Handbook of Environmental Economics

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By

Debalina Saha

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To the one for whom Environmental Economics was not just an academic field of study but an endeavor to reach a sustainable social order—one who has been more of a father to me than a research guide…Professor Rabindra Nath Bhattacharya.

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PREFACE

The environment and economics are two inseparable domains of human civilization. Our economic activities essentially depend on the environment for the resources for production and consumption, and also as a receptacle for the disposal of wastes. Overt use of the resources and waste disposal beyond the nature's assimilation capacity has resulted in environmental degradation, which has threatened the very existence of our civilization. Halting economic activities cannot be a solution as that will also threaten the existence of the human race. Environmental problems cannot be solved without taking economic issues into consideration. Policies need to be modified to continue with economic well-being along with environmental recovery and rejuvenation. Attempts to frame policies to reduce environmental degradation and recover environmental damages without considering the economic implications have largely proved futile or have had repercussions that were economically damaging like shut down of industries and loss of livelihood. In recent times, it has been largely realized by the policy makers that it is essential to take economics into the ambit of environmental policies for a successful march towards sustainable development.

Environmental economics has emerged as an important discipline in the last few decades, especially in the later part of the last millennium. It has now found its place in the university curriculum and training modules for administrators and bureaucrats. The need to make the young students aware of the interdependence and complementarities between the economy and the environment has been felt by the curriculum developers. In the same way, the administrators and policy makers also essentially require knowledge of environmental economics to pursue the goal of sustainable development through policy-making and implementations. This can ensure policies that are economically sound in making effective environmental interventions.

The study of environmental economics has been limited to highly academic discourse; hence, the academic literature in this sphere included books and articles that mainly appealed to researchers and scholars with high academic pursuits. As the discipline enters the palates of young

students and bureaucrats, the need has been felt for books that can find acceptability among this segment. This book aims to fill this void, to some extent, by providing a reading material on environmental economics that is written in simple language without too many technical details. This content has been presented so that people from any discipline can understand the basics of the subject well and apply the knowledge in their domain of work. Students aiming at higher studies in this field can use this book as an initial step to grasp the fundamentals of environmental economics.

I hope this book meets the objectives of appealing to readers from various disciplines to understand the subject and to realize the importance of the interdependence of the environment and economics.

ACKNOWLEDGEMENTS

In the training sessions on environmental economics for young officers at the Administrative Training Institute (presently renamed Netaji Subhas Administrative Training Institute), West Bengal, India, I came to realize that very few people (apart from economists), if any, ever thought that environmental policies needed economic prudence. The training sessions were designed so that the officers could understand the economic implications of implementing environmental policies. Though there were quite a number of good books on the subject, there was no comprehensive material to suit the purpose of training or that the officers could refer to. But the idea of writing a book myself never dawned on me at that time. It was when I was asked to help with some notes for college students and came across the syllabus of the environmental economics course of the university that I felt "why not write a book rather than some scattered notes?" I received immediate encouragement.

I take this opportunity to thank my closest friend and all my well wishers for motivating me in this journey. I am grateful to my PhD supervisor Professor Rabindra Nath Bhattacharya for introducing me to the world of research and inculcating in me the love for the subject. Mrs. Shikha Bhattacharya has always motivated me to move along.

I express my gratitude towards Mr. Sushanta Majumdar, Former Course Director, Civil Services Study Centre (CSSC, presently renamed SNTCSSC), Administrative Training Institute, West Bengal, India, for giving me the opportunity to be a part of the CSSC. He has always encouraged me to aim higher and expand the horizons of my knowledge. I also thank Ms. Gargi Ghosh, Associate Professor, Netaji Subhas Administrative Training Institute, for giving me the responsibility of conducting the Environmental Economics Course at the Institute.

My family is always beside me in all my endeavors, whether I succeed or fail. My parents, Mr. Salil Kumar Saha and Mrs. Niyati Saha, and in-laws, late Mr. Pranab Kumar Ukil and Mrs. Anuva Ukil, have always been my source of peace and solace. In all my ventures, I have found my husband, Mr. Prabhas Kumar Ukil, by my side. My daughters, Arushi and Anandi, have always been my source of inspiration.

I also thank all my colleagues at Amity School of Economics, Kolkata, for the love and friendship I received from them, which has provided me with the energy to work with enthusiasm. A special thanks to Amity University, Kolkata, for providing the space for research and writing to me.

CHAPTER 1

THE ECONOMY AND THE ENVIRONMENT

1.1 Introduction to Environmental Economics

The discussion on the environment is not restricted to environmental conferences, seminars and TV talk shows anymore. It has come to our living rooms, college canteens and office coffee breaks. When we had meetings with our overseas colleagues in the Unites States and Europe, we began with the discussion of the unusual heatwave ravaging through these continents. I too shared my complaints about deficient monsoon rains in the Asian region and the discomfort and difficulties that this brings. We are face to face with climate change now. One fact that tickles me about all these discussions on environmental degradation and climate change is that it is more of an economic issue than it is biological, geological or environmental engineering. In one of our sessions on sustainable development with the forest officers, one of the officers said that the solution to the problems is in our hands. She pointed out that during the Covid-19-pandemic lockdown air quality improved and marine life took a fresh breath with less water pollution—there was an overall improvement in the quality of the environment. I understand and appreciate her passion for the environment and her love for nature and wildlife. But let us also recall that the entire shut down of production activities led to losses of jobs and miseries for millions of people for a prolonged period of time. The concerns for the environment cannot be viewed in isolation from the concerns of economic and social development.

1.1.1 How Is Economics Related to the Environment?

While economics deals with the consumption and production activities of humans, the environment provides humans with resources for production, amenities for living and recreation, and also acts as a waste sink that assimilates these wastes, which return back to the system as useful materials. The water cycle, carbon cycle, nitrogen cycle, etc., are maintained by nature, whereby the materials produced, consumed and then disposed of by the humans in their everyday activities get assimilated by

nature and returned back to the system, maintaining the flow of resources. As long as human activities are within the regenerative and assimilative capacity of the environment, environmental problems do not arise. Far back in history, before the industrial revolution, environmental degradation, pollution or depletion of essential resources were not common occurrences. With the increase in population, rapid pace of growth, improvement in the standard of living and changing lifestyles, the pressure on the Earth's resources has increased, leading to the depletion of resources and environmental degradation. Generating wastes beyond the assimilative capacity of nature results in pollution. Over exploitation of resources leads to depletion. Loss of habitat for different species leads to their extinction. But, to amend this, we cannot stop economic activities as that will threaten the human race. Here lies the necessity of the study of environmental economics.

1.1.2 Necessity of Economics in the Study of the Environment

Environmental problems should be viewed with a wider perspective to find their socioeconomic roots. Only then can we find a holistic solution that can correct the problems without affecting people and society. It had been the norm to view the problems from the angle of the effects they produce without delving into the root of the problem. For example, when there are some polluting industries in an area the authority imposes restrictions on the emissions of pollutants or mandates the use of abatement devices. It has been observed, in the past, that such restrictions often lead to the shutdown of industries as the cost of abatement is too high for the industry to stay profitably in business. This actually leads to loss of jobs and hampers economic growth and development. Sometimes, the solution to one particular environmental problem brings in another one. For example, replacing paper cups to serve tea in railway stations and trains in India with earthen pots (known as kulhars) has led to the overuse of the topsoil to produce the pots made of burnt clay, affecting agricultural productivity. So, environmental issues should be viewed and solved in a more comprehensive and holistic manner. The entire life-cycle of a product needs to be assessed, from the extraction of resources to production, from consumption to disposal, and also the way the society is involved in the whole process. If a certain community harvests forest resources for their livelihood, leading to depletion of the resources, the solution will not be to ban the harvest of the resources but to harvest resources in a way that saves the livelihood of the community and, at the same time, stalls the depletion of those resources. Or, when some pollution abatement device

has to be installed, the calculation of economic costs and benefits can find the best way of applying the abatement norms without making production economically non-viable.

1.1.3 What Is Environmental Economics?

Environmental economics applies the tools of economics to identify the causes of environmental problems, including resource depletion, and their effects on the economy and society. It also finds solutions to the problems that involve environmental science and technology, along with social and economic instruments. In other words, environmental economics applies the science of the environment to economic principles to find solutions to environmental problems that resolve environmental issues without adversely affecting the economy and society or leading to the emergence of further environmental issues. It encompasses a wide perspective to find a comprehensive solution incorporating the social costs and benefits involved in environmental damage. A major task is identifying the optimal set of solutions, from the possible set of solutions that inflict the least cost, ensuring maximum benefit.

In the study of environmental economics, we begin with the understanding of the interface between the economy and the environment, and the interrelationship between economy, ecology and the environment. Since the root cause of environmental damage and resource depletion are the human activities of production and consumption, environmental economics is involved in identifying failures in the economic system, incorporating the environmental costs and benefits that lead to the damage, and finding solutions to correct the damage and prevent further degradation of the environment. Thus, an important part of the study of environmental economics is the valuation of the environment and the estimation of the cost of intervention to the environment. It also involves the formulation of strategies to minimize the environmental damage caused due to human activities and the design of appropriate policies and measures to induce society to modify their activity in an environmentally sustainable manner.

Box 1.1: Why Environmental Economics?

Organic Farming in Sri Lanka Leading to Catastrophe for the Economy

In April 2021, the government of Sri Lanka, an island nation in South Asia, imposed a ban on imports and the use of synthetic fertilizers and pesticides, and ordered the country's two million farmers to adopt organic farming methods.

It is known that the overuse of chemical fertilizers pollutes ground and surface water—the nitrates from fertilizers lead to eutrophication in water bodies, disrupting aquatic ecosystem. It has been reported that cadmium contamination in water resulting from fertilizer run-off is a major cause of chronic renal failures in Sri Lanka. Some forms of cancers are also believed to have been triggered from the use of pesticides.

Though the environmental and health hazards caused by the use of chemicals in farming seem to be reason enough to impose a ban on chemical fertilizers and pesticides in Sri Lanka, the effect of the ban proved to be disastrous. Production of rice fell by 20% within six months of the imposition of the ban, forcing the economy, which was otherwise self-sufficient in food grains production, to import rice worth $450 million. Furthermore, the price of this staple product rose by 50%. Production of tea, a major export item, fell by 18%, resulting in a loss of income from export. This drastic change made the country fall into a deep economic depression.

The lesson to learn from this policy intervention is that, to take remedial action against environmental damage or to prevent further damage, economic factors should essentially be considered. In the example described here, agricultural products are a major foreign exchange earner for Sri Lanka. But consideration of only ecological factors without paying attention to the economic implications led the country to a catastrophe, forcing the government to ultimately lift the ban on chemical fertilizers and pesticides. So, environmental economics is relevant and important to remedy and prevent environmental damage.

1.2 Economy–environment Interface

1.2.1 Ecology and Environment

To begin the study of environmental economics, the first step is to understand the interrelationship between the economy and the environment. Another term that comes to our minds when we discuss environment is "ecology." Though they are often used interchangeably, the concept of ecology differs from the concept of environment. Ecology is the study of the ecosystems. That means it studies the interdependence between the biotic (living beings-plants and animals) and abiotic (air, water, minerals, etc.) components in nature. Environment is an anthropocentric concept that studies how human beings interact with the living and non-living components of nature. So, the part of the ecology that affects humans falls under the ambit of the study of the environment.

1.2.2 Closed or Open System?

If we consider the environment, in a broader sense, to encompass the Earth as a whole and not beyond that, we have a somewhat closed system as far as material inputs and outputs are considered. The number of spaceships and satellites sent beyond the planet's atmosphere (which can be considered as exports from the system) and the meteorites striking the Earth (which can be considered as imports into the system) are negligible in terms of the history of humankind. The same is not true for energy. The sun is a constant external source of energy to our planet. All activities upon this Earth are dependent, either directly or indirectly, on the energy provided by the sun, which sets an upper limit to these activities termed as the ***sunlight budget***. That means in terms of material inputs and outputs we are a closed system but in terms of energy we are an open system with the sun as the only source of energy setting an unalterable upper limit to the energy supply.

1.2.3 Economy and the Environment—the Interrelationship

The economy consists of firms that produce goods and services, and supply them to households, which consume the goods and services, on the one hand, and supply factor services to other firms for their production processes, on the other. Thus, the firms and households are connected through these circular flow dynamics, which we are already acquainted with. These dynamics operate within the broader fold of the environment,

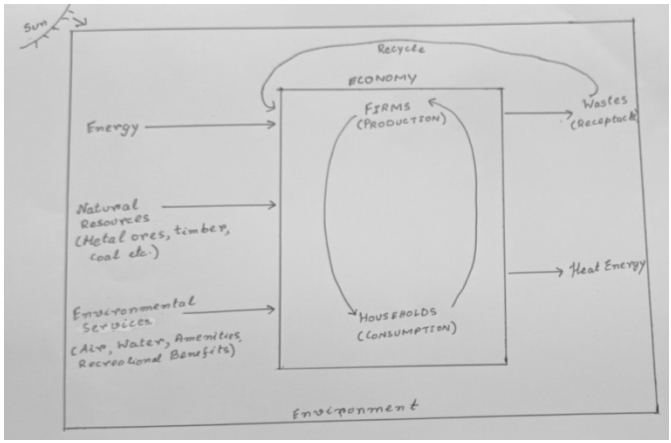
which consists of all the natural resources—plants, animals, minerals, air, water, and energy sources like coal and petroleum. This interrelation is depicted in Figure 1.1. Some of these resources are exhaustible like iron ore, bauxite, etc., and some are renewable like forest resources and fisheries.

The economy is dependent on the environment for three major purposes. First of all, the environment provides raw materials for the firms to produce goods and services, like iron ores for steel plants, cotton for the textiles sector, and food items like fruits, vegetables and cereals, and so on.

Secondly, the environment provides amenities and life-support services. The oxygen we breathe in and the water we drink are part of the life support services. When we go to some hill station for holidaying or enjoy the serenity of the sea in a beach resort or enjoy rafting in some mountainous river, we draw the pleasure of recreation and relaxation.

Thirdly, the environment provides us with another very important service. It acts as a waste sink. Waste is generated both from production and consumption activities. Emissions of oxides of nitrogen and sulfur, and carbon dioxide, etc., from factories or effluents discharged in water bodies from tanneries or textile mills are examples of wastes generated by firms. The daily garbage disposed by households is part of the waste created from consumption activities. The environment is not a passive sink for these waste products to be dumped into. It actively works on them to convert them to useful materials that again become a part of the resources.

Figure 1.1: Interconnection between Environment and Economy

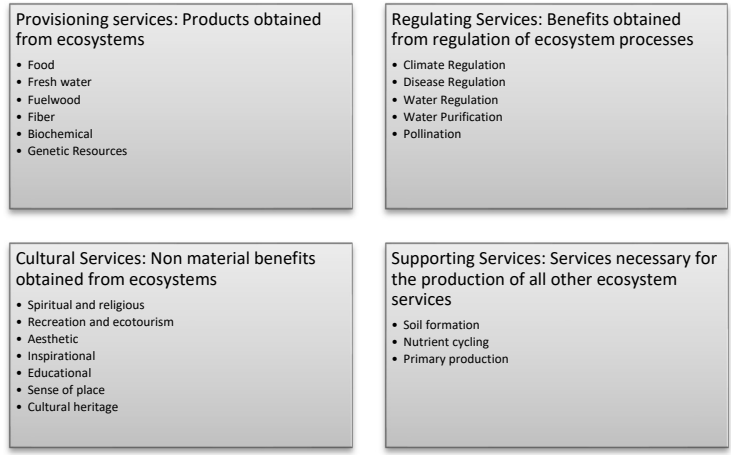


Environmental problems arise when there is some tweak in this environment-economy interface. Overexploitation of resources beyond their regenerative capacity leads to resource depletion, dumping of wastes to a far greater extent than the nature's ability to assimilate them leads to pollution, indiscriminate cutting of forests for agricultural or mining purposes leads to loss of biodiversity and reduces nature's ability to provide amenities such as clean air and/or its ability to act as a recreational retreat.

1.3 The Ecosystem Services

The Millennium Ecosystem Assessment has termed the services provided by the environment as the ecosystem services and identified four vistas of these services. The four vistas are depicted in Figure 1.2.

Figure 1.2: Ecosystem Services



Source: Millennium Ecosystem Assessment

1.4 Environment-economy Relations in the Light of the Laws of Thermodynamics

The relationship between the activities of humans and the environment are bound by the two laws of thermodynamics.

Thermodynamics deals with the transformation of energy from one form to another. According to the first law of thermodynamics (also known as materials balance principle), matter and energy can be neither created nor destroyed but they can be converted from one form to another. This implies that in a closed system the total amount of materials and energy remains the same. For example, when coal is burnt to obtain electricity the total amount of electrical energy obtained equals the amount of chemical energy that was present in coal.

The second law of thermodynamics, also known as the "entropy law," states that the conversion of energy from one form to another is never one hundred per cent efficient, implying that some energy is always lost during the conversion process. Moreover, the part of the energy that is converted cannot be obtained any longer for further work. The amount of energy unavailable for work is known as the "entropy." So, "entropy increases" when energy is converted from one form to another. For example, while

driving a car the chemical energy, which is diesel or petrol, is converted to mechanical energy that makes the car move. The converted energy cannot be used further to run the car or to run another car as the chemical energy used cannot be reconverted from the mechanical energy produced in the car.

This means that a closed system will run out of energy once it uses up the available energy sources. A system without energy will be unable to survive. As we have already stated before, in terms of energy we are not in a closed system as we receive energy from the sun, which sets an upper limit for the amount of energy that we, on Earth, can use.

Review Questions

Short Answer Type Questions

1. What is environmental economics?

2. What is the difference between ecology and environment?

3. What are ecosystem services?

4. List the different types of ecosystem services

5. What are provisioning services? Give two examples.

6.What are regulating services? Give two examples.

7. What are cultural services?

8. What are supporting services?

9. State the first law of thermodynamics.

10. What is entropy?

Long Answer Type Questions

1. Give a brief account of the classification of the ecosystem services.

2. With the help of a diagram explain how the economy is related to the environment.

3. Is our environment a closed system? Discuss.

4. What is the implication of “entropy increase” for the environment?

5. Explain the relationship between the environment and the economy.

6. Discuss how the first and second law of thermodynamics is related to the environment-economy interface.

CHAPTER 2

ECONOMIC EFFICIENCY AND ENVIRONMENT

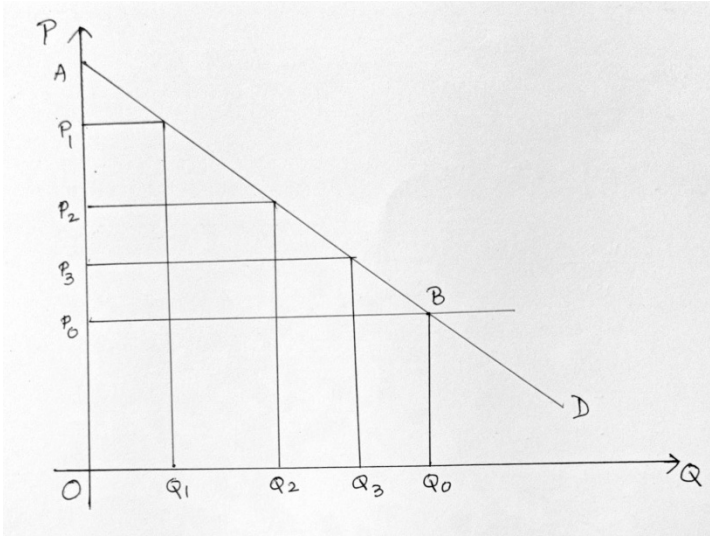
Environmental degradation adversely affects the economy. To reduce the adverse impact of economic activities on the environment, the resources have to be utilized efficiently so that both social welfare and environmental balance are maintained. In this chapter, we discuss the issues related to economic efficiency, welfare and the conditions under which efficiency can be ensured. We begin with some of the tools of measuring economic efficiency and discuss the situations under which the market system fails to attain efficiency.

2.1 Consumer Surplus and Producer Surplus

We all are acquainted with the demand curve. Let us begin with the simple downward sloping linear demand curve D, as shown in Figure 2.1. Every point on the curve shows the amount of money the consumer is willing to pay for that particular quantity of goods.

To purchase the quantity Q_1 the consumer is willing to pay a maximum amount of P_1. Similarly, for Q_2 and Q_3, the consumer is willing to pay P_2 and P_3, respectively. Now, let us suppose that the market price for goods has settled at P_0. From the demand curve, we find that the consumer will buy Q_0 amount at this price. The total expenditure for the consumer will be $P_0 \times Q_0$. We observe that, now, the consumer is paying P_0 for the quantity Q_1, while the consumer was willing to pay P_1. The consumer has a gain of $P_1 - P_0$. Similarly, the consumer has gain of $P_2 - P_0$ and $P_3 - P_0$ for Q_2 and Q_3, respectively. If we consider this for all units of goods to Q_0, we find that the area of the triangle ABP_0 is the consumer's gain, which we term as the consumer's surplus. This means that the area between the demand curve and the price line gives us the consumer surplus. The concept of consumer surplus is an important tool in assessing the welfare implications of environmental changes or the government interventions that induce them.

Figure 2.1: Consumer Surplus

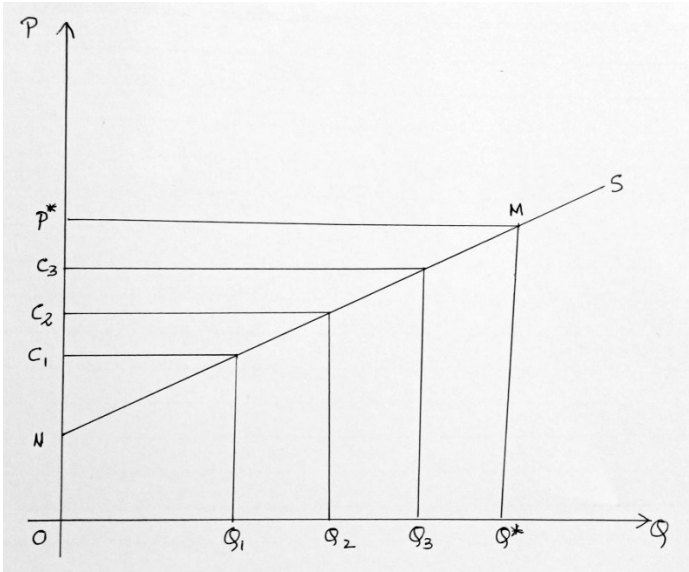


As we discover the consumer surplus, it is equally important to view the welfare implications from the producers' side. Following similar lines of reasoning, we can arrive at the producer surplus. In Figure 2.2, we represent the supply curve (curve S). We know that, for a firm in a perfectly competitive market, the supply curve is nothing but the marginal cost curve. So, for every quantity of goods, the supply curve shows the minimum amount of money the producer is willing to accept for that quantity. Any amount below that will result in a loss for the seller and so the seller will not be willing to sell that quantity of goods at a price that is below the supply curve.

In Figure 2.2, we see that, for producing quantity Q_1, the producer incurs cost C_1. The producer will not be willing to accept any amount less than C_1 to sell Q_1 amount of the product. Similarly, for quantity Q_2, the producer will be willing to accept a minimum of C_2 as a price and for Q_3 the minimum is C_3. Let us suppose that the market price for the product has settled at P*. The producer sells Q* amount at this price as determined by the supply schedule. The revenue received by the producer is $P^* \times Q^*$. Now, from the figure, we find that for quantity Q_1 the producer was willing to accept the amount C_1 but now the producer is receiving P*. So, the producer is receiving the amount $P^* - C_1$ in excess of the cost incurred in producing Q_1. By the same line of reasoning, the producer receives the

amounts P* - C_2, P* - C_3, and so on in excess of the amount spent in producing these quantities. If we consider this excess amount for each unit of the product to Q*, we find that the entire area of the triangle MNP* represents the surplus received by the producer for selling quantity Q* at price P*, over and above the cost incurred in producing the amount Q*. This area MNP* represents the producer surplus. We infer that the area above the supply curve bounded by the price line represents the producer surplus.

Figure 2.2: Producer Surplus



2.2 Pareto Efficiency

In a free market economy, the market forces are expected to ensure the efficient allocation of resources. As we have already discussed, the demand curve represents the consumer's willingness to pay for different quantities of a product and the supply curve represents the producer's willingness to accept payment for different quantities of a product, the market provides a system through which the buyers and sellers come to an agreement over the quantity they are willing to trade at a price acceptable to both the buyer and seller. This is considered to be an efficient allocation as the consumer maximizes her satisfaction or utility from the consumption of the given quantity and the producer maximizes profit from the sale of

the quantity decided upon. In terms of Pareto efficiency, an allocation is considered to be efficient if no further reallocation is possible that can make at least one person better off without making anyone worse off. This underlying principle is true both for product and factor markets.

The Pareto Criterion for efficiency was suggested by Vilfredo Pareto (1848–1923). This criterion states that any change that makes at least one person better off and no person worse off is an improvement in social welfare. Thus, it also suggests that a change that makes no one better off but at least one person worse off implies a decrease in social welfare. Thus, a situation is Pareto-optimal or Pareto-efficient when it is impossible to make anyone better-off without making someone worse-off. This is explained in Box 2.1.

Box 2.1

PARETO OPTIMALITY AND THREE MARGINAL CONDITIONS

In welfare economics, we always try to search for the concept of welfare and norms in economic activities. In this context, welfare is very closely interlinked with the normative approach.

We know an economic system has the objective of the efficient allocation of scarce resources to produce commodities and services for the use of individuals and society. In market economy, the price is determined through the two market forces—demand and supply. This price mechanism ensures the optimal allocation of resources and products. The price of the products that have an excess demand rises. Accordingly, producers employ more factors for the production of a product that has an excess demand. This leads to optimal resource allocation. Hence, the income of the producers producing such goods, along with that of the owners of the specific factors, rises considerably. On the other hand, the producers of other goods and services remain outside the domain of this excess demand-led rise in income. As a result, the question of whether the total welfare of the economy rises or not, since welfare is often treated as a subjective concept, arises. At the same time, the term “efficiency” is also of immense importance and should be dealt with using proper care.

A solution to this problem was provided by the famous Italian economist Vilfredo Pareto who depicted the conditions of welfare maximization in the economy. He showed three marginal conditions for avoiding economic inefficiency. According to Pareto, given the allocation of resources and output, if it is possible to make someone better-off without making anyone

worse-off, then the original allocation is definitely inefficient. Thus, a condition is known to be Pareto-efficient or Pareto-optimal if it is impossible to make one better-off without making someone worse-off. In order to achieve Pareto-optimal situations, three marginal conditions have to be satisfied. Furthermore, to satisfy the above mentioned marginal conditions the following assumptions are relevant:

1. Only two commodities, X and Y, are produced in the economy where the technology is given.
2. There are two factors of production, labor (L) and capital (K), that are homogeneous and perfectly divisible.
3. There are two consumers, A and B, in the economy whose preferences are represented by convex indifference curves.
4. The objective of the consumer is to maximize utility.
5. The objective of the producer is to maximize the profit.
6. The factors of production are fully employed.
7. The product and factor market are perfectly competitive.

The marginal conditions to obtain a Pareto-optimal situation can be classified as follows:

a. Efficiency of the distribution of commodities among the consumers (efficiency in consumption)
b. Efficiency of the allocation of factors among producers (efficiency in production)
c. Efficiency of the allocation of factors among commodities (efficiency in the product-mix)

a. Efficiency of the distribution of commodities among the consumers (efficiency in consumption)

This is the first marginal condition of Pareto optimality. This condition actually tells us that it is impossible to redistribute a given set of commodities among consumers in such a way that the welfare of one person can improve without making the other one worse-off. For this, the marginal rate of substitution (MRS) of X for Y for both of A and B should be equal. It should be noted that MRS measures the units of one commodity that has to be sacrificed in order to get one extra unit of the other commodity, provided the total utility remains constant. Thus, here, the efficiency in consumption requires

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

If the condition above holds good, it is impossible to redistribute the commodities, X and Y, in such a way between A and B that utility of one can be increased without hampering the utility of the other. If the MRS_{XY} between A and B is unequal then only a redistribution will be effective to ensure the improvement of one individual without hampering the utility of the other. In that case, Pareto improvement can be done. Therefore, efficiency in consumption requires the equality of MRS_{XY} between A and B.

b. Efficiency of the allocation of factors among producers (efficiency in production)

This is the second marginal condition of Pareto optimality. This condition implies that it is impossible to redistribute factors to produce more of one product without reducing the production of the other commodity. Hence, it is the optimal condition that will ensure Pareto efficiency. In order to satisfy the condition, the Marginal Rate of Technical Substitution (MRTS) of labor for capital should be same for both products, X and Y. It should be noted that MRTS measures the units of one factor that has to be sacrificed in order to employ one extra unit of the other factor, provided that the total output remains constant. Thus, here, the efficiency in production requires

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

If the condition above holds good, it is impossible to redistribute the factors, L and K, in such a way between X and Y that production of one can be increased without hampering the production of the other. If the $MRTS_{LK}$ between X and Y is unequal then only a redistribution will be effective to ensure the increase in the production of one commodity without hampering the output of the other. Since there is a scope of improvement, the situation is often termed as a Pareto sub-optimal condition. In that case, Pareto improvement can be done. Hence, to ensure Pareto optimality, in terms of efficiency in production, the equality of $MRTS_{LK}$ between X and Y is necessary.

c. Efficiency in the allocation of factors among commodities (efficiency in the product-mix)

This is the third marginal condition of Pareto optimality. This condition conveys that it is impossible to increase the production of one product without reducing the production of another one. This condition depicts the requirement for a proper mix of outputs so that there is neither

overproduction of nor the dearth of a product. To satisfy the condition, the Marginal Rate of Product Transformation (MRPT) of X for Y ($MRPT_{XY}$) should be the same for Marginal Rate of Substitution (MRS) of X for Y (MRS_{XY}). Here, it should be noted that MRPT refers to the slope of Production Possibility Frontier (PPF). MRPT measures the units of one commodity that have to be sacrificed in order to get one extra unit of the other commodity, provided resources remain constant. So, the condition for the efficiency in the product mix requires

$MRPT_{XY} = MRS_{XY}^{A} = MRS_{XY}^{B}$

As MRPT shows the rate of transformation of one product into another, and MRS shows the rate of exchange of one product for another, these rates have to be equal in order to ensure Pareto optimality. Unless these ratios are equal, the economy cannot attain equilibrium. This equality implies a perfect match between the production plans of the firms and the consumption plans of the household sector. If MRPT ≠ MRS, there will be overproduction of one product and underproduction of another.

Thus, the third marginal condition of Pareto efficiency requires that the product mix, i.e., the combination of outputs, should be consistent with the optimal choice of both the producers and consumers.

Pareto optimality requires the fulfillment of the three above-mentioned marginal conditions. However, Pareto optimality does not ensure the maximization of social welfare. It is necessary but is not the sole condition for welfare maximum. In this context, the interpersonal comparison of the individual consumer's utility can be done to verify whether the Pareto optimal situation ensures maximum social welfare or not.

The free-market system ensures efficiency as the principle of ***comparative advantage*** operates behind the market forces. A person tends to produce and sell goods and services that they can produce relatively more efficiently than others or for which they have less opportunity cost than others have. In a market system, a person can specialize in the activity in which they have comparative advantage and trade that product in exchange for the product in which they do not have any comparative advantage. In this way, Pareto efficiency can also be attained as the person is producing the goods or rendering the services that they can do more efficiently than others. So, for attaining efficiency, the market system has to operate successfully. For a market to operate, it is essential to have a well defined system of property rights.

2.3 Property Rights and Efficiency

Property rights become all the more important when we discuss environmental resources. It is the existence, or non-existence, of well defined property rights that becomes a determining factor in the manner in which environmental resources are used. Property rights refer to a set of rules that define a person's or community's entitlement to use a resource and also state the extent to which the resource can be used, demarcating both the privileges and limitations of such use. A property right structure can be termed as well defined if it corroborates to the following four factors:

1. Comprehensiveness: The property right structure applies to all the resources in the economy and is well defined and enforceable for all these resources.
2. Exclusivity: For both private property and common property, all costs and benefits arising from the use of resources accrue to the owners, and to the owners alone, either directly or indirectly, through their sale to others.
3. Transferability: Property rights can be transferred by the owner to another person at the owner's discretion.
4. Enforceability: The legal system ensures that there is no involuntary seizure of the property or encroachment on the property. The right should be enforceable by law.

The presence of a well defined property right itself is an inducement for the owner to use the property efficiently or make an efficient exchange when transferring this right. In a market system, the producer will allow the consumer to have goods only when the consumer pays the price for them. The price the producer will accept is the profit maximizing price for the producer. The consumer, on the other hand, will purchase the quantity that will maximize their utility at the given price. In Figure 2.3, we see that the consumer and producer agree upon the quantity Qe and price Pe, which is determined by the point of intersection of the demand curve of the consumer and the supply curve of the producer. Area A is the consumer surplus and B is the producer surplus. The sum of the areas A+B gives us the total economic surplus or economic welfare. The market has determined both the efficiency as well as the allocation of the efficiency between the consumer and the producer. Another important point to note, here, is that neither the producer nor the consumer aims to improve economic efficiency but attempts to maximize their own surpluses, and ends up maximizing the welfare for the society together.