR) to estimate the ASDR of a population and this information is used to fix the premium of an insured life.

Types of Life Table

Life tables are generally constructed for two types of age categories. If life table information is given for each year of age it is referred to as a complete life table.

If one uses age groups instead of a single year of age, it is called an Abridged Life table (ALT). ATLS are the ones commonly used by demographers.

If one constructs a life table based on the occurrence of deaths within a cohort of individuals born in the same year or group of years, it is called a cohort life table. Thus,a cohort life table is often referred to as a generation life table and it represents the overall mortality rates of a certain population’s entire life time.

However, a period life table assumes a hypothetical cohort and is based on the experience of age-specific rates of a particular period and is normally used in mortality analysis. Period life table represents mortality rates during a specific time period of a certain population. Basically, it is used when the time period is short.

Assumptions of a Life Table

1. The cohort under study is closed to migration. Its size decreases only through attrition of death of its members.

2. Each member of the cohort is exposed to the risk of death at each age according to the schedule which is fixed in advance and is unchanged.

3. The size of the cohort is always a fixed number of births of the same sex say, 10000 or 100000 which is called the radix of the life table.

4. The number of deaths during the year is assumed to be evenly spread over the age interval, (except the first few years) especially when it is one year.

Columns of a Life Table

A life table, as the name suggest, is usually presented in a tabular form. It consists of seven basic columns. The various rows represent the set of life table functions by age.

Column 1: This column represents age (x): for a complete life table, x takes on **(x)** values 0, 1, 2………, when age interval is more than a year, it is called an abridged life table. When age interval is 5, x takes on values 0, 5, 10,…….. In general when age interval is c, x takes on values 0, c, 2c, 3c, …..w , w being the last considered age.

Column 2: In case of a complete life table the probability of dying between an exact age X $_nq_x$ and exact age x+1 is q_x . For an abridged life table with age interval n, the probability of dying between exact age x and exact age x+n is $\mathbf{_nq_x}$

Column 3: Radix of the life table or the base of the life table i.e. survivors of initial cohort of l_x age x(l_x). This column represents survivorship

Column 4: Number of deaths between exact age x and x+n is $_nd_x$. In a complete life table, where n = 1, the number of deaths between exact age x and exact age x+1 is dx.
When age Interval is n, it is $_nd_x$ as mentioned before.

Column 5: Number of survivors between age x and x+n, $_nL_x$. This column shows the age $\mathbf{_nL_x}$ distribution of the life table population i.e. the person years lived between exact age x and exact age x + n

Column 6: It stands for total or aggregate population of the life table: the total years, T_x lived by survivors, at age x. When x = 0, $T_X = T_0$
T_0: Aggregate population; T_{10}: Total population aged 10 and above;
T_{20}: Total Population aged 20 and above, and so on

Column 7: Life expectancy at age X is (e_x^0). The average number person years a survivor of **e_x^0** Age x expects to live is $e_x^0 = T_x / l_x$

The expectation of life at age x (e_x) is the end product of life table.

Relationship between Life table functions

In a life table there are two types of functions – one type relates to a point in time and the other type refers to a period of time. In economics, variables defined at a point in time are called stock variables, for example: capital, population, etc, while the variables which are defined for a period of time are called flow variables; common examples being income, consumption, etc. At a point in time a flow variable vanishes to zero. Similarly, in life table, x the exact age refers to a point in time while ${}_nq_x$ refers to a period of time. At a particular point in time the probability of dying is zero. Of course, when the time period is very small, in the limiting case of the vanishing time, the number of deaths represents what is called 'force of mortality'. l_x is stock variable defined at a point in time.

Lx or ${}_nL_x$ refers to a period of time. L_x is the size of the lifetable population in the age interval x and x + 1. If age interval is n, then ${}_nL_x$ refers to the number of survivors (Life table population) aged x and x +n . More technically or in the demographic language, L_x is called person years lived between exact age x and x +1. When age interval exceeds 1, we have ${}_nL_x$, n being the interval of x, and ${}_nL_x$ is the person years lived between exact age x and exact age x + n. L_x represents the age distribution of the life table population. The sixth column, T_x represents the total person years lived after age x. T_0 is the total population of the life table. Lastly, $e^0{}_x = T_x / l_x$ and $e^0{}_x$ is the life expectancy at age x.

Formulae's used

From the given age-specific death rate, ${}_nM_x$; the probability of dying ${}_nq_x$ can be derived as below: by definition ${}_nM_x = {}_nd_x/{}_nL_x$ Where, ${}_nd_x$ is the number of deaths in the age interval x and x + n in the population being studied and ${}_nL_x$ is the size of the population in the same age interval.

Therefore,

$$ {}_nM_x = \frac{{}_nd_{xn}d_x/l_x}{{}^n/_2\,(l_x + l_{x+n})} = \frac{{}_nq_x}{{}^n/_2(l_x + l_{x+n})/l_x} = \frac{2({}_nq_x)}{{}^n/_2\,(1 + l_{x+n}/l_x)} $$

$$ {}_nM_x = \frac{2\,({}_nq_x)}{n(2 - {}_nq_x)} $$

$$ {}_nM_x = \frac{{}_nd_{xn}}{{}_nL_x} = \frac{d_x}{{}^n/_2\,(l_x + l_{x+n})} $$

Dividing both the numerator and denominator by l_x, we have

$$ {}_nM_x = \frac{{}_nd_x/l_x}{{}^n/_2\,(l_x + l_{x+n})\,/l_x} $$

Again, multiplying both the numerator and the denominator by 2,

$$ {}_nM_x = \frac{2.\ {}_nq_x}{2.\ {}^n/_2\,(l_x/l_x + l_{x+n}/l_x)} $$

We know that ${}_nd_x/l_x$ is the probability of dying between exact age x and exact age x+1, that is ${}_nd_x/l_x = {}_nq_x$.

Again l_{x+n} is the number of survivors at exact age x+n and l_x is the number of survivors at exact age x, therefore $l_{x+n}/l_x$is the probability of surviving age, x+n or $l_{x+n}/l_x = {}_nP_x$ which is same as 1- ${}_nq_x$

Therefore,

$$ {}_nM_x = \frac{2({}_nq_x)}{n\,(1+1-{}_nq_x)} $$

$$ {}_nM_x = \frac{2({}_nq_x)}{n\,(2 - {}_nq_x)} $$

Or, $2({}_nq_x) / n\,(2 - {}_nq_x) = {}_nM_x$

Or, $2({}_nq_x) = 2n\,({}_nM_x) - n\,({}_nM_x)\,({}_nq_x)$

Or, $2\,({}_nq_x) + n\,({}_nM_x)\,({}_nq_x) = 2n\,({}_nM_x)$

Or, ${}_nq_x[\,2 + n\,({}_nM_x)] = 2n\,({}_nM_x)$

Therefore, $${}_nq_x = \frac{2n({}_nM_x)}{2 + n\,({}_nM_x)}$$

1. $${}_nq_x = \frac{2n\,({}_nM_x)}{2 + n\,({}_nM_x)}$$

Where ${}_nM_x$ = Age specific Death Rate (ASDR) per person.

Age specific death rate is transformed into probability of dying by the formula

$${}_nq_x = \frac{2n\,({}_nM_x)}{2 + n\,({}_nM_x)}$$

In the problem given suppose n = 10

Therefore, $${}_{10}q_x = \frac{2 \times 10\,(10\,M_x)}{2 + 10\,(10\,M_x)}$$

Using this formula, age specific death rate is transformed into the probability of dying.

2. L_x is assumed to be given and its value is equal to 100000.
3. ${}_nd_x = {}_nq_x \times l_x$
4. ${}_nL_x = n/2\,(l_x + l_x + n)$
5. T_x = Cumulative of ${}_nL_x$
6. $e_x = T_x / l_x$

5.4. Trends of Mortality in Developed and Developing Countries

During the twentieth century, mortality had the most rapid decline in the history of humanity. Although the sustained reduction of mortality started in the eighteenth century, it gained momentum in the early part of the twentieth century as better hygiene, improved nutrition and medical practices based on scientific evidence became the rule in the more advanced countries. Despite the setbacks brought about by the two world wars, by 1950-1955 the widespread use of antibiotics and the growing use of vaccines had contributed to reduce mortality markedly in the more developed regions and the average life expectancy at birth for their populations had reached 66.2 years. It increased to 74.9 years in 1995-2000 and in 2017-18 it further increased to 78.9 years. The mid-century also marked an important turning point in the less developed regions. With the expanded use of antibiotics, vaccines and insecticides, mortality in the developing world began to decline rapidly, so that life expectancy increased by 53.4 per cent between 1950-1955 and 1995-2000 rising from 41 years to 62.9 years and further to 69.8 years in 2017-18. As a result, the world's life expectancy at birth increased from 46.5 years in 1950-1955 to 65 years in 1995-2000, a gain of 18.5 years and further to 71.4 years in 2017-18. Furthermore, the mortality differentials between the less developed and the more developed regions narrowed, so that by 1995-2000 the difference in life expectancy between the two groups amounted to 12 years instead of the 25.2 years difference that existed in 1950-1955 (Table:1)

As regard to life expectancy at birth by major area, it is observed that Africa (61.5 years) has the lowest, followed by Asia (72.4 years), while North America (79.5 years) has the highest, closely followed by Oceania (78.4 years) and Europe (77.7 years) during 2017-18 (Table: 2).

There remains, however, a group of countries where the reduction of mortality has lagged behind. In the least developed countries life expectancy rose from 35.5 years in 1950-1955 to 50.3 years in 1995-2000, a 41.6 per cent gain, but the difference between their life expectancy and that of the less developed regions as a whole increased from 5.5 years in 1950-1955 to 12.6 years in 1995-2000. A major reason for such increase is that the 48 countries classified as least developed include 26 that are highly affected by HIV/AIDS epidemic. Furthermore, the less developed regions include several very populous countries that have made strides in reducing mortality and where levels of life expectancy are today similar to those of more developed regions.

China, with a 1.3 billion population, is among those countries. Clearly, the countries that constitute the less developed regions are heterogeneous both in terms of the levels of life expectancy achieved and with respect to the pace at which those levels have been reached. In the long run, however, mortality differentials between the major development groups are expected to narrow further. By 2045-2050, life expectancy at the world level is expected to reach 76 years, being the result of 82.1 years of life expectancy in the more developed regions and 75 years in the less developed regions as a whole, among which the least developed countries are expected to reach a life expectancy of 69.7 years. Consequently, the difference in life expectancy between the less developed regions as a whole and the least developed countries is expected to decrease significantly in the future, reaching 5.3 years in 2045-2050, a figure similar to that estimated for 1950-1955.

Table: 1
Life Expectancy at Birth for the World and Development Groups:
For Selected Period: 1950-2050

Year	World	More Developed Regions	Less Developed Regions	Least Developed Regions
(1)	(2)	(3)	(4)	(5)
1950-1955	46.5	66.2	41.0	35.5
1995-2000	65	74.9	62.9	50.3
2017-2018	71.4	78.9	69.8	63.7
2045-2050	76.0	82.1	75.0	69.7

Source: World Population Prospects, 2017-18

Table: 2
Life Expectancy at Birth by Major Area for Selected Periods: 1950-2050

Year	Africa	Asia	Latin America and the Caribbean	Oceania	Europe	North America
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1950-1955	37.8	41.3	51.4	60.9	65.7	68.9
1995-2000	51.4	65.8	69.3	73.5	73.2	76.7
2017-2018	61.5	72.4	75.2	78.4	77.7	79.5
2045-2050	69.5	77.1	77.8	80.6	80.8	82.7

Source: World Population Prospects, 2017-18

Trends of Mortality in the World

Worldwide, the number of years that a new born is expected to live, if current mortality patterns remain constant in the future, exceeded 71 years in 2015 and the life expectancy at birth is still growing. The history of increasing life expectancy at birth, however, is not long. In most countries, it started only after the Second World War. The fast increase of life expectancy at birth reflects the success of human development. Yet remarkable differences exist in mortality levels, age patterns and time trends between countries and regions. The socioeconomic implications of the diverse mortality levels and age patterns, their dramatic changes and their potential future trends are critical for understanding the implementations of the 2030 Agenda for Sustainable Development. “Global Health and Well-Being”, one of the goals (No. 3) of sustainable development comprises targets that contribute directly to rising life expectancy.

Life expectancy at birth reached unprecedented high levels, but significant differences persist across regions

In 2015, the average life expectancy at birth for Africa, where 16 per cent of the world’s population lived, was 61 years; and the average life expectancies for the other five regions, where 84 per cent of world’s population lived, varied between 70 and 80 years. Across regions, the highest life expectancy at birth was 80 years in Northern America, where 5 per cent of the world’s population lived, followed by Europe and Oceania with 78 years and 11 per cent of the world’s population, Latin America and the Caribbean with 75 years and 8 per cent of the world’s population, and Asia with 72 years and 60 per cent of the world’s population.

Average life expectancy at birth for the world was 64.2 years in 1990

In 1990, the average life expectancy at birth for the world was about 64 years. Life expectancy at birth was below 60 years in 55 countries most of which were in Africa, between 60 and 69 years in 64 countries, and 70 years or higher in 82 countries. No country had yet reached a life expectancy at birth above 80 years in 1990.

Average life expectancy at birth for the world reached 71.4 years in 2015

In 2015, the average life expectancy at birth for the world had risen to more than 71 years. Life expectancy at birth was below 60 years in only 21 countries, between 60 and 69 years in 49 countries, between 70 and 79 years in 97 countries and 80 years or higher in 34 countries. Most countries with low life expectancy are in sub-Saharan Africa.

Increases in life expectancy at birth between 1990 and 2015 were remarkable, but uneven between regions

In Africa, the life expectancy at birth increased by 9.7 years between 1990 and 2015 During the same period, Africa's population grew from 635 million to 1.2 billion. Africa's increase of life expectancy was the largest among the six regions. Africa was followed by Asia, where the life expectancy at birth increased by 8.0 years between 1990 and 2015, while the population grew from 3.2 billion to 4.4 billion. The two regions were more influential than the others in driving the overall improvement in life expectancy for the world because their life expectancies increased rapidly and they contained a large share of the world's population.

Compared to Africa and Asia, life expectancy at birth was higher and population growth was slower in Europe, Latin America and the Caribbean, Northern America, and Oceania. The life expectancy at birth increased by 4.9 years between 1990 and 2015 in Europe and 4.1 years in Northern America. The increases in Latin America and the Caribbean, at 7.1 years, and Oceania, at 6.1 years, were considerably faster than in Europe and Northern America. Therefore, the disparities in life expectancy at birth among the four regions declined between 1990 and 2015

Great success in reducing child mortality was achieved between 1990 and 2015, but more progress is needed to reach the SDG target

Child mortality, or under-five mortality, is the probability of dying between birth and age 5 years expressed per 1,000 live births. The reduction of child mortality by two thirds between 1990 and 2015 was the central target of Millennium Development Goal (MDG) 4 of the United Nations Millennium Declaration and the further reduction to below 25 deaths of children under age 5 per 1,000 live births by 2030 is target 3.2 of the Sustainable Development Goals (SDGs).

Of the six regions, only Europe achieved the MDG target, with a two thirds reduction of the under-five mortality rate between 1990 and 2015. Europe was followed by Asia with a reduction of 60 per cent, and Latin America and the Caribbean with 59 per cent. In Northern

America, the under-five mortality rate declined by 42 per cent between 1990 and 2015 and in Oceania it fell by 35 per cent. In Africa, under-five mortality declined by 53 per cent between 1990 and 2015, while the number of children aged 0-4 years grew from 110 million to 187 million. By contrast, in all other regions, the number of children under age five was unchanged or declined.

Africa is unlikely to reach the SDG target for the reduction of child mortality by 2030

Based on the most reliable estimates, the 2017 Revision of World Population Prospects projects that, in 2030, under- five mortality in Africa would be 54 deaths under age 5 per 1,000 live births. While that would mark a substantial reduction from 2015, when there were an estimated 80 deaths under age 5 per 1,000 live births in Africa, it would remain far above the SDG target of 25 deaths under age 5 per 1,000 live births. By contrast, Asia is projected to achieve the SDG target for under-five mortality by 2030. Latin America and the Caribbean (LAC) and Oceania achieved under-five mortality below 25 deaths per 1,000 live births before 2015 and Europe and Northern America did so even before 2000.

Whether or not Africa will achieve SDG target 3.2 depends on the average annual rate of decline of the under-five mortality rate over the period from 2015 to 2030. The projected average annual rate of decline during 2015-2030 for Africa is slower than that estimated for 2000-2015. To reach the 25 per 1,000 under-five mortality target in 2030, Africa would need to achieve an average annual rate of decline of about 8 per cent during 2015-2030. Since 8 per cent is significantly faster than the average annual rates of decline estimated for 2000-2015 for each of the six regions, it is unlikely that Africa will achieve SDG target 3.2 without an unprecedented effort to accelerate the pace of reduction of child mortality in many countries.

Reductions of adult mortality between 1990 and 2015 were much slower than for child mortality

Adult mortality refers to the probability of dying between exact ages 15 and 60 years, measured in deaths per 1,000 persons reaching age 15 years. Observed data on adult mortality are available for an increasing number of countries. In the 2017 Revision of World Population Prospects, for about 80 per cent of countries, adult mortality was estimated on the basis of observed data.

In Africa, adult mortality declined by 23 per cent between 1990 and 2015, while the population aged 15-59 years increased from 319 million to 640 million. In Asia, adult mortality decreased even more, by 30 per cent between 1990 and 2015 and the population aged 15-59 years grew from 1.9 billion to 2.8 billion. In Latin America and the Caribbean, a 33 per cent decline in adult mortality was also accompanied by an increase of population in that age group. In Northern America, Oceania and Europe, all with lower levels of adult mortality compared to the other regions, the number of people aged 15-59 years changed little between 1990 and 2015.

More than half of all deaths worldwide now occur at older ages

Everyone aspires to live to old age, but, until recently, fewer than half of all people born in the world survived to their sixty-fifth birthday. An increasing percentage of deaths at ages 65 years and over marks significant progress in socioeconomic development and prevention of premature deaths. In 2015, the percentage of deaths at ages 65 years and over reached 55 per cent worldwide, up from around 41 per cent in 1990. This achievement mostly reflects progress in Asia and Latin America and the Caribbean, where the share of deaths at ages 65 and over increased from 38 to 58 per cent and from 40 to 56 per cent, respectively, between 1990 and 2015. In Africa, with lower life expectancy at birth and higher mortality risks at all ages, the percentage of deaths at older ages remains low, at 16 in 1990 and 25 in 2015.

Europe had the highest share of deaths at ages 65 and over with 76 per cent in 2015, rising from 69 per cent in 1990. Europe is followed by Northern America, where the share was around 74 per cent in 1990 and 2015. In Oceania, the share increased from 61 to 69 per cent. Because of the relatively small number of deaths in Oceania, the contribution of this region to the global increase of the percentage of deaths at ages 65 and over was small.

5.6 Mortality trends country wise

As of 2017 the crude **death rate** for the whole **world** is 8.33 per 1,000 (up from 7.8 per 1,000 in 2016) according to the current CIA **World** Factbook. More than 1.25 million people die each year from road traffic accidents, 90 percent of which occur in low- or middle-income **countries**. According to WHO, **causes** of road traffic accidents include unsafe vehicles, inadequate law enforcement, drivers under the influence and speeding. The countries in the world which have the highest mortality rate i.e death per 1000 population are Lesotho (15), followed by Lithuania (14.6), Bulgaria (14.5) and Lativia (14.5). While

Qatar **has** the absolute **lowest death rate** in the world, with 1.53 deaths per 1000 people annually.

Most of the 25,000 children under five that die each day are concentrated in the world's poorest countries in sub-Saharan Africa and South Asia. There, the child mortality rate is 29 times greater than in industrialized countries: 175 deaths per 1000 children compared with 6 per 1000 in industrialized countries.

The major causes of death in the developing world are many. Severe poverty is the root cause of the high mortality rates in the developing world. Poverty results in malnutrition, overcrowded living conditions, inadequate sanitation, and contaminated water.

Environmental and social barriers prevent access to basic medical resources and thus contribute to an increasing infant mortality rate; 99% of infant deaths occur in developing countries, and 86% of these deaths are due to infections, premature births, complications during delivery, and perinatal asphyxia and birth. Afghanistan has the highest infant mortality rate in the world, with 110.6 deaths per 1,000 children 5 years old and younger. Other countries with high infant mortality rates are Somalia (94.8), the Central African Republic (86.3), and Guinea-Bissau(85.7). While on the other hand France's infant mortality rate is among the lowest in the world, at 3.2 deaths per 1,000 live births followed by Cuba (4.4) and United States(5.8).
Japan(0.9) leads the world for lowest new born mortality, according to the latest report by the (UNICEF, 2018), followed by Iceland (1.0), Singapore (1.1), Finland (1.2), Estonia (1.3) and Slovenia (1.3). At the other end of the spectrum, Pakistan(45.6) is the riskiest country to be born in, having the highest new born mortality, with one in 22 babies born there die before they turn one month old. Followed by the Central African Republic (42.3), Afghanistan (40.0) and Somalia (38.8).Each year, some 2.6 million babies do not survive through their first month — an average of 7,000 deaths every day(UNICEF, 2018). Neonatal mortality rate (NMR) is defined as the number of baby deaths per 1,000 live births during the first 28 days of life.

5.7 Determinants of Mortality

The causes of mortality vary both in space and time. Since causes of death are intimately related to the socio-economic and technological background of medical technology and soundness of health services, therefore the causes of mortality vary from one population to another. Broadly the factors responsible for mortality are divided into two categories; - *endogenetic* (biological) and *exogenetic* (environmental) factors.

The *endogenetic* factors are essentially biological in nature, which cause death due to rapid alterations in the functioning of human body. The disease of the circulatory system, the disease that may cause infant mortality and cancer.

The *exogenetic* factors which are environmental in nature comprise environmental influences giving rise to infectious pulmonary and digestive diseases. The environmental conditions which have their link largely with climate (excessive cold, excessive heat) have been found to have adverse effect on the human body. The role of such factors is most prominent in countries, which are at low level of technological advancement.

Broadly speaking, the mortality rate in any population is governed by its age structures, social advancement and economic development. The determinants of mortality may be classified into three basic categories – demographic, social and economic factors.

Demographically, the age structure is most prominent. Other demographic factors like sex composition and degree of urban development are also significant.
Socially, incidence of infanticide, restrictions on widow remarriage, adequacy of medical facilities, general conditions of nutrition, housing and sanitation, literacy standards and religious beliefs are important.

Among the *economic* factors the standard of living or per capita income and type of economy are considered significant.

Besides, the factors like natural calamities, wars, epidemics, food-shortage also cause mortality on a large scale as and when they come.

5.8 Questions

5.9 Key words

Crude birth rate, Age specific death rate, Infant mortality rate, Maternal mortality rate, Abridged and complete Life table.

5.10 Suggested Readings

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