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ENVIRONMENTAL ECONOMICS AND POLICY

MASUDEM

MASTER STUDIES IN SUSTAINABLE DEVELOPMENT AND MANAGEMENT

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ENVIRONMENTAL ECONOMICS AND POLICY

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INTRODUCTION

Although throughout the past the economic, social and environmental developments of the world have progressively improved. But one must admit that development over the past 20 years has caused serious environmental pollution and natural resource degradation problems in many countries. Today, environmental pollution problems, which were once considered less important than economic, social, and political problems, have become increasingly serious problems. Until it often causes conflict between people. Throughout the years, despite the fact that there are many measures and solutions to solve the problem of environmental pollution. However, environmental laws that emphasize regulatory and control measures are still limited in solving problems. Due to the lack of strict enforcement of the law, low legal penalties and government agencies still lack timely monitoring and inspection of pollution sources for reasons of personnel, budget, and others. Therefore, it appears that those affected by injustice and inefficiency in environmental pollution management often fall to the poor and underprivileged groups in society. Nowadays, many countries have introduced "economic instruments" to strengthen governance and control measures in managing environmental pollution problems. Because economic tools are considered one of the important mechanisms for reflecting environmental costs according to “Polluter Pays Principle: PPP” is a measure that creates incentives for polluters and consumers to change their behavior and carry out activities that reduce environmental pollution. The law on economic tools for environmental pollution management is therefore a new innovation that will help strengthen existing environmental laws. By opening it up to various agencies, a variety of economic tools can be used to manage environmental pollution as appropriate and according to the mission of each agency. It also promotes decentralization for local administrative organizations to play an important role in solving problems and earning income from environmental pollution management. These economic tools include fines, taxes on emissions, buying, selling or applying for emissions permits. Permission fee uses different tax systems. Subsidy measures placing insurance against risk or damage to the environment deposit refund system. Economic tools have two important objectives: to change producer and consumer behavior reducing environmental pollution and to create incentives reducing pollution. Collection of pollution taxes based on the amount of wastewater or polluted air that is released into the environment. This will cause polluters to try to take measures or improve production processes to create less wastewater or polluted air. The use of economic tools is therefore not supervision and control. Rather, it creates economic incentives to make organizations or executives aware of the true cost of resources and consider the impact outside the organization of that activity.

Therefore, it gives producers or consumers the opportunity to decide for themselves what measures to take next. In this textbook, there are 12 chapters integrated all the necessary details related to students who will study the principles of economics as they apply to resource and environmental management. Business management and green economy and economic principles in dealing with natural disasters from climate change so that they can be applied in design the policy for developing the country and promoting the business sector to be able to compete in the future world sustainable development. It is a mainstream case studies and implication for agriculture and the environment.

CHAPTER 1: INTRODUCTION TO ECONOMICS FOR SUSTAINABLE DEVELOPMENT

In the expedition for social wellbeing, the relationship between economics and sustainability has currently become a fundamental concern nowadays. The term "sustainable development" is commonly used to summarize the interdependence of economic, social, and environmental systems. The traditional economic models, which often prioritize short-term gains and resource exploitation, may not be compatible with the long-term well-being and the prosperity of human societies. The idea of economic sustainability has risen to importance in recent decades as the world confront with the complex challenges such as climate change, environmental degradation, poverty, and inequality.

This extensive exploration seeks into the field of economics for sustainable development, providing a comprehensive overview of the concept and its multifaceted dimensions. In this material, we will uncover the principles, methodologies, and practices that can examine the evolution, assess the impacts on societies and the environment, and explore the challenges and opportunities for the future. These topics provide a starting point for research and policy initiatives that can help integrate economic theories into the broader framework of sustainable development.

1.1 Understanding Sustainable Development

Sustainable development is an evolving concept that find a harmonious balance between economic, social, and environmental dimensions. The goals of sustainable development are to ensure that development is not only ecologically responsible but also socially equitable and economically viable. The term was introduced internationally in 1987 with the release of the Brundtland Report, which defined sustainable development as

"The development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

This definition is a widely accepted. Sustainable development is closed related to environmental issues. It also faces environmental challenges to achieving a better quality of life while protecting natural resources for current and future generation.

There are 3 components of sustainable development

1. Environmental Sustainability

This aspect focuses on conserving natural resources, reducing pollution, and minimizing environmental degradation. It involves practices such as responsible resource management, renewable energy use, waste reduction, and biodiversity conservation.

2. Economic Sustainability

Economic sustainability purposes to promote prosperity and economic stability. It also refers to the ability of an economic system to maintain and support a certain level of economic activity and wellbeing in long term while avoiding practices that lead to overconsumption and inequality. The concept attempts to promote economic growth with encouraging the internalization of externality.

3. Social Sustainability

Social sustainability is about guaranteeing that the development should benefit and distribute fairly among all members of society. It includes issues related to equity such as poverty, social equity, access to education and healthcare, the promotion of social justice and cultural preservation.

Initially, it was seen as an abstract and idealistic. However, it has become more tangible and integrated into policies and decision-makings. It has transformed from an abstract ideal to a practical and integrated approach, with clear policy objectives and action plans to address pressing issues since

UN announced the United Nations Sustainable Development Goals (SDGs) in 2015 as a universal call to action to end poverty, protect the planet, and ensure prosperity for all. The 17 SDGs set a comprehensive and integrated agenda for sustainable development, covering aspects from poverty eradication to climate action.

In common with Paris Agreement in 2015, most countries discourse climate change and other environmental issues are significant steps toward sustainable development. Frequently, sustainable development has also found expression in various local and regional as environmental policies; for instance, taking action to reduce greenhouse gas emissions and promote sustainable transportation.

1.2 Economics for Sustainable Development

"Economics for Sustainable Development" is an approach to economic theory and practice that focuses on fostering long-term well-being for both current and future generations while respecting the limits of the natural environment. This approach seeks to strike a balance between economic growth, social equity, and environmental preservation.

Environmental economics integrates environmental factors into economic analysis. It considers the external costs and benefits associated with environmental degradation and preservation. It focuses on the economic aspects of environmental issues and examines the interactions between the environment and the economy. It studies how economic activities impact the environment and how environmental changes, in turn, affect economic systems. It also provides a framework for understanding and addressing the complex and interconnected challenges of environmental protection and economic growth.

Economics for sustainable development is closely related to environmental economics. Both fields focus on the interaction between economic activities and the environment, with the goal of achieving economic sustainability. They believe that there are tradeoffs between economic growth and environmental protection.

In summary, economics for sustainable development and environmental economics share a common goal of reaching sustainability by integrating economic analyzes and environmental considerations. Understanding environmental economics is essential in comprehending the concept of sustainable development

1.2.1 Economic and Environment

Economic and environment are closely related. Nowadays people interest on the environment more and more since the people realizes environment problems which are happened recently. Additionally, the policy makers interest on environmental issues because they understand the advantages and the results of good environment condition as well as law and regulation about environment. People believe that environment affects directly or indirectly to their lives. Then they interest on the effect of economic activity on the environment and they conversely interest on how environment affect economical values. People interest and worry about the deterioration of the environment and realize the cost of environment preservation. Therefore, sustainable development idea is concerned and become a main discussion among economists. From these reasons, economics does not interest only on money issues such as economic values of products but the cost of the prevention and how to restore environment are also important topics to concern.

To study the relationship between economic system and environment the question that we simply ask is “How are the economics and the environment related?” As we know, economics system is working within environment system. These two systems are the bilateral system which relates in many ways as shown in figure 1.1.

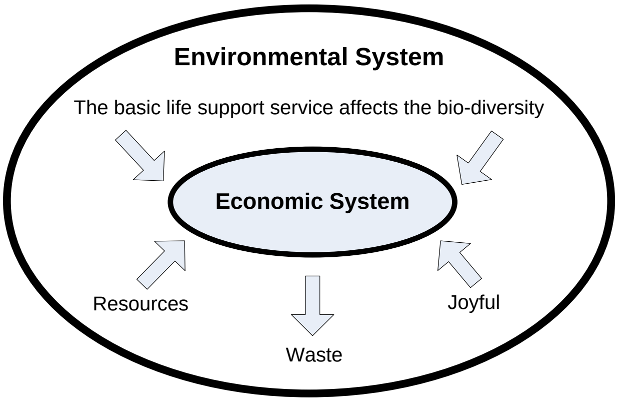

Figure 1.1 Relationship between environment and economic system
Source: Summarized from Field, 2002 and Tietenberg, 2003

First, environment system gives the production factor (Input factor) and the energy to economy system. These resources are brought into the process by economy system to the production process to meet the requirement of consumers. These resources include renewable and non-renewable resources such as raw material and energy. Second, economic system use environment as a trash can since the system put the leftover from the production and consumption to the environment such as garbage. Third, environment gives joyful to human and households. Lastly, environment gives the basic life support services to economy.

The most important thing is "if economy increases demand of the environmental services, it may affect other capabilities of serving in other aspects". Then the key point is how environment can increase its capacity to serve the unlimited demand. Consequently, the structure of the dependence between economy and environment must change along together.

When we study on the environmental issues, we always ask "Why human usually damages the environment?" The answer is because human does not have ethical and moral and because it is the cheapest way to eradicate waste and residuals. As we know, the problems are the improper human behaviors and how to solve these problems. We must understand all dimensions of human behaviors related to environment to identify the policies. Reinforcement and the effectiveness of the policies are also important.

1.2.2 Economy and Nature

As discuss previously, the economic and environment are related. In this section, we argue about the roles of nature in economy and vice versa

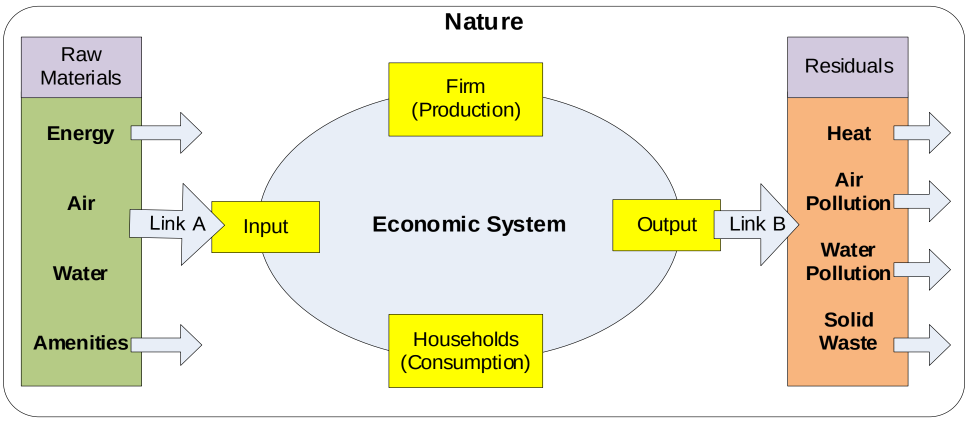

Figure 1.2 Roles of nature and economy
Source: (Tietenberg 2003) p. 17

First of all, nature gives the endowment which is the permanent provision for support economy such as energy, air, water, and other amenities. Secondly, all resources are the assets which owned by the Earth. The resources have economic values that countries own or control with the expectation that it will provide future benefits. Therefore, natural resource gives material to economy in the sense of raw material as an input in the production process. Lastly, nature also gets the residual from economic activities. Environment gives the natural treatment of waste, which are from the production and consumption, to the economy.

1.3 Environmental Economics and Its Fundamental Concepts

Environmental economics is the study of the allocation of resources which are limited. It also studies how consumers, businesses, organizations, governmental and non-governmental organizations decide to use the valuable resources and gain benefits of goods and services in order to meet the unlimited human needs. Additionally, environmental economics is concerned with the impact of the economy on the environment, the significance of the environment to the economy, and the appropriate way of regulating economic activity so that balance is achieved among environmental economics and other social goals. Environmental economics concerns with identifying and solving the problem of environmental damage, or pollution, associated with the flow of residuals from production and consumption. Its analysis concepts are determined both economic and environment simultaneously. Consequently, the free-market system can generate the "wrong" level of environmental quality. Resources are scarce and have alternative uses. That always creates the opportunity costs. Therefore, environmental protection costs some money. Economic growth may cause some environmental problems. From these reasons, the ideals of environmental economics get along with the sustainable development concept. Furthermore, environmental economics plays a critical role in shaping policies that aim to protect and enhance the environment while promoting economic well-being. It provides a framework for decision-makers to assess the economic implications of environmental choices and to develop strategies that lead to more sustainable and responsible resource management.

Environmental economics is a subfield of economics that focuses on the relationship between economic activities, human well-being, and the environment. It explores how economic decisions and policies impact the environment and seeks to develop strategies to address environmental issues while maintaining or improving overall economic welfare. Environmental economics combines economic principles with environmental sciences to analyze and solve environmental problems. In order to study of environmental economics, the uses of economic attitude and analysis through human activities are applied. Environmental economics also undertakes theoretical or empirical studies of the economic effects of national or local environmental policies. Understanding the basic theory of economics is important to apply economic principles to analyze environmental problems. Also, to understand the individual's development of decision making which affects environmental quality and natural resource uses. The understanding help decision makers decide which choice is the best solution and when several options are occurred. For example, according to the reasonable economics, the outcome is selected because its value is higher than the opportunity cost as well as to find the appropriate way to regulate economic activity, to identify the reasonable amount for natural resources use, and to achieve a balance between the society, environment and economy. In other words, it explores how to achieve long-term environmental and economic sustainability.

1.3.1 The roles of markets

Since resource allocation is an important obligation of economists, the significance of the market concept in economics lies in its central role as the mechanism through which goods, services, and resources are exchanged. Markets facilitate the interaction between buyers and sellers, enabling the allocation of resources. Understanding the market is crucial for economists as it provides insights into pricing, resource allocation, competition, and efficiency. Additionally, the study of markets helps economists analyze factors such as consumer behavior, production, and overall economic performance. Market definition is important. It can define who the actual and potential competitors are. It must also know the product boundaries and geographical boundaries of its market in order to set price, determine budgets, and investment decisions. Market definition can be important for public policy decisions. A market is the collection of buyers and sellers that, through their actual or potential interactions, determine the price of a product or set of products. Buyers include consumers, who purchase goods and services, and firms, which buy labor, capital, and materials that they use to produce goods and services. Sellers include firms, which sell their goods and services. It also defines as workers who sell their labor services; resource owners who rent land or sell resources to firms.

Markets make possible transactions between buyers and sellers. Quantities of a good are sold at specific prices. In a perfectly competitive market, a single price – the market price – well usually prevails. In an imperfectly competitive market, different firms might change different prices for the same product. When we refer to the market price, we will mean the price averaged across all products.

The objectives of the allocation are to achieve the efficient allocation (Efficiency) and the income distribution (Equity) in order to utilize using the resources and take advantage of the resources equally. Economists therefore have to provide and suggest the mechanisms for resource allocation.

Allocation Mechanisms

In the society, there are two extreme mechanisms for resource allocation which is completely opposite. There are price mechanisms – using a market mechanism to allocate resources and government mechanism – the allocation of the state (Government provides the allocation).

A. *Price Mechanisms*

The price mechanism can explain the three basic economic problems. First, what goods and services are produced? According to price mechanism, society will use of resources to produce the products which give the highest yield and leave the lower return products. Price mechanism can also sort the return on their investment activities in order to rank the worthiness of the projects including agriculture and industry so that manufacturers can decide what should be produced. Secondly, how the products are produced? This question concerns on issues of technology, pollution, and harvest techniques. Environmental economists concern on which technology discharge the least pollution while containing the lowest costs. According to price mechanism, the producers will choose the technology which provides lowest cost with the given factor endowment. They also consider the competitive advantage whether they are labor intensive, capital intensive or informative. Lastly, for whom to produced or who get things? Regarding to price mechanism, person who can get products is the one who has the purchasing power. Therefore, this question considers price allocation between rich and poor.

Adam Smith, the classical economist, believed in the Invisible hand. He additionally believed that the most satisfied (Maximize Utility) is a target of the individual or consumer. Therefore, when everyone can have maximized utility, the overall social welfare would be at the maximum point as well. So that in the way of price mechanism the government should not interfere since the resources are directed to move through the price mechanism. For example, the capital flows from low-yield industry to activities that have higher returns.

B. *Government Mechanism*

Government intervention can be done in several ways. The government has the power to legislate it in order to build up the mechanism and transfer of resources to meet the government requirements. Government can decide to transfer resources to the affairs of the government such as the manufacturer and the operators themselves. In this case, the government may use the resources to produce. Government can establish Department of Natural Resource and Environment in order to construction of pollution treatment plants and work as a Public Corporation. In some cases, government may not be a manufacturer itself, but do not want the competition because government considers that competition may result in loss of lots of resources. Thus the government may give the authority to any companies to produce the products. In this case, monopoly power is happening to private companies. A natural monopoly business is also the reason for the government to intervene such as the infrastructure service.

Besides, the resource allocation mechanism can reflect the economy system in any countries. For example, market capitalism is a socioeconomic system based on the use of a complete set of decentralized markets to allocate scarce resources, good and services. In pure capitalism, capital is also privately owned by individuals, and production and employment decisions are decentralized. Conversely, socialist systems in which allocation decisions are centralized in some level of community of government control. However, in fact the pure capitalism does not exist in present. For example, the United States' government, which represents the pure capitalism, continues to influence interest rates as well as provides educational services and health services to the poor and elderly. Also, ownership can reflect economy system. If there is private owned property, it is in the capitalism. If the country is the capitalist economic system, it is a state-owned.

Thus if we consider only the criteria for resource allocation, there is no country is extremely polarized or use one system alone. Presently, countries are placed between two economic systems. The method to the allocation the resources bases on a combination of a price mechanism and government mechanism.

Properties of a Well-Functioning Competitive Market

Competitive market should well-defined and enforceable private property rights to the resources, goods and services traded. A market institution made up of various rules governing how buyers and sellers interact and set prices. The absence of collusion among buyers and sellers will be occurred. There are no unpaid-for-benefits (Positive externalities) and uncompensated costs (Negative externalities) in the society. Transaction costs not too high and all agents have full information of goods and services. Quality, availability, pricing, and location of goods or services are fully known by all market participants. Additionally, there are possibilities to entry into the market in the long run by new firms. As a result, buyers can exhibit their willingness-to-pay (WTP) for a certain number of units of a good, and this willingness-to-pay reflects a combination of a preference for the goods and an ability to pay, which illustrated by demand curves. Sellers can also exhibit a willingness-to-supply (WTS) for a certain number of units of goods at a given price which illustrated by supply curves – the marginal cost curve. Then market is made up of a number of buyers and sellers. The role of an institution governing is examining how buyers and sellers communicate and trade. A well-functioning competitive market in equilibrium is efficient because price and quantity at the equilibrium is neither shortages nor surpluses. There is neither too much nor too little produced. Positive gains from trade are maximized at equilibrium and negative gains from trade occur for output levels beyond equilibrium because price is above the maximum buyers are willing to pay and below minimum sellers required.

In this case, the concept of efficiency should be applied to the society as a whole. The efficiency can be measured by comparing the willingness to pay for the additional unit of output with the marginal cost of that output. This is the optimal distribution of resources in society by taking into account all external costs and benefits as well as internal costs and benefits. Social efficiency occurs at an output where

Marginal Social Benefit (MSB) = Marginal Social Cost (MSC)

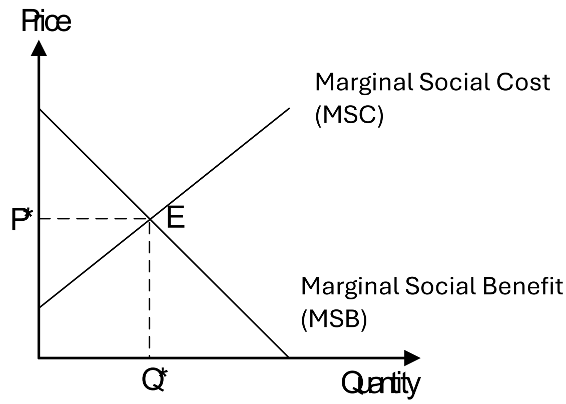

Figure 1.3 Graph shows the social efficiency rate of output

Social efficient rate of output is at point E, where MSB = MSC. Marginal Social Cost (MSC) refers to all the costs of producing a good must be included. Marginal Social Benefit (MSB) represents correctly all the value that the people in the society are really willing to pay in order to consume goods. Social efficient rate of output can be determined at the equality of MSB and MSC.

1.3.2 Fundamental concepts: Scarcity, opportunity cost, marginalism

Scarcity

The concept of scarcity is fundamental to economics and refers to the fundamental imbalance between unlimited human wants and the limited resources available to fulfill those wants. In other words, it's the idea that resources, including time, money, labor, and natural resources, are finite, while human desires and demands are virtually limitless. Scarcity leads to the need for individuals, businesses, and societies to make choices about how to allocate their limited resources among competing uses. Since resources are limited, people must prioritize and make trade-offs, deciding what to produce, how to produce it, and for whom to produce it.Scarcity is the driving force behind econom ic decision-making and the study of economics as a whole. It underlies concepts such as opportunity cost, which refers to the value of the next best alternative forgone when a choice is made. Economic systems and mechanisms, such as markets and prices, emerge in part as responses to the challenge of scarcity, helping to allocate resources efficiently through supply and demand dynamics.

In environmental economics, scarcity refers to the condition where the demand for environmental goods and services exceeds their limited availability. It acknowledges the finite nature of natural resources and the increasing pressures exerted by human activities on the environment. The concept of scarcity in environmental economics is closely tied to the idea that certain resources, such as clean air, water, and biodiversity, are not limitless and must be managed carefully to ensure sustainability. Environmental economists examine how scarcity influences decision-making regarding the use and conservation of natural resources. They analyze how market forces, regulatory frameworks, and human behavior interact in the context of limited environmental resources. Recognizing and addressing scarcity in environmental economics is crucial for developing policies and strategies that promote sustainable practices and balance the needs of current and future generations with the constraints of the natural environment.

Opportunity Cost

Opportunity cost is a critical concept of decision making in economics. It encourages individuals and entities to consider the potential benefits of all available options before making a choice. It refers to the value of the next best alternative forgone when a decision is made to allocate resources. It represents the benefits that could have been gained from choosing the next best alternative instead. The concept of opportunity cost in environmental economics is applied to the choices made in the use of environmental resources. Opportunity cost refers to the value of the next best alternative that must be forgone when a decision is made to allocate resources in a particular way. In the context of environmental economics, when a society or individual decides to use a specific environmental resource for a particular purpose (e.g., converting land for agriculture or using water for industrial processes), there is an opportunity cost associated with not using that resource for other potential uses. This might include alternative uses like preserving the land for biodiversity, maintaining water for ecological systems, or utilizing it for recreational purposes. Understanding the opportunity cost in environmental economics is essential for making informed decisions about resource allocation. Policymakers, businesses, and individuals need to consider the trade-offs involved in choosing one course of action over another, especially in the context of environmental conservation and sustainable resource management. Analyzing opportunity costs helps in evaluating the overall economic and environmental impacts of different choices and in making decisions that align with long-term sustainability goals.

Marginalism

Marginalism is a concept that is widely used in economics to analyze the incremental changes in a particular variable. It involves examining the additional cost or benefit associated with a small, incremental change in the quantity of a good, service, or activity. The basic idea of marginalism is that decisions are often made at the margin, meaning individuals and businesses consider the impact of small adjustments to their current situation. The marginal cost is the additional cost incurred by producing one more unit of a good or service, while the marginal benefit is the additional satisfaction or utility gained from consuming one more unit. Marginal analysis is employed in various economic contexts, including production, consumption, pricing, and resource allocation. It helps in determining the optimal level of output or consumption by comparing the marginal cost and marginal benefit. If the marginal benefit is greater than the marginal cost, it is generally considered beneficial to produce or consume more, and vice versa.

Additionally, the concept of marginalism is crucial in environmental economics because it helps policymakers, businesses, and individuals make decisions that optimize the allocation of resources. In particular, it involves evaluating whether the last unit of a resource or the last increment of a policy measure provides more benefits than costs. In environmental economics, marginalism refers to the analysis of the incremental or marginal changes in the use of environmental resources or the provision of environmental services. It involves examining the additional benefits and costs associated with small changes in resource use or environmental policies. For example, in the context of pollution control, environmental economists might assess the marginal abatement cost, which is the cost of reducing one additional unit of pollution. Similarly, they may examine the marginal benefits of conservation efforts, such as protecting an additional acre of natural habitat. By applying marginal analysis, environmental economists aim to find the balance where the marginal benefits equal the marginal costs, helping to determine efficient resource use and environmental management strategies. This approach contributes to making decisions that maximize overall welfare and promote sustainable use of environmental resources.

1.3.3 Basic economic models for sustainability analysis

Economy provides the activities such as production and consumption which use natural assets, consume raw materials and energy. Economy use directly of all types of natural assets by drawing upon raw materials to keep the system functioning. Production and consumption activities also produce leftover waste products which we call “residuals” as an output to the nature such as heat, air pollution, water pollution, and waste. Depending on how they are handled, theses residuals may lead to pollution or the degradation of the natural environment.

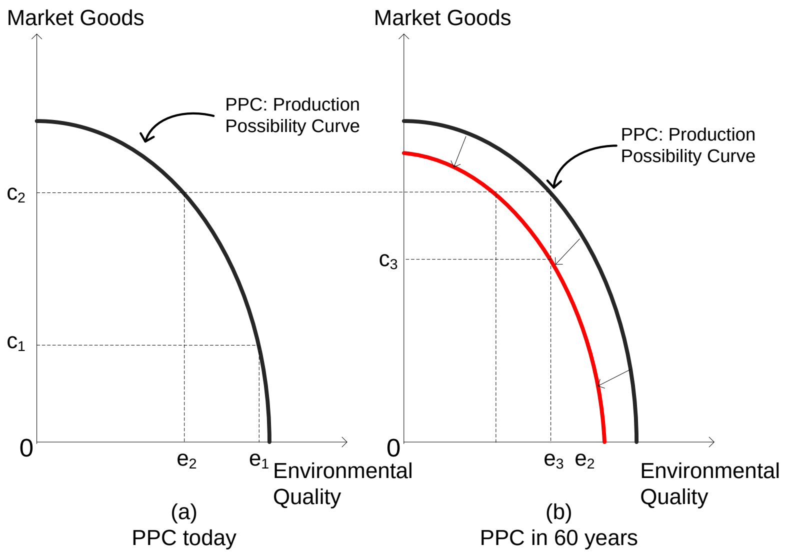

Figure 1.4 Production Possibility Curves for Current and Future Generations
Source: (Field & Field, 2002) p. 31

One good way of thinking about the environment is as an asset that produces important services for humans and nonhuman organisms. But the ability of the environment to produce these services can be degraded. In recent years the concept of sustainability has become popular as a criterion for evaluating decisions that have environmental implications. Sustainability is a matter of making decisions in the short run that does not have serious negative impacts in the long run. A way of thinking about this is in terms of a trade-off between conventional economic output and environmental quality. A trade-off this type is depicted in figure 1.3. Consider fist panel (a), this shows a production possibility curve (PPC), which is simply a curve showing the different combinations of two things a society may produce at any time, given its resources and technological capabilities. The vertical axis has an index of the aggregate output of an economy, that is, the total market value of conventional economic goods traded in the economy in a year. The horizontal axis has an index of environmental quality, derived from data on different dimension of the ambient environment. Therefore, the PPC shows the different combinations of these two outcomes – marketed output and environmental quality – that are available to a group of people who have a fixed endowment of resources and technology given at the time.

If the current level of economic output is c_1, and increase to c_2, it can be obtained only at the cost of decrease in environmental quality from e_1 to e_2. One major objective of any society is to change the production possibility curve so that the underlying trade-off is more favorable. If a society puts too much stress on increasing its output, it may end up at a point like (c_2, e_2). However, the true social welfare may be higher at a point like (c_1, e_1). One of the fundamental distinctions that can be made in environmental analysis and development of environmental policy is that between the short run and the long run. Panel (a) shows the trade-offs facing the current generation. Panel (b) shows the production possibility curves for people in 60 to 80 years (The generation consisting of your great grandchildren). According to panel (a), the present generation could choose combinations (c_1, e_1) or (c_2, e_2). However, the future is not independent of the choice made today. Therefore, if society degrades the environment too much today, it will affect future possibilities by depleting certain important resources. The future generation will find themselves on the inner production possibilities curve which can still have the same level of marketed output we have today (c_2), but only at a lower level of environmental quality than we have today (consume less than e_3). Otherwise, it could enjoy the same level of environmental quality, but only with a reduced level of marketed output (c_3).

Summary

Economics for sustainable development represents a paradigm shift in the way we conceive of and pursue progress. It recognizes that the well-being of humanity and the health of the planet are intertwined and that economic decisions have far-reaching consequences for the environment and society. The path to sustainable development is multifaceted, involving policies, regulations, business practices, and individual choices. While challenges remain, the opportunities presented by sustainability are significant. Innovation, market growth, public awareness, and collaboration offer the potential to create a more equitable, prosperous, and environmentally responsible world. Achieving sustainable development is not merely an aspiration goal; it is an imperative for addressing the pressing challenges of our time and securing a better future for generations to come.

As we continue to explore the principles and practices of economics for sustainable development, it is important to recognize that this concept is not only a matter of policy and economics but also a reflection of our values, priorities, and responsibilities to one another and to the planet. The evolution of sustainable development reflects the shared understanding that we must balance prosperity, equity, and environmental stewardship in our pursuit of a better world. It is a call to action that resonates across nations and generations, reminding us that we are all interconnected in the shared endeavor of creating a sustainable and thriving future. Economics for sustainable development is closely related to environmental economics which its ideas run through efficiency, optimality and sustainability. The field of environmental economics originates primarily from mainstream economics, with distinct foundations. Emphasizing the comprehension of market mechanisms and the identification of causes for market failures, particularly externalities, should be given priority.

Discussion questions

1. Does economic growth inevitably lead to environmental degradation and unsustainability?
2. Do you agree with this statement "Sustainable development seeks to improve the lot of the world's poor without reducing the capacity of the natural environment to deliver a diverse set of services to the global economy"? Discuss.
3. Do you think that individuals typically have enough information for it to make sense to have their preferences determine environmental policy?
4. Suppose there is a technological change that allows firms to produce goods with less pollution. How would this affect the production possibility curves? And how it benefits sustainable development?

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CHAPTER 2: MARKET FAILURES AND THE ENVIRONMENT

Classical microeconomic theory predicts and efficient outcome given certain assumptions about pricing, product definition, cost conditions, and entry barriers. If any of these assumptions fails to hold, market forces cannot operate freely. Depending on which assumption is violated, the result will be any of number of inefficient market condition, collectively term market failures. These include imperfect competition, imperfect information, public goods and externalities as mention above. Economists model environmental problems as market failures using either the theory of public goods or the theory of externalities. Each is distinguished by how the market is defined. If the market is defined as "environmental quality," the source of market failure is that environmental quality is a public good. If the market is defined as the good whose production or consumption generates environmental damage, then the market failure is due to an externality. Although each of these models suggests a different set of solution, the theories are not totally unrelated. In the context of environmental problems, both are exacerbated by another type of market failure, imperfect information. In this section, the chapter introduces the concepts and the economic theories which explain public goods, externalities, and information asymmetry.

2.1 Exploration of Market Failure

a. Public Goods

Public goods idea was first developed by Pual A. Samuelson. He wrote "the Pure Theory of Public Expenditure", "Review of Economics and Statistics" and "Review of Diagrammatic Exposition of a Theory of Public Expenditure". Economists distinguish public goods from private goods by examining their inherent characteristics – not by whether they are publicly or privately provided.

1.1.1 Definition

There are many definitions of public goods as follows:

"Goods and services have two characteristics. They are nonexclusive and nonrival good: the marginal cost of provision to an additional consumer is zero and people cannot be excluded from consuming it[1]".

"Public goods exhibit neither rivalry nor excludability. The example given is the services of the national defense force. Whatever level that it is provided at is the same for all citizens of the national. There are no discrete units, entitlement to which can be traded. One citizen's consumption is not rival to, at the cost of, that of others, and no citizen can be excluded from consumption[2]". This term is used to describe whatever it is that governments provide, from streetlights to defense to a system of courts. Economists, however, use the term public goods in a more precise sense to describe goods that have two key characteristics which are nonrivalry in consumption and nonexcludability. These two characteristics must both be present in significant degree for something to qualify as a public good[3]".

1.1.2 Public Goods' Characteristics

In order to distinguish public and private goods, economists characterized by two key features: non-excludability and non-rivalry.

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[1] Robert S. Pindyck and Daniel L. Rubinfeld. Microecnomics, Seventh Edition, Pearson International Edition, 2009
[2] Roger Perman, Yue ma, Michael Common, Devid Maddison, and James McGilvray, Natural Resource and Environmental Economics, Forth Edition, Pearson Education, 2011
[3] Ulbrich, Holley H. Public Finance in Theory & Practice, First Edition, Thomson South-Western, 2003

A. *Non-rivalness*

Non-rivalry means that consumption of the good by one individual does not reduce availability of the good for consumption by others. A good that is nonrival in consumption can be consumed by any number of people simultaneously, without diminishing the amount available to be consumed by other. On other words, non-rivalness refers to the notion that the benefits associated with consumption are indivisible. For example, the sunlight is a pure public goods. Assumed there are 4 persons: Mr. A, Mr. B, Mr. C and Mr. D. All of them consume sunlight. If Mr. A consumes a brightness of sunlight, Mr. B, Mr. C and Mr. D can consume a brightness of sunlight without the diminishing of light. On the other hands, assume that there are 2 bowls of rice and rice is a private good, if Mr. A consumes a bowl of rice, then there will be just another bowls of rice that can be consumed by others. Otherwise, if Mr. A consumes 2 bowls of rice, then there is no rice for others. Consumptions of goods X of Mr. A equal to the consumption of goods X of Mr. B, Mr. C and Mr. D.

$$X_A = X_B = X_C = X_D$$

The marginal cost (MC) of another individual sharing in the consumption of the good is zero. For example, the network television broadcast of football championship. The benefits to the existing television audience are completely unaffectly when another person tunes into view the broadcast. There are also "public bads" which is the environmental deterioration, or crime that makes large areas unsafe. Therefore, the public activities of government can be viewed not so much as the provision of public goods, but as the elimination of public bads. Nonetheless, the elimination or reduction in a public bad can be defined as a public goods. Improved environmental quality, neighborhood revitalization, and increase public safety would be the obverse of the public bads. Noticeably, the idea of how consumers determined the public goods' values is also important. However, non-rivalness does not imply that all consumers have equal values on public goods. While all individuals may consume the same quantity of the good, it does not necessarily mean that its value is universally perceived. Instead, consumption is shared in a noncompetitive manner. For instance, the shared apartment with multiple roommates is exhibiting public good characteristics. The cleanliness of the bathroom benefits everyone, and excluding anyone from these advantages is difficult. However, some roommates may prioritize cleanliness more than others. Similarly, in the defense example, people who are deeply concerned about the intention of hostile foreigners place a higher value on national defense than people who feel relatively safe. Other instances of nonrival goods include public services such as garbage pickup and early childhood education.

Consider air quality improvement initiatives in a city. Suppose the local government implements measures to reduce air pollution, such as stricter emission standards for vehicles and industries, promoting cleaner energy sources, and creating green spaces. As a result, the overall air quality in the city improves benefit all consumers in the city while. Consumers with health problems may values the clean air more than others

B. *Non – excludablility*

Non-excludability means that no one can be effectively excluded from using the good. This term describes the inability to keep people from consuming the goods or services. Since it is difficult to locate and collect payment from all those who benefit. In the sense of private goods consumption, individual has to pay for consuming the goods. He will have a right and full authority to use or consume the goods and can exclude them from others. In other words, non – excludable goods are goods that, once produced, are difficult to keep people from consuming without paying for them. Price can prevent others from sharing in the benefits of a goods' consumption are not possible. An example of a good with this characteristic is a public park. A public park with a beautiful, scenic view. The Park is accessible to the public, and anyone can enter and enjoy the view without facing any direct charges or exclusionary measures.

Thus, excludability consider on whether the price mechanism works, but rivalry consider the amount of consumption among consumers. We conclude that public goods have character of joint consumption and equal consumption. Although non-rivalness and non-excludability may seem similar, they are not identical. A good way to distinguish them is: Non-rivalness means that rationing of the good is not desirable, whereas non-excludability means rationing of the good is not feasible. Although a televised football game is a nonrival good, it can be made excludable by broadcasting it over a cable network only to subscribers who have paid for it. Similarly, while the creation of a jogging path that is non-excludable avoids prohibitively high costs, it lacks the non-rivalry characteristic. As the number of runners using the path increases, congestion could ensue, impacting the experience of every individual utilizing the jogging path.

1.1.3 Types of Goods

The study of types of goods clearly identifies the nature of goods and services how price mechanism affects the goods and why it does or does not work. From the characters of public goods, we can categorize goods into four main types as follows.

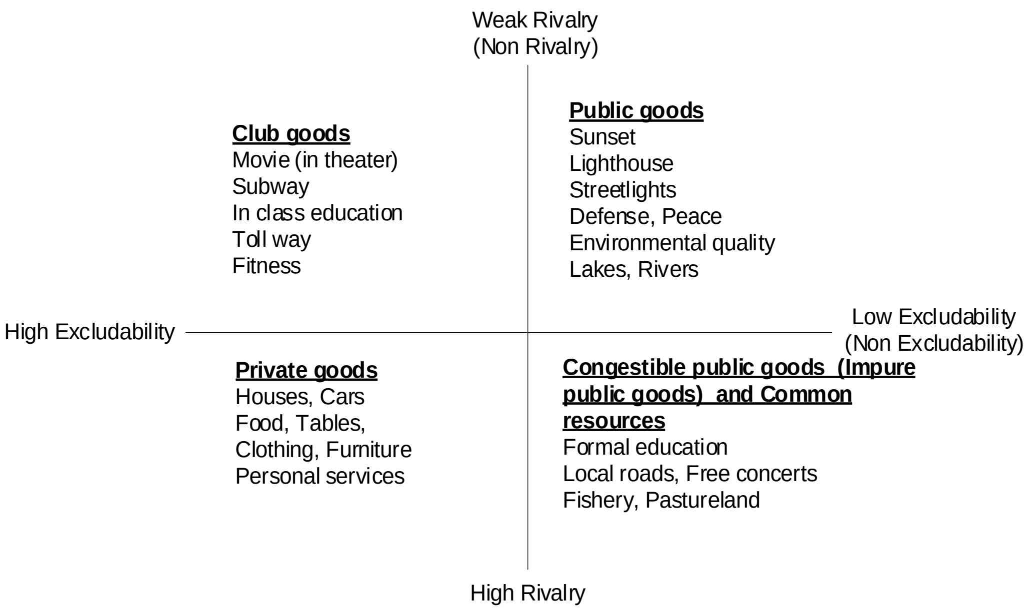

Figure 2.1 Table shows the different types of public goods

A. *<u>Pure public goods: non excludability and non rivalry</u>*

Goods and services in which one person's consumption is not diminished by sharing it with another and where exclusion is difficult or costly are clearly public goods. Peace is one of the good examples of pure public goods. It is non-excludability and non-rivalry. No one own peace but everyone needs peace and enjoy if there is peace in the world. However, no one wants to pay for peace but wants to consume. This create free rider problem. Nowadays, United Nation (UN) pays for peace. A few developed countries support all expenses of UN but they also haggle to pay because they think this is not their obligation.

B. *Club goods: non rivalry but excludability*

In class education is the sample of club goods. The students who register can exclude other students from studying in class but any students in class cannot rival other students who also are in class from getting the knowledge from the class. The movies in cinema and indoor concerts are also the samples of the same case as in class education. This kind of goods is a jointly consumed by club members or residents but easily kept from non-members or non-residents. The goods can be congestible. It is non rivalry in consumption until capacity is approached. Once that point is reached, competition for parking spaces and seats on the subway makes congestible goods rival in consumption. Then they become private goods (with excludability and rivalry)

C. *Congestible Public Goods (Impure public goods) and common resources: rivalry but non excludability*

Price mechanism does not work for this type of goods. The goods are provided by public sector as free goods such as local road, park, and formal education. Thus, they are non excludability but rivalry by the congestible situation. Since limited space of the road during peak time, cars cannot access to the road.

Additionally, common resources, also known as common-pool resources, are goods or systems that are rivalrous but non-excludable. This means that multiple individuals or groups can consume or use the resource, but the consumption by one party diminishes its availability for others. Examples of common resources include fishery, pastureland, and wildlife in forest. The oceans are a common resource for fishing. Fish populations are rivalrous because the catch by one fisherman reduces the number of fish available for others. However, it is difficult to exclude fishermen from accessing fishing grounds in open seas.

D. *Private goods: rivalry and excludability*

The goods and services with high rivalry and excludability. It is feasible and practical to exclude individuals or consumers who have not paid for the good from enjoying its benefits. Also, the consumption of the good by one individual reduces the amount available for others. For example, If you buy a shirt, you can exclude others from using it, and your use of the shirt diminishes its availability for others. Ownership of a car allows you to exclude others from using it, and the use of the car by one person at a given time reduces its availability for others. Indeed, classification of the public good is not an absolute. It depends on market conditions and the technology. For example, one ship can take advantage of the lighthouse without impinging on another ship's ability to do the same. Also, no particular vessel can be excluded from taking advantage of the signal. Under these conditions, the lighthouse is a pure public good. Yet, suppose that a jamming device were invented that made it possible to prevent ships from obtaining the lighthouse signal unless they purchased a special receiver. In this case, the lighthouse is no longer a pure public good and becomes club goods instead.

In many cases, it makes sense to think of publicness as a matter of degree. A pure public good satisfies the definition exactly. Consumption of impure public goods is to some extent rival or excludable. There are not many examples of pure public goods. However, just as analysis of pure competition yields important insights into the operation of actual markets, so the analysis of pure public goods helps us to understand problems confronting public decision makers. In addition, some things that are not conventionally thought of as commodities have public good characteristics such as honesty and income distribution. Honesty in commercial transactions benefits to all of society due to lower cost of business. Cost reductions are both non-excludable and non-rivalness. Income distribution is also a public good. If income is distributed fairly, each person gains satisfaction from living in a good society, and no one can be excluded from having that satisfaction. Of course, because of disagreements over notions of fairness, people may differ over how a given income distribution should be valued. However, consumption of the income distribution is non-rivalness and non-excludable.

1.1.4 Modeling Public Goods Market for Environmental Quality

Public goods generate a market failure because the non-rivalness and non-excludabiliy characteristics prevent natural market incentives from achieving an allocatively efficient outcome. In this part, we reintroduce the supply and demand model but redefine the market as the public good such as air quality.

A. *Allocative efficiency in a public good market*

What is the efficient amount of public goods? This is the question that we have to answer in order to decide how many units of public goods should be provided. If we examine the private goods, we know that the market is in equilibrium when supply and demand are equal. Firms will produce according to the equilibrium of the market. In public good market depends on the existence of well-defined supply and demand functions. To develop these functions for air quality, we adjust the market definition so that output can be quantified. Air quality can be defined as "an acceptable level of pollution abatement," which for this discussion is assumed to be some percentage reduction in carbon dioxide (CO_2) emissions.

B. *Market supply for air quality*

Normally, government decides the supply of public goods. It determines the production level, as opposed to those of private firm. In this case, we assume that there is some number of hypothetical producers, each of which is willing and able to supply various reductions in CO2 at different price levels. Quantity supplied is measured as a percentage of CO2 abatement. The market supply function is:

$$P = 4 + 0.75\ Qs$$

Quantity Supplied (% of CO2 abatement)	Market Supply Price (baht)
0	4.00
5	7.75
10	11.50
15	15.25
20	19.00
25	22.75
30	26.50

On other words, the supply can be represented by marginal cost of production. The marginal cost increases when the abatement activities increase. For example, if government wants to abate CO2 5 percent the cost of production is 7.75 baht per unit while it costs 11.50 baht per unit if abating at 10 percent.

C. *Market Demand for Air Quality*

The private market demand is the summation (horizontal summation) of individuals' demands. In other words, the total amounts of production will equal to the units of the first person's consumption plus the units of second person's consumption and so forth until the units of all consumers are added up. Individuals' demands are derived by maximizing utilities subject to budget constraint where

$$MRS_{xu}^{A} = MRS_{xy}^{B} = \frac{P_x}{P_y}$$

$$MRS_{xu}^{A} = MRS_{xy}^{B} = MRT_{xy}$$

These equations are the necessary condition for Pareto efficiency. As long as the market is competitive and functions properly, the First Welfare Theorem guarantees that this condition holds. However, the conditions of public goods are different. The A's enjoyment of fireworks does not diminish B's and vice versa, and it is impossible for one person to exclude the other from watching the display. Individuals prefer bigger to smaller display. Each unit produced can be consumed by all consumers equally. Therefore, the total value of the public goods is the value placed on it by the first consumer plus the value placed on it by the second consumer, and so forth until the values of all viewers are added up.

The market demand for public goods is found by vertically summing the demands of individual to determine the price at each and every market quantity. Once the public goods are provided, it is available at the same quantity to all consumers which a direct consequence of the non-rivalness characteristic.The relevant question in deriving this demand must be, “What price would you be willing to pay for each quantity?” These express derive of willingness to pay (WTP) for the public good based on the benefits each expects from the consumption. In this case, we consider only 2 consumers. We will ask them how much each would be willing to pay each year for various amounts of CO2 abatement. Then it can result the demand equations, which are expressed in inverse from to signify the price is the decision variable as follows:

Demand for Consumer 1: $P_1 = 10 - 0.12Qd$

Demand for Consumer 2: $P_2 = 15 - 0.18Qd$

Market Demand for Public Goods: $P = 25 - 0.30Qd$

Quantity Demanded (% of CO2 abatement)	Consumer 1’ WTP	Consumer 2’ WTP	Market Demand Price (baht)
0	10.00	15.00	25.00
5	9.40	14.10	23.50
10	8.80	13.20	22.00
15	8.20	12.30	20.50
20	7.60	11.40	19.00
25	7.00	10.50	17.50

For example, for a 5 percent reduction of CO2, consumer 1 willing to pay 9.40 baht while consumer 2 willing to pay 14.10 baht. Different consumers are willing to pay different amount of money depending on their benefits from the reduction.

D. *<u>Equilibrium in the Air Quality Market</u>*

The demand can be curved as shown in figure 2.2. The demand curve combines the consumption decisions of 2 consumers for air quality. For any quantity on this curve, the corresponding price is equal to the vertical sum of the individual price responses for that same quantity as given on curves D1 and D2. Like the equilibrium in private good market, the equilibrium condition is “market demand equal market supply at the equilibrium point”. Therefore, the algebraically solving is

Market Supply = Market Demand

$4 + 0.75Qs = 25 - 0.30Qd$

Thus, quantity at the equilibrium is 20 percent and price at equilibrium point is 19 baht. This is the market-based solution to environment pollution. As show in figure 2.2, it represents the efficient or optimal level of abatement measured from left to right and implicitly the optimal level of pollution measured from right to left. This equilibrium point represents an allocatively efficient solution. Qe implies the optimal level of abatement. As the model suggests, this optimal level is not necessarily zero.

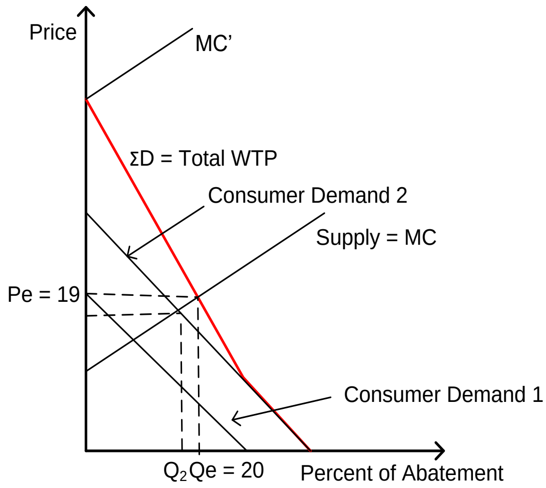

Figure 2.2 Graph show the market equilibrium of air quality

From abating at the 100 percent level to reduce pollution to zero involves prohibitive opportunity costs. These include the forgone production and consumption of any goods creating pollution. Therefore, the zero-pollution world would be without electricity, and all manufactured products. It makes little sense to argue for the elimination of all pollution in our environment.

From graph, if the marginal cost of producing the good last unit provided (the sum of the MRS) equal the incremental cost to society of providing it (MRT). The marginal social value is given by MC, then the optimal amount of the good to produce is determined by the point at which the marginal social cost o f production equals the marginal social value of the output, which is the same whether this is a private good or a public good. Thus, the efficient quantity is found where total willingness to pay intersects the supply curve. Since everybody must consume the same amount of the public good, its efficient provision requires that the total valuation they place on the of the output is given by ΣD (derived by vertically summing individuals' demand curves), so the point at which MC = ΣD yields Qe as the optimal amount of the good (abatement of air quality) to be produced which equal 20 percent in the graph. Noticeably, if consumer 1 does not express his preference on the good, the total demand which reflect the total value of the good will be equal to demand of consumer 2. Then the production level will be at D2 = MC which underproduction. Nonetheless, consumer 1 can enjoy consuming the public good at the same amount as consumer 2 (Q2) since consumer 2 cannot exclude and rival consumer 1 from consuming the good. In this case, a free rider problem is occurred.

Yet, if this good is so expensive to produce (the MC shift to MC') that no person should be willing to purchase even one unit of the good individually because the marginal cost of the first unit is above all the individual demand curve. But if all individuals share in the expense, they can all benefit. How they should share the costs? One obvious way would be for the costs to be split equally among the users.

E. *<u>Free rider problem</u>*

As we mention above, the achievement of an allocatively efficient outcome is a public goods markets depends on the identification of well-defined demand and supply functions. Although we developed both functions for our market for air quality, market demand was identified only because we implicitly made one critical assumption that consumers would reveals their willingness to pay for CO_2 abatement. However, without the third-party intervention, the non-excludability of this or any public good makes it difficult, if not impossible, to ascertain such information. If consumers' WTP responses are unknown, market demand cannot be identified, and an efficient outcome cannot be obtained. It is precisely the inability of free markets to capture the WTP for a public good that causes the market failure. If we drop the conventional assumption of perfect information, adding more realism to the model, the identification of market demand becomes even more obscure. In many public goods markets, consumers are not fully aware of the benefits associated with consumption. This is certainly the case for environmental quality. Most people are not aware of all the health, recreational, and aesthetic benefits associated with pollution abatement. So even if consumers could be induced to express their WTP for a cleaner environment, it is highly likely that the resulting demand price would underestimate the true benefits. This added complication is due to imperfect information, which is another source of market failure.

Public goods provide a very important example of market failure, in which market-like behavior of individual gain-seeking does not produce efficient results. The production of public goods results in positive externalities which are not remunerated. If private organizations don't reap all the benefits of a public good which they have produced, their incentives to produce it voluntarily might be insufficient. Consumers can take advantage of public goods without contributing sufficiently to their creation. This is called the free rider problem, or occasionally, the "easy rider problem" (because consumer's contributions will be small but non-zero). The free rider problem depends on a conception of the human being as homo economicus (purely rational and also purely selfish) or extremely individualistic, considering only those benefits and costs that directly affect him or her. Public goods give such a person an incentive to be a free-rider. For example, consider national defense, a standard example of a pure public good. Suppose homo economicus thinks about exerting some extra effort to defend the nation. The benefits to the individual of this effort would be very low, since the benefits would be distributed among all of the millions of other people in the country. There is also a very high possibility that he or she could get injured or killed during the course of his or her military service. On the other hand, the free rider knows that he or she cannot be excluded from the benefits of national defense, regardless of whether he or she contributes to it. There is also no way that these benefits can be split up and distributed as individual parcels to people. The free rider would not voluntarily exert any extra effort, unless there is some inherent pleasure or material reward for doing so (for example, money paid by the government, as with an all-volunteer army or mercenaries). In the case of information goods, an inventor of a new product may benefit all of society, but hardly anyone is willing to pay for the invention if they can benefit from it for free.

b. Externalities

An externality is a cost or benefit not transmitted through prices that is incurred by a party who did not agree to the action causing the cost or benefit. It is something that, while it does not monetarily affect the producer of a good, does influence the standard of living of society as a whole. Externality sometimes is called as external effect, spillover effect, third party effect and the neighborhood effect. Externality also is another reason to support the government to intervene in the economy, like public goods as mentioned in previous chapters. By the way, intervention is not necessary that the state must make its own.

i. Definition

An externality is a concept in economics that refers to the unintended side effects or consequences of an economic activity that affect third parties who are not directly involved in the activity. Externalities can be either positive or negative and arise when the actions of producers or consumers have spillover effects on others, leading to consequences that are not reflected in the market price.

ii. The Nature of Externalities

It may be caused by any consumption or production. The externalities (benefits) of consumption, such as education, do not fall for students only but benefits fall on society. Otherwise, externalities (costs) of consumption, such as smoking, do not fall on smokers, but costs would cause an impact on other parties. There are externalities from production such as waste materials, air pollution and water pollution. Externalities can be unilateral or reciprocal. For example, in case of smoking – the negative effects disturb people living nearby the person who performed such the externalities. Sometimes negative effects have two directions. The effects cost both victim and offender such as the case of common property. For instance, the cutting down of forests, where the common property is applied, affects the whole ecosystem and the environment. As a result, this activity affects both the one who cuts and other who do not cut down the forests. Externalities can be positive or negative. Positive effect will increase other's utilities such as planting flowers in front of the house. Negative effect will cause the opposite way. It will decrease other's utilities such as discharging waste, water pollution, and air pollution. Externalities have characters of public goods. Environmental externalities are those affecting air, water, or land, all of which have public goods characteristics. Therefore, although public goods and externalities are not the same concept, they are closely related. In fact, if the externality affects a broad segment of society and if its effects are non – rivalness and non – excludable, the externality is itself a public good. Technically, if the externality provides benefits to a large component of society, it is a public good. However, if it has negative effects, the externality is a public bad. For example, greenhouse effect is international public goods. It is non – rivalness and non – excludability. The effects of greenhouse fall on everyone and it does not have less impact to others.

iii. Costs and Benefits Comparison Model for Externality

In the analysis, the rational consumers always compare their costs and benefits in order to reflect demand and supply. Supply implies the costs and demand reflects benefits from consumption.

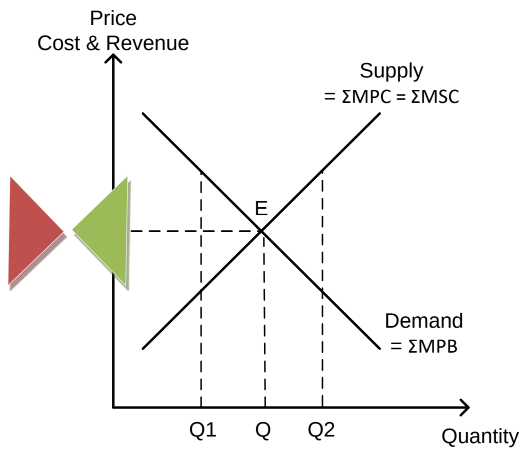

Figure 2.3 Graph show the comparison of consumption's costs and benefits

In this case, we assume the individual's supply curve equals the social supply. Positive externality does not cause adverse effects (no costs to the society). Then Marginal Private Cost (MPC) equals Marginal Social Cost (MSC). Consumers will have a utility maximizing when Marginal Private Benefit (MPB) = Marginal Private Cost (MPC). At the equilibrium point, consumer decides to consume at Q and the price is at P.

If the consumer consumes more than Q such as at Q2, the costs are more than benefits at this level of consumption. Consequently, the consumer will not consume. The consumer loses equal to the green area. Thus, he will reduce his consumption until costs equal benefits or he will reduce his consumption until the consumption level equal Q. If the consumer consumes less than Q such as at Q1, the costs are less than benefits. Therefore, the consumer can increase his consumption in order to get more benefits until costs equal benefits or he will increase his consumption until the consumption level equal Q. The additional benefits from increasing consumption equal the red area.

As consumers increase their consumption in order to enhance the utility, we can say that the equilibrium is at point E, where P is the equilibrium price and equilibrium quantity is Q.

iv. Types of Externalities

As mention above, externalities can be positive or negative. Economics studies two types of externalities

A. *Positive externality*

A positive externality is something that benefits society. We assume that the production does not cause social costs, and it has affected the positive to consumers and other community. Examples of positive externalities are environmental clean-up, vaccine treatment, establishing bee farming near by the flower garden and research. A cleaner environment certainly benefits society, but does not increase profits for the company responsible for it. Likewise, research and new technological developments create gains on which the company responsible for them cannot fully capitalize. A merit good is a product that society values and judges that everyone should have regardless of whether an individual wants them. It was judged to be worth more than their value according to the market. Thus, this kind of goods creates high positive externality. In this sense, it may be under-supplied in proportion to their perceived value if left to private enterprise, and are sometimes provided by governments or nonprofit organizations. The government is normally acting paternally in providing merit goods and services. They believe that individuals may not act in their own best interest in part because of imperfect information about the benefits that can be derived. Good examples of merit goods include health services, education, work training programs, and public libraries. In this case, government needs to stimulate an increase in the demand for an increase in consumption in order to stimulate growth of external benefit.

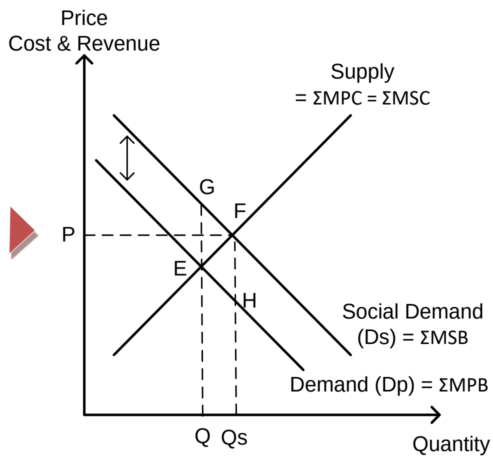

Figure 2.4 Graph show the positive externality analysis

In this case, MPC = MSC, but MPB ≠ MSB. From the graph, if we let the price mechanism works, consumer will assess the level of consumption by considering only Marginal Private Benefit. The consumer chooses to consume at the point E, where MPC = MPB. Consumption equals Q and price is P, which is considered as consumption is lower than the equilibrium of society. The consumption level is less than the social optimum output. In the case of positive externality, the social demand is greater than the demand for personal (MPB ≠ MSB). The social demand is Ds and private demand is Ds. The differences between these two demands reflect an external benefit or benefits that fall on others in the social. Thus, if we concern on the social optimal, the equilibrium should be at point F where MSC = MSB which is the Pareto Optimality. The society can increase benefits by increase the consumption from Q to Qs. The additionally benefit equal the red triangle. Some people will not see the benefits of positive externality, so consumers may not make the Social Optimum Output Level. If a person does not increases consumption of the Q to Qs, government must intervene in order to stimulate consumption at the MSC = MPB.

From the graph, it can be measured external benefit from the difference in the vertical dimension. In other words, the external benefit equals the distance between the Ds and Dp. At Q, the marginal private benefit (MPB) = distance between Q and E (QE), and positive externalities is defined as EG. Thus, if the consumer decides to consume at Q, the MPB is lower than MSB and the consumption level less than the Social Optimum Output. Therefore, government must intervene in order to increase consumption to the Qs. To increase consumption to this point, social welfare increase equal the area of Δ GEF (red area). Increasing consumption from Q to Qs, causes increasing in MPB = QEHQs and increasing in external benefit = EHFG while increase MPC/ MSC equal to QEFQs (MPC = MPS). Then we can conclude that

MPB + External Benefit – MPC = Net Social Welfare

(+) (+) (–) = (+)

QEHQs + EHFG – QEFQs = Δ GEF

B. Negative Externality

A negative externality is something that does not cost the producer, but it is costly to society in general. Negative externalities, unfortunately, are much more common. Pollution is a very common negative externality. A company that pollutes loses no money in doing so, but society must pay heavily to take care of the pollution problems. The problem which is created is that companies do not fully measure the economic costs of their actions. They do not have to subtract these costs from their revenues, which mean that profits inaccurately portray the company's actions as positive. This can lead to inefficiency in the allocation of resources. The samples of negative externalities to society are wastewater discharge, air pollution, and noise. Assume that there is no external benefit equal. Consequently, the marginal social benefit equals marginal private benefit (MSB = MPB). However, the consumption of goods or products causes external cost to society. In other words, it harms others in society.

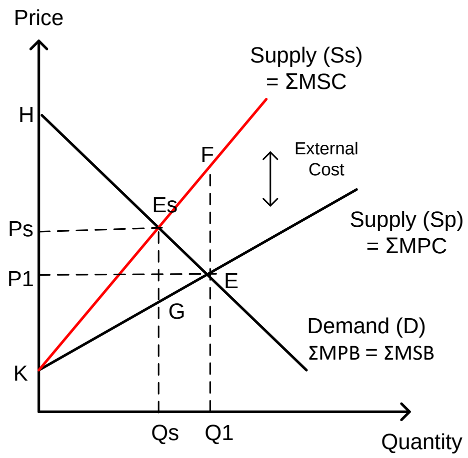

Figure 2.5 Graph show the negative externality analysis

According to the figure 2.5, if we let the producer decides the production level, he does not include the cost to society in the cost of production. He will produce at point E where the marginal private benefit equal to the marginal private cost (MPB = MPC). At this point, the production volume in the market is equal to Q1 and the price is P1. The production level is overproduction. This activity causes negative effects to other people in society as negative externalities. It creates external cost such as pollution which equals the distance between the social supply (Ss) and private supply (Sp). The social equilibrium is Es, where the marginal social benefit equals marginal social cost. At this point, the optimal level of production is Qs and the price is Ps. At Q1, society loss equals the external cost (Δ KEF), but society also benefits from the consumption and production as represented by consumer's surplus and producer's surplus. At this point, the consumer's surplus is area HEP1 and producer's surplus is area KEP1. Thus, the social welfare is HEP1 + KEP1 – KEF, or equivalent to area HEsK – EsEF. The result still needs to discuss. If HEsK is greater than EsEF, the society still gains while if the HEsk is less than EsEF, the society gets loss. Considering the social equilibrium where allocative efficiency occurs. The output level will be at point Es where marginal social benefit equals marginal social cost (MSB = MSC). The production level decrease from Q1 to Qs. The decreasing of output reduces the external cost equal area EFEsG. Also, this creates change in overall social welfare. The producer's surplus and consumer's surplus decrease equal area GEEs. As a results, the net change in social welfare is EFEsG – GEEs = area EsEF, which considers as a gain due to the reducing of the production.

v. Modeling Environmental Damage as A Negative Externality

In this section, we develop a formal model of a negative environmental externality. We elect to model a production externality because this approach defines the most prevalent source of environment pollution. The example that we define in this case is a coal electricity plant. This is a fitting choice, because the plants are major air pollution. To avoid complicating analysis with the market failure of imperfect competition, we assume that the private market for produce electricity by coal is competitive. At the plant level, supply and demand are

Supply (MPC): $P = 20 + 0.075Q$
Demand (MPB): $P = 40 – 0.125 Q$

where Q is measure in million mega watt per day and P is the price per unit.

Supply reflects the marginal costs of production and demand represents the marginal benefits of consumption. In the plant level, the decision based on private interest. Therefore, the plant defines their marginal private cost (MPC) of production equal to supply while ignoring the external cost of cleaning the air. Also, the demand is marginal private benefit (MPB).

The decision making for production is at MPB = MPC (D = S)

$$40 - 0.125\,Q = 20 + 0.075Q$$
$$Q = 100$$
$$P = 27.5$$

The equilibrium occurs at the intersection of MPB and MPC where Q = 100 million mega watt and price is 27.5 baht per unit. However, this point ignores the external cost to society of cleaning air caused by electricity production because the market mechanism motivates firms to satisfy their own interests, not the society. In other words, this point is allocative inefficiency. The efficiency requires the marginal benefits equal to all marginal costs of production. In this case, the MPC is undervalued the opportunity costs of production, and resulting output level is too high.

Assume that the marginal external cost (MEC) is MEC = 0.05Q. The MEC is the results from air pollution. Increasing production rise the MEC at the constant rate. To achieve allocative efficiency, we have to reconsider the cost of production which the additional of marginal private cost and marginal external cost.

Marginal social cost (MSC) = MPC + MEC
$= 20 + 0.075Q + 0.05Q$
$= 20 + 0.125Q$

As you see, the MSC is above MPC. On the demand side, assume that there is no external benefit from the production, so the marginal private benefits (MPB) equals marginal social benefits (MSB). Then the efficient equilibrium must be set as

$$MSB = MSC$$
$$40 - 0.125\,Q = 20 + 0.125Q$$
$$Q = 80$$
$$P = 30$$

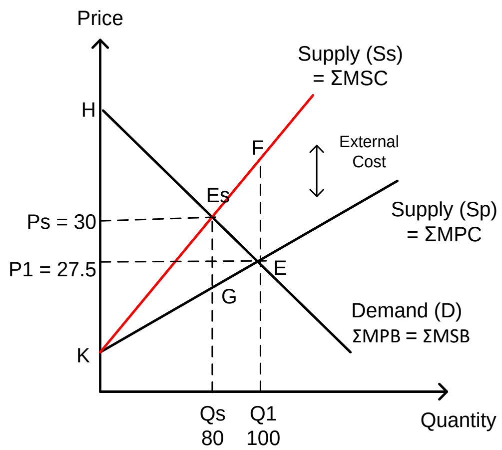

Figure 2.6 Graph show the negative externality analysis

From the figure 2.6, at Q1, MSB is below MSC. This signifies that society is giving up more in scarce resources to produce electricity than it gains in benefits from consuming it. To restore the equality of MSB = MSC, signifying allocative efficiency, output must be decreased – precisely what is predicted by theory.

vi. Possible Solution

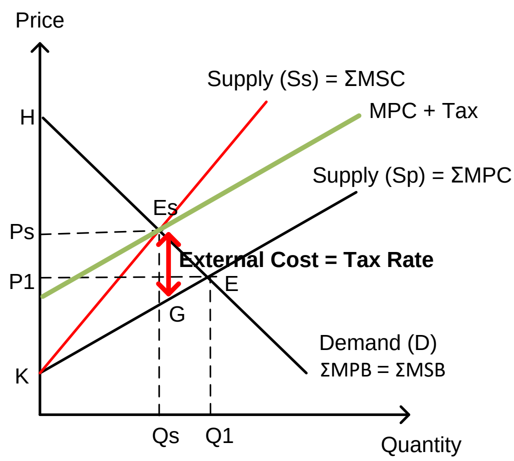

Figure 2.7 Graph show the Pigouvian tax in case of negative externality

A Pigouvian tax is a tax levied to correct the negative externalities of a market activity. The taxes are named after economist Arthur Pigou who also developed the concept of economic externalities. Figure 2.7 present the diagram of the working Pigouvian tax. As you can see, the tax shifts the marginal private cost curve (MPC) up by the amount of the tax to MPC + Tax. Therefore, the firm faces the cost increasing; the producers have an incentive to reduce output to the socially optimum level. The firm reduces production from Q1 to Qs. At this level, the marginal externality is also reduced, so the effect of the negative externality will be mitigate. A key difficulty with Pigouvian tax is calculating what level of tax will counterbalance the negative externality. The tax is considered one of the traditional means of bringing a modicum of market forces, and thus better market efficiency, to economic situation where externality problems exist. For the opposite case, the Pigouvian theory can be encourage the particular behaviors by subsidizing as we call "Pigouvian subsidy". The subsidy can support the positive externality activities. For instance donating to socially beneficial non-profits or installing solar panels to avoid pollution. The motivation for such a subsidy is trying to reach economic efficiency. When positive externality is present, a firm's solution of its utility maximization problem does not account for the additional utility produced as a by-product. Thus, this causes the firm to produce less than the Parato efficient level. The subsidy internalizes the externality into the agent's utility function, by giving the firm incentive to produce more than it otherwise would.

c. Information asymmetry

Asymmetric information refers to the fact that the buyer and the seller of a commodity may have different amounts of information about that commodity's attributes. As consumers have imperfect information to assess the utility, the decision of consumption is inaccurate. Therefore, consumers may over-consumption of the bads. In other words, asymmetric information is the situation in which a buyer and a seller possess different information about a transaction. This information asymmetry can lead to various challenges and outcomes that may not be optimal for both parties. Adverse selection and moral hazard are also the examples of the information asymmetry. Adverse selection occurs when the party with less information is more likely to engage in a transaction, leading to a situation where the quality of the goods or services being exchanged is lower than expected. This can result in an unfavorable outcome for the less-informed party. Moral hazard arises when one party, typically after a transaction has occurred, takes risks or behaves in a way that the other party did not anticipate or would not have agreed to if they had known about it. This can occur in financial transactions, insurance contracts, or employment relationships.

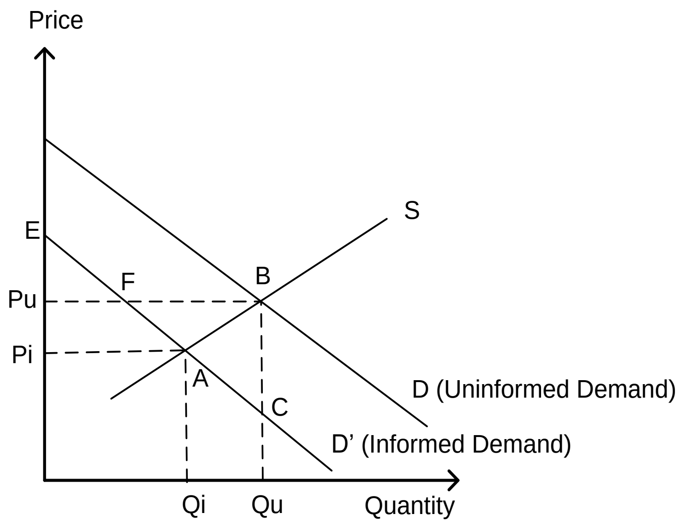

Figure 2.8 Graph show the asymmetry information between producers and consumers

From the figure 2.8, D and D' represent the consumer's demand schedule in, respectively, the absence and presence of perfect information. They are, respectively, the consumer's uninformed and informed demands. If the government does not interfere in the market, the consumption is at Qu where demand for individual equals supply for individual (uninformed demand equal supply). The consumer decides to consume according to one's utility while ignoring the society's interest. For example, in the case of smoking if the consumer has perfect information the demand will be less than the original one since smoking harm both smokers and others. It also causes a lung disease. Demand will be D' not D since and the harm of smoking and smokers. Therefore, if consumers have perfect information, consumption is equal to Qi. The gain in producer's surplus from 'over-consumption' is PuBAPi. The loss in consumer's surplus from over-consumption is

Loss from over-consumption	= Difference between gains of 2 cases
Gain from informed – Gain from uninformed	= APiE – (OPuBQu – OECQu)
	= APiE – (PuEF – FBC)
	= APiPuF + FBC

Thus, the net loss to society from 'overconsumption' is loss in consumer's surplus less gain in producer's surplus is

The net loss to society =	Loss in consumer's surplus – Gain in producer's surplus
Loss in consumer's surplus:	APiPuF + FBC = APiPuF + AFB + ABC
Gain in producer's surplus:	PuBAPi = APiPuF + AFB
The net loss to society =	APiPuF + AFB + ABC – (ApiPuF + AFB)
=	ABC

When consumers overestimate quality, through a lack of information, producers lack incentives to provide information. Accurate information would lead to a lower surplus for the producer. An analysis, identical to that above, would apply if, due to lack of information, consumers underestimated quality so that there was 'under-consumption'. Now, however, producers would have an incentive to provide information since accurate information would now lead to a higher surplus for the producer.

2.2 The Tragedy of the Commons and Its Implications

The basic ideas of tragedy of the commons in environmental economics and resource management that illuminates the challenges arising when individuals, acting in their self-interest, deplete shared resources, leading to detrimental consequences for the collective. Fundamentally, the tragedy unfolds in situations where a shared, open-access resource, or "commons," is available to multiple individuals. This resource can encompass a wide array of environmental assets, including grazing land, fisheries, water bodies, and even the atmosphere. The tragedy arises when individuals, driven by their self-interest, exploit the resource without considering the long-term impact on its sustainability. The tragedy is deeply rooted in the conflict between individual rationality and the well-being of the collective. In a scenario where no one has exclusive ownership or control over the resource, each individual has an incentive to maximize their own use of it, fearing that others will exploit it if they do not. This leads to a race to exploit the resource, resulting in overuse, degradation, and ultimately, the collapse of the shared resource. A classic example illustrating the tragedy is the overgrazing of common pastureland. If each herder seeks to maximize their herd size to increase personal gain, the pastureland becomes overgrazed, leading to soil erosion and reduced productivity. Despite the collective knowledge that such overuse is detrimental, each herder may continue to exploit the resource, fearing that if they restrain themselves, others will not, and they will be left with a smaller share of the resource.

Causes of Tragedy of the Commons

The tragedy of the commons occurs when individuals deplete shared resources leading to detrimental consequences for the collective. Several underlying causes contribute to the emergence of the tragedy of the commons as follows:

i. Lack of exclusive property rights

In the absence of exclusive property rights, individuals do not have a direct chance in the well-being or preservation of a shared resource. Without ownership, there is little incentive for individuals to act as stewards and ensure the sustainable use of the resource. Therefore, the lack of exclusive property rights creates an environment where there is no clear ownership or responsibility for shared resources, leading to overuse and degradation in the absence of effective management and regulation. Establishing and enforcing property rights can be a crucial step in mitigating the tragedy of the commons and promoting sustainable resource management. Exclusive property rights create a sense of responsibility among owners. When no one has a clear ownership stake, there is a tendency for individuals to act in their immediate self-interest, often leading to the over-extraction or degradation of the resource. In addition, without clear ownership, regulating and managing the use of a resource becomes challenging. It is difficult to enforce rules or establish sustainable practices when there is no legal framework defining who has the right to control and benefit from the resource.

ii. Open access to resources

Open access is associated with tragedy of commons. There are typically no restrictions on who can use a particular resource. As a result, individuals have an incentive to maximize their own benefit from the resource without considering the long-term consequences. This often leads to overexploitation, as people extract more from the resource than it can naturally replenish. Moreover, open access creates a competitive of extracting resources. This competitive dynamic can intensify the rate of resource extraction, hastening the tragedy of the commons.

iii. Population growth

As the global population continues to rise, the food supply needs to increase just as quickly. The demand for products and services of common exceeding its supply are increase in human and animal population. For example, a growing population can lead to overfishing and excessive use of farmland. Without proper regulations or sustainable practices, this can result in the depletion of fish stocks and degradation of soil fertility. It also can lead to habitat encroachment and increased urbanization, placing additional stress on ecosystems. This pressure can disrupt the balance of natural systems and contribute to the overuse of resources.

d. <u>Economics Analysis of the Tragedy</u>

Common property resources are those to which anyone has free access. As a result, they are likely to be overutilized. The inefficiencies occur when resources are common property rather than privately owned. The theory explains individuals' tendency to make decisions based on their personal needs, regardless of the negative impact it may have on others. In some cases, an individual's belief that others won't act in the best interest of the group can lead them to justify selfish behavior. Potential overuse of a common-pool resource—hybrid between a public and private good— can also influence individuals to act with their short-term interest in mind, resulting in the use of an unsustainable product and disregard the harm it could cause to the environment or general public. It's helpful to understand the tragedy of the commons; therefore, we can make more sustainable and environmentally-friendly choices. Considered the fisheries, suppose that because the catch is sufficiently small relative to demand, fishermen take the price of fish as given. Additionally, fishermen confront the increasing the fishing costs. According to this assumption, the demand curve is a horizontal line and supply curve is the upward sloping equaled to the private cost of fishing as shown in figure 2.9.

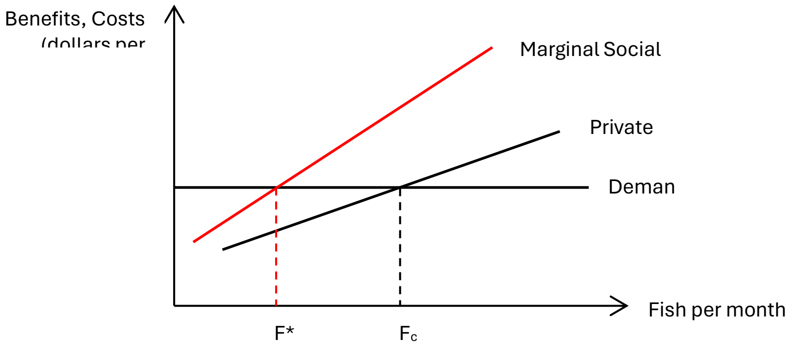

Figure 2.9 Common property resources

The demand curve represents the marginal benefit of fishery which reflects the revenue generated from selling fishes. The supply reveals the marginal private cost of fishery which are all expenses incurred by individuals involved in fishing activities such as labor costs, fuel costs, maintenance and repair costs. When a common property resource is accessible to all, the resource is used to the point F_c at which the private cost is equal to the additional revenue generated. This usage exceeds the efficient level F* at which the marginal social cost of using the resource is equal to the marginal benefit. As you can see, the marginal external costs of common property resources are not taken into account and each fisherman fishes until there is no longer any profit to be made which defined at F_c level. At this level, too many fish will be caught. However, if there are someone can control the number of fishermen with access to the resources. The efficient level of fish per month F* is determined at the point at which the marginal benefit from fish caught is equal to the marginal social cost. The marginal benefit is the price taken from the demand curve. The marginal social cost shown in the diagram includes not only the private operating costs but also the social cost of depleting the stock of fish. As a result, the simple solution to common property resource problem is consenting to a single owner manage the resources. The owner will set a fee for use of the resource that is equal to the marginal cost of depleting the stock of fish. Facing the payment of this fee, fishermen in the aggregate will no longer find it profitable to catch more than F* fish. Unfortunately, as single ownership is not always practical, most common property resources are vast. In such cases government ownership or direct government regulation may be needed.

Environmental and Social Solutions

Addressing the tragedy of the commons requires a multifaceted approach that combines economic, legal, and social interventions.

i. Defined property right

One key solution involves the establishment of clear property rights or ownership structures for the shared resource. When individuals have a stake in the resource, they are more likely to act as stewards, considering its long-term sustainability. Additionally, regulatory frameworks, such as quotas and permits, can limit the amount of resource extraction and prevent overuse.

ii. International cooperation

International cooperation is vital, especially for global commons like the atmosphere and oceans. As they are outside the national jurisdiction, they could be managed only through international cooperation and agreements. Agreements and treaties that promote sustainable resource management on a global scale can mitigate the tragedy of the commons. However, the challenge lies in overcoming geopolitical differences and ensuring that nations adhere to their commitments.

Although an international environmental management policy still seems a rather distant possibility, there are many historical cases of international cooperation and conventions in this field. We could learn from their experience and try to develop some semblance of an international policy for management of global commons.

The following four major tools have been used in the past to secure international cooperation in environment management

(i) officially sponsored international conferences
(ii) treaties (conventions)
(iii) establishment of permanent international agencies
(iv) international commodity agreements

Most of the early successful attempts at international regulation of fugitive resources were concerned with individual resources in limited areas. For example, marine fish was the first fugitive resource that was brought under international regulation through a series of regional conferences and conventions. Recently, more ambitious but as yet less successful attempts have been made to cover more resources and wider geographic extent.

iii. Education and persuasion

This instrument seeks to change perceptions and priorities of users of natural resources and services by internalizing environmental awareness and responsibility into individual decision making. Besides education and persuasion, this instrument could also take the form of provision of information and training as well as forms of 'moral suasion' such as social pressure and negotiation. They can complement economic and regulatory instruments and assist in their successful implementation. Most scholars and practitioners in environment management recognize the need for education as an instrument of averting 'the tragedy of the commons'. Most users of environmental resources and services in both developed and developing countries of the world do not use them as they 'should', partly because they are ignorant about the nature and causes of environmental problems and partly because of many economic and institutional factors such as poverty, property rights, and tenure. This stands in the way of their adopting socially desirable behavior. In the short run, education seems to be a logical and simple solution to the extent that environmental problems arise out of ignorance. Education should therefore be mainly used as a means of alleviating ignorance. In the long run, education also affects environment management in two other ways. First, it influences population growth. With all else equal, people with more education tend to have somewhat smaller families and to that extent population pressure on the environment and consequently its exploitation and misuse are reduced. Second, education increases incomes. Many developing countries are trapped in the extreme poverty associated with rapid population growth, illiteracy, unemployment, poor nutrition and hygiene. All these factors tend to have an adverse effect on the environment. Increased incomes therefore help improve the status and management of the environment. In designing education programs, it is important to keep these questions in mind: who is to be educated, in what subjects, and with what kind of information, by whom, and how?

iv. Finding alternative and sustainable products

The tragedy of the commons illustrates the absence of incentives for individuals to restrain themselves from excessive consumption in the absence of regulation or public transparency regarding choices and actions related to public goods. The concept of the tragedy of the commons highlights the overuse and depletion of shared resources when individuals act in their self-interest without considering the collective well-being. Driving change and preventing the tragedy of the commons necessitates boycotting products or brands linked to alleged harm and exploring alternative options.

Regrettably, this approach lacks widespread support, as many consumers doubt its ability to generate a substantial impact. To avoid the tragedy of the commons and promote sustainable practices, it is crucial to explore alternative and environmentally friendly products. Finding alternatives involves seeking products and brands that prioritize ethical and sustainable practices throughout their production and distribution processes. This may include products made from renewable resources, employing eco-friendly manufacturing methods, and minimizing waste and carbon footprint. Choosing sustainable alternatives helps create a demand for environmentally conscious products, encouraging businesses to adopt greener practices. Additionally, supporting companies with transparent and ethical supply chains contributes to a more responsible and equitable consumption ecosystem. By making informed and environmentally conscious choices, consumers play a vital role in mitigating the tragedy of the commons and fostering a more sustainable future.

2.3 Historical Case Studies Highlighting Market Failures

Case Studies I: London Great Smog

One historical case study that illustrates the concept of externalities is the "London Great Smog." This environmental disaster serves as a compelling example of negative externalities associated with air pollution. In December 1952, London experienced a severe air pollution event, known as the Great Smog. The city was already grappling with high levels of air pollution due to the widespread use of coal for heating and industrial processes. However, a combination of weather conditions, including a temperature inversion, trapped pollutants close to the ground, leading to a thick and persistent layer of smog. These created negative externalities. The pollutants released into the air had severe health consequences for the population. Thousands of people suffered from respiratory illnesses, and the mortality rate spiked dramatically during the smog episode. The negative health externalities were not borne by the industries emitting pollutants but by the broader public. It also impacted economic activities. The economic activities of the city were disrupted as transportation, including the London Underground, came to a standstill. This had cascading effects on various sectors, showcasing the economic externalities of unchecked pollution. As you can see, the polluters did not bear the full costs of the health impacts on the affected population. The loss of life and long-term health costs resulting from the smog imposed a significant burden on public health services and the affected individuals, representing external costs not considered by the industries emitting pollutants. The London Great Smog of 1952 serves as a historical case study illustrating the real and tangible consequences of environmental externalities and the importance of regulatory responses to address and prevent such negative impacts on society.

Case Studies II: Deepwater Horizon Oil Spill

An example of an externality in the 21st century is the Deepwater Horizon oil spill, which occurred in 2010 in the Gulf of Mexico. This environmental disaster had wide-ranging negative externalities, affecting marine ecosystems, wildlife, and the livelihoods of coastal communities. On April 20, 2010, the Deepwater Horizon offshore drilling rig experienced a blowout while drilling an exploratory well in the Macondo Prospect, leading to a catastrophic explosion and subsequent oil spill. The spill, considered one of the largest environmental disasters in history, released millions of barrels of crude oil into the Gulf of Mexico. The oil spill generated negative externalities which caused extensive damage to marine ecosystems. The negative environmental externalities included the contamination of coastal habitats, the death of marine life, and long-term ecological consequences. Additionally, coastal communities faced economic losses due to the impact on fisheries, tourism, and related industries. It also reduced fishery yields, damage to the tourism industry, and financial hardships for local businesses. Moreover, the exposure to oil and dispersants posed health risks to both human and animal populations included respiratory problems, skin issues, and long-term health concerns for individuals and communities residing near the affected areas. The Deepwater Horizon oil spill serves as a significant case study of externalities in the 21st century, demonstrating the far-reaching consequences of industrial activities on the environment, communities, and economies. The incident spurred discussions on regulatory reforms, corporate responsibility, and the importance of considering externalities in decision-making processes.

Case Studies III: Degradation of the Aral Sea

One of the case studies of a natural resource problem and its management is the degradation of the Aral Sea and the subsequent efforts to address this environmental crisis. The Aral Sea, once one of the world's largest inland bodies of water, is located in Central Asia, bordered by Kazakhstan and Uzbekistan. In the mid-20th century, the Soviet Union initiated large-scale irrigation projects diverting water from the two main rivers that fed the Aral Sea—the Amu Darya and Syr Darya—for agricultural purposes. The diversion of water for irrigation led to a significant reduction in the inflow of water into the Aral Sea. The sea began to shrink, causing a drastic reduction in its size and volume. The diminishing water levels had severe consequences for the environment, ecosystems, and the communities dependent on the sea. The shrink of the Aral Sea resulted the significant environmental problem. There was the exposure of the lakebed, leading to the release of salt and toxic chemicals. It impacted sanitization of the soil, loss of biodiversity, and the decline of fishing industries had profound environmental and economic impacts. The degradation of the Aral Sea gained international attention, prompting awareness of the environmental catastrophe. Countries in the region, including Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan, collaborated on efforts to address the crisis. Additionally, the World Bank and the United Nations implemented projects to support the Aral Sea Basin Program, focusing on sustainable water management, ecosystem restoration, and community development. These resulted in improving the awareness of water management and the efficiency of water use in agriculture, including the adoption of water-saving technologies and crop choices that required less water. The efforts address the Aral Sea crisis underscore the importance of integrating sustainable development practices, balancing the needs of agriculture with environmental conservation. While the Aral Sea crisis represents a historical case of natural resource mismanagement, ongoing efforts continue to address the environmental consequences and promote sustainable water use in the region. The case serves as a valuable lesson in the importance of proactive and collaborative management of natural resources to prevent irreversible degradation.

Summary

Market failure can lead to environmental problems. Market failure is identifying the inefficient of price mechanism and leads to environmental problems. Therefore, examining the environmental problems is best addressed by reviewing the causes of market failure. For instance, environmental problems often result from externalities, where the costs or benefits of an economic activity are not fully reflected in the prices. The lack of internalization of external costs can lead to overuse or degradation of environmental resources. People may not have full information of the environmental impact of their choices, and this asymmetric information can disturb a well-functioning market which may results of inefficiency of resource allocation. As a result, understanding the reasons of market failure and economic tools allow policy makers to address the deficiency and limitation of unregulated markets. It helps to promote sustainable practices and ensure the responsible use of natural resources. Additionally, the information is essential for developing effective policies that balance social and economic development with environmental conservation.

Discussion questions

1. There are three homeowners around the lake. Suppose the lake was cleaned up to the efficient level and that the total costs of the cleanup were shared equally among the homeowners. Will all three homeowners be better off? What problems does this bring up about sharing the costs of public goods?
2. Suppose there is a river on which is located several paper mills, each of which discharges pollutants into the water. Suppose somebody invents a new technology for treating this waste stream that, if adopted by the pulp mills, could substantially diminish emissions. What are the impacts of the invention on the actual level of emissions and the efficient level of emission?
3. Why some economists argue that the creation of private-property rights is to protect the environment? What are the essential issues in this argument?
4. Evaluate the arguments for the use of market or incentive-based instruments versus "command and control" instruments in the regulation of environmental externalities under condition of certainty.
5. What is meant by adverse selection and show why it can lead to asymmetric information? Why does adverse selection make it difficult to regulate pollution efficiently?

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CHAPTER 3: ECONOMIC VALUATION OF ENVIRONMENTAL RESOURCES

3.1 Introduction to non-market valuation techniques

Non-market valuation techniques play a crucial role in assigning economic value to goods and services that do not have a readily observable market price. In conventional economic transactions, market prices serve as signals of value, but certain environmental, social, and cultural assets defy the standard market mechanisms. In such cases, non-market valuation techniques become essential tools for assessing the worth of these intangible or non-traded goods. This introduction explores the significance of non-market valuation, the major techniques involved, and their applications across various domains (Hanley, Shogren & White, 2007).

3.1.1 Significance of Non-Market Valuation

Non-market valuation techniques are of paramount significance in economics and policy analysis, filling a critical void where traditional market mechanisms fall short. The inherent limitations of market transactions, particularly in the context of public goods, externalities, and intangible assets, underscore the need for methods that can ascribe economic value to entities without a readily observable market price. The significance of non-market valuation can be elucidated through several key dimensions.

1) Quantifying Public Goods:

Public goods, characterized by non-excludability and non-rivalry, defy the conventional supply-and-demand dynamics of markets. Clean air, biodiversity, and scenic landscapes are classic examples of goods that benefit everyone without being diminished by individual consumption. Non-market valuation techniques, such as the Contingent Valuation Method (CVM) and Travel Cost Method (TCM), enable the quantification of the economic value associated with these public goods. This valuation is crucial for informing public policies, resource allocation, and environmental conservation strategies (Mitchell & Carson, 1989).

2) Internalizing Externalities:

Externalities, the positive or negative side effects of economic activities that affect third parties, often go unaccounted for in market transactions. Non-market valuation provides a means to internalize externalities by assigning a monetary value to these spillover effects. For instance, the Hedonic Pricing Method allows researchers to estimate the economic impact of factors like air quality on property values, leading to a more comprehensive understanding of the true costs and benefits associated with various activities.

3) Environmental and Conservation Policy:

Non-market valuation techniques are indispensable tools for crafting effective environmental and conservation policies. As governments and organizations grapple with the challenges of sustainable resource management, these methods offer insights into the economic value of ecosystem services, natural resources, and the preservation of biodiversity. The valuation of such non-market goods informs decision-makers about the trade-offs involved in different policy choices, facilitating more informed and balanced environmental stewardship.

4) Cultural Heritage Preservation:

Cultural heritage, encompassing historical sites, artifacts, and traditions, often lacks a market price but holds immense value for societies. Non-market valuation, particularly through methods like Contingent Valuation, allows for the assessment of the public's willingness to pay for the preservation of cultural heritage. This information is critical for policymakers seeking to allocate resources effectively, ensuring the safeguarding of valuable cultural assets for future generations.

5) Health and Well-being:

Non-market valuation is increasingly applied to assess the economic value of factors influencing public health and well-being. For instance, improved air quality, green spaces, and access to recreational amenities contribute to enhanced quality of life and reduced healthcare costs. Valuation techniques help quantify these health-related benefits, providing evidence for policies that promote environmental sustainability and public health. Therefore, market transactions are based on the principle of willing buyers and sellers reaching a mutually agreeable price. However, certain goods, often referred to as public goods, lack a market because of non-excludability and non-rivalry. Public goods like clean air, biodiversity, and cultural heritage cannot be easily divided among individuals, and consumption by one person does not reduce availability to others. Non-market valuation steps in to quantify the value of such goods and incorporate them into decision-making processes. The significance of non-market valuation techniques extends far beyond the realm of academic inquiry; it permeates the fabric of decision-making in both the public and private sectors. As societies grapple with complex challenges related to environmental degradation, public health, and cultural preservation, these valuation methods offer a structured approach to understanding the often intangible but undeniably valuable aspects of our collective well-being. Through the lens of non-market valuation, policymakers, economists, and researchers gain a more holistic understanding of the multifaceted dimensions of value that extend beyond the boundaries of traditional markets.

3.1.2 Addressing Externalities

Externalities, both positive and negative, present another challenge for market-based valuation. For instance, a factory emitting pollutants might negatively impact the health of residents, but these health impacts are often not reflected in the market price of the goods produced by the factory. Non-market valuation helps to internalize externalities by assigning a value to the positive or negative effects associated with a particular activity. Externalities, the unintended side effects of economic activities that impact third parties, pose a significant challenge to achieving economic efficiency and societal well-being. Addressing externalities is a crucial aspect of economic governance, requiring innovative approaches to internalize these effects and promote a more harmonious and sustainable economic system. Externalities come in two forms: positive and negative. Positive externalities, such as education or vaccination, confer benefits on individuals beyond those directly involved in the activity. Negative externalities, on the other hand, result in costs borne by third parties who are not part of the transaction. Pollution from industrial production is a classic example of a negative externality, where the costs of environmental degradation are often not reflected in the market price of the goods produced. Traditional market mechanisms, driven by the forces of supply and demand, often fail to internalize externalities. In a laissez-faire system, where prices are determined solely by market interactions, producers and consumers may not consider the external impacts of their choices. This leads to an inefficient allocation of resources and, in the case of negative externalities, overproduction of goods that impose societal costs. Governments play a pivotal role in addressing externalities through regulatory measures. Imposing taxes on activities with negative externalities, such as carbon taxes on industries emitting greenhouse gases, serves to internalize the social costs associated with these activities. Similarly, subsidies for positive externalities, like those supporting research and development in clean energy, encourage activities that generate societal benefits. The Coasian approach suggests that externalities can be efficiently addressed through negotiations between affected parties. If transaction costs are low, parties can engage in bargaining to reach agreements that internalize externalities without government intervention. However, in many real-world situations, transaction costs are high, hindering the effectiveness of this approach. Tradable permits, also known as cap-and-trade systems, offer a market-based solution to address externalities. In these systems, a government sets an overall cap on a certain activity, such as emissions. Participants are then issued permits, and these permits can be bought or sold in a market. This approach provides an economic incentive for participants to reduce their emissions, as those who can do so at a lower cost can sell their permits to those facing higher costs. Companies adopting socially responsible business practices can also contribute to addressing externalities. By voluntarily internalizing the external costs associated with their operations, businesses can enhance their reputation, attract conscientious consumers, and contribute to a more sustainable and socially aware economic landscape. Despite the array of approaches available, challenges persist in effectively addressing externalities. Determining the appropriate level of regulation, estimating the true social costs or benefits of an externality, and ensuring equitable distribution of the burdens and benefits are complex tasks. Moreover, the global nature of many externalities, such as climate change, demands international cooperation and coordinated efforts, posing additional challenges. Addressing externalities is not just an economic necessity but a moral imperative. As the global community grapples with the environmental, social, and health consequences of externalities, finding effective solutions becomes paramount. A combination of regulatory measures, market-based instruments, and corporate responsibility can pave the way for a more sustainable and equitable economic future. By internalizing externalities, society can move towards an economic system that not only allocates resources efficiently but also fosters the well-being of present and future generations. The journey toward economic harmony requires a collaborative effort from governments, businesses, and individuals to navigate the complexities of externalities and forge a path to a more balanced and sustainable world.

3.1.3 Policy and Conservation

The intersection of policy and conservation forms a critical nexus in the global endeavor to balance human development with environmental preservation. As societies grapple with the increasing demands on natural resources, effective policies are indispensable for fostering conservation efforts that ensure the sustainable use and protection of ecosystems, biodiversity, and cultural heritage. Policies act as the guiding force that sets priorities and goals for conservation. Governments formulate strategies to safeguard natural resources, wildlife, and landscapes based on a combination of ecological science, public opinion, and economic considerations. Policies articulate the vision for sustainable stewardship, outlining the steps necessary to achieve long-term environmental health. Legislation and regulations play a pivotal role in conservation efforts. Environmental laws prescribe limits on resource exploitation, emissions, and habitat destruction. These frameworks establish the legal foundation for conservation activities, ensuring that individuals and organizations adhere to standards that protect the environment and its diverse ecosystems.

1) Conservation Strategies Shaped by Policy

Policies often embrace ecosystem-based management approaches, recognizing the interconnectedness of species, habitats, and ecological processes. This holistic perspective considers the broader ecosystem when making decisions about resource use and conservation interventions. It promotes resilience and adaptive strategies to address dynamic environmental challenges. Designating protected areas and reserves is a common conservation strategy endorsed by policies. These areas serve as sanctuaries for biodiversity, allowing ecosystems to thrive without the pressures of intensive human activities. Policies delineate the boundaries, management plans, and usage restrictions for these protected zones, ensuring their effectiveness in preserving biodiversity.

2) Economic Instruments for Conservation

Policies increasingly explore market-based instruments to align economic incentives with conservation goals. Tradable permits, payments for ecosystem services, and eco-certification programs are examples of mechanisms that integrate economic considerations into conservation practices. These approaches aim to demonstrate that economic development and conservation can be mutually reinforcing. Policies can incentivize sustainable practices through fiscal measures, subsidies, or tax breaks. By rewarding businesses and individuals for adopting environmentally friendly practices, policies encourage a shift towards conservation-minded behavior. This can include support for sustainable agriculture, renewable energy initiatives, and environmentally responsible production methods. One of the primary challenges in policy-driven conservation is striking a balance between economic development and environmental protection. Policies must navigate the delicate terrain of fostering growth while preventing irreversible harm to ecosystems. This requires a nuanced understanding of the trade-offs and synergies between development goals and conservation imperatives. Conservation often transcends national borders, especially in the face of challenges like climate change and habitat loss. Effective policies require international cooperation to address transboundary issues. Agreements, conventions, and collaborative efforts become essential tools for harmonizing conservation strategies on a global scale.

3) Emerging Trends and Future Directions

Advancements in technology, such as satellite imagery, remote sensing, and data analytics, empower policymakers to make informed decisions. These tools facilitate real-time monitoring of ecosystems, enabling more adaptive and responsive conservation strategies. Policies are increasingly recognizing the importance of involving local communities in conservation efforts. Community-based conservation, guided by inclusive policies, not only enhances the effectiveness of initiatives but also ensures that the benefits of conservation are equitably distributed. Policy and conservation are intertwined forces that shape the trajectory of our relationship with the environment. In the quest for sustainable stewardship, policies serve as the catalysts that guide, regulate, and incentivize conservation efforts. The effectiveness of conservation strategies hinges on the development of policies that strike a harmonious balance between ecological health, economic development, and social well-being. As we navigate the complex challenges of the Anthropocene, the synergy between thoughtful policies and conservation initiatives becomes paramount in ensuring a resilient and sustainable future for our planet. The Non-market valuation is integral to environmental and conservation policy. Governments and organizations use these techniques to assess the economic impact of environmental degradation, justify conservation efforts, and design policies that account for the value of natural resources. For example, the valuation of ecosystem services, such as water purification, pollination, and carbon sequestration, informs policies aimed at sustainable resource management.

3.1.4 Non-Market Valuation Techniques

1) Contingent Valuation Method (CVM)

The Contingent Valuation Method is one of the most widely used techniques in non-market valuation. It involves directly asking individuals about their willingness to pay (WTP) for a specific non-market good or service. Surveys, interviews, or hypothetical scenarios are employed to elicit responses. CVM provides a direct measure of the economic value individuals place on a good or service, making it applicable to a wide range of contexts, from environmental conservation to cultural heritage preservation. The Contingent Valuation Method (CVM) stands as a cornerstone in the toolkit of non-market valuation techniques, allowing researchers to gauge the economic value that individuals place on goods and services without observable market prices (Boyle & Bishop, 1978). Developed to assess the value of non-market goods such as environmental quality, cultural heritage, or public services, CVM employs surveys, interviews, or hypothetical scenarios to elicit individuals' willingness to pay (WTP) for these intangible assets. CVM starts with the presentation of a hypothetical scenario to individuals, describing a particular non-market good or service and the associated changes or improvements. Respondents are then asked how much they would be willing to pay (WTP) or willing to accept (WTA) for the described changes (Carson & Hanemann, 2005). The hypothetical nature of the scenario is a key feature, as it allows for the valuation of goods that may not have an existing market or where market prices do not accurately reflect the true value. The success of CVM hinges on the careful design and implementation of surveys. Researchers must craft questions that are clear, unbiased, and capable of eliciting genuine responses (Diamond & Hausman, 1994). The surveys often include a series of questions to establish respondents' baseline preferences, their understanding of the good or service in question, and their financial capacity to contribute to its preservation or improvement. CVM's versatility makes it applicable across diverse contexts, from environmental conservation to cultural heritage preservation. It accommodates goods with varying degrees of visibility in the market, offering a flexible framework for valuing public goods, ecosystem services, and intangible assets. One of the primary advantages of CVM is its ability to directly measure the economic value that individuals place on a non-market good. By eliciting individuals' WTP, researchers obtain a quantitative measure of the perceived value, providing policymakers and stakeholders with tangible data for decision-making. CVM goes beyond the traditional market perspective by capturing non-use values. These include individuals' willingness to pay for the existence of a non-market good, even if they do not directly use or benefit from it. This broader perspective allows for a more comprehensive understanding of the total economic value associated with the good. One of the primary criticisms of CVM is the potential for hypothetical bias. Respondents may not accurately reflect their true WTP in a hypothetical scenario, leading to overestimation or underestimation of the actual value. Researchers employ various techniques, such as embedding real payment questions or employing different elicitation formats, to mitigate this bias. The scope and scale of the non-market good being valued can influence respondents' perceptions and WTP. CVM studies must carefully define the boundaries of the good or service to ensure consistency in respondents' understanding and valuation. Ensuring a representative sample is crucial for the validity of CVM results. Biases may arise if certain demographic groups are overrepresented or underrepresented in the survey, potentially skewing the estimated values. CVM has been widely applied in environmental economics, providing insights into the value of natural resources, conservation efforts, and ecosystem services (Freeman, 2003). Additionally, it has found applications in assessing the value of cultural heritage, healthcare services, and public amenities. As technology advances, there is potential for incorporating virtual reality or other immersive techniques to enhance the realism of hypothetical scenarios in CVM studies. In conclusion, the Contingent Valuation Method serves as a vital tool for unraveling the preferences and values associated with non-market goods. Its adaptability, direct measurement of value, and capacity to capture non-use values make it a valuable instrument in the arsenal of economists, policymakers, and researchers striving to quantify the worth of intangible assets that shape our societies and environment. Despite its challenges, CVM continues to evolve, offering new avenues for understanding and incorporating societal preferences into decision-making processes.

2) Hedonic Pricing Method

The Hedonic Pricing Method estimates the value of a non-market good by examining the prices of related market goods and isolating the contribution of the non-market good to those prices. For instance, in the context of environmental valuation, researchers might analyze housing prices and environmental quality to determine the implicit price of clean air or scenic views. This method is particularly useful when market transactions indirectly reveal preferences for non-market goods. The Hedonic Pricing Method stands as a robust and widely utilized economic tool, offering insights into the intricate interplay between market prices and the various characteristics that define goods and services. Developed to quantify the implicit value of non-market attributes, this method has found extensive application in assessing the economic worth of diverse elements such as environmental quality, housing amenities, and even cultural assets. At the heart of the Hedonic Pricing Method lies the concept of decomposing the observed market prices of goods or services into their constituent characteristics. Whether it's a house, a car, or a piece of art, each possesses a set of attributes that contribute to its overall value. The method aims to isolate and quantify the influence of these attributes on the market price. One of the notable applications of the Hedonic Pricing Method is in environmental economics. For instance, consider air quality as an attribute influencing housing prices. By examining the prices of homes in different areas, researchers can discern the impact of varying levels of air pollution on the perceived value of residential properties. The successful application of the Hedonic Pricing Method hinges on the availability of relevant data. Researchers gather information on both the market prices of the goods or services in question and the characteristics associated with them. For environmental quality, this might involve pollution levels, proximity to parks, or the availability of clean water. Sophisticated statistical techniques, such as regression analysis, are then employed to tease out the relationships between market prices and the identified attributes. The model aims to quantify the impact of each characteristic on the overall value, providing a nuanced understanding of how different factors contribute to the perceived worth of the good or service. One of the key strengths of the Hedonic Pricing Method is its ability to assign a monetary value to attributes that may not have a direct market price. Clean air, scenic views, or historical significance often lack a tangible market, yet the method allows for the estimation of their implicit value based on their impact on market prices. The insights garnered through the Hedonic Pricing Method have far-reaching implications for policy development. For instance, in environmental economics, the method helps policymakers understand the economic costs and benefits associated with different levels of pollution or the preservation of natural landscapes. This information informs decisions related to environmental regulation and resource allocation. One challenge associated with the Hedonic Pricing Method is the potential for endogeneity, where the characteristics being studied may be correlated with unobservable factors that also influence prices. Mitigating this challenge requires careful model specification and consideration of potential confounding variables. The method assumes homogeneity in the impact of attributes across space and time. However, the value individuals assign to certain characteristics may vary based on cultural, temporal, or regional factors. Researchers must account for this variability to ensure accurate and meaningful results (Kahneman & Knetsch, 1992).

Applications Beyond Environmental Economics

Housing Markets:

The Hedonic Pricing Method has found extensive application in housing markets. Characteristics such as the number of bedrooms, proximity to amenities, and neighborhood safety influence housing prices. By isolating these factors, researchers and real estate professionals can gain a deeper understanding of market dynamics.

Cultural Heritage:

In the realm of cultural economics, the method has been employed to value attributes of cultural heritage sites. For example, the historical significance or architectural uniqueness of a site can be assessed through its impact on market prices, guiding preservation efforts and tourism management.

As technology and data availability continue to advance, the Hedonic Pricing Method is poised to become even more sophisticated. The integration of machine learning algorithms and big data analytics holds the promise of refining our understanding of how various attributes contribute to economic value. In conclusion, the Hedonic Pricing Method stands as a versatile and powerful approach to unraveling the economic tapestry that underlies market prices. Whether applied to environmental resources, housing markets, or cultural assets, its ability to quantify the value of attributes enriches our comprehension of economic decision-making. As we navigate the complexities of a world where intangible qualities are increasingly paramount, the Hedonic Pricing Method remains a valuable instrument for both researchers and policymakers seeking to uncover the hidden values within market transactions.

3) Travel Cost Method (TCM)

The Travel Cost Method assesses the value of a non-market good by analyzing the costs individuals incur to access it. This is often applied in recreational or cultural contexts, such as valuing national parks or historic sites. By examining travel expenses, researchers can infer the value people place on the non-market good based on their willingness to spend time and money to experience it. The Travel Cost Method (TCM) is a widely employed economic tool designed to estimate the economic value of non-market goods and services, particularly those related to recreation and cultural experiences. This method is rooted in the idea that individuals incur travel costs to access and enjoy certain sites or activities, and by examining these costs, researchers can infer the economic value people place on the associated non-market goods. The fundamental premise of TCM is that the costs incurred by individuals to reach a particular destination or site reflect the value they place on the recreational or cultural experience associated with that location. Whether it's a national park, historical site, or cultural event, individuals invest time and money to partake in these experiences, and these costs serve as a proxy for the perceived value. TCM is often applied in the context of recreational activities. By examining the demand for visits to parks, beaches, or other leisure destinations, researchers can estimate the economic value of these areas to individuals and society at large. The method provides insights into the preferences and trade-offs people make in allocating their time and resources for recreational pursuits.The core of TCM involves gathering data on the costs individuals incur to travel to a particular site. This includes transportation costs, entrance fees, and any other expenses related to the visit. Surveys and interviews are common tools for collecting this information, and researchers aim to capture a representative sample of visitors to the site. The distance traveled and the time spent at the destination are crucial factors in TCM. These elements reflect the effort individuals are willing to invest in reaching and enjoying the recreational or cultural site. The costs associated with travel are then analyzed in relation to these factors to derive meaningful estimates of economic value. TCM provides a quantitative approach to valuing assets that contribute to recreational and cultural well-being. Whether it's a natural reserve, a historical landmark, or an annual cultural festival, the method allows for the estimation of the economic value of these non-market goods. Governments and policymakers can use TCM results to make informed decisions about resource allocation and management. Understanding the economic value that individuals place on certain recreational sites guides decisions about conservation, infrastructure development, and the establishment of user fees. The validity of TCM results relies heavily on the representativeness of the sample. If the sample of visitors is not demographically or behaviorally diverse, the estimates may not accurately reflect the preferences and values of the broader population. TCM assumes that individuals have similar preferences and derive similar value from the recreational or cultural site being studied. This assumption may not hold in cases where visitors have diverse motivations and expectations. While TCM is commonly associated with recreational activities, it has also been applied to value cultural experiences. Museums, historical sites, and cultural events are subject to TCM analysis, providing insights into the economic value individuals place on these aspects of cultural heritage. Beyond valuation, TCM is employed in economic impact studies. By analyzing travel costs and expenditures associated with visits to specific sites, researchers can quantify the economic contribution of these sites to local economies, informing regional development strategies. As the demand for recreational and cultural experiences continues to evolve, TCM remains a dynamic and adaptable tool for economists and policymakers. Advances in data collection methods, including the use of mobile applications and digital surveys, hold promise for enhancing the precision and efficiency of TCM studies. In conclusion, the Travel Cost Method offers a valuable lens through which economists can unravel the economic value embedded in recreational and cultural activities. By analyzing the costs individuals willingly incur to access these non-market goods, TCM enriches our understanding of the multifaceted dimensions of value that extend beyond traditional market transactions. As societies strive to balance economic development with the preservation of natural and cultural assets, TCM stands as a pertinent and insightful approach for guiding informed decision-making and sustainable resource management.

3.1.5 Applications of Non-Market Valuation

1) Environmental Conservation

Non-market valuation is extensively employed in environmental economics to assess the value of ecosystem services, biodiversity, and natural resources. For example, the valuation of wetlands may consider their role in flood control, water purification, and habitat provision. These valuations inform conservation policies, allowing decision-makers to weigh the economic benefits against potential trade-offs. Environmental conservation is a holistic and imperative approach aimed at safeguarding the planet's ecosystems, biodiversity, and natural resources. It recognizes the intrinsic value of nature, its vital role in sustaining life, and the interconnectedness between environmental health and human well-being. This multifaceted endeavor encompasses a range of strategies, policies, and actions designed to mitigate environmental degradation, promote sustainability, and foster a harmonious coexistence between humanity and the natural world. Environmental conservation acknowledges the critical role of ecosystems in providing essential services such as clean air, water purification, pollination, and climate regulation. Conserving biodiversity and maintaining the integrity of ecosystems contribute to the resilience and functionality of these services, ensuring the well-being of both human and non-human inhabitants. Establishing protected areas and wildlife reserves is a cornerstone of environmental conservation. These designated zones serve as sanctuaries for diverse flora and fauna, shielding them from the pressures of habitat loss, pollution, and over-exploitation. The preservation of these areas is essential for maintaining biodiversity and supporting ecological balance (Johnston & Rosenberger, 2010).

Environmental conservation involves the formulation and enforcement of regulations to control and reduce pollution. Regulatory frameworks address issues such as air and water quality, waste management, and the discharge of harmful substances. These measures aim to minimize the negative impact of human activities on the environment. Efforts to restore degraded habitats play a crucial role in conservation. Reforestation, wetland restoration, and other habitat rehabilitation initiatives help reverse the damage caused by deforestation, urbanization, and industrial activities. Restoration projects contribute to the recovery of ecosystems and enhance their capacity to support biodiversity. A key aspect of environmental conservation is the transition to renewable energy sources. Shifting away from fossil fuels towards cleaner alternatives such as solar, wind, and hydroelectric power reduces greenhouse gas emissions and mitigates climate change. Sustainable energy practices contribute to both environmental preservation and the mitigation of human-induced ecological disruptions. Conservation extends to the sustainable management of agricultural and fisheries practices. Adopting agroecological methods, reducing pesticide usage, and implementing responsible fishing practices contribute to maintaining soil health, preserving biodiversity, and ensuring the long-term viability of food production systems. Addressing global environmental challenges requires international cooperation. Agreements such as the Paris Agreement on climate change and the Convention on Biological Diversity exemplify collaborative efforts to tackle issues that transcend national boundaries. These agreements emphasize the shared responsibility of nations in conserving the planet's ecosystems and addressing climate-related threats (Pearce & Turner, 1990).

Environmental conservation is inherently linked to climate action. Mitigating the impacts of climate change, such as rising temperatures, extreme weather events, and sea-level rise, is integral to preserving ecosystems and protecting vulnerable species. Conservation strategies often align with climate adaptation and resilience-building measures. Promoting environmental awareness and education is a vital component of conservation efforts. Fostering a deeper understanding of ecological systems, biodiversity, and the impact of human activities cultivates a sense of responsibility and encourages sustainable behaviors. Engaging communities in conservation through citizen science initiatives empowers individuals to actively contribute to data collection and monitoring efforts. This involvement enhances public appreciation for the environment and strengthens the connection between local communities and the ecosystems they inhabit (Ready & Navrud, 2002; Smith, Pattanayak & Van Houtven, 2002)).

One of the ongoing challenges in environmental conservation is finding a balance between preserving natural habitats and supporting human development. Striking this balance requires innovative solutions that integrate conservation goals with sustainable development practices. As the global landscape evolves, new environmental challenges emerge. Issues such as plastic pollution, invasive species, and the impacts of emerging technologies pose novel threats that demand adaptive and informed conservation strategies. In conclusion, environmental conservation is an imperative undertaking that transcends borders and ideologies. It is a commitment to safeguarding the intricate web of life on Earth, recognizing that the well-being of humanity is intricately linked to the health of the planet. Through a combination of regulatory frameworks, sustainable practices, global collaboration, and public engagement, environmental conservation endeavors to create a future where ecosystems thrive, biodiversity flourishes, and the delicate balance between nature and humanity is preserved for generations to come (Pope, Thun, Namboodiri, Dockery, Evans, Speizer & Health, 1995).

2) Cultural Heritage Preservation

Non-market valuation techniques are also applicable in the realm of cultural heritage. The preservation of historical sites, monuments, and artifacts holds intrinsic value, but quantifying this value is challenging without a market price (Champ, Boyle & Brown, 2003). Contingent valuation studies, for instance, can gauge the public's willingness to pay for the conservation of cultural heritage, aiding policymakers in allocating resources for preservation efforts. Cultural heritage preservation is a profound and essential commitment to safeguarding the diverse manifestations of human creativity, knowledge, and identity that have shaped societies throughout history (Arrow, Solow, Portney, Learner, Radner & Schuman, 1993; Adamowicz, Boxall, Williams & Louviere, 1998)). Embracing tangible and intangible elements, cultural heritage encompasses monuments, artifacts, traditions, languages, and rituals that embody the richness of human civilization. The preservation of cultural heritage not only safeguards the treasures of the past but also fosters a sense of continuity, identity, and shared values among present and future generations. Cultural heritage is an integral part of a community's identity, reflecting its history, values, and collective memory. Preserving cultural heritage ensures that communities maintain a connection with their roots, fostering a sense of continuity and belonging that transcends generations. Cultural heritage serves as a repository of knowledge, wisdom, and artistic expression. Preserving heritage sites, manuscripts, and traditional practices facilitates the transmission of this cultural capital to succeeding generations. It becomes a living classroom, where individuals can learn about their cultural legacy and the diversity that enriches humanity. Preserving tangible cultural heritage involves the careful conservation and restoration of physical artifacts, monuments, and historical sites. This may include employing advanced restoration techniques, implementing protective measures, and establishing museums or cultural institutions to house and display precious objects (Portney & Weyant, 1999).

In the digital age, documentation and digital preservation have become crucial aspects of cultural heritage preservation. High-resolution imaging, virtual reality, and digital databases enable the creation of comprehensive records, ensuring that even fragile or endangered artifacts can be accessed and studied without compromising their physical integrity. Natural disasters, climate change, and environmental degradation pose significant threats to cultural heritage (Navrud & Ready, 2007). Floods, earthquakes, and rising sea levels can irreversibly damage historical sites and artifacts. Mitigating these risks requires both proactive conservation measures and adaptive strategies to address the impact of climate change. Rapid urbanization and development often place cultural heritage at risk. Historic neighborhoods, archaeological sites, and traditional landscapes may face encroachment or destruction due to urban expansion. Balancing development goals with heritage preservation necessitates thoughtful planning and sustainable urban strategies. International organizations, notably UNESCO (United Nations Educational, Scientific and Cultural Organization), play a pivotal role in cultural heritage preservation. The World Heritage Convention identifies and protects sites of outstanding universal value, fostering international collaboration to ensure their safeguarding for future generations. Many countries have enacted laws and regulations to protect and preserve their cultural heritage. These legal frameworks provide the basis for designating heritage sites, regulating archaeological excavations, and implementing conservation measures. Local communities are often actively involved in these efforts, contributing to the sustainable preservation of their cultural treasures. Engaging local communities in the preservation of their cultural heritage is fundamental to its sustainability. Community-led initiatives empower individuals to take an active role in safeguarding their heritage, ensuring that preservation efforts align with the values and needs of the people directly connected to the cultural assets. Tourism, when managed sustainably, can contribute to the preservation of cultural heritage. Responsible tourism practices prioritize the protection of historical sites, promote cultural sensitivity among visitors, and channel economic benefits back into local communities. Balancing tourism with conservation efforts helps ensure that heritage sites remain accessible without compromising their integrity. Advanced technologies such as 3D scanning and printing offer innovative solutions for preserving and replicating cultural artifacts. These technologies enable the creation of detailed digital models and physical replicas, allowing for enhanced study, conservation, and public engagement with cultural heritage. AR and VR technologies provide immersive experiences that allow individuals to explore cultural heritage sites virtually. These technologies have the potential to make cultural heritage more accessible to a global audience while preserving the physical integrity of fragile sites. Cultural heritage preservation is a dynamic and evolving endeavor that demands a multidimensional approach. It requires a delicate balance between conservation, community engagement, technological innovation, and international collaboration. As custodians of the cultural tapestry that defines humanity, individuals, communities, and nations bear the responsibility of ensuring that the treasures of the past endure for the benefit and inspiration of generations to come. In nurturing cultural heritage, societies not only honor their roots but also contribute to the shared legacy of human creativity, resilience, and diversity (Loomis & Ekstrand, 1998).

3) Health and Well-being

The non-market valuation of health-related factors is vital for understanding the economic impact of environmental and social determinants on public health. For instance, the Hedonic Pricing Method can be employed to estimate the economic value of improved air quality in terms of reduced healthcare costs and enhanced quality of life. While non-market valuation techniques are powerful tools, they are not without challenges and criticisms. One common criticism is the potential for hypothetical bias in contingent valuation studies, where respondents may overstate their willingness to pay in a hypothetical scenario compared to real-world situations. Additionally, the choice of valuation method and the assumptions made in the process can introduce uncertainties and affect the reliability of the results. Non-market valuation techniques provide a valuable framework for assessing the economic value of goods and services that fall outside the traditional market paradigm. From environmental conservation to cultural heritage preservation, these techniques offer insights into the preferences and values of individuals and societies. As we navigate complex challenges related to resource management, public health, and the preservation of our cultural heritage, non-market valuation remains an indispensable tool for policymakers, researchers, and practitioners alike (Bockstael & McConnell, 1983)

3.2 Contingent valuation, hedonic pricing, and travel-cost methods

The Hedonic Pricing Method seeks to quantify the economic value of individual characteristics of goods or services by examining their impact on market prices. It is often applied to real estate and housing markets but can be extended to other goods with identifiable attributes. Hedonic pricing involves decomposing observed market prices into the implicit values of various characteristics. For instance, in the housing market, the price of a house is influenced by factors like the number of bedrooms, location, and proximity to amenities (Rosen, 1974). The method aims to isolate and quantify the impact of these attributes on the overall market price. Researchers collect data on market prices and the characteristics of goods or services. Statistical techniques, such as regression analysis, are then employed to discern the relationships between market prices and the identified attributes. Hedonic pricing allows for the quantification of the economic value of attributes that may not have a direct market price. Results from hedonic pricing studies inform policymakers about the economic costs and benefits associated with different attributes, guiding decisions related to regulation and resource allocation. There is a risk of endogeneity, where the characteristics being studied may be correlated with unobservable factors that also influence prices. The method assumes homogeneity in the impact of attributes across space and time, which may not always hold. In a hedonic pricing study for housing, researchers might analyze how the presence of a nearby park, the quality of local schools, and the crime rate influence housing prices. This information can guide urban planning and policy decisions (Hanemann, 1984).

Travel Cost Method (TCM)

The Travel Cost Method (TCM) focuses on estimating the economic value of recreational or cultural sites by analyzing the costs individuals incur to visit these locations. It provides insights into the demand for and value of non-market goods related to leisure activities. TCM starts with the premise that the costs individuals bear, such as travel expenses and entrance fees, to access a particular site reflect the value they place on the associated non-market goods. By analyzing these costs in relation to the distance traveled and time spent, researchers estimate the economic value of the site. Data collection for TCM involves gathering information on the costs individuals incur to travel to a particular site. Surveys, interviews, or visitor logs may be used to collect this information, and factors like distance traveled and time spent at the destination are crucial. TCM provides a quantitative approach to valuing assets contributing to recreational and cultural well-being. TCM results inform decisions about resource allocation, conservation, and the establishment of user fees. The validity of TCM results relies heavily on the representativeness of the sample. TCM assumes that individuals have similar preferences and derive similar value from the recreational or cultural site being studiedIn a TCM study, researchers might assess the economic value of a national park by examining the costs visitors incur to travel to the park, including transportation expenses and entrance fees. This information can guide decisions on park management and visitor access. Contingent Valuation, Hedonic Pricing, and the Travel Cost Method are powerful tools in the economist's toolkit for valuing non-market goods. Each method offers distinct advantages and faces specific challenges, but together they contribute to a comprehensive understanding of the economic value associated with goods and services that extend beyond traditional market transactions. These methods play a crucial role in informing policy decisions, resource allocation, and conservation efforts, ensuring that the full spectrum of human preferences and values is considered in the pursuit of sustainable and equitable economic outcomes (Parsons, 2003).

3.3 Challenges and criticisms of valuation techniques

Valuation techniques, employed to estimate the economic worth of goods and services, play a crucial role in decision-making processes across various fields. However, these techniques are not without their challenges and criticisms. As economists strive to quantify the value of both market and non-market attributes, they encounter methodological complexities, ethical dilemmas, and uncertainties that demand careful consideration. Here, we explore the primary challenges and criticisms associated with valuation techniques, ranging from issues of accuracy and bias to broader concerns related to societal values and environmental ethics. One pervasive challenge faced by valuation techniques, especially contingent valuation methods, is the issue of hypothetical bias. Respondents in surveys or experiments may not accurately reflect their true preferences or willingness to pay in hypothetical scenarios. This bias can lead to overestimation or underestimation of the economic value of a good or service, impacting the reliability of the valuation results. Valuation techniques often grapple with the challenge of endogeneity, where the characteristics being studied are correlated with unobservable factors that also influence the economic value (Bateman & Willis, 1999). For example, in hedonic pricing, housing prices may be influenced by factors like neighborhood safety, which are challenging to isolate from other unobservable variables. Mitigating endogeneity is crucial for ensuring the robustness and validity of valuation outcomes. The economic value assigned to goods and services can vary spatially and temporally, posing a challenge for valuation techniques. Preferences, especially for environmental amenities or cultural heritage, may differ across regions and change over time. Valuation studies must carefully consider these variations to avoid misrepresenting the true economic value associated with a particular attribute. Valuation techniques raise ethical concerns, particularly in the context of assigning monetary values to aspects of the environment or cultural heritage. Critics argue that reducing these values to monetary terms may overlook intrinsic or non-use values and may not adequately capture the diverse perspectives and values held by different communities. There is a risk of undervaluing goods and services that are culturally significant or have intangible, non-market benefits. Valuation techniques face inherent challenges when applied to non-market goods and services. Non-use values, such as existence value or bequest value, are complex to quantify as they involve valuing goods or services for their mere existence or for the benefit of future generations. Contingent valuation methods may struggle to accurately capture these non-use values. The quality and representativeness of data are fundamental to the success of valuation techniques. Biases could emerge if the sample used in a study is not representative of the broader population or if data collection methods introduce errors. Ensuring data accuracy and representative sampling is a constant challenge for researchers employing valuation techniques. While valuation techniques provide a means to assign monetary values to goods and services, critics argue that overreliance on monetary metrics can lead to a narrow understanding of value. Some dimensions of well-being, cultural significance, or environmental health may defy precise monetary quantification, and an exclusive focus on economic metrics may overlook these broader dimensions of value. Valuation techniques applied to ecosystem services face challenges due to the dynamic nature of ecological systems. The benefits derived from ecosystem services, such as water purification or pollination, can be influenced by various factors like climate change, land-use patterns, and human activities. Valuation studies may struggle to capture and predict the complexities of these dynamic relationships. Public perception and behavioral biases can impact the accuracy of valuation techniques. Individuals may have difficulty expressing their true preferences, and their responses may be influenced by framing effects, cognitive biases, or social desirability bias. Understanding and mitigating these biases are ongoing challenges for researchers seeking reliable valuation outcomes. In conclusion, the challenges and criticisms associated with valuation techniques highlight the nuanced and multifaceted nature of assigning economic values to goods and services. As these techniques evolve, researchers must navigate methodological intricacies, address ethical considerations, and strive for a more comprehensive understanding of value that encompasses diverse perspectives and dimensions of well-being. Acknowledging the limitations and actively seeking improvements will contribute to the refinement and credibility of valuation techniques in informing policy decisions, resource allocation, and environmental conservation efforts (Bishop & Heberlein, 1979).

Summary

Economic valuation of environmental resources is a multidisciplinary field that seeks to ascribe monetary values to the often-intangible benefits derived from ecosystems and natural resources. This approach is driven by the recognition that the environment provides a wide range of services and functions that contribute to human well-being, and assigning economic values can inform decision-making processes, policy formulation, and resource management strategies. The summary below provides an overview of the key concepts, methods, and significance of economic valuation in the context of environmental resources. At its core, economic valuation acknowledges that the environment is not merely a backdrop for human activities but a source of valuable goods and services. These include provisioning services (such as food, water, and raw materials), regulating services (like climate and disease control), supporting services (such as nutrient cycling and habitat provision), and cultural services (including aesthetic and recreational values). Economic valuation assigns monetary values to these services, making them comparable to other economic considerations. Several methods are employed to assess the economic value of environmental resources, each catering to specific contexts and objectives. These methods can be broadly categorized into revealed preference methods, stated preference methods, and cost-based methods. 1) Revealed Preference Methods: These infer individuals' preferences by observing their actual behavior in the marketplace. Contingent valuation, hedonic pricing, and travel cost methods fall under this category. For example, hedonic pricing analyzes the prices of goods and services to estimate the value people place on certain environmental attributes, like clean air or scenic views. 2) Stated Preference Methods: These involve directly asking individuals about their preferences and willingness to pay for specific environmental attributes. Contingent valuation, choice experiments, and conjoint analysis are common methods within this category. Through surveys, individuals are presented with hypothetical scenarios, and their responses help estimate the economic value they attach to environmental goods or services. 3) Cost-Based Methods: These calculate the economic value of environmental resources based on the costs associated with their preservation or restoration. This includes methods like the opportunity cost approach, where the value is derived from the benefits foregone by not using the resource for alternative purposes (Bateman & Langford, 1997).

The Significances of Economic Valuation are 1) Informed Decision-Making: Economic valuation provides decision-makers with information on the economic importance of environmental resources. This informs choices about resource allocation, development projects, and land-use planning, ensuring that economic considerations are aligned with environmental sustainability. 2) Policy Formulation: By assigning monetary values to environmental goods and services, economic valuation aids in the development of policies that balance economic development with environmental conservation. It helps identify trade-offs and design policies that account for the full range of benefits derived from ecosystems. 3) Natural Resource Management: Economic valuation is instrumental in guiding sustainable natural resource management. It helps assess the impacts of various uses and interventions on ecosystems, guiding decisions that minimize negative environmental externalities. 4) Market Integration: By assigning economic values to environmental resources, there is potential for integrating environmental considerations into markets. Mechanisms like payments for ecosystem services (PES) allow for the creation of markets that incentivize the conservation of natural resources by compensating individuals for maintaining or enhancing ecosystem services. 5) Disaster Preparedness: Economic valuation can be crucial in estimating the potential economic losses associated with environmental degradation or disasters. This information is essential for risk assessment, insurance pricing, and developing strategies for disaster preparedness and recovery. Therefore, the economic valuation of environmental resources plays a pivotal role in integrating ecological considerations into economic decision-making. By translating the value of nature into monetary terms, this approach contributes to a more comprehensive understanding of the relationship between the environment and the economy, fostering sustainable practices and policies for the benefit of present and future generations.

Discussion questions

1. How does the Contingent Valuation Method attempt to estimate the economic value of environmental resources?
2. What are the main steps involved in conducting a Contingent Valuation survey for environmental goods?
3. How does the Hedonic Pricing Method quantify the economic value of environmental attributes in real estate markets?
4. Can you provide examples of environmental attributes that are commonly valued using the Hedonic Pricing Method?
5. In what way does the Travel Cost Method estimate the economic value of recreational and cultural resources?
6. What types of costs are considered in TCM studies, and how are they related to the value of the environmental resource?
7. In what way does the Travel Cost Method estimate the economic value of recreational and cultural resources?
8. What types of costs are considered in TCM studies, and how are they related to the value of the environmental resource?
9. Explain the concept of endogeneity in the context of valuation techniques. How does it affect the validity of results?
10. Provide examples of environmental goods or services that fall into the category of non-market goods. How does this classification impact valuation methods?

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CHAPTER 4: COST-BENEFIT ANALYSIS IN ENVIRONMENTAL DECISION MAKING

Cost-Benefit Analysis (CBA) is a widely used method in environmental decision-making to assess the economic feasibility of projects and policies by comparing the costs and benefits associated with them. Here are some key references that delve into the application of Cost-Benefit Analysis in the context of environmental decision-making.

4.1 Principles of Cost – Benefit Analysis

Definition of 'Cost' and 'Benefit'

To a non-economist, 'cost' is what you pay for a good or service. This is a tangible record of incurring cost. However, to an economist, cost refers to the sacrifice of benefits by using resources for a particular use rather than for some other (best) use. For this reason, economists refer to the sacrifice of benefits as 'opportunity cost'. The existence of forgone opportunities may have nothing to do with money payments. Payments may be incurred for which there is no use of resources and hence no economic cost (as with sales tax payments to the government); and no money payments may be involved yet resources maybe utilized (as when industries cause pollution by dumping waste products into rivers that require filtering). Opportunity cost also may have nothing to do with receipts. A clear example involves charitable tax deductions. A person who bake sand donates cookies for a hospital sale of refreshments for an open day can get a tax deduction for the gift, if they can get a receipt from the hospital. But if a person gives up their time actually to sell the refreshments, then the value of that time given up does not have a receipt and is therefore not tax deductible. The opportunity cost of time is a major component in many health care interventions, but is often excluded from economic evaluations, whether it be the time of volunteers or the time given up for patient care by family members (Brent, 2003).

Table 4.1 Cost-benefit analysis of the projects

Alternative	Benefits ($)	Costs ($)	B/C ratio	Net benefit
Park	10	8	1.25	2
Sky train	18	12	1.50	6
Stadium	13	10	1.30	3
Shopping mall	18	14	1.29	4
Museum	5	1	5.00	4
Football field	4	5	0.80	-1
Road	2	4	0.50	-2

What if we are told that the benefits/costs of each project are uncertain, for example, plus or minus 10%? Instead of Park having benefits of $10 million, it could be as low as $9 million or as high as $11 million. Repeat the calculation for all the project combinations. Now which project is the 'best'?

Table 4.2 Projects with sensitivity (million $)

Alternative	Benefits ($)	Costs ($)	Benefits ($) (+ 10%)	Costs ($) (+10%)	Benefits ($) (- 10%)	Costs ($) (-10%)
Park	10	8	11	9	8.8	7.2
Sky train	18	12	19.8	16.2	13.2	10.8
Stadium	13	10	14.3	11.7	11	9
Shopping mall	18	14	19.8	16.2	15.4	12.6
Museum	5	1	5.5	4.5	1.1	0.9
Football field	4	5	4.4	3.6	5.5	4.5
Road	2	4	2.2	1.8	4.4	3.6

From the Table 4.2, it is easier to describe and compare data by plotting it in a bar chart, as in Figure 4-1, or in a scatter plot with uncertainty as in Figure 4-..

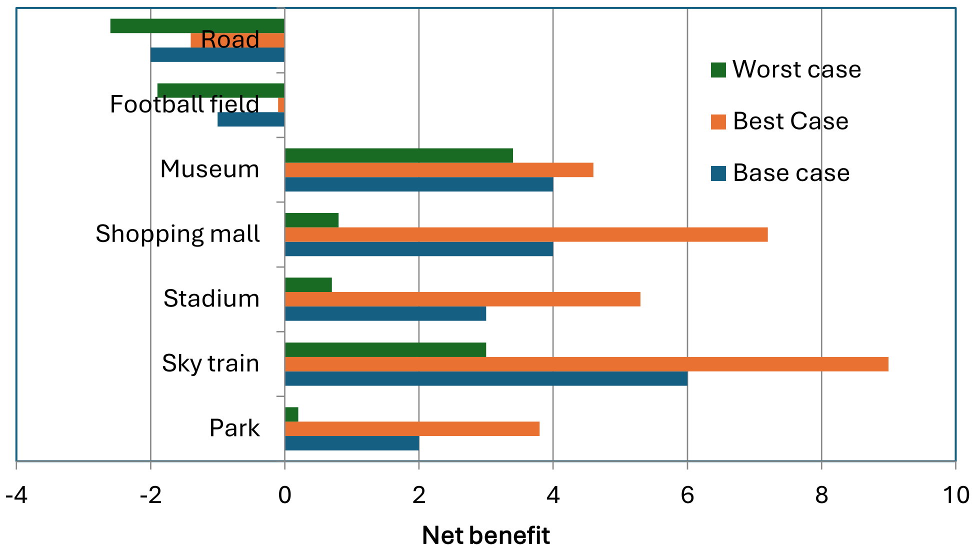

Figure 4.1 Projects: worst, base, and best cases

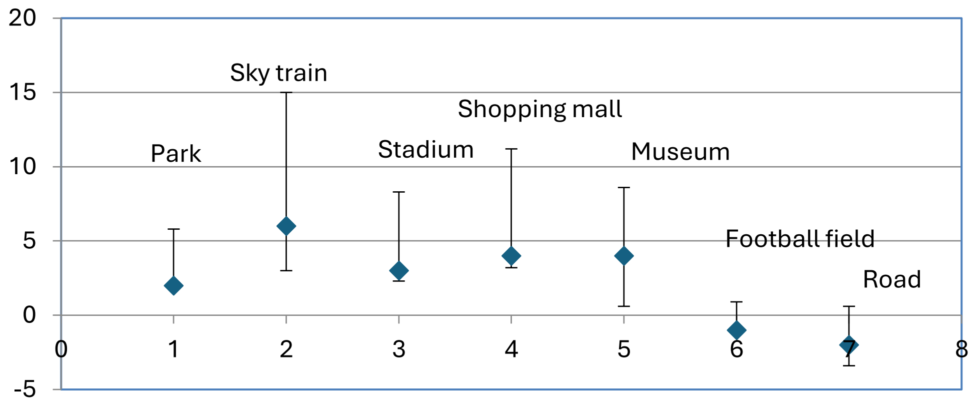

Figure 4.2 Cost-benefit of the projects with error bars

Issues in Benefit estimation

The analyst charged with the responsibility for performing a benefit-cost analysis encounters many decision points requiring judgment. If we are to understand benefit-cost analysis, the nature of these judgements must be clear in our minds. Primary versus secondary effects. Environmental projects usually trigger both primary and secondary consequences. For example, the primary effect of cleaning a lake will be an increase in recreational uses of the lake. This primary effect will cause a further ripple effect on services provided to the increased number of users of the lake. Are these secondary benefits to be counted? The answer depends upon the employment conditions in the surrounding area. If this increase in demand results in employment of previously unused resources, such as labor, the value of the increased employment should be counted. If, on the other hand, the increase in demand is met by a shift in previously employed resources from one use to another, this is a different story. In general, secondary employment benefits should be counted in high unemployment areas or when the particular skills demanded are underemployed at the time the project is commenced. This should not be counted when the project simply results in a rearrangement of productively employed resources.

Tangible versus intangible benefits

Tangible benefits are those which can reasonably be assigned a monetary value. Intangible benefits are those which cannot be assigned a monetary value, either because data are not available or reliable enough or because it is not clear how to measure the value even with data.

How are intangible benefits to be handled? One answer is perfectly clear: they should not be ignored. To ignore intangible benefits is to bias the results. That benefits are intangible does not mean they are unimportant.

Intangible benefits should be quantified to the fullest extent possible. One frequently used technique is to conduct a sensitivity analysis if the estimated benefit values derived from less than perfectly reliable data. We can determine, for example, whether or not the outcome is sensitive, within wide ranges, to the value of this benefit. It not, then very little time has to be spent on the problem. If the outcome is sensitive, the person or persons making the decision bear the ultimate responsibility for weighting the importance of that benefit.

Approaches to cost estimation

Estimating costs is generally easier than estimating benefits, but it is not easy. One major problem for both derives from the fact that benefit-cost analysis if forward-looking and thus requires an estimate of what a particular strategy will cost, which is much more difficult than tracking down what an existing strategy does cost (Tom Tietenberg, 2004). Another frequent problem is posed by collecting cost information when availability of that information is controlled by a firm having an interest in the outcome. Pollution control is an obvious example. Two approaches have been used to deal with this problem.

The survey approach. One way to discover the costs associated with a policy is to ask those who bear the costs, and presumably know the most about them, to reveal the magnitude of the costs to policymakers. Polluters, for example, could be asked to provide control-cost estimates to regulatory bodies. The problem with this approach is the strong incentive not to be truthful. An overestimate of the costs can trigger less stringent regulation; therefore, it is financially advantageous to provide overinflated estimates.

The engineering approach. The engineering approach bypasses the source being regulated by using general engineering information to catalog the possible technologies that could be used to meet the objective and to estimate the costs of purchasing and using those technologies. The final step in the engineering approach is to assume that the sources would use technologies that minimize cost. This produces a cost estimate for a typical, well-informed firm.

This approach has its own problems. These estimates may not approximate the actual cost of any particular firm. Unique circumstances may cause the costs of that firm to be higher, or lower, than estimated; the firm, in short, may not be typical.

The combined approach. To circumvent these problems, analysts frequently use a combination of survey and engineering approaches. The survey approach collects information on possible technologies, as well as special circumstances facing the firm. Engineering approaches are used to derive the actual costs of these technologies, given the special circumstances. This combined approach attempts to balance information best supplied by the source with that best derived independently.

In the cases described so far, the costs are relatively easy to quantify, and the problem is simply fining a way to acquire the best information. This is not always the case, however, some costs are not easy to quantify, though economists have developed some ingenious ways to secure monetary estimates even for those costs. Take, for example, a policy designed to conserve energy by forcing more people to carpool. If the effect of this is simply to increase the average time of travel, how is this cost to be measured? For some time transportation analysts have recognized that people do value their time, and quite a literature has now grown up to provide estimates of this valuation. The basis for this valuation os opportunity cost-how the time might be used if it weren't being consumed in travel. Although the results of these studies depend on the amount of time involved, individuals seem to value their time at a rate not more than half their wage rates.

4.2 Integrating environmental considerations

Asbestos is a naturally occurring substance whose unique physical properties have made it an important component in many diverse manufacturing activities. Used for thousands of years, asbestos became increasingly important after 1850 because of two characteristics for which it is probably best known: it is extremely effective insulation properties and resistance to wear. Hence, asbestos has traditionally been used where heat protection is important, such as in fire resistant clothing, and in friction materials, such as automobile brakes (Arnold, 1994). Despite its highly desirable industrial properties, the unfortunate fact is that asbestos kills people. Indeed, throughout the twentieth century evidence of the adverse health effects of asbestos has been mounting. Exposure to asbestos dust has been shown to significantly increase an individual's risk of contracting a number of potentially serious diseases. These diseases frequently end in death, and when they do not, individuals' activities are circumscribed because respiratory function typically is drastically impaired.

Over the years, a variety of federal regulations have been enacted targeting relatively high levels of worker exposure to asbestos. However, recent medical studies point to the likelihood that even low doses of exposure are potentially hazardous. In response to this information, the Environmental Protection Agency (EPA) sought to address the remaining asbestos exposure and risk problems using one of its many enabling statutes - the Toxic Substances Control Act, or TSCA. This law is perhaps unique in that its reach is broad and the powers conferred on the agency to enforce it are significant. Many U.S. environmental protection statutes focus on pollution control and risk reduction associated with a particular exposure medium or with specific types of sources. For example, the Clean Air Act targets risks to human health and the environment that are posed by pollutants that impact the troposphere and stratosphere. Similarly, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) focuses on occupational, consumer, and other sources of risk due to the use of a variety of toxic pest-management substances. TSCA, on the other hand, authorizes several different programs regulating toxic substances regardless of the medium causing the potential exposure or the nature of the economic activities that impact these environmental risks. Section 6 of TSCA, in particular, authorizes the administrator of EPA to undertake whatever regulatory actions are deemed necessary to address a risk that is determined to be unreasonable. Under this provision, virtually any regulatory action can be taken, from banning a substance to requiring exposure controls, and these remedies can be applied across the entire nation or only to a specific process in a particular plant. Section 6, however, does require the administrator to adopt the "least burdensome" approach for addressing unreasonable risks. Because of the EPA's broad regulatory authority under TSCA and the fact that the remaining uses of asbestos included quite diverse products and activities that posed a wide variety of risks to human health, the EPA began the process of regulatory development and implementation for asbestos under this statute. Many different analyses in support of such a proposed rule are required, including hazard assessment (toxicity of the substance), exposure evaluation, regulatory options development, a benefit-cost analysis, and various ancillary impact assessments. These studies are normally summarized in what is referred to as a regulatory impact analysis (RIA). This case study reviews the benefit-cost analysis conducted for the regulation of asbestos, and, in doing so, identifies a number of analytical and empirical aspects of practical environmental economics applicable to a wide range of environmental and other regulatory program settings.

There are 3 options:

Option A: a complete ban on all products immediately (1987 in the simulation modeling).

Option B: a fiber phase out starting in 1987 and ending in 1997, combined with an immediate ban on protective clothing and some construction products (expect for A/C sheet and shingle), but with diaphragms and missile liner exempt.

Option C: a three-stage product ban with products 7, 9, 10, 12, 14,15, 16, 17 and 25 banned in 1987, products 18, 19, 20, 21, 22, 23, 24, 36, and 37 banned in 1991, and all remaining products banned in 1997, except for diaphragms and missile liner.

Option A produces the largest costs and benefits of the three alternatives because it is the most stringent policy, imposing domestic costs of nearly $7 billion and avoiding some 266 cancer cases (Tables 4.1 and 4.2). While these results clearly represent the upper bounds for the costs and benefits of addressing the remaining asbestos risks, they are perhaps more instructive in determining the relative magnitudes of the product-by-product costs and benefits of eliminating asbestos use. For example, most of the risk reduction provided by an immediate ban is largely in the friction products categories. This is the direct influence of the no-threshold dose-response function used to translate asbestos exposure into estimated adverse health effects. Friction products expose numerous people, most of the U.S. population in fact, to small doses of asbestos over a long period of time. Even small doses over time, multiplied by some one-quarter of a billion people, can amount to a number of cancer cases that cannot be viewed as trivial.

The detailed results for Option A also reveal that there are some products with almost no cancer risk due to asbestos exposure and the banning of which imposes extremely high costs. A ban on asbestos diaphragms, in particular, generates virtually no risk reduction and is extremely costly, amounting to over $2.5 billion. This is because diaphragms are necessary for manufacturing chlorine using one of two processes. Diaphragms are integral to the process and, according to all available information, have no technologically feasible substitutes. If the continued production and use of these diaphragms were to be banned, about half of the U.S. chlorine manufacturing plants would be rendered essentially worthless. Similarly, banning missile liner also imposes very high cost, nearly $2 billion, due to the high cost of asbestos alternatives. The detailed cost and benefit results for the immediate and complete product ban indicate that the risk-reduction benefits and the cost of eliminating asbestos use are quite different, depending on the availability and cost of substitutes and the types of exposure being avoided. Moreover, there is no clear correlation between the magnitude of the benefits and the costs other than through the volume of the products produced and used.

In light of these facts and findings, the EPA considered many possible variations of the two primary regulatory strategies. The asbestos fiber phase out's results were computed for numerous different phase out periods, with and without exemptions for certain product categories, and with and without imposing specific product bans. Option B is one example of this. Under this ten-year fiber phase out, the asbestos diaphragm and missile liner product categories are exempted from the phase out, although a few specific products are banned immediately. For several reasons, the results for Option B (as shown in Tables 4.1 and 4.3) are dramatically different from those of an immediate ban. First, by exempting the asbestos diaphragms and missile liner markets from the phase out, the very large producer and consumer surplus losses for those uses are avoided. Second, whatever consumer and producer surplus losses are experienced in this case occur later in time, so they are lower in present-value terms under a lengthy phase out than under an immediate product ban. This gradual tightening of the phase out is also responsible for the drop in the number of cancer cases prevented by the immediate ban's 266 to 208 cases under the phase out. Finally, under this option, the government gains over $250 million in revenue from the sale of permits that enforce the phase out of asbestos fiber use.

Option C is an example of tailoring the staged product bans to try to reduce the costs of asbestos controls while still generating many of the risk-reduction benefits. Under this option, protective clothing and construction products are banned immediately, friction products are banned some five years later, and all remaining products except diaphragms and missile liner are banned in ten years' time. This option was constructed more or less on the basis of the relatively low cost and immediate availability of substitutes for products banned earlier, and allowed adequate time for redesign of friction product uses to avoid any safety problems. The exemptions, of course, were included to avoid extreme cost burdens. For option C, as shown in Tables 4.3 and 4.6, costs are slightly lower than Option B, while the benefits in terms of cancer cases avoided are about 149.8 cases which is less than under Option B. This disproportionate decline in the benefits relative to costs in moving from Option B to Option C is almost entirely due to the difference in timing of shifting away from asbestos in the vehicle brakes aftermarkets. Under the Option B phase out, substitution occurs relatively early because of the modest incremental costs of brake substitutes. Under Option C's staged ban, however, these markets are not required to substitute until fairly late in the regulation's timeframe. Again, the EPA's concerns about the safety of using non-asbestos brakes in systems designed to use asbestos drove the decision to delay the brake aftermarket product ban under Option C.

Table 4.3 Costs of asbestos regulatory options by affected entity (present values, in millions of dollars, at 3%)

Entity	Option A	Option B	Option C
Domestic Miners and Millers	12.32	10.55	9.21
Foreign Miners and Millers	134.29	115.04	100.42
Domestic Primary Processors	2,778.41	102.48	87.51
Foreign Primary Processors	9.81	10.94	8.93
Domestic Product Purchasers	4,143.77	1,228.62	911.54
Government	0.00	-262.69	0.00
U.S. Welfare Cost	6,934.49	1,078.96	1,008.26
World Welfare Cost	7,078.59	1,204.94	1,117.61

Source: ICF Incorporated, 1989. "Regulatory Impact Analysis of Controls on Asbestos Products," Volume IV.

Table 4.4 Costs and benefits of option A (costs and benefits discounted at 3%, million dollars)

	Product Category	Domestic Consumer Surplus Loss	Domestic Producer Surplus Loss	Gross Domestic Total Loss	Total Cancer Cases Avoided	Cost per Cancer Case Avoided
1.	Commercial Paper	.00	.00	.00	.0000	n/a
2.	Rollboard	.00	.00	.00	.0000	n/a
3.	Millboard	10.99	.00	10.99	.9286	11.83
4.	Pipeline Wrap	1.96	.01	1.97	1.4052	1.40
5.	Beater-Add Gaskets	310.13	.04	310.17	8.7628	35.40
6.	High-Grade Electrical Paper	114.72	.00	114.72	.6410	178.97
7.	Roofing Felt	8.90	.00	8.90	1.2196	7.30
8.	Acetylene Cylinders	10.56	.00	10.56	.0000	-[a]
9.	Flooring Felt	.00	.00	.00	.0000	n/a
10.	Corrugated Paper	.00	.00	.00	.0000	n/a
11.	Specialty Paper	.02	.00	.03	.0414	.62
12.	V/A Floor Tile	.00	.00	.00	.0000	n/a
13.	Asbestos Diaphragms	.26	2,683.24	2,683.50	.2686	9,991.41
14.	A/C Pipe	438.45	43.87	482.32	5.0204	96.07
15.	A/C Sheet, Flat	1.35	1.38	2.73	.8475	3.22
16.	A/C Sheet, Corrugated	.62	.00	.62	.1158	5.33
17.	A/C Shingles	63.31	8.10	71.42	.5160	138.42
18.	Drum Brake Linings (OEM)	14.92	5.65	20.57	9.3392	2.20
19.	Disc Brake Pads, LMV (OEM)	.16	3.94	4.10	1.1052	3.71
20.	Disc Brake Pads, HV	.03	.35	.38	.2445	1.56
21.	Brake Blocks	25.70	2.45	28.15	16.2894	1.73
22.	Clutch Facings	36.85	.92	37.77	.6833	55.27
23.	Automatic Trans. Components	.25	.15	.40	.0005	745.38
24.	Friction Materials	.43	2.09	2.52	.5923	4.25
25.	Asbestos Protective Clothing	.00	.00	.00	.0000	n/a
26.	Asbestos Thread, etc.	303.38	.00	303.38	.7810	388.48
27.	Sheet Gaskets	235.37	7.88	243.25	2.7854	87.33
28.	Asbestos Packing	.99	.00	.99	.0143	69.00
29.	Roof Coating	319.92	.56	320.48	2.4015	133.45
30.	Non-Roofing Coating	87.79	1.09	88.88	.4811	184.75
31.	Asbestos-Reinforced Plastics	78.49	.23	78.72	.8246	95.45
32.	Missile Liner	1,961.33	.17	1,961.50	.3967	4,944.40
33.	Sealant Tape	79.58	.10	79.67	.1399	569.53
34.	Battery Separator	.00	.00	.00	.0000	n/a
35.	Arc Chutes	.00	.00	.00	.0000	n/a
36.	Drum Brake Lining (Aftermarket)	36.26	9.05	45.31	168.1760	.27
37.	Disc Brake Pads LMV (Aftermarket)	1.05	7.13	8.18	40.4240	.20
38.	Mining and Milling	.00	12.32	12.32	1.9145	6.43
	Total			6,934.49[b]	266.3603	26.03

Source: ICF Incorporated, 1989. "Regulatory Impact Analysis of Controls on Asbestos Products," Volume IV.

[a] Exposure data not available. [b] U.S. net welfare cost.

Table 4.5 Costs and benefits of option B (costs and benefits discounted at 3%, million dollars)

	Product Category	Domestic Consumer Surplus Loss	Domestic Producer Surplus Loss	Gross Domestic Total Loss	Total Cancer Cases Avoided	Cost per Cancer Case Avoided
1.	Commercial Paper	.00	.00	.00	.0000	n/a
2.	Rollboard	.00	.00	.00	.0000	n/a
3.	Millboard	5.32	.00	5.32	.4872	10.92
4.	Pipeline Wrap	1.96	.01	1.97	1.4052	1.40
5.	Beater-Add Gaskets	157.20	.06	157.25	3.5130	44.76
6.	High-Grade Electrical Paper	34.62	.00	34.62	.1569	220.61
7.	Roofing Felt	8.90	.00	8.90	1.2196	7.30
8.	Acetylene Cylinders	5.81	.00	5.81	.0000	-[a]
9.	Flooring Felt	.00	.00	.00	.0000	n/a
10.	Corrugated Paper	.00	.00	.00	.0000	n/a
11.	Specialty Paper	.02	.00	.03	.0414	.62
12.	V/A Floor Tile	.00	.00	.00	.0000	n/a
13.	Asbestos Diaphragms	-1.54	.00	-1.54	.0000	n/a
14.	A/C Pipe	438.45	43.87	482.32	5.0204	96.07
15.	A/C Sheet, Flat	.82	1.55	2.37	.5988	3.95
16.	A/C Sheet, Corrugated	.40	.00	.40	.0769	5.18
17.	A/C Shingles	30.67	9.34	40.02	.3345	119.65
18.	Drum Brake Linings (OEM)	12.99	6.25	19.24	6.3090	3.05
19.	Disc Brake Pads, LMV (OEM)	.10	3.88	3.98	.6751	5.90
20.	Disc Brake Pads, HV	.02	.39	.41	.1641	2.49
21.	Brake Blocks	17.11	2.92	20.03	9.6853	2.07
22.	Clutch Facings	17.42	1.22	18.63	.2123	87.77
23.	Automatic Trans. Components	.06	.11	.17	.0001	1,341.00
24.	Friction Materials	.43	2.09	2.52	.5923	4.25
25.	Asbestos Protective Clothing	.00	.00	.00	.0000	n/a
26.	Asbestos Thread, etc.	78.96	.00	78.96	.3576	220.80
27.	Sheet Gaskets	98.40	10.44	108.84	.9144	119.03
28.	Asbestos Packing	.25	.00	.25	.0035	70.76
29.	Roof Coating	206.79	.73	207.52	1.1433	181.50
30.	Non-Roofing Coating	40.15	1.46	41.61	.1377	302.28
31.	Asbestos-Reinforced Plastics	19.96	.23	20.19	.7680	26.29
32.	Missile Liner	-1.10	.00	-1.10	.0000	n/a
33.	Sealant Tape	20.78	.10	20.88	.1325	157.55
34.	Battery Separator	.00	.00	.00	.0000	n/a
35.	Arc Chutes	.00	.00	.00	.0000	n/a
36.	Drum Brake Lining (Aftermarket)	32.62	10.46	43.08	136.4880	.32
37.	Disc Brake Pads LMV (Aftermarket)	1.05	7.37	8.42	36.3111	.23
38.	Mining and Milling	.00	10.55	10.55	1.3468	7.83
	Total			1,078.96[b]	208.0948	5.18

Source: ICF Incorporated, 1989. "Regulatory Impact Analysis of Controls on Asbestos Products," Volume IV.

[a] Exposure data not available. [b] U.S. net welfare cost.

Table 4.6 Costs and benefits of option C (costs and benefits discounted at 3%, million dollars)

	Product Category	Domestic Consumer Surplus Loss	Domestic Producer Surplus Loss	Gross Domestic Total Loss	Total Cancer Cases Avoided	Cost per Cancer Case Avoided
1.	Commercial Paper	.00	.00	.00	.0000	n/a
2.	Rollboard	.00	.00	.00	.0000	n/a
3.	Millboard	2.36	.00	2.36	.2274	10.40
4.	Pipeline Wrap	-2.00	.00	-2.00	.3441	-5.81
5.	Beater-Add Gaskets	66.48	.03	66.51	2.1456	31.00
6.	High-Grade Electrical Paper	27.53	.00	27.54	.1569	175.45
7.	Roofing Felt	8.90	.00	8.90	1.2196	7.30
8.	Acetylene Cylinders	2.24	.00	2.24	.0000	-[a]
9.	Flooring Felt	.00	.00	.00	.0000	n/a
10.	Corrugated Paper	.00	.00	.00	.0000	n/a
11.	Specialty Paper	-.06	.00	-.06	.0101	-6.10
12.	V/A Floor Tile	.00	.00	.00	.0000	n/a
13.	Asbestos Diaphragms	-1.26	.00	-1.26	.0000	n/a
14.	A/C Pipe	438.45	43.87	482.32	5.0204	96.07
15.	A/C Sheet, Flat	1.35	1.38	2.73	.8475	3.22
16.	A/C Sheet, Corrugated	.62	.00	.62	.1158	5.33
17.	A/C Shingles	63.31	8.10	71.42	.5160	138.42
18.	Drum Brake Linings (OEM)	6.99	4.83	11.82	5.6962	2.08
19.	Disc Brake Pads, LMV (OEM)	-.06	3.39	3.33	.6751	4.93
20.	Disc Brake Pads, HV	-.01	.30	.29	.1454	1.99
21.	Brake Blocks	14.54	2.11	16.65	9.6853	1.72
22.	Clutch Facings	21.60	.79	22.39	.4063	55.12
23.	Automatic Trans. Components	.15	.13	.28	.0003	877.15
24.	Friction Materials	-.19	1.80	1.61	.3522	4.58
25.	Asbestos Protective Clothing	.00	.00	.00	.0000	n/a
26.	Asbestos Thread, etc.	73.66	.00	73.66	.1912	385.19
27.	Sheet Gaskets	53.29	5.86	59.61	.6820	86.74
28.	Asbestos Packing	.24	.00	.24	.0035	68.86
29.	Roof Coating	62.11	.42	62.53	.5880	106.34
30.	Non-Roofing Coating	19.72	.81	20.53	.1178	174.31
31.	Asbestos-Reinforced Plastics	18.67	.17	18.84	.2019	93.30
32.	Missile Liner	-.90	.00	-.90	.0000	n/a
33.	Sealant Tape	18.25	.07	18.33	.0343	535.05
34.	Battery Separator	.00	.00	.00	.0000	n/a
35.	Arc Chutes	.00	.00	.00	.0000	n/a
36.	Drum Brake Lining (Aftermarket)	16.65	8.21	24.85	101.6571	.24
37.	Disc Brake Pads LMV (Aftermarket)	-1.09	5.21	4.12	17.6735	.23
38.	Mining and Milling	.00	9.21	9.21[b]	1.1014	8.36
	Total			1,008.26[b]	149.8147	6.73

Source: ICF Incorporated, 1989. "Regulatory Impact Analysis of Controls on Asbestos Products," Volume IV.

[a] Exposure data not available. [b] U.S. net welfare cost.

Summary

In the end, the EPA chose to promulgate its asbestos regulation as a variant of the staged ban strategy for several reasons. Probably most important was that the regulatory posture of rule-making procedure was geared toward eliminating asbestos from the workplace and from products and to do so as expeditiously as possible. At the same time, the EPA wanted to avoid any safety problems, especially in the friction product categories, due to the use of non-asbestos substitutes. Thus, the degree of control and timing offered by the staged product ban approach was superior to that offered by the phase out approach. Under the phase out strategy, substation costs and the stringency of the production limitations determined when the various asbestos producers would adopt substitutes, not policymakers. The phase out approach also entailed establishing an entire regulatory infrastructure to design, initiate, administer, and enforce the asbestos phase out production and importation limitations. While marketable permit schemes have certain desirable features in many regulatory situations, using one to accomplish what was effectively a desire to eliminate asbestos from the marketplace seemed cumbersome at best.

Discussion questions

1. How does cost-benefit analysis contribute to the process of environmental decision making?
2. What are the challenges or limitations associated with applying cost-benefit analysis to environmental issues?
3. Can you provide examples where cost-benefit analysis has influenced significant environmental policy decisions?
4. How do uncertainties, such as future environmental impacts or economic conditions, affect the outcomes of a cost-benefit analysis?

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CHAPTER 5: NON-RENEWABLE RESOURCES: ECONOMICS AND POLICY

The uneven distribution of non-renewable resources around the world often leads to an oligopolistic market structure, where a small number of producers dominate the global market. This concentration of resource wealth can have significant implications for both producing and consuming countries. For producing countries, the presence of a few dominant players in the global market can give them substantial bargaining power and influence over prices. However, this can also create dependency on resource revenues, making their economies vulnerable to fluctuations in global commodity prices and market demand. Additionally, the concentration of resource wealth may exacerbate governance challenges, leading to issues such as corruption, rent-seeking behavior, and conflict over resource control.

On the other hand, consuming countries may face challenges related to resource security and supply disruptions, particularly if they rely heavily on imports from a small number of producing countries. Oligopolistic market structures can also result in price manipulation and market distortions, affecting consumers and industries dependent on non-renewable resources.

Efforts to address the challenges associated with oligopolistic markets for non-renewable resources often involve promoting transparency, competition, and sustainable management practices. This may include measures to diversify economies, strengthen regulatory frameworks, promote responsible investment practices, and enhance international cooperation on resource governance.

Overall, the uneven distribution of non-renewable resources and the resulting oligopolistic market structure underscore the importance of effective governance, cooperation, and sustainable management practices to ensure that resource wealth contributes to inclusive and sustainable development for both producing and consuming countries.

5.1 Economic Principles Governing Non-Renewable Resources

Non-renewable resources are natural resources that cannot be replenished within a human lifespan. Unlike renewable resources, which can be sustained indefinitely, non-renewable resources are finite and deplete over time. This inherent limitation underscores the importance of efficient management and sustainable practices to ensure their responsible utilization and minimize depletion (figure. 5.1).

Fossil fuels, including coal, oil, and natural gas, have long been indispensable for energy production, constituting the bulk of the global energy supply. However, their combustion also leads to significant greenhouse gas emissions, contributing to climate change. These resources are formed from organic matter over millions of years and require exploration, extraction, and refining processes to harness their energy potential.

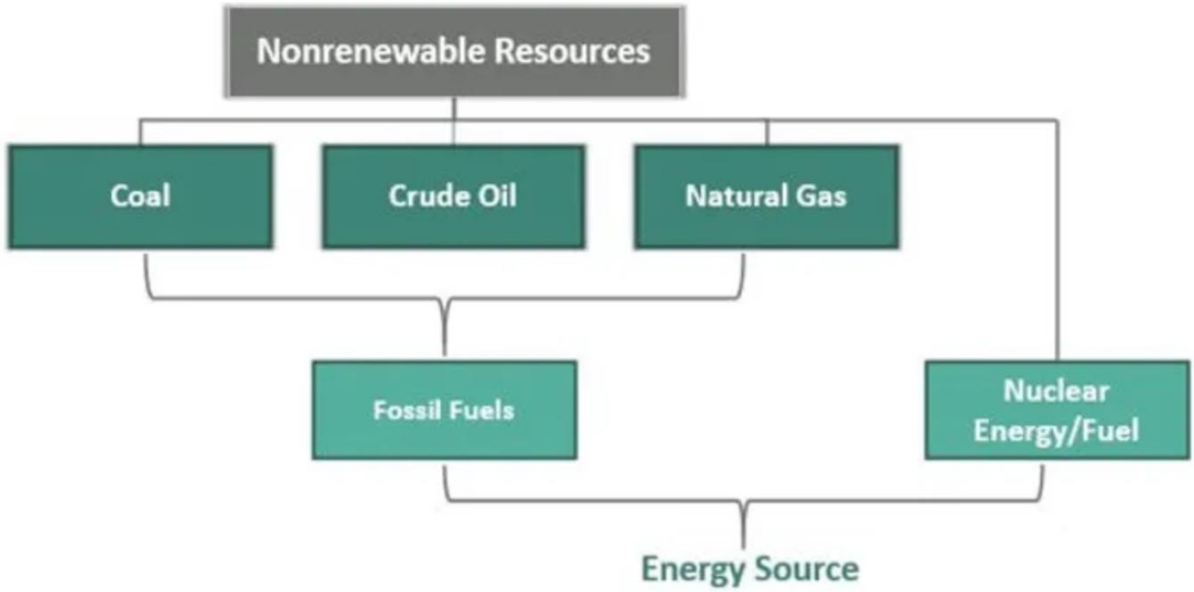


Figure 5.1 Non-renewable resource
Source: Wallstreet Mojo (2002)

Minerals and metals, such as gold, silver, copper, and iron ore, are vital for various industries, including construction, manufacturing, and technology. Nonetheless, their extraction processes can result in adverse environmental impacts like deforestation, habitat destruction, and water pollution.

Nuclear fuels, primarily uranium, are utilized in nuclear power plants to generate electricity. However, their mining and processing require specialized operations due to the radioactive nature of the material. While nuclear energy offers a relatively low-carbon alternative to fossil fuels, it also poses challenges such as waste management and the risk of accidents.

Crude oil plays a pivotal role in the global energy market and financial landscape. Its exploration and production involve complex processes such as drilling and extraction. Recent advancements in unconventional extraction techniques, like hydraulic fracturing, have significantly influenced oil production, particularly in regions like the United States. Fluctuations in oil prices can profoundly impact national economies, stock markets, and investment portfolios.

Coal has historically been a significant energy source, but concerns over its environmental impact, notably greenhouse gas emissions and air pollution, have led to its scrutiny. Many countries are transitioning away from coal-fired power plants in favor of cleaner alternatives. However, this transition presents economic and social challenges for coal-dependent regions.

Rare earth elements (REEs) constitute a group of minerals possessing distinctive properties crucial for numerous modern technologies. They serve as essential components in electronics, renewable energy systems, and defense applications. Historically, China has maintained dominance over the global supply of REEs. However, efforts are underway to diversify the supply chain and explore alternative sources.

Investors interested in advancing technological innovations may discover opportunities in rare earth mining. As the demand for REEs continues to rise, particularly in emerging sectors like renewable energy and electric vehicles, investments in rare earth mining projects could prove lucrative. Additionally, supporting initiatives aimed at enhancing the sustainability and environmental responsibility of rare earth mining operations can align with socially responsible investment strategies.

The management of natural resources plays a crucial role in maintaining environmental balance. The interconnectedness of various environmental components means that overconsumption or misuse of resources can disrupt this equilibrium, leading to harm to all forms of life, directly or indirectly.

Non-renewable resources, once used or depleted, cannot be replaced or recovered. Examples of such resources include minerals and fossil fuels. Minerals are categorized as non-renewable because they are naturally formed through geological processes that take thousands of years. Similarly, fossil fuels are finite resources that are extracted from the Earth's crust and cannot be replenished on a human timescale.

In addition to minerals and fossil fuels, some animal species, particularly endangered ones, may also be considered non-renewable resources. This classification arises from their dwindling populations and the inability to restore their numbers once they are lost.

Effective management of non-renewable resources is essential to ensure their sustainable use and minimize environmental degradation. This involves strategies such as conservation, responsible extraction practices, and the development of alternative sources of energy and materials.

The management of nonrenewable resources encompasses several key components:

– Ensuring Availability: This involves overseeing the exploitation and extraction of resources to maintain a steady supply for current and future needs.

– Resource Allocation: Allocating resources among competing stakeholders, which may involve balancing the interests of local and international players in resource utilization.

– Creating an Enabling Environment: Establishing favorable conditions for resource industries to thrive, including regulatory frameworks, investment incentives, and infrastructure development.

– Revenue Management: Ensuring integrity in the management of revenues generated from resource extraction, mining, and processing to maximize benefits for the nation.

– Ownership Policies: Developing policies to manage national ownership of non-renewable resources, including regulations on ownership rights, royalties, and licensing.

– Environmental Impact Mitigation: Implementing measures to limit the environmental impact of resource exploitation, including conservation efforts, pollution control, and reclamation of affected areas.

– Health and Safety: Ensuring the health and safety of workers involved in resource exploitation through stringent regulations and workplace safety standards.

– Sustainable Economic Development: Converting resource use into sustainable economic development through linkages with other sectors, value addition, and diversification of the economy.

– Utilizing Resource Rents: Using revenue generated from resource exploitation for the development of economic and social capital, thereby contributing to the overall creation of wealth and well-being in the country.

A significant concern is that governments, particularly those that are major producers of fossil fuels and minerals, may not be receiving sufficiently large rents or revenues from the production of these extractive products. This issue can be attributed to various factors, including fiscal regimes that are not optimized to extract maximum rents and mineral policies that primarily prioritize attracting investments without adequately considering changing global dynamics and national interests.

There is a growing need to challenge conventional wisdom, including resource governance policies established by multilateral institutions in the 1970s, as these policies may no longer be suitable given the evolving circumstances. Many of these policies tend to favor the private sector and may not ensure maximum benefits for the countries supplying the resources. A key emerging concern is tax avoidance, often facilitated by transfer pricing practices, which were not anticipated by existing mineral policies.

Addressing these challenges requires a reevaluation of resource governance frameworks and the development of new policies that prioritize the interests of resource-rich countries. This includes designing fiscal regimes that effectively capture resource rents, revising mineral policies to align with national objectives, and implementing measures to combat tax avoidance and ensure fair revenue distribution. By doing so, countries can better harness the benefits of their natural resources to promote sustainable development and economic prosperity.

The key feature of the framework (table 5.1), which consists of experience and track records, is that a sound natural resource policy entails not only a legislative framework but also fiscal terms and policies that encourage the sustainable exploitation of natural resources. This framework provides a detailed description of the objectives and attributes of effective natural resource management, highlighting the importance of policy implementation and enforcement. In essence, successful natural resource management hinges on the effective execution of policies and strategies outlined within the framework.

Table 5.1 Framework for management of non-renewable resources

Criteria	Description	Purpose
Natural resource policy	A key document that outlines the stakeholder's objectives in the exploitation of natural resources. It addresses all issues related to the exploitation of natural resources	– coordinate the use of natural resources by prescribing the role of the government and that of stakeholders (those who affect or are affected by the natural resources) in relation to the exploitation of natural resources. – enable the exploitation of natural resources in line with sustainable development practices; – ensure the use of revenues accrued from the exploitation of natural resources for investments, e.g. infrastructure or socio-economic development program
Legal and regulatory framework	The legislative framework outlines the relevant elements of the natural resources policy in detail, setting the legal and regulatory framework, including procedures to be followed in the exploitation of natural resources	– provide a legislative framework that administers the exploitation of natural resources. This includes penalties for those who violate that laws governing the exploitation of national resources; – provide licenses, permits and rights for natural resources exploitation
Fiscal regime	This section of the natural resources policy illustrates fiscal terms and policies pertaining to the exploitation of natural resources	– provide fiscal terms that administer all commercial activities pertaining to exploitation of natural resources; for example, the imposition of taxation measures that are enforced to compel those who exploit natural resources to provide compensation; – non-renewable resources should generally have higher (and specialized) taxation levels than other resources as they cannot be replaced; i.e. so economic rents compensate for their removal
Sustainable development	The section of the natural resource policy that promotes sustainable exploitation of natural resources. Sustainable development entails social, economic, and environmental issues. Non-renewable natural resources and renewable natural resources are managed differently, due to the "unsustainable nature" of non-renewable resources recourses	– ensure respect of sustainable development principles. If properly prepared and implemented, policies tied to sustainable development promote socio-economic and environmentally sustainable exploitation of natural resources. This also includes "derived effects" of the exploitation. For example, promoting proper co-coordination of waste management. Waste that emanates from the exploitation of natural resources should be managed effectively so that it does not surpass the capacity of the natural environment to absorb the waste products

Regarding fiscal regimes for fossil fuels and minerals, it's crucial to note that they are not standardized. Instead, a variety of mechanisms such as royalties, taxes, resource rent, incentives, and state equity levels have been devised to encourage exploration and investment while also capturing some of the benefits for the state and the public.

Sustainable development of non-renewable resources involves policies, principles, and practices aimed at utilizing mineral resources in a manner that ensures access to these resources and their benefits for future generations. A primary objective is to ensure that nations with mineral wealth benefit both in the short and long terms. This can include using revenues from mineral resource development for socioeconomic programs, establishing manufacturing industries, and supporting other initiatives aimed at fostering sustainable economic growth and development.

Mining labor inputs and employment related to natural resource extraction are critical aspects that warrant efficient coordination within a country's mining policy. A robust extraction policy should include guidelines for incorporating foreign labor, along with a clear framework for local district hiring and trans-migration. Additionally, provisions for education, training, and skills development for employees should be established, alongside strict adherence to safety and health measures. Another frequently overlooked aspect of resource management and mining operations is the significant number of individuals involved in artisanal and small-scale mining.

Several specific principles can enhance extraction practices to promote more sustainable development:

– preserving strategic minerals: ensure the preservation of strategic minerals essential for future development and generations, safeguarding their availability for long-term needs;

– enforcing production quotas: implement production quotas or caps to regulate extraction rates and prevent overexploitation of resources.

– limiting exploitation licenses: control the number of exploitation licenses issued, restrict the areas available for exploitation, or limit the number of extraction sites to manage environmental impacts and resource depletion.

– extending my life: ensure longer mine life by limiting annual capacity or implementing measures to optimize resource use and minimize waste generation.

– establishing profit trust framework: establish a profits trust framework to allocate revenues from resource extraction towards sustainable development initiatives, environmental conservation, and future generations.

– implementing incentives and punishments: introduce incentives to promote alternative approaches and technologies that minimize environmental impacts, while implementing penalties for non-compliance with sustainability standards.

– managing tailings and spoils: strategically position and manage current unprofitable tailings and spoils to minimize environmental contamination and maximize resource recovery through reprocessing or recycling initiatives.

The global push to mitigate climate change has accelerated the transition towards renewable energy sources. Technologies like solar, wind, and hydropower offer clean and sustainable alternatives to fossil fuels. Governments worldwide are implementing policies and incentives to drive the adoption of renewable energy, facilitating a shift towards greener energy systems. Additionally, the finance industry plays a crucial role in funding renewable energy projects and supporting the growth of this sector, contributing to a more sustainable energy landscape.

The future of non-renewable resources (figure. 5.2).

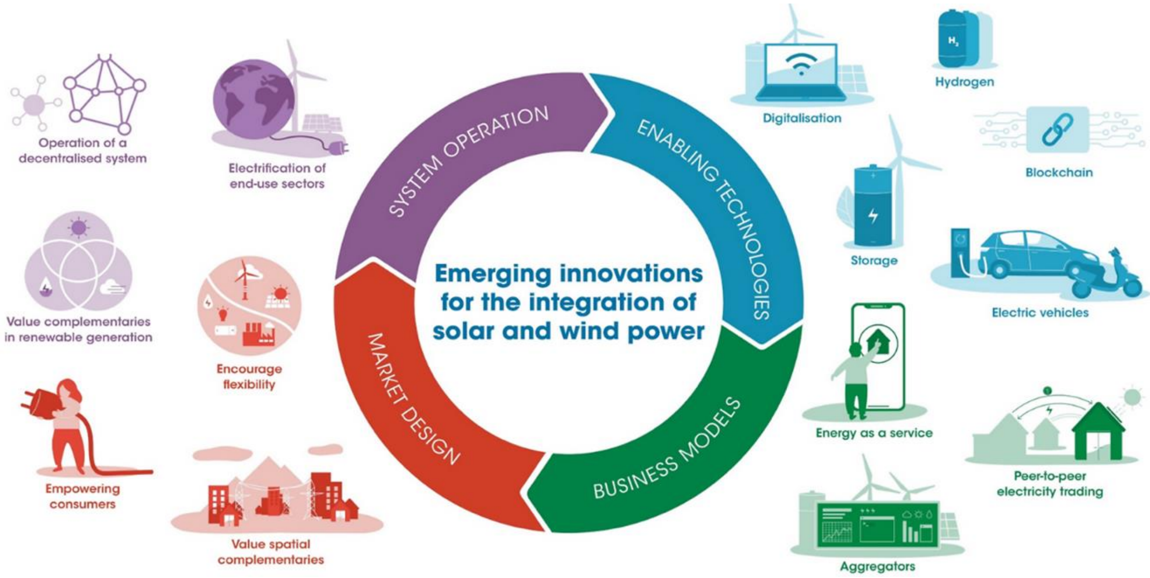


Figure 5.2 The future of non-renewable resources
Source: The World Economic Forum (2020)

In the mining sector, companies are increasingly embracing sustainable practices to minimize their environmental footprint. Technological advancements, including the use of autonomous vehicles, advanced sensors, and machine learning algorithms, are revolutionizing mining operations, making them more efficient and environmentally friendly. Investors who prioritize environmental, social, and governance (ESG) factors can identify opportunities in companies that prioritize sustainable mining practices, contributing to responsible resource extraction and management. This shift towards sustainability in the mining industry aligns with broader efforts to promote sustainable development and reduce environmental degradation.

5.2 Hotellling's Rule, Scarcity and Exploration

Harold Hotelling regarded exhaustible resources as assets that could be extracted either immediately or in the future. According to Hotelling's rule, producers and resource owners are primarily motivated by profit, and production is driven by the pursuit of financial gain. The theory posits that exhaustible resources should be viewed as investments that have the potential to appreciate over time. This perspective leads to comparisons between the future prices of resources, such as oil, and alternative investments like bonds or savings accounts (Hotelling, 1931).

In essence, Hotelling's theory suggests that resource owners will only extract a limited supply of the resource if its future value exceeds that of alternative interest-based assets. While short-term market fluctuations may influence resource prices due to changes in supply and demand, the theory predicts that in the long run, the net price of the resource should surpass the prevailing interest rate each year. For instance, if the price of the resource (inclusive of storage and production costs) fails to increase at a rate higher than the interest rate, there would be no economic incentive to restrict the supply of the resource.

In simpler terms, if resource owners anticipate that the price of the resource will rise at a slower rate than interest rates, they would find it more profitable to sell the resource and invest the proceeds in interest-bearing assets like bonds. Conversely, if the price of the resource, such as oil, is expected to increase at a faster pace than interest-based investments, it would be more advantageous for producers to retain the resource underground as its value would likely appreciate more in the future.

Hotelling’s theory suggests that this dynamic applies to all exhaustible resources. As prices increase, demand for the resource may decrease, leading to a reduction in production until the resource is eventually depleted. This process reflects a rational response by resource owners to maximize their profits over time while considering the interplay between resource prices and alternative investment opportunities.

Indeed, Hotelling’s theory posits that resource owners view their resources as assets with the potential to appreciate over time. If owners anticipate that future prices of exhaustible resources will increase, they may opt to decrease current production and refrain from extracting the resource. Conversely, if the outlook for future prices is less favorable, owners may accelerate extraction and redirect their investments elsewhere, such as bonds.

This short-term behavior described by Hotelling reflects rational decision-making by resource owners seeking to maximize their profits in the present. However, in the long run, Hotelling predicts that resource prices will increase annually at the same rate as the market rate of interest.

Hotelling further assumes that resource owners aim to maximize the present value of their future profits. As a result, resources are extracted in order of accessibility, with the easiest and cheapest to extract being utilized first. Additionally, prices of resources are always considered as net prices, implying that extraction costs have already been accounted for. This perspective provides a framework for understanding how resource owners navigate decisions about extraction and investment over time.

It's true that while cartels like OPEC exist and have the potential to influence oil prices, the oil market still exhibits characteristics closer to perfect competition compared to other market forms. OPEC, being the largest cartel, controls around 40% of the market share and could indeed impact prices. However, the influence of OPEC is somewhat mitigated by the significant market shares held by other major producers such as Saudi Arabia, the United States. This diversification of production among various countries reduces the cartel’s overall influence (British Petroleum, 2015).

In this context, it’s worth noting that Hotelling used an equation to describe future prices of exhaustible resources in a scenario of free competition. This equation helps to model how prices of such resources would evolve over time in a competitive market environment:

$$p = p_0 e^{yt} \qquad (1)$$

Price p, stands for the net price received after paying for the extraction cost and placing the resource on the market. The force of interest or the compound rate is denoted by γ, which makes $e^{-\gamma t}$, the present value of a unit of profit, which will be obtained at time t. The assumption while using this equation is that the interest rate will remain unchanged as well as initial price remaining the same throughout time (figure. 5.3).

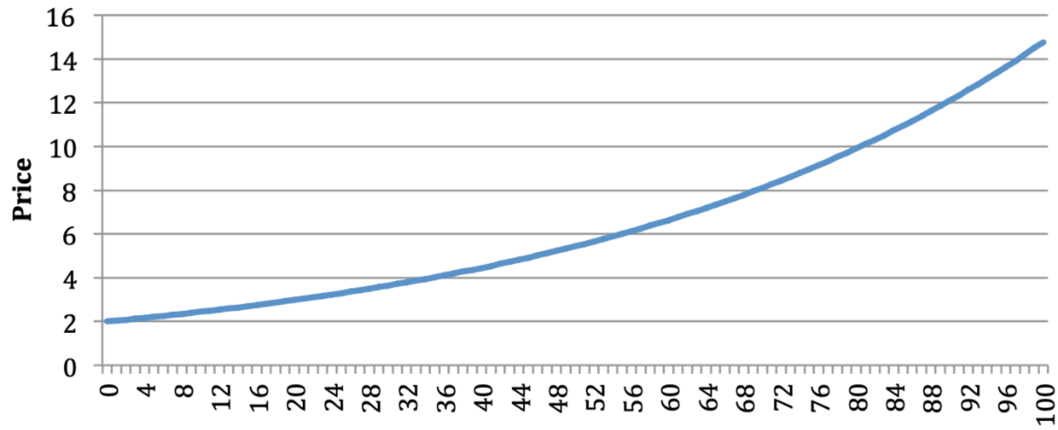


Figure 5.3 Hotelling's price path with a time period of 0-100
Source: Ukani (2016)

The graph above shows a representation of equation (1), when assuming two percent compound rate, and it can be observed that the function is exponential resulting in prices increasing constantly with time. Furthermore, the equation tells us that the price of an exhaustible resource is a function of time. Price, p_0 (which has been assumed to be two in this example), stands for the price now or today (t = 0), this value will depend on the demand and the total supply of the resource. If we denote the latter by a, and use

$$q = f(p, t) \tag{2}$$

we observe that the production rate of the resource is a function of time as well as price of the resource. For quantity taken at time t, if the price is p, we get an equation, which show us the total supply of the resource:

$$\int_0^T q dt = \int_0^T f(p_0 e^{\gamma t}, t) dt = a \tag{3}$$

The upper limit T, stands for the final time of exhaustion whilst the lower limit 0, stands for the initial time. The above equation shows that quantity supplied at different time periods, is a function of the price at the given time, which in turn shows us how much of the total supply or known resource stock is left.

While dt stands for the different time periods between 0 and T, the former letter d is an infinitesimal and is 1 for simplicity in this research, and since q will be zero at the time of final exhaustion, we will get the equation to determine T:

$$f(p_0 e^{\gamma t}, T) = 0 \tag{4}$$

The solution for the final time of exhaustion will depend on the function *f (p,t)*, which in turn will also give us the answer to q. We can use an example to simplify the equation. Suppose the demand function is given and it is:

$$q = 5 - p \tag{5}$$
$$0 \le p \le 5 \tag{6}$$
$$when\ q = 0, then\ p \ge 5 \tag{7}$$

It's intriguing that Perman et al. (1996) present an alternative solution to the optimal resource extraction problem within a competitive market. This approach offers insights into how various factors influence the price dynamics of non-renewable resources, addressing some of the criticisms directed at Hotelling's theoretical framework.

The graph provided by the authors illustrates the net price path over time and its relationship to factors such as demand, resource stock, and time. By examining this graph, one can better understand how the Hotelling rule operates and how changes in these variables impact the price trajectory of non-renewable resources. Moreover, the graph highlights the concept of maximum social welfare and how it aligns with the optimal resource extraction over time (fig. 5.4).

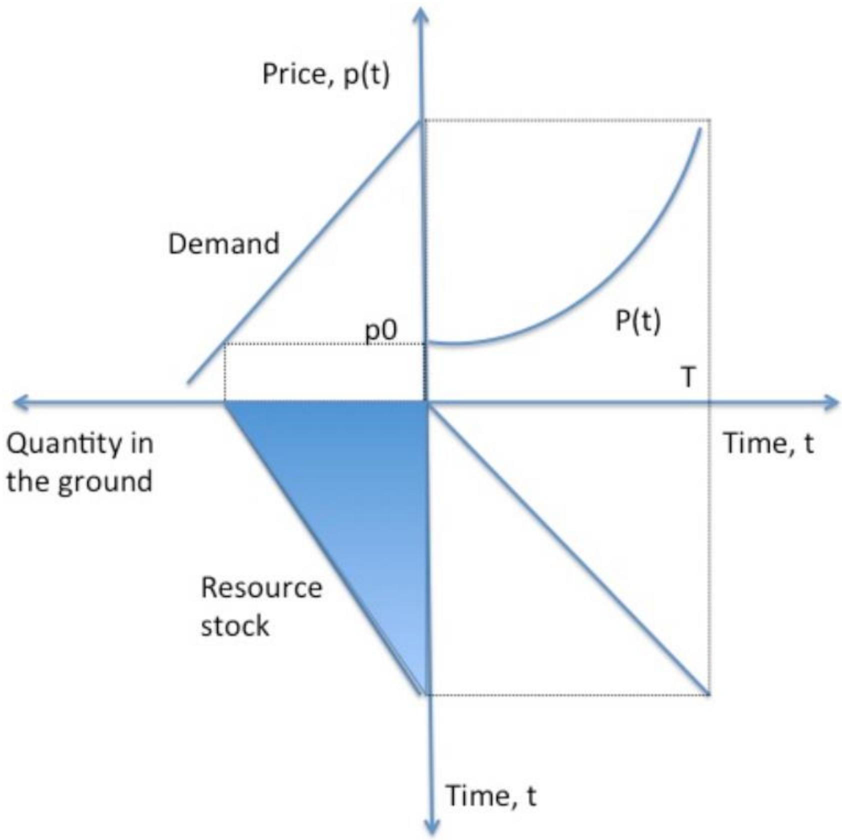


Figure 5.4 Optimal resource depletion model
Source: Ukani (2016)

Perman et al. also delve into the implications of changes in the known resource stock size and extraction costs on their model. If the known resource stock size increases, the resource price would decrease due to decreased demand. However, the price path would shift outward while remaining parallel to the previous one, as the interest rate remains constant. With a larger resource stock, the depletion of the resource would occur later, resulting in a delayed arrival at the point of resource exhaustion and the associated peak price.

Regarding changes in extraction costs, an increase would lead to a higher initial resource price and subsequently a new price path. This higher initial price would dampen demand, causing a shift along the demand curve to the right. Consequently, the rate of resource depletion would slow down because agents would be less incentivized to invest in or extract the resource at a higher price.

Indeed, Perman et al.'s model provides valuable insights into the factors influencing resource prices and helps explain the observed volatility in contrast to Hotelling's more simplistic prediction. While the model may not necessarily offer improved predictive capabilities, it offers a more nuanced understanding of how various variables affect resource prices.

The criticism levied against Hotelling's rule likely served as the impetus for Perman et al. to develop their model. By addressing the shortcomings of Hotelling's framework and incorporating additional complexity, the authors were able to provide a more comprehensive analysis of resource price dynamics.

5.3 Policy Implications for Fossil Fuels, Minerals, and Other Non-Renewables

5.3.1 Global Fossil Fuel Reduction Pathways

The developments outlined in the 2021 Glasgow Climate Pact and subsequent events highlight a growing recognition of the urgent need to address fossil fuel production and consumption to meet global climate goals. The launch of alliances and commitments to phase out oil and gas production reflect a shift towards prioritizing renewable energy sources and reducing reliance on fossil fuels.

However, despite these commitments, global fossil fuel emissions have continued to rise, underscoring the challenges and complexities of transitioning to a low-carbon economy. The 2022–2023 global energy crisis has further complicated efforts, leading some countries to prioritize short-term energy security over long-term sustainability goals (Atewamba, 2015).

The debate over the role of natural gas as a "bridge fuel" adds another layer of complexity to the transition. While natural gas is often seen as a cleaner alternative to coal, its long-term impact on emissions and climate goals remains a subject of debate.

Overall, the global community faces significant challenges in aligning fossil fuel production and consumption with climate objectives. Addressing these challenges will require coordinated action at the international level, as well as ambitious policies and investments to accelerate the transition to renewable energy sources and achieve net-zero emissions by 2050.

Process-based integrated assessment models (IAMs) play a crucial role in informing policy discussions and decision-making regarding energy transitions and climate action. These models offer valuable insights into the complex interactions between energy systems, land use, emissions, and climate change, allowing policymakers to assess the impacts of different policy options and pathways. IAMs help policymakers understand the implications of various strategies for reducing coal, oil, and natural gas emissions, and provide guidance on the most cost-effective pathways to achieve climate goals. By simulating different scenarios and considering factors such as technology deployment, energy efficiency improvements, and policy interventions, IAMs can help identify optimal strategies for transitioning to a low-carbon future while minimizing economic costs and maximizing social benefits (Azizi, 2018).

Furthermore, IAMs facilitate interdisciplinary collaboration by integrating knowledge from various fields, including climate science, economics, engineering, and policy analysis. This interdisciplinary approach allows for a comprehensive assessment of the challenges and opportunities associated with energy transitions, and helps stakeholders make informed decisions based on the best available evidence. Overall, process based IAMs are powerful tools for guiding policy development and implementation in the context of climate change mitigation and sustainable development. As policymakers grapple with the urgent need to transition to a net-zero future, IAMs will continue to play a vital role in shaping effective and equitable strategies for achieving climate goals.

To achieve a given carbon budget consistent with limiting global warming, integrated assessment models (IAMs) rely on a range of strategies across multiple sectors. These strategies include:

– Phasing out fossil fuels: this involves transitioning away from coal, oil, and natural gas in energy production, buildings, transportation, and industry. This transition may involve increasing the use of renewable energy sources such as solar, wind, and hydroelectric power, as well as improving energy efficiency and implementing electrification in various sectors.

– Transforming agricultural and land-use practices: changes in agricultural practices, such as reducing deforestation, enhancing soil carbon sequestration, and promoting sustainable land management, can contribute to emissions reductions and carbon sequestration. This includes afforestation and reforestation efforts, as well as sustainable agriculture practices that minimize emissions from livestock and land use change.

– Reducing energy and material consumption: efforts to reduce energy consumption through efficiency improvements, lifestyle changes, and shifts to less resource-intensive production methods can help lower emissions. Similarly, reducing material consumption and promoting circular economy principles can mitigate emissions associated with resource extraction, manufacturing, and waste disposal.

– Carbon dioxide removal (CDR) and carbon capture and storage (CCS): CDR technologies, such as bioenergy with carbon capture and storage (BECCS) and direct air capture with carbon capture and storage (DACCS), aim to remove CO_2 from the atmosphere and store it underground. CCS involves capturing CO_2 emissions from industrial processes or power plants and storing them underground to prevent their release into the atmosphere.

Addressing non-CO_2 greenhouse gases (GHGs), such as methane, is also important for limiting peak warming. Reductions in methane emissions, which can come from sources like agriculture, waste management, and fossil fuel production, can help mitigate climate change.

The feasibility and implications of these mitigation strategies vary depending on factors such as technological advancements, economic conditions, policy interventions, and environmental considerations. IAMs help evaluate the potential effectiveness, costs, and trade-offs associated with different mitigation pathways, providing valuable insights for policymakers and stakeholders as they work towards achieving climate goals. However, uncertainties remain regarding the scalability, cost-effectiveness, and potential side effects of certain mitigation options, highlighting the need for continued research and innovation in climate change mitigation strategies (Dogan, 2016).

The Working Group III (WGIII) contribution to the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6) has compiled and assessed a comprehensive database of scenarios to inform discussions on energy system transformations and climate change mitigation efforts. This database includes 3131 scenarios generated by nearly 100 different model versions from over 50 model families, each offering different regional scopes and temperature outcomes.

These scenarios provide valuable insights into the potential pathways for reducing fossil fuel use and achieving the objectives outlined in the Paris Agreement. By analyzing a wide range of scenarios, policymakers and stakeholders can better understand the implications of various mitigation strategies and make informed decisions about energy policies and investments.

The scenarios database compiled in the AR6 is expected to play a significant role in shaping socio-political discourse and informing policy debates on climate change mitigation in the coming years. It provides a robust foundation for identifying pathways to decarbonize energy systems and transition to more sustainable and resilient economies.

Overall, the extensive collection of scenarios presented in the AR6 serves as a valuable resource for policymakers, researchers, and the broader public, offering a comprehensive understanding of the challenges and opportunities associated with addressing climate change and reducing reliance on fossil fuels.

5.3.2 Mineral Policy within the Framework of Limited Critical Resources and a Green Energy Transition

The European Green Deal, introduced by the European Union (EU) in late 2019, aims to mobilize industries toward a clean and circular economy (CE). This strategy builds on the concept of transitioning from a linear economic model, characterized by take-make-dispose, to a circular model that emphasizes resource efficiency, waste reduction, and recycling. One of the key objectives of the CE model is to increase the recovery rate of valuable materials, such as cobalt and nickel, through recycling processes. To achieve this, new mineral recycling technologies are being developed, particularly focusing on hydrometallurgical processes. These processes are less energy-intensive compared to traditional pyrometallurgical methods.

The goal of these new recycling technologies is to achieve recycling rates of over 90%. Companies involved in developing these technologies are primarily interested in direct recycling or cathode-to-cathode recycling, which allows for the recovery of chemicals and chemical powders suitable for direct sale back to initial product manufacturers. However, despite the promising developments, none of these technologies are currently operating at scale. Scaling up these technologies to industrial levels poses a significant challenge but is crucial for realizing the full potential of mineral recycling and advancing the goals of the circular economy. Continued research, investment, and collaboration will be essential to overcome these challenges and facilitate the transition to a more sustainable and circular economic model (Way, 2022).

The consideration of non-renewable natural resources as a factor in economic growth has been a topic of discussion for over a century. Initially, models focused on predicting the peak of mineral production and the onset of physical depletion of available reserves, with hypotheses suggesting that technological advancements could only mitigate resource constraints to a limited extent.

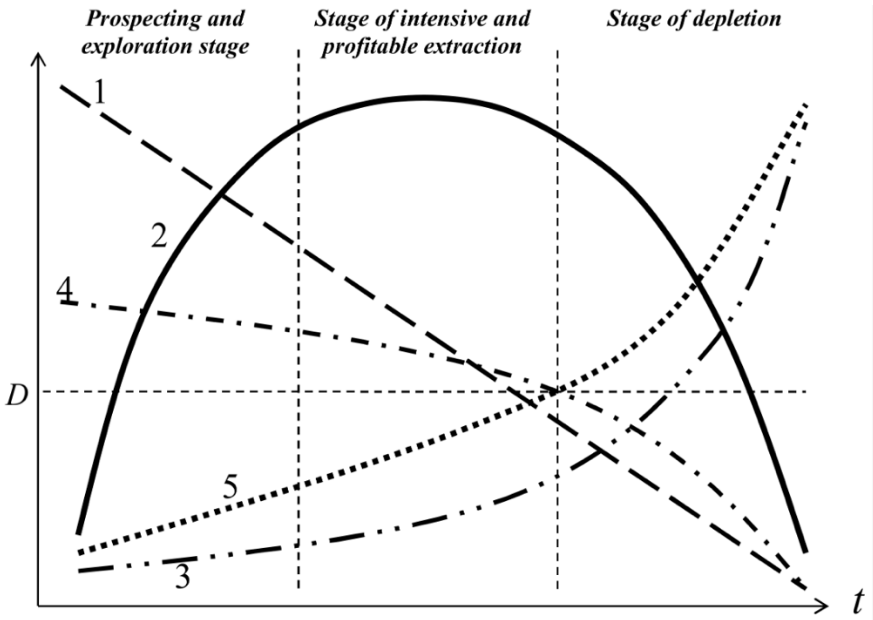
However, modern economies acknowledge their dependence on strategic minerals, and in recent decades, conflicts related to mineral use in geopolitics have been addressed. This is evident in the revision and updating of lists of critical minerals in countries like the USA, Canada, and the EU, which categorize minerals based on the level of supply risk for each country. With the increasing adoption of green energy technologies, battery metals have been added to these lists, while rare earth metals have gained significance due to supply conflicts with China.

Despite advancements in raw material recycling and the emergence of new materials and substitutes, discussions about the physical depletion of minerals have waned. However, crises related to accessibility and unpredictable price increases for various minerals continue to occur periodically, highlighting the ongoing importance of strategic mineral resources in global economics and geopolitics.

The inaccessibility of minerals occurs at the confluence of several factors in time and space, the most real of which are the following (Calvin, 2021):

- regional division of production and consumption of metals.
- monopolization of sources of raw materials and production.
- growth in demand with changes in technology.
- use of the resource as a geopolitical tool.

In any case, for a theoretical understanding of the dynamics of mineral development, it is appropriate to identify three stages of mineral development, which reflect changes in certain economic indicators and indicators of the geological environment: geological study, intensive use and depletion (figure. 5.5). Most often, production risks, cost increases and price increases are overcome at the end of stage 2 and stage 3.



1 – the ratio of inferred resources to minable reserves;
2 – total return on investment in exploration and operation;
3 – the degree of involvement of secondary resources and substitutes;
4 – stability of the geological environment;
5 – costs for environmental protection and rehabilitation of territories;
D – assimilation potential of the geological environment

Figure 5.5 Stages of mineral development and characteristic changes in indicators of the mineral resources and geological environment state
Source: Nate et. al (2021)

The typical stages of deposit development are highlighted in figure. 5:5: 1 – prospecting and exploration stage; 2 – stage of intensive and profitable extraction; 3 – stage of depletion.

The scheme presented provides a theoretical framework for understanding the stages of resource development and underscores the importance of modeling risks and availability in the implementation of new technological scenarios, particularly those reliant on specific resources. It highlights the criticality of minerals by examining specific countries and minerals.

The measurement of natural resource scarcity is a topic of ongoing debate, with various indicators such as unit costs, prices, rents, elasticity of substitution, and energy costs being considered. Recent studies have also focused on optimizing modern energy production facilities, but there is a notable oversight regarding the availability of critical raw materials and metals for these processes.

Addressing this gap in research is crucial for ensuring the sustainability and resilience of energy systems, as the availability of essential minerals and metals can significantly impact the feasibility and effectiveness of energy production technologies. By integrating considerations of resource availability and criticality into energy optimization models, researchers can better inform decision-making and policy development in the transition to sustainable energy systems.

Summary

Non-renewable resources can be defined as a substance of economic value that cannot be easily replaced by natural means or equally in quantity to its consumption. Contrary to renewable resources these resources are not replaced or renewed as quickly as they are being used, leaving lesser quantity in the long run. Some other examples of non-renewable resources as Hotelling (1931) describes them are minerals, forests, and fish. The latter two, which he also describes as semi replaceable assets, can be renewed but it a takes a longer time than the other renewable resources. His study "Economics of exhaustible resources" however focuses more on completely irreplaceable assets, which are fossil fuels and minerals.

Hotelling's theory states that when a holder or owner of exhaustible natural resources produces the required commodities, its revenue can surpass the earnings from other simple interest-bearing financial instruments. The gap between the marginal extraction costs and the market price of such nonrenewable resources is called scarcity rent. Thus, this can be achieved by emptying the stock of market resources. Besides, it is also understood as the net return from the sales of a natural resource in a perfectly competitive market. Moreover, economists use this concept to forecast future prices of nonrenewable resources.

The mitigation scenarios database of the Intergovernmental Panel on Climate Change's Sixth Assessment Report is an important resource for informing policymaking on energy transitions. However, there is a large variety of models, scenario designs, and resulting outputs. The green energy transition is associated with the use of a wide range of metals and minerals that are exhaustible. Most of these minerals are limited in access due to small resource fields, their concentration in several locations and a broader scale of industry usage which is not limited exclusively to energy and environmental sectors.

Discussion questions

1. What are non-renewable resources?
2. What are the types of non-renewable resources management?
3. What is sustainable management of non-renewable resources?
4. What is Hotelling's theory?
5. What are the problems with Hotelling's theory?
6. What is Hotelling's theory for dynamic efficiency?
7. How does Hotelling's theory apply in politics?
8. What strategies are used to achieve a given carbon budget?
9. What stages of mineral development do you know?

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CHAPTER 6: ECONOMICS OF RENEWABLE RESOURCES

The central economic inquiry regarding the administration of renewable natural resources has revolved around determining the optimal balance of harvesting between the present and future timeframes. For instance, in ocean fisheries, the economic quandary centers on determining the appropriate amount to harvest in the current season while preserving enough in the sea to ensure future growth for subsequent seasons. Similarly, in commercial forestry, the economic focus lies in determining the interval between harvests that maximizes profits for forest owners. Analogous scenarios, involving discounted income streams, can also be contemplated for renewable water, soil, or animal resources.

Determining the timing and quantity of harvests has been framed as a delicate balance between immediate gains and long-term benefits and costs. To achieve this equilibrium, economists have employed dynamic optimization methods, which involve finding the most efficient allocation of resources over time.

The predominant aim of economic efficiency, where the additional benefits of a specific course of action equal the additional costs, has been a central focus in many economic models concerning renewable resources. These traditional economic principles, originally developed for managing manufactured capital, have been extended to natural capital. This approach predominantly concerns itself with the utilization of natural capital flows (e.g., materials and energy) rather than the preservation of capital stocks (e.g., life-support systems, regenerative capacity).

Criticism has arisen against this focus on flows, as it’s viewed as short-term oriented, akin to living off the capital rather than the income. Conversely, a more intricate understanding of renewable resources has emerged from a natural science standpoint, broadening the focus to encompass the scale of impact and resilience of ecosystem services. Recognizing the intricate interdependencies on natural capital shifts the emphasis towards safeguarding non-substitutable capital stocks essential for sustained economic activity.

This perspective, rooted in adaptive systems thinking, advocates for renewable resource management strategies centered on controlling system parameters within stable domains, rather than pursuing targets for marginal extraction. The parametric management approach may sacrifice some potential economic profits that remain unrecovered, whereas marginal management, by its nature, drives a competitive resource industry towards a state of zero economic profit.

6.1 Dynamics of renewable resources

The behavior of a renewable resource X at time t can be represented by the following discrete-time, first-order difference equation:

$$X_{t+1} - X_t = F(X_t) - Y_t \tag{1}$$

where $F(X_t)$ represents a net growth function (i.e., birth less mortality), and Y_t is the period t harvest.

In this framework, each period’s contribution to the current stock is calculated as the disparity between growth and harvest. If harvest consistently surpasses growth, the renewable resource is on a declining trajectory. Conversely, if growth consistently outpaces harvest, the renewable resource is experiencing expansion. The presence and stability of steady states, where harvest precisely matches growth in every time period *(Y=F(X)* for all *t)*, can also be determined within this context and are frequently the primary focus of analysis.

For numerous renewable resources, the growth function is often defined based on an intrinsic growth rate *(r),* a carrying capacity *(K),* and periods where marginal additions to the stock increase or decrease. In the case of resources like forests, a phase of negative growth can also be incorporated to address the impacts of aging and decay. One commonly used growth curve among analysts is the logistic form:

$$F(X_t) = rX_t(1 - {}^{X_t}/_{K}) \tag{2}$$

Graphically, this form is shown in Figure 6-1, where the parameters normalized at *r = 1 and K = 1.*

The harvest (Y_t) can be defined as the decision variable itself or can be modeled as a production function subject to various factors such as technology, effort, and market conditions. For instance, in fisheries literature, it's common to estimate a catchability coefficient *(q)* to represent technology. Production is then modeled as a function of the stock (X_t) and effort (E_t) in a constant return to scale Cobb-Douglas function:

$$Y_t = H(X_t, E_t) = qX_tE_t \tag{3}$$

Effort, in turn, can be modeled as a function of profitability:

$$E_{t+1} = E_t + \eta[pH(X_t, E_t) - cE_t] \tag{4}$$

where $\eta > 0$ represents the speed to which effort adjusts to profit, *p* captures the price per unit of harvest, and *c* equals the cost per unit effort.

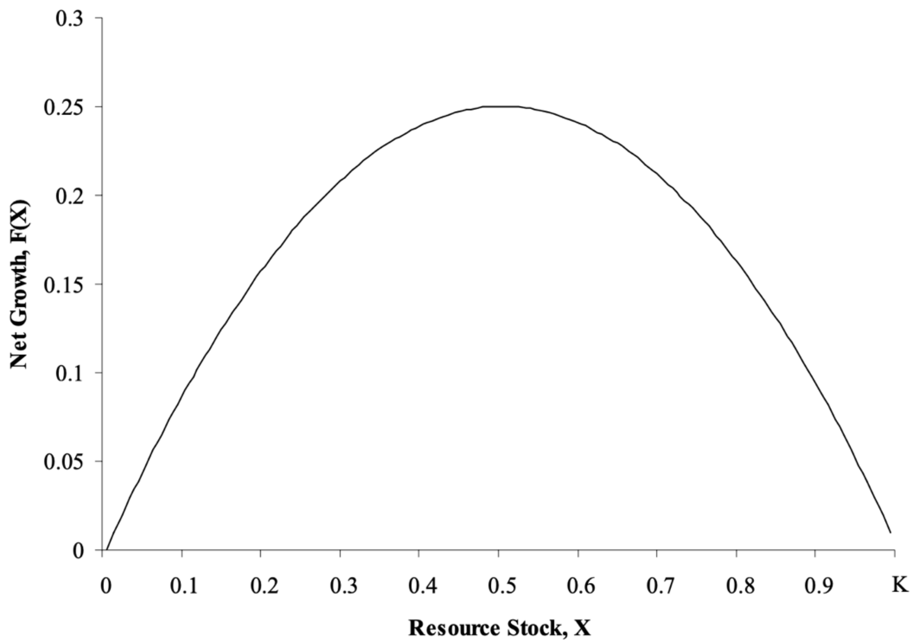

Figure 6.1 Theoretical Logistic Net Growth Function of a Renewable Resource
Source: Erickson (2002)

Within this framework, the allocation decision revolves around finding a balance, or marginal trade-off, between the net benefits of having more harvest (Y_t) in the current period versus having more stock (X_{t+1}) in the subsequent period, which serves as the source of future growth and benefits. Additionally, larger future stocks may yield the added benefit of reducing future harvest costs.

By defining a net benefit function, $\Pi(X, Y)$, and incorporating a discount rate, δ, methods of dynamic optimization can be employed to determine specific optimal time paths for effort, harvest, and resource stock. Various methods are available for this purpose, with marginal valuation and discounting being fundamental components across these methods.

To elucidate the economic intuition inherent in this type of resource allocation problem, let's examine the conditions for optimal management of a renewable resource in a steady state. Analytically, we can remove the time subscript to solve for steady-state levels of *X* and *Y*. By specifying a net benefit function $\Pi(X, Y)$ that depends on both the steady-state stock size and harvest level, along with a discount rate (δ), and resource dynamics as described in equation (1), the following two conditions must hold in an optimal steady-state:

$$Y = F(X) \tag{5}$$

$$F'(X) + \frac{\partial \Pi(X,Y) / \partial X}{\partial \Pi(X,Y) / \partial Y} = \delta \tag{6}$$

The first condition is straightforward: at a steady-state point, the harvest must equal the growth rate. The second condition, often referred to in the literature as the fundamental equation of renewable resources, demonstrates the economic rationale commonly found in classical resource economics. On the left-hand side, there are two terms. The first term, the total derivative of the growth function, represents the marginal addition to the net growth rate at the steady state. The second term, known as the marginal stock effect, is the ratio of partial derivatives of the net benefit function with respect to stock in the numerator and harvest in the denominator. This term quantifies the marginal value of *X* relative to *Y*. Together, the left-hand side of equation (6) encapsulates the internal rate of return of the resource at the steady state. At an optimal steady-state, equation (6) implies that this internal rate of return must precisely match the opportunity cost of managing the resource (i.e., the discount rate).

The rationale follows that an investor in a renewable resource will continue to harvest and deplete a resource stock if its internal rate of return exceeds what could be earned from the next best investment alternative. However, if this marginal return drops below what could be gained by liquidating assets and investing in an alternative with a certain return of δ, then the investor should reduce harvesting in the short term and restore equilibrium where marginal benefits equal marginal costs. In the long run, they may need to exit the industry altogether.

Figure 6.1 illustrates a range of points where $Y = F(X)$, varying from $X = 0$ (extinction), $X = 0.5$ (maximum sustainable yield), to $X = K = 1$ (carrying capacity). With the condition implied by equation (6), a steady-state optimum can lead to high $(X > 0.5)$, low $(X < 0.5)$, or extinct resource levels, depending on the specified bioeconomic parameters. For example, Colin Clark utilized this framework to show that driving a species to extinction can, in some cases, be the market optimum.

6.2 Concept of Maximum Sustainable Yield

Fishery resources, while renewable in nature, are susceptible to extinction if subjected to continuous and indiscriminate harvesting practices, as observed in numerous instances globally. The population size of fish stocks is influenced by a combination of biological, economic, and social factors. Given that fisheries resources often fall under the category of common property resources, their management poses complex challenges, making it difficult to implement comprehensive management measures. As a result, various management intervention options are necessary to ensure sustainable harvest levels and maintain inter- and intra-generational equity.

Among the various fishery management indicators or reference points, which are typically estimated using systematic landing data and stock assessment studies, one key indicator is the maximum economic yield (MEY). This reference point serves as the basis for formulating various management measures aimed at ensuring sustainable fisheries management.

The concept of Maximum Sustainable Yield (MSY) in fishing primarily relates to a biological phenomenon (figure. 6-2). MSY represents the level of fish catch or yield that can be harvested from a given system indefinitely without causing depletion of the stock (or the sea). Essentially, a catch level is deemed sustainable when it matches the growth rate of the population, ensuring that it can be maintained indefinitely. If the population size remains constant, the growth rate will also remain constant, allowing for a sustainable yield over time.

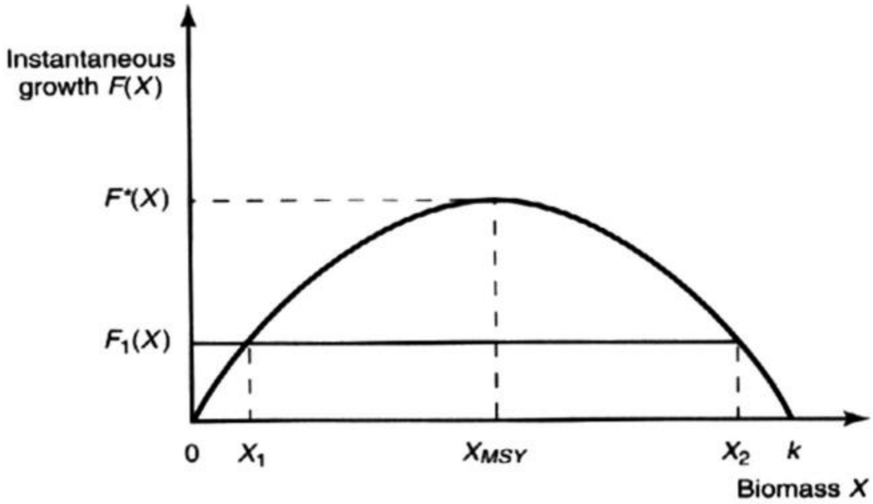

Figure 6.2 Sustainable Yield Curve
Source: Dixon (2005)

Maximum Economic Yield (MEY) is the yield level that aligns with the harvest or effort level that maximizes the sustainable net returns from fishing activities. Achieving a MEY harvest is desirable because it represents the catch level that allows society to optimize the utilization of the resources provided by nature.

MEY is a concept of long-term equilibrium that pertains to the output level and the corresponding effort level maximizing the expected economic profits in a fishery (fig 6-3). In many instances, this situation leads to yields and effort levels lower than those at maximum sustainable yield (MSY), and consequently, stock biomass levels are greater than those at MSY (Bromley, 2009).

In the past, fisheries management primarily focused on biological aspects, particularly in controlling fishing effort, without much consideration for the economic or social dimensions of fishing practices. However, it became evident that the net income derived from fishing and its subsequent use in supporting the livelihoods of fishers are crucial factors. Additionally, the costs and returns associated with fishing serve as significant incentives for individuals to engage in fishing as an occupation. Recognizing this, there was a shift towards incorporating economics into fisheries management to ensure a more comprehensive and sustainable approach.

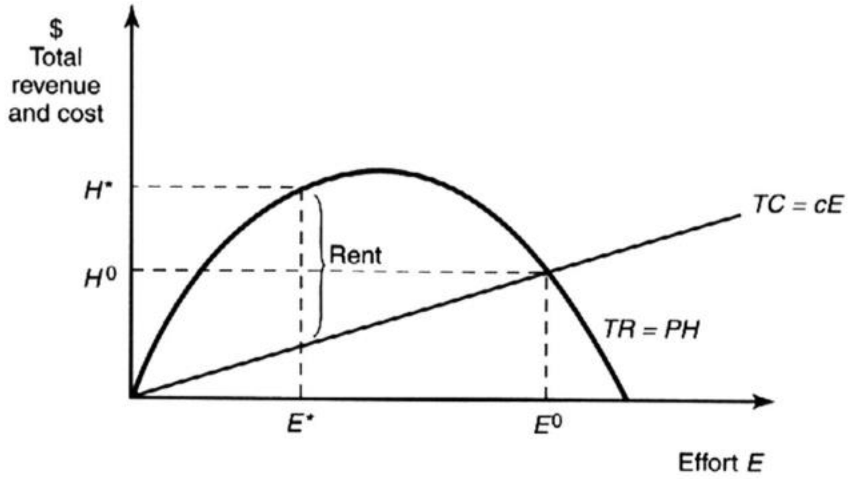

Figure 6.3 Maximum Economic Yield
Source: Narayanakumar (2017)

Economists have consistently contended that a fishery operating at its maximum economic potential typically also fulfills its conservation goals (Walters 1993; Mardie 2002). In such cases, yields and effort levels are often lower than those at maximum sustainable yield (MSY), leading to stock biomass levels higher than those at MSY (Mardie 2002, Bromley, 2009). Furthermore, reduced levels of fishing effort generally result in fewer adverse environmental impacts.

When examining the relationship between effort and revenue, it's observed that when the stock is low, effort must be high.

$$\text{Total revenue (TR)} = \text{Price (P)} \times \text{Catch (H)} \tag{7}$$

$$\text{TC} = \text{Unit cost (c)} \times \text{Effort} \tag{8}$$

$$\text{Rent} = \text{TR} - \text{TC} \tag{9}$$

The rent is maximized at the point E*, where:

- MEY is left of MSY
- Optimal harvest (H*) is less than the MSY harvest
- But rent is larger than at MSY.

The point E* represents the effort level at which the Maximum Economic Yield (MEY) occurs. At this specific effort level, the difference between the total revenue from fishing and the total cost of fishing is maximized. This difference is commonly referred to as resource rent.

Through marginal analysis, it can be shown that MEY occurs at the point where Marginal Cost (MC) equals Marginal Revenue (MR). It's observed that for each marginal unit of effort, the marginal rent is equal to 0, and the average rent is greater than 1 (figure 6-4).

"Goal of traditional fisheries management: achieve MSY. However, the economists aim for MEY in contrast to MSY. AT MEY, compared to MSY, the fish catch is lower, fishing profit is higher, fishing effort is lower, and the fish stock is higher. Thus, the author concludes that MEY is where more fish is conserved (Dixon, 2005).

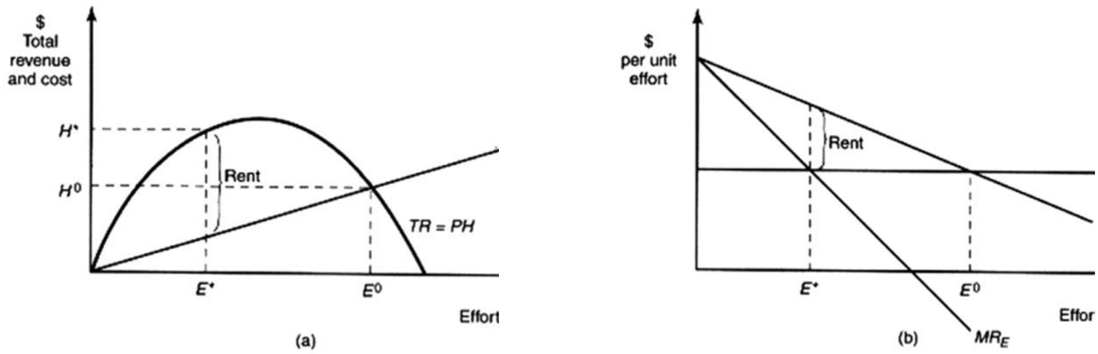

Figure 6.4 Resource rent
Source: Dixon (2005)

Steps in estimation of MEY

$$p = a - by \tag{10}$$

where, *p* is the price per unit weight of fish, *y* is the annual yield

The average price per unit weight of fish *(p)* is generally a monotonically decreasing function of annual yield *(y).*

The profit is obtained as a difference between total revenue *(TR)* and total cost *(TC)*, i.e.,

$$\Pi = TR - TC = (p - c)y \tag{11}$$

where *c* is the cost of harvesting one unit weight of fish.

From this, a cost function will be fit from the data collected:

$$MEY = {}^{(a-c)}\!/_{2b} \tag{12}$$

$$f_{mey} = [a +/-(a^2 - 4b\ MEY)]^{1/2}/2b \tag{13}$$

where, *a* = intercept; *b, c* =regression coefficients.

From f_{mey}, the optimum fleet size is obtained by dividing *b* by the average annual fishing days.

When estimating the Maximum Economic Yield (MEY), three key assumptions are typically made:

- zero discount rate.
- cost of fishing is a simple linear function of stock size;
- fishing costs rise proportionately with effort.

The cost of fishing plays a critical role in determining MEY. Generally, fishing costs increase as stock size decreases, and this increase occurs at an accelerating rate, reflecting the characteristics of fishing practices. In such a scenario, it's preferable to have a catch and effort level positioned to the left of the biologic equilibrium.

If the discount rate is very high or large, MEY will correspond to a biologic equilibrium (Clarke, 1990), because it becomes profitable to harvest the stock immediately, disregarding future net returns that are heavily discounted. Maximizing the economic viability of fisheries is aligned with the economic sustainability of the fisheries.

MEY serves as a valuable target reference point for fisheries management, despite the underlying assumptions. It ensures that stock levels in many fisheries are maintained at levels higher than those associated with traditional MSY targets. Moreover, MEY ensures optimal utilization of major inputs such as fuel and labor to maximize profits. It also helps in estimating excess fishing capacity within the sector, thereby providing a solid basis for recommending an optimum fleet size. Exceeding the MEY target leads to excess fishing capacity, lower returns, and consequently, reduced profits. Therefore, adhering to MEY is highly beneficial for achieving sustainable fisheries.

MEY serves as a crucial link between the biological and economic aspects of fisheries management. Drawing from the concept of the tragedy of the commons, which highlights the depletion of unmanaged natural resources, regulatory measures are necessary to ensure sustainable utilization. In the case of fisheries, the economics of fishing operations, including costs and returns, not only determine the profitability of the profession but also act as the driving force for continued involvement in the sector. MEY, by incorporating the costs and revenue earned from fishing into sustainable yield models, provides a viable method for formulating fishery management plans.

Several studies have demonstrated that the biological reference point (MSY) and the economic reference point (MEY) complement each other and should both be considered in the formulation of fishery management policies. This integrated approach ensures a balanced and sustainable management of fisheries resources.

6.3 Policies for sustainable management

6.3.1 Returning to inshore local fisheries to sustainably manage fish

The movement back to inshore fisheries at a global level is key to the "sustainability" or preservation of fish, as well as associated livelihoods and culture. The proposition is based largely on the consideration of mobile finfish populations where the stock (and management of stock) covers a large geographical range only part of which falls in coastal regions. It does not mean complete removal of all quota systems or unrestricted capacity of the inshore or artisanal fleets, and other important conservation measures such as establishing marine protected areas (MPA) could still be utilized in inshore waters. Movement towards re-establishing inshore fishing, at the expense of (rather than in addition to) subsidized and damaging offshore practices, would be a step forward for truly sustainable use of the oceans' living resources. The proposed return to inshore local fisheries, although more ambitious, is similar in many ways to the proposed 30% target for marine reserves, with fisheries control measures for the remaining 70% of the ocean (O'Leary et al. 2016). The advantages of the move to local fisheries are given below.

Advantage 1: Enhanced Stock Sizes

Coastal fisheries, particularly those operated by smaller boats known as "artisanal" fisheries, often face limitations in their ability to fully exploit a stock that covers a large geographical area, even if the current definitions of "inshore" were extended beyond 6 nautical miles. Simulation studies of large marine reserves have shown that such reserves effectively conserve mobile stocks with diverse movement patterns and can lead to increased catches of these stocks outside the reserve boundaries (Cornejo-Donoso et al., 2017). By creating large offshore marine reserves, these areas can act as effective sanctuaries, allowing fish to move into inshore waters where they can be harvested. This approach can contribute to enhanced stock sizes and improved sustainability of coastal fisheries.

Advantage 2: Enhanced Economic Efficiency

While large-scale industrial and commercial fishing operations may contribute to gross domestic product and economic growth, the significant subsidies primarily directed towards offshore fishing can render the process economically unsustainable in many cases. Studies have highlighted that these subsidies create economic inefficiencies, particularly in offshore fishing in the high seas (Sala et al., 2018). The removal of such subsidies by individual states could potentially create an uneven playing field and lead to political discontent, unless managed internationally.

Moreover, fisheries face various other economic challenges beyond simple "cost per tonne of fish" metrics, which are relevant across many countries worldwide. Locally caught fish often hold higher value for fishers, especially when sold directly or locally to fishmongers or restaurants (Bloom and Hinrichs, 2011). Furthermore, the sale of fish to local restaurants can bring tourist revenue into fishing towns. Finally, locally caught fish are likely to require fewer resources, such as diesel fuel, for the fishing process (Jacquet and Pauly, 2008). These factors collectively contribute to enhanced economic efficiency in coastal fisheries, promoting sustainability and supporting local economies.

Advantage 3: Preserved Cultural Values

Fish play a significant role in the coastal heritage of many towns and cities, and the closure of small-scale inshore fisheries has led to considerable deprivation in numerous Western communities (Reed et al., 2013). Local fisheries not only create employment opportunities but also serve to preserve the cultural values of these towns and the people residing in them.

These cultural values associated with fishing can attract additional economic incentives, such as tourism. For instance, towns like Padstow in the UK have vibrant tourism industries centered around fishing and seafood (Busby et al., 2013).

Moreover, cultural values linked to fishing extend beyond just catching fish. Local mollusc aquaculture, such as oyster or mussel farming in sheltered bays, harbors, and estuaries, can provide many of the same cultural values and employment opportunities as the fishing industry. Additionally, mollusc aquaculture produces high-value products with low carbon emissions and can potentially have positive effects on pollution levels (Hilborn et al., 2018). These cultural aspects contribute to the preservation of local heritage and support sustainable economic development in coastal communities.

Advantage 4: Enhanced Local Governance

Local governance systems for fisheries have demonstrated successes in the past (Pinkerton and Weinstein, 1995; Townsend et al., 2008). These systems offer an alternative to top-down regulated approaches commonly seen in fisheries management. While rights-based systems like individual transferable quotas have been shown to prevent fisheries collapse by limiting processes such as discarding, they also remove local decision-making, leading to resentment among fishers (McCormack, 2016). However, local governance can empower communities to take control of their fisheries management. Although the removal or restriction of fishing rights may cause resentment among those affected, the increase in the value of fish and profitability of inshore fishing, which most fishers partake in, can provide a solid foundation for successful local governance.

Local governance initiatives can extend beyond fishers themselves. Local seafood industries, including fish processing and seafood restaurants, can ensure markets for locally caught fish that are abundant in the area, reducing reliance on specific species. Conservation organizations can utilize catches to showcase the local diversity of marine life, generating interest in the marine environment, which is often lacking in many countries (Jefferson et al., 2014). These efforts collectively contribute to enhanced local governance and sustainable fisheries management.

6.3.2 Sustainable Forest management

The need to accommodate changing perceptions and demands into forestry practice (including influences from the broader environmental movement and discussions of sustainable development), and to supply a more diverse collection of ecosystem goods and services, has led to a strong focus on sustainable forest management (SFM) (Wilkie et al., 2003). The most widely used definition defines this as: "The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems".

The 1992 Earth Summit in Rio de Janeiro first set international targets for forest conservation through its Forest Principles (Anon, 1993). In the years since, other more quantifiable targets have been developed by institutions such as the International Tropical Timber Organisation (ITTO). Having agreed to the principle of measurable targets, governments have had to make some effort to find ways of recording these criteria and indicators of good forest management assumed much higher political importance than in the past. A summary of some of this activity is given in table 6-1; all the processes described have a general target of measuring "sustainable forest management" or something similar but use a variety of different indicators.

Table 6.1 Existing indicator systems for sustainable forest management

Relevant convention or process	Indicators
Global level processes seeking to measure sustainable forest management on a country scale	
Millennium Development Goals	Under goal 7: "Ensure environmental sustainability" there is an indicator:" proportion of land area covered by forest" but no reference to forest quality or sustainability of management
Convention on Biological Diversity	The CBD secretariat is developing indicators for its 2010 target including, "Area of forest…ecosystems under sustainable management". It seeks to develop outcome-oriented targets to assess the programme of work on forest biological diversity with some indicators relevant to SFM
International Tropical Timber Organization	ITTO has drawn up various C&I including for biodiversity conservation, natural forest management, plantations, and restoration
UN Forest Resources Assessment	The Forest Resource Assessment 2000 included aspects of biodiversity, naturalness, and non-timber forest products particularly in the temperate and boreal component
Regional level criteria and indicator processes seeking to measure forest quality on a country scale	
Ministerial Conference for the Protection of Forests in Europe	MCPFE has drawn up indicators of good forest management at a national level, and used them to report on European forest status
Montreal Process	Has drawn up C&I with 10 non-European temperate and boreal countries including a definition of sustainable forest management
Tarapoto Process	Indicators were developed by the Amazon Cooperation Treaty, but this process has not yet been reported in detail
Dry-Zone Africa Process	A series of C&I were agreed, but have not been measured
Central American Process	Draft C&I were developed in 1997, but have yet to be fully applied
North Africa and the Middle East	FAO process – draft C&I were produced in 1997
African Timber Organization	C&I developed with the International Tropical Timber Organisation with plans for implementation
National level criteria and indicator schemes seeking to measure forest quality on a country scale	
France	Detailed indicators for French forests were developed in the 1990s and are still used for reporting to the MCPFE process
Finland	Criteria and indicators were developed in 1997
Stand and landscape-level attempts to set criteria of forest quality and biodiversity	

Relevant convention or process	Indicators
Forest Stewardship Council	An accreditation body for independent assessment of sustainable forest management. The Principles and Criteria guide certification bodies, which draw up their own standards
Relevant convention or process	Indicators
Programme for Endorsement of Forest Certification Schemes	Formerly the Pan European Forest Certification scheme, previously operating just in Europe but now seeking a global programme
ISO 14000	The International Organization of Standardization has developed a certification scheme for timber, although this does not use independent assessment at stand level
Center for International Forestry Research (CIFOR)	CIFOR conducted a series of field-test to develop a generic set of C&I for SFM as well as toolkits for developing, choosing and testing C&I for stand-level forest management, along with specific criteria and indicators for plantations
Non-governmental attempts to define good forest management	
WWF/IUCN/École Polytehnique Fédérale de Lausanne	A landscape-scale system for measuring forest quality was developed and tested, based on indicators of authenticity, environmental benefits and social and economic benefits
IUCN The World Conservation Union	IUCN developed a computer software approach to measuring forest well-being using variable indicators
WWF European forest scorecards	The WWF European programme developed detailed scorecards for forest condition on a national scale
ProForest	Indicators of High Conservation Value Forest have been developed at stand and landscape level

Source: Dudley (2005)

The primary indicator for assessing sustainable forest management should be the area of forest land under sustainable management, which has already been identified by the Convention on Biological Diversity (CBD). Additionally, including produce from sustainably managed forests would provide further refinement by indicating the proportion of traded goods sourced from these improved management systems. However, there are potential challenges associated with implementing these indicators, and the information they convey may be limited. Therefore, it may be necessary to expand the overall picture by including data on natural forest cover and, if feasible, on key species that serve as indicators of good management practices.

To effectively utilize these indicators, agreement is needed on their specific forms, as well as on a series of definitional and methodical requirements. This may involve conducting new survey work to gather necessary data. Table 6-2 summarizes these requirements, providing a framework for developing and implementing comprehensive indicators for assessing sustainable forest management.

Table 6.2 Summary of development requirements for indicators of sustainable forest use

Form of indicators	Terms requiring definition	Methodical requirements	Survey requirements	Possible partners	Potential problems
Indicator 1: Area under sustainable forest management					
Either an indicator with a series of stages or a scoring system	"Sustainable management"	Agreement on measuring levels of sustainability	Global surveys	ITTO, World Bank, CIFOR, certification bodies, wood product companies	Agreement on what constitutes sustainable
Indicator 2: Products from sustainably managed forests					
Volume or value of products	"Sustainably managed"	Accounting methods	Existing surveys amalgamated into global figure	Certification bodies, major retailers, FAO	Agreement on what constitutes sustainable
Indicator 3: Area of natural forests					
Proportion of existing forest in natural state	"Natural"	Rapid survey methods (ideally satellite images) in tropics	Data available for most temperate forests, still needed in tropics, Southern Arc and north Asia	FAO, UNECE, ITTO, NASA, World Resources Institute	Identifying natural forests; agreement on what is "natural" in some areas
Indicator 4: Indicator species					
Status of key species reliant on sustainably managed forests	Identification of indicator species or surrogates	Survey methods exist	Major survey task unless data already collected for other indicators	National biodiversity surveys, Red List, NGOs, universities, research institutes	Costs of identifying and surveying relevant species may be prohibitive

Source: Dudley (2005)

Many methods for defining "natural" forests already exist (Dudley, 2003) and data, albeit of varying quality, are available for North America, Europe, the CIS, Japan, Australia, and New Zealand through the UNECE Temperate and Boreal Forest Resource Assessment (Anon, 2000). These increasingly focus on status rather than ecological history, i.e., assuming that "naturalness" is an attribute that can be both lost and gained rather than a condition that can only be lost once. Aiming to refine and expand knowledge of natural forests could be a key additional indicator of sustainable use, giving information about the overall status of the forest estate.

If our ability to track trends in wild populations dependent on the larger forest estate improves, it would permit the use of outcome measures to back up those looking at management practices and overall habitat area. This would be an important failsafe against misinterpretation. In some regions, such information is already available or will become so, for instance the dead wood and biodiversity surveys now obligatory in the signatory countries to the Ministerial Conference on the Protection of Forests in Europe. In other cases, information may be transferable from that collected in other surveys, inside or outside the CBD framework.

Summary

Renewable natural resources include those resources useful to human economies that exhibit growth, maintenance, and recovery from exploitation over an economic planning horizon. The economics of such resources has traditionally considered stocks of fish, forests, or freshwater. From an economic point of view, the management of biomass, soil fertility or aquifer depth has been forced into a framework of discounted, marginal, zero profit valuation.

MEY acts an important link between the biological and economic implications of fisheries management. In case of fisheries the economics of fishing operations (cost and returns) determine not only the profitability of the profession but also the driving force for remaining in the sector. In this context, the MEY which incorporates the costs of fishing the revenue earned into the sustainable yield models, provide an acceptable method for formulating fishery management plants.

Sustainable fishing in its current form is a broken concept. The proposal outlined above to limit fishing solely to inshore waters is radical, helps to break the concept of a global fishing industry, and provides opportunity (and admittedly challenges) of consider wild resources such as fish in a new light. Alongside other marine conservation measures such as MPAs, this approach could provide a good solution, ecologically, socially, and economically (given the need for subsidies to ensure viability of much fishing). The more natural marine ecosystems that would result because of this proposal would also help with beneficial ecosystem functions, such as limiting CO2 production, and ensure that many fish remain where they need to be for resilient marine ecosystems in the face of climate change.

Discussion questions

1. Define the concept of “renewable resources”.
2. What is the essence of dynamics of renewable resources?
3. Explain the basic ideas of the concept of maximum sustainable yield.
4. Explain the essence of the concept of “resource rent”.
5. What are the advantages of the move to local fisheries?
6. What indicators are used to assess sustainable forest management?
7. How is sustainable forest management manifested?

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CHAPTER 7: CLIMATE CHANGE ECONOMICS

Economic theory offers a valuable framework for optimizing the effectiveness of public expenditure. Utilizing cost-benefit analysis, coupled with an examination of distributional impacts, allows for the strategic prioritization of adaptation programs and other development initiatives, facilitating an efficient and equitable transition in response to a changing climate. In situations where compensations are necessary to counter damages that are either impractical or prohibitively expensive to mitigate, it becomes crucial to carefully calibrate subsidies for adaptation to prevent unwarranted risk-taking(Bellon & Massetti, 2022).

7.1 Cost of inaction VS. Cost of mitigation

Cost of inaction

Considering a target for stabilizing temperatures at 2(1.5) degrees Celsius, the peak costs are higher and occur sooner when mitigation efforts commence later. By 2085(2070), the costs reach 15(17)% of global GDP with a start date of 1990, while a 2020 start sees costs at 18(35)% in 2080(2035). The expenses associated with achieving a 1.5-degree target show a significant increase, escalating from 1.3 trillion dollars per year of inaction in 2010 to over 5 trillion dollars per year in 2020. These figures align closely with the findings of31, which estimated a cost of approximately 0.5 trillion dollars per year for a 2-degree target (measured from 2005). (Callan & Thomas, 2000) Failing to address climate change comes with severe consequences, impacting ecosystems, global economies, and societies. The economic ramifications of extreme weather events, such as hurricanes, droughts, and floods, are considerable. These occurrences can result in infrastructure damage, supply chain disruptions, and substantial financial losses. Agriculture, being highly sensitive to climate conditions, faces threats from changes in temperature and precipitation patterns, influencing crop yields and potentially causing food shortages with associated price increases. Reports from authoritative bodies like the Intergovernmental Panel on Climate Change (IPCC) and organizations such as the World Bank underscore the comprehensive economic impact of climate change, encompassing both direct and indirect costs. Health Impacts: Climate change can affect human health through various channels, including the spread of vector-borne diseases, heat-related illnesses, and disruptions to food and water supplies. The heightened frequency and intensity of extreme weather events can result in increased injuries, fatalities, and mental health issues.

Biodiversity Decline: Climate change contributes to habitat loss, impacting plant and animal species. Changes in temperature and precipitation patterns can disturb ecosystems, leading to the extinction of certain species and a reduction in biodiversity. The decline in biodiversity can have cascading effects on crucial ecosystem services, such as crop pollination, water purification, and disease regulation. Rising Sea Levels: The melting of ice caps and glaciers, coupled with the thermal expansion of seawater, contributes to the rise in sea levels. This poses a threat to low-lying coastal areas, increasing the risk of flooding, saltwater intrusion, and the displacement of communities. Small island nations, in particular, are vulnerable to sea level rise, facing potential loss of land and infrastructure. Social and Political Ramifications: Climate change can exacerbate existing social inequalities. Vulnerable populations, including those in low-income communities, may experience disproportionate impacts due to limited resources and adaptive capacity. Climate-induced migration and displacement can result in social tensions and conflicts, potentially contributing to political instability.

Cost of Mitigation

Investment in Renewable Energy: Transitioning to renewable energy sources involves upfront costs but is considered a key mitigation strategy. The cost of solar and wind power has been decreasing, making them increasingly competitive with fossil fuels. Energy Efficiency Measures: Improving energy efficiency in industries, buildings, and transportation can reduce greenhouse gas emissions. While there are initial costs associated with implementing efficiency measures, they can lead to long-term savings. Carbon Capture and Storage (CCS): Technologies that capture and store carbon emissions from industrial processes can be expensive to implement but are seen as essential for reducing emissions from certain sectors.

R&D and Innovation: Investing in research and development for new technologies and innovations is crucial for achieving long-term, cost-effective solutions for climate change mitigation.

7.2 Market – based solutions: carbon pricing, cap – and – trade

Emissions trading program

The regulatory approach applied to stationary sources employs a command and control strategy, which entails setting emission standards (legal ceilings) for major emission sources. These standards are applied to specific emission points such as stacks, vents, or storage tanks.

In the 1970s, the United States introduced an emissions trading program aimed at introducing greater flexibility in achieving clean air objectives. Sources were incentivized to alter the mix of control technologies outlined in the standards, provided that air quality was improved or at least not adversely affected by the modifications. This program was implemented through four distinct policies, connected by a common element known as the emission reduction credit. Emission reduction credits serve as the trading currency among emission points, while the other four policies—offset, bubble, emissions banking, and netting—govern how these credits can be utilized or saved (Tom Tietenberg, 2004).

The emission reduction credit

If a source chooses to exceed the required level of control for any emission point to meet legal obligations, it has the option to seek certification from the control authority for the additional control as an emission reduction credit (ERC). These certified credits can be stored, utilized in the bubble, offset, or netting programs. Certification requires that the emission reduction is 1) surplus, 2) enforceable, 3) permanent, and 4) quantifiable.

The offset policy

The offset policy was established to address the conflict between economic growth and the goal of meeting ambient standards in nonattainment areas. The challenge was how to accommodate new or expanded sources while ensuring compliance with the statutory requirement to promptly meet ambient standards. As these new sources would introduce additional emissions to the region, a method of offsetting had to be devised. Under the offset policy, qualified new or expanding sources can initiate operations in a nonattainment area by obtaining enough emission reduction credits from existing sources. Typically, they must secure credits for a 20 percent greater reduction in emissions than the increase anticipated with the commencement of the new facility's operations. By purchasing these credits, new sources effectively fund emissions controls implemented by existing sources, thereby contributing to improved air quality. As a result, regional emissions, including the acquired emission reduction credits, are lower after the new source begins operations than they were before. In this way, economic growth becomes a means to achieve better air quality rather than a source of further deterioration. To be eligible for this program, major new or modified sources must 1) control their own emissions to the extent required by the LAER standard and 2) ensure that all existing major sources owned or operated by the applicant in the same state as the proposed source comply with their legal control responsibilities.

The bubble policy

The bubble policy enables existing sources to fulfill their State Implementation Plan (SIP) control obligations by utilizing emission reduction credits. For instance, existing sources located in nonattainment areas can comply with their designated standards either by adopting the control technology defining the standard or, if they choose a technology emitting the pollutant at a somewhat higher rate, by compensating for the difference through acquired emission reduction credits. The total of emission reduction credits plus actual reductions must match the assigned reduction. This policy gets its distinctive name from the treatment of multiple emission points, treating them as if enclosed within an imaginary bubble. Essentially, the policy regulates solely the amount exiting the bubble. These bubbles can encompass not only emission points within the same facility but also emission points in plants owned by other firms.

Netting

Netting permits sources undergoing modification or expansion to be exempt from the requirements of new-source review, as long as any net increase (considering emission reduction credits) in plantwide emissions is deemed insignificant. Traditionally, the determination of whether a source was subject to the new-source review process involved calculating the anticipated increases in emissions resulting from modernization or expansion. If these increases exceeded predetermined thresholds, the source was subject to review. Netting enables emission reduction credits earned elsewhere in the facility to offset the expected increases from the expanded or modernized section, thereby determining whether the threshold has been surpassed. By opting for netting and avoiding review, the facility may be spared from acquiring preconstruction permits and meeting associated requirements, such as modeling or monitoring the impact of the new source on air quality, installing Best Available Control Technology (BACT) or Lowest Achievable Emission Rate (LAER) control technology, and fulfilling offset requirements. It may also circumvent any applicable prohibitions on new construction. However, facilities that surpass the significant increase threshold must still adhere to emission limits set by the New Source Performance Standards (NSPS), and emission reduction credits cannot be utilized to circumvent this national standard.

Banking

The banking aspect of the emissions trading program outlines procedures enabling firms to store emission reduction credits for future utilization in the bubble, offset, or netting programs. States have the authority to develop their own banking programs, provided the rules define ownership rights concerning banked credits, identify eligible sources for banking emission reduction credits (ERCs), and stipulate the conditions for the certification, holding, and utilization of these credits.

Smog trading and Emission charge

Several countries, including France and Japan, have implemented air pollution emission charges. In France, the charge was introduced in 1985 and renewed in 1990. It targets industrial firms with a power-generating capacity of 20 megawatts or more or those discharging over 150 metric tons of taxable pollutants annually. The revenue from the charge serves as a subsidy for pollution control equipment for the payers, with a portion allocated to new technological developments. However, the charge level is deemed insufficient to provide a significant incentive, generating only about one-tenth of the revenue needed to align French industries with European Community air pollution control standards. The Japanese emission charge, established in response to legal cases compensating pollution victims, operates differently. Enacted in 1973, the Law for the Compensation of Pollution-

Related Health Injury provides compensation for certified victims of designated diseases. The program is funded by an emissions charge on sulfur dioxides and an automobile weight tax, with the tax level determined by the compensation fund's revenue needs. The Japanese charge is based on the compensation paid in the previous year, leading to unexpectedly high rates due to decreasing emissions. Sweden's nitrogen oxide emission charge, initiated in 1992, aimed to incentivize emission reduction rather than generate revenue. Applied to large energy sources, the tax is unique in that it rebates revenue to emitting sources based on energy production. This system rewards plants emitting less per unit of energy and penalizes those emitting more, encouraging a reduction in emissions per unit of energy produced. While the exact effect is challenging to quantify, the Swedish Ministry of the Environment and Natural Resources estimates that the benefits of the NOx charge exceeded the costs by more than a 3-to-1 ratio.

The banking aspect of the emissions trading program outlines procedures enabling firms to store emission reduction credits for future utilization in the bubble, offset, or netting programs. States have the authority to develop their own banking programs, provided the rules define ownership rights concerning banked credits, identify eligible sources for banking emission reduction credits (ERCs), and stipulate the conditions for the certification, holding, and utilization of these credits.

Summary

While air quality has shown improvement in industrialized nations, it has worsened in developing nations due to the historical reliance on a traditional command-and-control approach to air pollution control, which has proven neither efficient nor cost-effective. The existing Clean Air Act (CAC) policy lacks efficiency, primarily because it rests on a legal fiction—setting a threshold below which no health damages are assumed to occur. In reality, damages occur at levels lower than ambient standards, particularly affecting sensitive populations like those with respiratory issues. The attempt to formulate standards without considering control costs has been hindered by the absence of a scientifically defensible health-based threshold. Moreover, the policy neglects the timing of emission flows, leading to inadequate control during high-damage periods and excessive control during low-damage periods. Additionally, insufficient attention has been given to indoor air pollution, potentially posing greater health risks than outdoor pollution. The policy is also deemed not cost-effective, with the allocation of responsibility for reducing pollution among emitters resulting in control costs several times higher than necessary. The Environmental Protection Agency (EPA) has recently introduced the emissions trading program, aimed at providing economic incentives for more flexibility in meeting air quality goals, reducing costs, and addressing conflicts between economic growth and air quality preservation. Reforms like the bubble, offset, netting, and emission banking programs are expected to stimulate the development of new control technologies more rapidly than the traditional system allowed. Both France and Japan have implemented emission charges in their pollution control approaches, but neither aligns well with the textbook model. In France, the charge level is too low to have the intended incentive effects, while in Japan, the charge mainly aims to raise revenue for compensating victims of respiratory damage caused by pollution, with only sulfur oxides being taxed. The program to control hazardous pollutants is inefficient in both the speed of its operation and the quality of decisions made. Unrealistically short deadlines for publishing standards have led the EPA to take an overly cautious approach to listing hazardous substances. Past decisions have resulted in uniformly applied stringent standards, whereas tailored strategies based on the risk posed could substantially lower risks for the same expenditure. One proposed reform suggests imposing an exposure charge on emitters, considering not only the concentration of the emission and resulting health risks but also the number of people exposed.

Discussion questions

1. How does the field of climate change economics contribute to our understanding of the economic impacts of climate change?
2. How do economists assess the costs and benefits of different climate change mitigation and adaptation strategies?
3. What role does cost-benefit analysis play in informing climate change policy decisions?
4. What are some examples of market-based approaches to addressing climate change, and how effective are they in achieving emission reduction goals?
5. What are the challenges associated with valuing non-market goods and services affected by climate change, such as ecosystem services or cultural heritage?

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CHAPTER 8: ENVIRONMENTAL POLICY INSTRUMENTS, JUSTICE AND EQUITY

Recognizing the necessity for government intervention to address environmental market failures is a crucial insight derived from economic modeling, marking the initial step. These models also enable us to ascertain the most effective government responses to address policy issues. Economic theory suggests that the government should establish objectives to achieve allocative efficiency, balancing social benefits and costs at the margin. While it may be challenging to precisely determine these benefits and costs, the efficiency criterion proves valuable in evaluating policy objectives relative to their optimal levels. Additionally, the cost-effectiveness criterion can be utilized to assess the implementation of these objectives, even when set at levels other than their efficient counterparts. This chapter aims to understand the government's use of conventional policy solutions in addressing environmental standards and their role in policy development. Allocative efficiency serves as a metric to evaluate the level at which standards are established to define environmental objectives. Subsequently, we present an overview of two broadly defined approaches to implementing these standards-based objectives: the command-and-control approach and the market approach. Lastly, we delve into the cost-effectiveness of the command-and-control approach, which is the more conventional of the two (Tom Tietenberg, 2004).

8.1 Command – and – control VS. Market – based instruments, taxes, subsidies, and tradeable permits

Command and control policy framework

The historical method for controlling air pollution has primarily relied on emission standards, employing a traditional command-and-control (CAC) approach. In this section, we will outline the specific characteristics of this approach, analyze it from both an efficiency and a cost-effectiveness perspective, and examine how recent reforms based on economic incentives have aimed to address some of its shortcomings. For each conventional pollutant, the initial step typically involves establishing ambient air quality standards. These standards define legal limits for the allowable concentration of the pollutant in outdoor air, averaged over a specified time period. Many standards are based on both a long-term average (usually an annual average) and a short-term average (e.g., a three-hour average). Short-term averages are typically allowed to exceed the limit no more than once a year. While these standards must be met universally, they are practically monitored at numerous specific locations. Control costs can be highly sensitive to the level of these short-term averages.

In the United States, two ambient standards have been defined for each pollutant. The primary standard is crafted to safeguard human health, being the first standard established with the earliest compliance deadlines. Every pollutant has a primary standard. The secondary standard is designed to protect other aspects of human welfare from pollutants with distinct effects. The secondary standard provides protection for aesthetics (especially visibility), physical objects (such as houses and monuments), and vegetation. When a separate secondary standard is in place, both it and the primary standard must be adhered to. The existing primary and secondary standards are outlined in the Table 8.1.

Table 8.1 National ambient air quality standards

Pollutant	Standard value		Standard type
Carbon monoxide (CO)			
8-hour average	9 ppm	(10 mg/m3)	primary
1-hour average	35 ppm	(40 mg/m3)	primary
Nitrogen dioxide (NO2)			
Annual arithmetic mean	0.053 ppm	(100 µg/m3)	Primary and secondary
Ozone (O3)			
8-hour average	0.08 ppm	(157 µg/m3)	Primary and secondary
1-hour average	0.12 ppm	(235 µg/m3)	Primary and secondary
Lead (Pb)			
Quarterly average	1.5 µg/m3		Primary and secondary

Market approach

Environmental policies commonly involve defining a goal, whether it be general or specific, and determining the methods to achieve that goal. In practice, these two components are frequently interconnected within the political process. This chapter exclusively concentrates on the second component—the means or "instruments" of environmental policy. It specifically explores global experiences with the relatively recent category of economic incentive or market-based policy instruments (Stavins, 2003).

Characteristics of Market-Based Policy Instruments

In principle, when appropriately formulated and executed, market-based instruments enable the attainment of any targeted level of pollution cleanup at the most economical cost for society. This is achieved by offering incentives for significant pollution reductions from firms that can achieve these reductions at the lowest cost. Unlike uniform emission standards that aim to equalize pollution levels across firms, market-based instruments focus on equalizing the incremental expenditure that firms incur to reduce pollution—known as their marginal cost. (Montgomery 1972; Baumol and Oates 1988; Tietenberg 1995). Market-based instruments facilitate a cost-effective distribution of the responsibility for pollution control among sources, eliminating the need for the government to possess such information.

Unlike command-and-control regulations, market-based instruments possess the capability to offer compelling incentives for companies to embrace more cost-effective and superior pollution-control technologies. This is primarily due to the nature of market-based instruments, especially emission taxes, which consistently incentivize firms to enhance their cleanup efforts whenever a sufficiently low-cost method (technology or process) is identified and implemented, as noted in studies by Downing and White (1986), Malueg (1989), Milliman and Prince (1989), Jaffe and Stavins (1995), and Jung, Krutilla, and Boyd (1996). (Stavins, 2003)

Categories of Market-Based Instruments

Market-based instruments can be categorized into four main types: pollution charges, tradable permits, market friction reductions, and government subsidy reductions (Organization for Economic Cooperation and Development 1994a, 1994b, 1994c, 1994d). For voluntary initiatives in the United States, refer to the U.S. Environmental Protection Agency 2001. A deposit-refund system can be considered a special case of a "performance bond." The concept of using transferable discharge permits for allocating the pollution-control burden among sources was independently developed by Crocker (1966) and Dales (1968) thirty years ago. Montgomery (1972) provided the initial rigorous proof that such a system could serve as a cost-effective policy instrument. The subsequent literature, influenced by Hahn and Noll (1982) and early surveys by Tietenberg (1980, 1985), often traces its roots back to Coase's (1960) exploration of negotiated solutions to externality problems. Allocation mechanisms can involve free distribution ("grandfathering") or sale, including auctions. The described program operates as a "cap-and-trade" program, but other programs function as "credit programs," assigning permits or credits only when a source reduces emissions below existing, source-specific limits. Pollution charge systems impose fees or taxes based on the pollution generated by a firm or source (Pigou 1920). This encourages firms to reduce emissions until their marginal abatement cost equals the tax rate. The challenge lies in determining the appropriate tax rate, ideally set equal to the marginal benefits of cleanup at the efficient level. However, policymakers often think in terms of a desired cleanup level, and uncertainty surrounds how firms will respond to a given taxation level. A deposit refund system, a special case of pollution charges, involves consumers paying a surcharge when purchasing potentially polluting products, receiving a refund upon returning the product to an approved center for recycling or disposal (Bohm 1981; Menell 1990). Tradable permits offer a cost-minimizing allocation of the control burden similar to charge systems but avoid uncertainties in firm responses. Under this system, an overall pollution limit is established and distributed among firms in permit form. Firms can sell surplus permits to others or use them to offset excess emissions in different parts of their facilities. Market friction reductions, another category of market-based instruments, can lead to significant environmental protection gains by alleviating existing frictions in market activity. This includes creating markets for inputs/outputs related to environmental quality, establishing liability rules that encourage firms to consider potential environmental damages, and implementing information programs like energy-efficiency product labeling requirements. The fourth category, government subsidy reductions, represents the mirror image of taxes and theoretically can incentivize addressing environmental issues. However, in practice, many subsidies promote economically inefficient and environmentally unsound practices.

Type of environmental standards

When environmental standards are defined in the law, they can be specified as ambient standards, technology-based standards or performance-based standards. Ambient standards designate the desired quality level of some element of the environment such as the outdoor air or a body of water. These standards typically are expressed as a maximum allowable concentration of some pollutant in the ambient environment. The United States uses ambient standards to define both air quality and water quality. In each case, the ambient standard is not directly enforceable, but serves as a target level to be achieved through a pollution limit, which is in turn implemented through one of the other types of standards.

As its name implies, a technology-based standard stipulates the type of abatement control that must be used by all regulated polluting sources. In practice, the EPA is responsible for researching available technologies and evaluating their relative effectiveness in accordance with certain criteria outlined in the law. It then selects the “best” technology, which subsequently must be adopted by all regulated polluters. The motivation is straightforward-to assure

8.2 Analysis of policy efficiency and effectiveness

Cost-effectiveness analysis (CEA) is the techniques of economic evaluation designed to compare the costs and benefits of a healthcare intervention to assess whether it is worthwhile. The choice of technique depends on the nature of the benefits specified. In CEA, the benefits are expressed in non-monetary terms related to health effects, such as years of life gained or symptom-free days, whereas in cost–utility analysis they are expressed as quality-adjusted life-years (QALYs) and in CEA they are expressed in monetary terms. As with all economic evaluation techniques, the aim of CEA is to maximize the level of benefits relative to the resources available in monetary terms. As with all economic evaluation techniques, the aim of CEA is to maximize the level of benefits relative to the resources available. CEA involves comparing the monetary costs of an initiative to its outcomes, such as the amount of CO_2 emissions avoided or reduced due to an intervention project or program. This approach is akin to, and sometimes synonymous with, a value-for-money or social return on investment analysis, where the returns are assessed in non-monetary terms. CEA encompasses various forms, and a comprehensive analysis typically requires multiple components. These components include a thorough examination of costs, an analysis of baseline or business-as-usual scenarios when GHG emission reductions are the intended outcomes, consideration of both direct and indirect emission reductions, and an assessment of unintended effects. For interventions aimed at enhancing resilience or addressing other climate-related challenges, determining outcomes may be approached on a case-by-case basis. However, if outcomes are challenging to identify or measure credibly, CEA may not be the recommended approach. In applying CEA to complex systems, three requirements must be satisfied. First, the systems being evaluated must have common goals or purposes. The comparison of cargo aircraft with fighter aircraft would not be valid, but comparison with cargo ships would be if both the aircraft and ships were to be utilized in military logistics. Second, alternative means for meeting the goal must exist. This is the case with cargo ships being compared to cargo aircraft. Finally, the ability to bound the problem must exist. The engineering details of the systems being evaluated must be available or estimated so that the cost and effectiveness of each system can be estimated (Fabrycky, Thuesen, & Verma, 1998).

What constitutes a cost?

Perspectives on costs vary, with economics defining cost based on the value that could be derived by utilizing resources elsewhere, commonly known as opportunity cost. This implies that resources allocated to one program are foregone in terms of their potential use elsewhere. In the context of cost-effectiveness analysis, it becomes necessary to differentiate between direct costs, indirect costs linked to the intervention, and intangibles—consequences that may be challenging to quantify but are often outcomes of the intervention and should be incorporated into the cost assessment. Direct costs encompass expenses such as drugs, staff salaries, equipment, and transportation costs. Indirect costs involve production losses and time utilization for other purposes. Intangibles include factors like pain, suffering, and adverse effects. Clearly specifying which costs are considered in a cost-effectiveness analysis and which are excluded is crucial to prevent misinterpretation or overestimation of the findings.

How to use a cost-effectiveness analysis

On the adaptation front, cost-effectiveness can be employed in situations where, across various climate change scenarios, a predetermined minimum level of a public good or service (e.g., flood protection) is outlined, and the objective is to identify the most economical means of providing this good. This approach is especially relevant in cases where the analyst faces challenges in quantifying the most significant policy impact or is unwilling to monetize it. Cost-effectiveness is typically well-suited for individual project decisions that align with decision rules or procedures already established in policy, strategic, or program decisions. Using cost-effectiveness analysis with independent programs requires that cost-effectiveness ratios are calculated for each program placed in a ranked order:

$$\text{Cost-effectiveness ratio} = \frac{\text{Costs of intervention}}{\text{effectiveness (e.g. years of life gained, emissions reduction)}}$$

For example, in Table 8.1 there are three interventions for different patient groups, with the alternative for each of them of "doing nothing." According to cost-effectiveness analysis, program C should be given priority over A since it has a lower cost-effectiveness ration.

Table 8.1 Cost-effectiveness of three independent programs

Program	**Cost ($) [C]**	**Health effect (years of life gained) [E]**	**Cost-effectiveness ratio [C/E] ($/years of life gained)**
C	150,000	1,850	81.08
A	100,000	1,200	83.33
B	120,000	1,350	88.89

Cost-effectiveness analysis is relevant for public policy analysis because of limited resources and the opportunity costs of public spending, i.e. if we spend $100 million on agency A, it is $100 million we cannot spend elsewhere. There is no federal rule saying that each million dollars spent must save *x* number of lives. Cost-effectiveness could be applied when considering external effects or damages, e.g. environmental, safety, etc. The term benefits should be able to be reduced to one dimension. Instead of finding the net benefit of cost-effectiveness, find the cheapest cost per unit benefit (e.g. lives saved). Why should a policymaker consider cost-effectiveness analysis instead of cost-benefit analysis? Monetizing benefits may be difficult or controversial. Sometimes, monetizing cannot encapsulate the total social value or miscalculate its value, for example, it could be easy to find lives saved but hard to assign value. The cost effectiveness analysis ratio is equal to cost per unit of effectiveness e.g. $ per lives saved, tons of CO_2 reduced. Thus, cost-effectiveness should be minimized. Tables 8.2-8.3 show cost and lives saved using each alternative. Which alternative is the best?

Table 8.2 Cost and lives saved using each alternative

Value	**Alternative**		
	A	**B**	**C**
Cost	$10 million	$10 million	$10 million
Lives saved	5	10	15
Cost-effectiveness ratio	$ 2 million	$ 1 million	$ 0.67 million
Effectiveness-cost ratio	0.5 life	1 life	1.5 lives

Table 8.3 Cost and lives saved using each alternative

	Alternative	
Cost	$ 1 million	$100 million
Lives saved	4	200
Cost-effectiveness ratio	$ 250 thousand	$500 thousand
Effectiveness-cost ratio	4 lives	2 lives

Viscusi (2001) mentioned that the experiences using these benefit-cost regimes has been quite mixed and do not seem qualitatively different from the outcomes under the Carter administration, which did not have a benefit-cost test but instead quantified benefits, costs, and cost-effectiveness. The U.S. Office of Management and Budget has never been successful in blocking a regulation with a cost per life saved of below $142 million per life. This level is more than an order of magnitude greater than what is sensible based on implicit values of life reflected in market decisions. The result has been that many regulations promulgated have inordinately large costs per life saved. What one should use as a threshold for the appropriate cost per life saved depends on the methodological approach used. Historically, government agencies had used the present value of lost earnings as the value-of-life measure, or what agencies termed the "cost of death." Viscusi's analysis in 1982 prepared to settle the dispute between the U.S. Office of Management and Budget and the Occupational Safety and Health Administration over the proposed hazard communication regulation, which had been appealed to then Vice President Bush; the value-of-life methodology was introduced based on the willingness-to-pay estimates derived from labor market behavior. Since that time, agencies have widely adopted the value-of-life methodology, which has also been endorsed by the U.S. Office of Management and Budget, but the particular estimate of the value of life used by agencies may differ. Most importantly, the value-of-life benefit estimate is not binding on policy judgments because of the restrictive nature of agencies' legislative mandates.

8.3 Case studies on environmental justice challenges

Environmental justice on climate change

Climate change has surfaced as a significant environmental justice concern due to (a) its partial attribution to human activities generating greenhouse gas emissions, such as the combustion of fossil fuels, or activities that diminish the biosphere's capacity to absorb carbon dioxide, like deforestation; and (b) its disproportionate impact on low-income populations and countries, which generally contribute fewer greenhouse gas emissions compared to their high-income counterparts. Without substantial measures to curtail greenhouse gas emissions, it is projected that global average surface temperatures will increase between 2.1 and 3.5 °C by the year 2100. The repercussions of climate change encompass various environmental and public health challenges, including heightened occurrences of flooding, droughts, heatwaves, forest fires, tropical storms, and infectious diseases, alongside diminishing biodiversity, food security, and the availability of safe drinking water supplies (Resnik, 2022). In 2004, Hurricane Katrina thrust climate justice into the forefront of public policy discussions as it ravaged the US Gulf Coast, claiming the lives of 986 people and causing extensive property damage amounting to billions of dollars. The hurricane's most severe impact resulted from widespread flooding, disproportionately affecting low-income and communities of color situated in flood-prone areas. These communities lacked the social and economic resources necessary for self-protection and recovery. The mortality rate among African Americans was 1.7 to 4 times higher than that of Caucasians, with 51% of the deceased being African American. Scientists proposed that unusually high water temperatures in the Gulf of Mexico, partly attributable to global warming, contributed to the hurricane's size and intensity, escalating from a Category 3 to a Category 5 while traversing the Gulf. Scholars and advocates contended that Hurricane Katrina laid bare injustices tied to race, ethnicity, and income, emphasizing the imperative of integrating climate change mitigation and adaptation into the broader pursuit of social and economic justice. Similar revelations linking climate change to environmental justice have emerged globally. In 2010, extensive flooding, a consequence of intense monsoon rains, engulfed 20% of Pakistan's land area, displacing 20 million people and claiming over 5,000 lives. An analysis of atmospheric conditions indicated that the 2010 flooding aligned with a pattern of heavier monsoon rains linked to climate change. Pakistan, ranked as the 34th poorest country globally, harbors a population where 24.3% falls below the poverty level(Resnik, 2022).

Environmental justice on pollutant contaminations

Kingsgate Consolidated Ltd, the parent company of Akara Resources Plc, secured a concession contract for gold mining in Phichit province, covering a total area of 3,900 rai spanning Phichit, Phitsanulok, and Phetchabun provinces. Originally, the concession was split into two: Chatree Tai, expiring in 2020, and Chatree Nuea, expiring in 2028. However, on January 1, 2016, under Section 44, the National Council for Peace and Order (NCPO) closed the Akara gold mine due to environmental impact and local complaints, leading to a conflict with the Thai Government and initiating arbitration. In 2000, Kingsgate Consolidated Ltd secured a 20-year Chatree Gold Mining concession, expiring on June 18, 2020, for an area of 1,259 rai. Subsequently, an additional concession for Chatree Nuea was obtained, covering 2,466 rai, expiring on July 20, 2028. Between 2007 and 2016, residents in the concession area suffered health and environmental issues due to mine-related pollution, sparking protests against mining operations. Villager complaints, particularly about soil, water, and air contamination, alongside noise pollution, escalated over the years. Despite some local support for the mining operations, the NCPO, on December 13, 2016, ordered the closure of the Akara gold mine from January 1, 2017. After negotiations failed, Kingsgate initiated arbitration against the Thai government, seeking compensation under the Thailand-Australia Free Trade Agreement (TAFTA). Zurich Australia Insurance Limited agreed to pay Kingsgate US$82 million in a settlement. The Thai government hired an American lawyer for 70 million Baht to defend against the claim. The arbitration process began in Singapore from February 3-12, 2020, with the arbitral tribunal currently analyzing the facts. The decision is expected by the end of 2020, and the presiding arbitrator will be appointed by the Secretary-General of the Permanent Court of Arbitration (PCA) due to the parties' disagreement (Thailand Arbitration Center, 2020). The Bangkok Civil Court has set a timeline to review witness testimonies and reach a verdict on the case within the present year. Approximately 400 community members are actively involved in the legal proceedings. Led by a female community leader, residents of Phichit and Phetchabun have joined forces to bring a legal action against Akara Resources, alleging breaches of the Environmental Quality Act. Their combined lawsuit is pursuing approximately $438,000 in compensation per individual, totaling over $17.54 million (Hardstories, 2023).

Summary

Environmental policy instruments, justice, and equity are intertwined concepts critical to addressing environmental challenges while ensuring fairness and inclusivity. Environmental policy instruments refer to the tools and mechanisms employed by governments and other stakeholders to manage and mitigate environmental issues. These instruments can include regulations, command and control, market-based mechanisms such as carbon pricing, voluntary programs, and subsidies. Justice and equity within environmental policy focus on ensuring that the burdens and benefits of environmental policies are distributed fairly among all members of society, regardless of socioeconomic status, race, or other factors. In addition, policy analysis of policy efficiency and effectiveness strive to incorporate principles of justice and equity by addressing systemic inequalities, engaging affected communities in decision-making processes, and promoting environmental sustainability for the benefit of all present and future generations.

Discussion questions

1. What are the potential trade-offs between efficiency and equity in the implementation of environmental policies?

2. Are there examples of successful environmental policy interventions that have effectively promoted justice and equity at both local and global levels? What lessons can be learned from these examples?

3. How do different environmental policy instruments, such as regulations, market-based mechanisms, and voluntary agreements, address issues of justice and equity in environmental decision-making?

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CHAPTER 9: INTERNATIONAL ENVIRONMENTAL AGREEMENTS

The escalating challenges of global climate change necessitate a concerted and international response, underscored by the continuous rise in global mean temperatures and the unprecedented levels of greenhouse gas concentrations. Chapter 9 delves into the complexities and critical importance of international environmental agreements, examining their pivotal role in fostering global cooperation towards mitigating climate change. The chapter begins by highlighting the recent alarming climate trends, including the notable increase in global mean temperature, which underscores the urgency for effective international collaboration. As the world grapples with these daunting environmental challenges, the chapter sets the stage for a comprehensive exploration of key international agreements, such as the Paris Agreement and the Kyoto Protocol, their mechanisms, achievements, and the hurdles they face in unifying global efforts against climate change.

9.1 Challenges in international cooperation

The global mean temperature from January to October 2018 surpassed the pre-industrial baseline by 0.98±0.12°C. Continuing a trend, 2018 was potentially the fourth warmest year on record, with the past four years (2015-2018) ranking as the warmest. Despite being the coolest among them, 2018 began with weak La Niña conditions, linked to lower global temperatures. Notably, the 20 warmest years occurred in the past 22 years. The IPCC Special Report on Global Warming of 1.5°C highlighted that the average global temperature for 2006-2015 was 0.87°C above the pre-industrial baseline. Comparatively, the average increase for the most recent decade (2009-2018) was 0.93±0.07°C, and for the past five years (2014-2018) was 1.04±0.09°C, including the warming effect of the 2015-2016 El Niño. Beginning with a weak La Niña, 2018 hinted at a return to El Niño conditions by October, potentially making 2019 warmer. Greenhouse gas concentrations peaked in 2017, with CO2 at 405.5 ppm, CH4 at 1859 ppb, and N2O at 329.9 ppb, significantly surpassing pre-industrial levels. Real-time data from 2018 indicated ongoing increases in CO2, CH4, and N2O. The IPCC SR15 report stressed the need for global net zero CO2 emissions by around 2050 and a reduction in non-CO2 forcers, particularly methane. Decadal predictions highlighted an increasing risk of temporary exceedance of the 1.5°C threshold, emphasizing the importance of closely monitoring the Paris Agreement targets (United Nations Framework Convention on Climate Change). Building on this climate context, the Paris Agreement outlines its origin, content, and fundamental features. Despite near universal support, the agreement, acknowledged as a third-generation treaty addressing climate challenges, requires robust collaborative efforts. Positioned as a multilateral environmental pact, the Paris Agreement integrates both "top-down" and "bottom-up" elements, presenting a pioneering example (e.g. Jennifer et al, 2017). The Kyoto Protocol is critiqued as an institutional design failure, with lessons drawn from the success of the Montreal Protocol. This underscores the importance of financing for mitigation efforts and the role of research and development in reducing greenhouse gas emissions (Barrett, 2008). Continuing the critique, the Kyoto Protocol's highlights path-dependent shortcomings, suggesting alternative approaches like soft commitments, comprehensive institutions, binding policies, and a bottom-up strategy. Despite limitations, Kyoto impacted global agendas, emphasizing the need for reevaluation, especially concerning mechanisms like emissions trading. Shifting focus to global climate negotiations, stagnating since the 1997 Kyoto Protocol suggests an alternative approach: studying effective lower-level programs to form a 'regime complex' for broader climate responsibility sharing. Recognizing the collective-action problem, this approach offers an alternative to the formal, global UN negotiations (Cole, 2013). The international climate regime, stagnant since the Kyoto Protocol in 1997, experienced a transformative shift with COP21 in 2015 and the Paris Agreement. This marked a departure, creating a new paradigm for international climate policy. The Paris Agreement reflects key policy and political shifts, emphasizing the UN's role in amplifying smaller countries' voices and engaging non-state actors. This new paradigm is seen as instrumental in achieving ambitious climate goals, preferably at 1.5°C (Morgan et al., 2017). To ensure the achievement of Paris Agreement goals, it underscores the importance of public support for nationally pledged emissions targets. A survey experiment conducted in Switzerland explores framing government policies as either national or international obligations. While framing policies internationally enhances the evaluation of emission targets, the substantive effects are modest. Despite this, eliciting the international obligation appears advisable, as it significantly improves the evaluation of emission targets, especially among young people, garnering more support from less climate-conscious respondents (Schaffer et al., 2023). Despite 25 UN Climate Change Conferences of the Parties, international cooperation to mitigate greenhouse gas emissions remains a significant challenge. The article emphasizes the need for a deeper understanding of challenges and opportunities arising from the interplay between domestic and international policies. Drawing on theoretical, experimental, and empirical literature, the article reviews lessons to illuminate the roots of the stalemate and proposes potential pathways forward (Tavoni et al., 2021).

9.2 Case studies

Kyoto Protocol

The Kyoto Protocol, adopted on December 11, 1997, came into force on February 16, 2005, following a intricate ratification process, and currently boasts 192 Parties. Functioning as the operational arm of the United Nations Framework Convention on Climate Change, it compels industrialized countries and transitioning economies to curtail and diminish greenhouse gas (GHG) emissions based on mutually agreed individual targets. In contrast, the Convention primarily urges these nations to adopt mitigation policies and periodically report on them. Structured in alignment with the Convention's principles and provisions, the Kyoto Protocol exclusively binds developed countries, emphasizing the principle of "common but differentiated responsibility and respective capabilities." This recognizes their substantial role in the heightened levels of GHG emissions. Annex B of the Protocol mandates emission reduction targets for 37 industrialized countries, economies in transition, and the European Union, targeting a 5 percent average reduction from 1990 levels during the initial commitment period from 2008 to 2012. The Doha Amendment, adopted in Qatar on December 8, 2012, extends the Kyoto Protocol for a second commitment period from 2013 to 2020. It reached the entry-into-force threshold on December 31, 2020, with 147 Parties submitting their instruments of acceptance, surpassing the required 144. The amendment introduces new commitments, revises the list of reportable GHGs, and amends several Protocol articles addressing issues from the first commitment period. During the second commitment period, Parties pledged to reduce GHG emissions by at least 18 percent below 1990 levels from 2013 to 2020. A key aspect of the Kyoto Protocol is the implementation of flexible market mechanisms, including International Emissions Trading, Clean Development Mechanism (CDM), and Joint Implementation (JI). These mechanisms promote cost-effective GHG abatement globally, stimulate green investments in developing nations, and involve the private sector in emission reduction efforts. The Protocol also instituted a robust monitoring, review, and verification system, along with a compliance mechanism to ensure transparency and accountability. Parties must monitor actual emissions, keep precise records of trades, and submit emission inventories and national reports regularly. The compliance system helps Parties fulfil their commitments and addresses challenges. In addition to mitigation, the Kyoto Protocol supports adaptation to climate change impacts. It established the Adaptation Fund, initially funded by a share of CDM proceeds. In the second commitment period, international emissions trading and joint implementation contribute a 2 percent share of proceeds to the Adaptation Fund, facilitating adaptation projects in developing countries.[4]

According to the article 2 of Kyoto protocol, the commitments and actions that Parties included in Annex I of the agreement must undertake to fulfil their emission limitation and reduction targets while promoting sustainable development. Key provisions include implementing policies to enhance energy efficiency, protect greenhouse gas sinks, promote sustainable forestry and agriculture, research and develop renewable energy sources, and phase out counterproductive incentives. Parties are also encouraged to cooperate, share experiences, and exchange information to enhance the effectiveness of their efforts. Additionally, there are specific directives for addressing emissions from aviation and marine bunker fuels through international organizations. The article emphasizes the importance of minimizing adverse effects on other Parties, particularly developing countries, and allows for coordination of policies and measures if deemed beneficial. The Conference of the Parties may take further action to promote implementation and coordination as needed (Jennifer et al, 2017).

The Paris Agreement

The Paris Agreement, a binding international treaty on climate change adopted by 196 Parties at COP21 in Paris on December 12, 2015, aims to limit the global average temperature increase to well below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C. The agreement recognizes the urgency of the 1.5°C goal due to severe climate change impacts. To achieve this, greenhouse gas emissions must peak by 2025 and decline by 43% by 2030. The agreement operates on a five-year cycle of increasing climate action, with countries submitting Nationally Determined Contributions (NDCs) reflecting higher ambition levels. COP27 urges Parties to strengthen their 2030 targets by the end of 2023. NDCs outline actions to reduce emissions and enhance resilience to climate change. Long-Term Low Greenhouse Gas Emission Development Strategies (LT-LEDS) provide a vision for countries' future development, complementing NDCs. The Paris Agreement offers financial, technical, and capacity-building support to countries, emphasizing the responsibility of developed nations. Climate finance is crucial for mitigation and adaptation, while technology development and transfer, along with capacity-building, are integral components. The agreement establishes an enhanced transparency framework (ETF) to track progress, with countries reporting actions, progress, and support transparently from 2024. The Global Stocktake assesses collective progress towards long-term climate goals, guiding countries to set more ambitious plans. Despite the need for increased climate action, the post-Paris Agreement years have seen the emergence of low-carbon solutions and markets. Carbon neutrality targets are widespread, and zero-carbon solutions are competitive in sectors representing 25% of emissions, particularly in power and transport. By 2030, these solutions could be competitive in sectors covering over 70% of global emissions, signifying progress in addressing climate change.[5]

The Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer, established in 1987, is a groundbreaking international agreement regulating the production and consumption of almost 100 man-made chemicals known as ozone-depleting substances (ODS). These substances, when released into the atmosphere, harm the stratospheric ozone layer, a crucial shield protecting humans and the environment from harmful ultraviolet radiation. This universal treaty sets out a phased reduction plan for the consumption and production of various ODS, with distinct timetables for developed and developing countries. Parties to the Protocol, both developed and developing nations, have specific responsibilities, including the phase-out of ODS, trade controls, data reporting, and national licensing

[4] United Nations Clamte Change: What is the Kyoto Protocol?Available at: https://unfccc.int/kyoto_protocol

[5] United Nations Clamte Change: The Paris Agreement Available at: https://unfccc.int/process-and-meetings/the-paris-agreement

systems. The Protocol continually evolves to incorporate new scientific, technical, and economic developments, with governance provided by the Meeting of the Parties and technical support from an Open-ended Working Group. The Multilateral Fund, established in 1991 under the Protocol, provides financial and technical assistance to developing countries with low ODS consumption. Over its existence, the Fund has supported numerous projects, including industrial conversion, technical assistance, training, and capacity-building, totalling over US$3.9 billion. The Montreal Protocol's success is evident in the phase-out of Hydrochlorofluorocarbons (HCFCs) and the adoption of the Kigali Amendment to phase down Hydrofluorocarbons (HFCs). HCFCs, used globally in refrigeration, air-conditioning, and foam applications, are being phased out due to their ozone-depleting and greenhouse gas properties. The Kigali Amendment, agreed upon in 2016, aims to reduce HFCs by 80-85% by the late 2040s, with developed countries starting reductions in 2019 and developing countries following with a freeze in 2024. The sustained implementation of the Montreal Protocol is expected to restore the ozone layer by the mid-21st century, preventing significant health and environmental risks. To date, Parties have phased out 98% of ODS globally, contributing substantially to reducing greenhouse gas emissions and protecting the climate. The Kigali Amendment alone is projected to prevent emissions of up to 105 billion tonnes of carbon dioxide equivalent, avoiding a 0.5-degree Celsius temperature rise by 2100. Recognized as one of the most successful environmental agreements, the Montreal Protocol serves as an exemplary model of international cooperation, achieving unprecedented accomplishments since its inception in 1987. Its impact extends beyond environmental preservation, contributing to the realization of the UN Sustainable Development Goals.[6]

9.3 Role of the international organizations

The United Nations Environment Programme

The United Nations Environment Programme (UNEP) serves as the foremost global authority on environmental matters, leading efforts to inspire, inform, and enable nations and individuals to enhance their quality of life while ensuring the well-being of future generations. With over 50 years of dedicated work alongside governments, civil society, the private sector, and UN entities, UNEP has been at the forefront of addressing critical environmental challenges, ranging from ozone layer restoration to the protection of oceans and the advancement of a green, inclusive economy. UNEP is actively engaged in driving transformative change by addressing the root causes of the triple planetary crisis encompassing climate change, nature and biodiversity loss, and pollution. The organization focuses on assisting countries in transitioning to low-carbon and resource-efficient economies, strengthening environmental governance and law, safeguarding ecosystems, and providing evidence-based data to shape informed policy decisions. Through cutting-edge science, coordination, and advocacy, UNEP collaborates with its 193 Member States to achieve the Sustainable Development Goals and foster harmony with nature. Established in 1972 following a UN General Assembly resolution, UNEP has evolved in response to the world's environmental challenges. Its role was strengthened, and membership expanded to include all 193 UN Member States after the UN Conference on Sustainable Development in 2012. UNEP's mandate includes setting the global environmental agenda, promoting the environmental dimension of sustainable development within the UN system, and serving as a authoritative advocate for the environment. The creation of the UN Environment Assembly, the highest-level decision-making body on the environment, further underscores UNEP's commitment to global environmental governance. UNEP's overarching goal is to catalyse action on the environment, addressing the triple planetary crisis and promoting solutions to climate change, nature and biodiversity loss, and pollution and waste. The organization works towards

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[6] UNEP. Available at: https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

fostering a more harmonious coexistence with nature, challenging unsustainable consumption and production practices that threaten the planet. UNEP's impactful initiatives over the past five decades have played a crucial role in countering climate change, protecting endangered species, ending deforestation, addressing the ozone layer depletion, and phasing out toxic leaded fuels. As part of the UN Secretariat, UNEP responds to the UN General Assembly and operates with its governing bodies based in Nairobi, namely the UN Environment Assembly and the Committee of Permanent Representatives. These bodies set the direction and priorities for global environmental policies, adopting resolutions, and overseeing the implementation of UNEP's Mid-Term Strategy and Programme of Work. UNEP's funding relies heavily on voluntary contributions, with over 95% of its operations funded through Member States and other partners. Core contributions, including the Environment Fund, provide flexibility for UNEP to implement its work, while earmarked contributions support specific projects, themes, or countries. New thematic funds launched in 2022 focus on climate stability, living in harmony with nature, and achieving a pollution-free planet.

The Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) serves as the global authority for evaluating scientific aspects of climate change. Established in 1988 through collaboration between the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the IPCC plays a crucial role in supplying policymakers with regular assessments on the scientific foundations, impacts, future risks, and potential strategies for adaptation and mitigation concerning climate change. The IPCC's assessments furnish the scientific groundwork for governments at various levels to formulate climate-related policies and inform discussions at the UN Climate Conference, specifically within the United Nations Framework Convention on Climate Change (UNFCCC). While these assessments are policy-relevant, they refrain from offering specific directives; instead, they present projections based on diverse scenarios, outline the risks posed by climate change, and explore the implications of various response options. Distinguished by its scientific and intergovernmental composition, the IPCC provides an unparalleled opportunity to deliver meticulous and unbiased scientific information to decision-makers. Membership is open to all WMO and UN member countries, with the current count standing at 195. The Panel, comprised of representatives from member states, convenes in Plenary Sessions to make significant decisions. The IPCC Bureau, elected by member governments, guides the Panel on scientific and technical matters, as well as management and strategic concerns. The preparation of IPCC assessments involves hundreds of leading scientists who volunteer as Coordinating Lead Authors and Lead Authors. These experts enlist additional Contributing Authors and Chapter Scientists, often early career scientists, to cross-check findings, conduct fact-checking, and manage references. The reports undergo meticulous drafting and review processes to ensure comprehensive, objective, and transparent outcomes. Thousands of experts, serving as reviewers, contribute to the reports, offering diverse perspectives within the scientific community. Review Editors play a critical role in monitoring and addressing review comments. The IPCC, distinctively, relies on assessing existing literature rather than conducting its own scientific research. The language used in the assessments communicates the authors' level of certainty in their conclusions. Currently organized into three working groups—Working Group I: the Physical Science Basis; Working Group II: Impacts, Adaptation and Vulnerability; and Working Group III: Mitigation of Climate Change—along with the Task Force on National Greenhouse Gas Inventories, the IPCC's structure ensures a comprehensive approach to climate change assessments. As an integral part of the IPCC, the Task Group on Data Support for Climate Change Assessments (TG-Data) guides the Data Distribution Centre (DDC) on data curation, traceability, stability, availability, and transparency. This replaces the former Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA). The IPCC's Assessment Reports cover the complete spectrum of scientific, technical, and socioeconomic aspects of climate change, with Special Reports focusing on specific issues, and Methodology Reports offering practical guidelines for greenhouse gas inventories under the UNFCCC.[7]

The introduction provides a comprehensive overview of the challenges in international cooperation on climate change, beginning with the alarming rise in global mean temperature from January to October 2018. Despite 2018 being the coolest among the past four years, the trend of warming continued, emphasizing the urgency of climate action. The chapter highlights the significance of the Paris Agreement, delving into its origin, content, and features, and explores challenges in enforcing climate change treaties, with a focus on the critique of the Kyoto Protocol. The Kyoto Protocol, adopted in 1997, mandates emission reduction targets for developed countries, reflecting the principle of "common but differentiated responsibility." It introduces flexible market mechanisms, including International Emissions Trading, Clean Development Mechanism, and Joint Implementation, promoting global GHG abatement. The Doha Amendment extends the Protocol, introducing new commitments. The article 2 emphasizes implementing policies for energy efficiency, sustainable development, and cooperation while considering adverse effects on developing countries. Despite shortcomings, the Kyoto Protocol has impacted global agendas. Adopted in 2015, the Paris Agreement aims to limit global temperature increase, emphasizing the importance of financial support from developed nations. It operates on a five-year cycle with Nationally Determined Contributions (NDCs) submitted by countries. Long-Term Low Greenhouse Gas Emission Development Strategies complement NDCs. The agreement establishes transparency mechanisms, including the Enhanced Transparency Framework (ETF) and the Global Stocktake. Despite challenges, low-carbon solutions have emerged post-Paris Agreement, indicating progress in addressing climate change. Established in 1987, the Montreal Protocol regulates ozone-depleting substances, showcasing international cooperation's success. The Multilateral Fund supports developing countries in phasing out ozone-depleting substances, contributing to achieving UN Sustainable Development Goals. The Kigali Amendment aims to phase down Hydrofluorocarbons, further demonstrating the protocol's adaptability to evolving environmental challenges. The United Nations Environment Programme (UNEP), established in 1972, plays a crucial role in addressing environmental challenges globally. UNEP focuses on transitioning to low-carbon economies, strengthening environmental governance, and providing evidence-based data. The Intergovernmental Panel on Climate Change (IPCC), founded in 1988, serves as the global authority for evaluating scientific aspects of climate change. Its assessments inform policymaking and contribute to discussions within the UNFCCC, showcasing the importance of science in shaping climate-related policies. Both UNEP and IPCC play integral roles in global environmental governance.

Summary

Chapter 9 provides an insightful overview of the intricacies and significance of international environmental agreements in combating climate change. It commences with an alarming depiction of the recent climate trends, emphasizing the dire need for global cooperation. The chapter intricately examines the Paris Agreement, highlighting its origins, content, and innovative approach that combines "top-down" and "bottom-up" elements, presenting a pioneering example of international climate policy. It scrutinizes the challenges of implementing such treaties, with a particular focus on the critique of the Kyoto Protocol's institutional design and its path-dependent shortcomings. Through case studies like the Kyoto Protocol, Paris Agreement, and Montreal Protocol, the chapter outlines the successes and limitations of these agreements, emphasizing the importance of financial mechanisms, market-based approaches, and the need for robust international cooperation.

[7] The Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/about/

Additionally, the chapter sheds light on the role of key international organizations, such as the United Nations Environment Programme (UNEP) and the Intergovernmental Panel on Climate Change (IPCC), in driving global environmental governance and policymaking. It underscores the critical function of these bodies in fostering a collective response to the environmental crisis, offering a blend of scientific insight and policy guidance that shapes the global agenda on climate change.

In essence, Chapter 9 navigates the complexities of international environmental agreements and their pivotal role in unifying global efforts towards a sustainable future. It underscores the ongoing challenges in international cooperation, the evolving nature of international environmental treaties, and the indispensable role of scientific and institutional frameworks in addressing the multifaceted crisis of climate change.

Discussion questions

1. How successful has the Kyoto Protocol been in reducing greenhouse gas emissions, and what can we learn from its strengths and weaknesses?

2. What role do Nationally Determined Contributions (NDCs) play in the Paris Agreement, and how can countries be encouraged to strengthen their climate targets?

3. Why is the Montreal Protocol considering a successful environmental agreement, and how can its adaptive approach be a model for future agreements?

4. What are the main challenges in enforcing climate change treaties, and how can we overcome them to enhance global cooperation?

5. Why is it crucial to closely monitor global temperature increases and adapt strategies to meet the Paris Agreement targets? What are the risks of temporary exceedance?

6. How can we encourage the widespread implementation of low-carbon solutions and markets globally to address climate change?

7. What is the importance of collaboration between international organizations like UNEP and IPCC with governments, civil society, and the private sector in tackling climate change?

8. How can financial assistance from developed nations be effectively mobilized to support climate efforts in developing countries, as emphasized in the Paris Agreement?

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CHAPTER 10: ECONOMICS OF BIODIVERSITY AND CONSERVATION

The demand for economic analysis of drivers of change and impacts on ecosystems, ecosystem services and biodiversity has never been as profound as it stands now in 2024. Decision makers at all levels are increasingly asking for the rationale for investment in restoration activities and they are willing to embrace economics-based response policies for the management of ecosystem services. The momentum in favor of economic analysis of change in ecosystems has accelerated in recent years owing to factors such as new evidence on declining ecosystem services and its linkages with apparatus such as monetary and fiscal policies of mainstream economic management.

10.1 Valuing biodiversity: instrumental vs. intrinsic values

Conservation biologists often argue natural entities (e.g. non-human species, ecosystems) should be attributed intrinsic value to secure a compelling ethical rationale for their protection. Soule' states that biotic diversity has intrinsic value irrespective of its instrumental or utilitarian value, and claims this is a necessary normative principle of conservation biology (Soule', 1985). Noss and Cooperrider similarly assert that intrinsic values...offer the least biased and ultimately most secure arguments for conservation (Noss, 1994), and McCauley recently invoked the concept of intrinsic value to criticize conservation actions based on monetization of ecosystem services (McCauley, 2006). Given its currency among conservation biologists, clarity about intrinsic value and its efficacy as an ethical basis for conservation is imperative.

Ascribing intrinsic value to non-human natural entities is intended to underscore reverence for nature by according to them a value independent of humans, thereby liberating humans from narrow anthropocentrism about value. Accordingly, conservation biologists have attributed intrinsic value to a broad range of things. One way of clarifying a concept is to search for patterns in the things to which it is applied. No pattern is apparent in the use of the term “intrinsic value” in conservation biology. It has been attributed to ecosystems, all biological entities and their environments, wilderness (Chambers, 2001), wasteland habitats and wild organisms, genetic variation that increases probability of population persistence and even all entities produced by natural processes (Angermeier, 2000). The apparent lack of any unifying principle underlying these attributions shows that the use of intrinsic value in conservation biology requires scrutiny.

One way to determine which entities of conservation interest have intrinsic value is to appeal to traditional ethical theories originally developed to govern human action. These theories argue that the properties of pleasure, rationality or virtuous character, and entities possessing them, are intrinsically valuable (Jamieson, 2000). For example, humans and other sentient organisms that experience pleasure have intrinsic value according to one theory, whereas only humans can exhibit rationality or virtuous character and thus have intrinsic value according to other theories. By analogy, entities of conservation interest could be considered intrinsically valuable if they possessed at least one of these intrinsically valuable properties.

Except sentient animals, however, non-human natural entities that are legitimate targets of conservation (e.g., plants, ecosystems) do not possess any properties considered intrinsically valuable by traditional ethical theories. Some nontraditional theories accord these entities intrinsic value, but such theories are not widely accepted and remain highly controversial (Grey, 1993). Proponents of intrinsic value in conservation biology therefore need a defensible account of the concept that allows these entities to possess it, and an argument showing they do. Besides unhelpful allusions – that an intrinsically valuable entity is valuable in itself or as an end in itself, valuable in the absence of humans and other intelligent organisms or of priceless and/or infinite value – explicit descriptions of what intrinsic value is and a convincing account of why non-human natural entities have it have not been given. The above characterizations are not compatible or defensible, and they do not provide workable criteria for determining which entities are intrinsically valuable.

Instead of saying what intrinsic value is, attempts to clarify the concept often focus on what it is not, namely, instrumental value. Entities with instrumentally valuable properties are valuable to the extent they are or will be considered valuable by valuers, such as humans and perhaps other cognitively complex organisms. For example, great art is instrumentally valuable because experiencing it is aesthetically and emotionally pleasurable. Art is instrumentally, not intrinsically, valuable because its value is dependent on and derives from the responses it produces in humans (e.g., pleasure). If experiencing a work of art ceased to produce these responses, if it no longer produced pleasure, for example, the art would lose its instrumental value.

Different properties of an entity can be valuable for different reasons, so instrumental value has a wide variety of different sources (fig. 10.1). Given its diverse sources, market-based assessments of an entity's instrumental value can be inappropriate, favoring those that can be evaluated with well-developed economic methods (e.g., natural resources, ecosystem services, visitor admission revenues) over those whose market value is more difficult to assess (e.g., aesthetic, cultural, educational, scientific value). Monetary measures might not accurately represent these diverse sources of value, and thus the instrumental value of an entity should not be narrowly equated with its monetary value. Because it is inappropriate to equate instrumental and monetary value, any antipathy toward instrumental value derived from an antipathy toward monetary value is therefore undeserved.

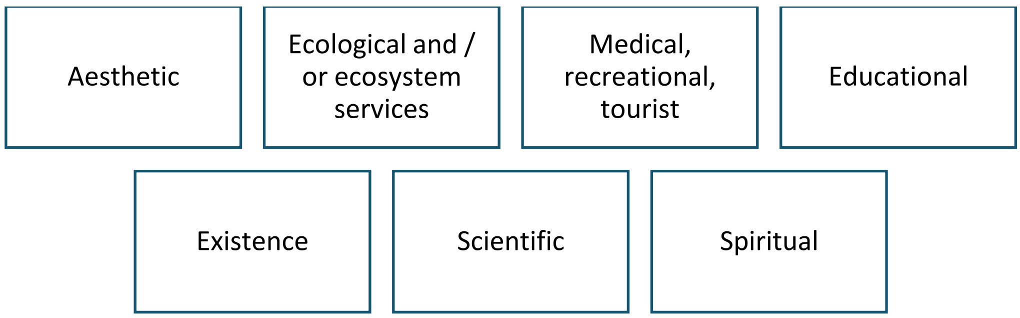

Figure 10.1 Sources of instrumental value of biodiversity
Source: Justus et al. (2009)

Labeling as 'intrinsic' values that markets find difficult to quantify, but that depend upon and derive from valuers such as humans, misrepresents the integral role these instrumental values have in conservation decision making. Once the mistaken conflation of instrumental value with monetary value is corrected, the diverse sources of instrumental value provide the best ethical basis for conservation.

10.2 Cost – effectiveness of conservation strategies

Meeting global conservation targets requires large-scale conservation and restoration action (Leclère et al., 2020), yet this is estimated to be underfunded by 598–824 billion USD per year (Deutz et al., 2020). To achieve global targets requires society recognizing the need for a massive increase in conservation funding, while defunding destructive practices, such as harmful subsidies (Deutz et al., 2020). At the same time, we need to ensure that conservation and restoration are cost effective to make the best use of the limited funds available. Enabling efficient and effective action requires a detailed knowledge of the costs and cost-effectiveness of interventions and projects. Information on costs helps us (i) understand the finance required to meet conservation goals, and (ii) identify the most cost-effective solutions. Comprehensive information on costs allows the greater application of decision-making tools, such as cost-effectiveness analyses, where conservation interventions are assessed on biodiversity benefits relative to socioeconomic costs (Cook et al., 2017).

The framework proposed aims to address the challenges associated with estimating the economic costs and benefits of conservation actions (fig. 10.2). It provides guidance for assessing both the costs and benefits incurred compared to the most likely alternative scenario, thus capturing the true opportunity cost. Additionally, the framework can be utilized to estimate direct financial costs and benefits, including explicit costs and benefits recorded in accounts. Conservation practitioners, including various stakeholders such as landowners, non-governmental organizations (NGOs), businesses, and governments, can utilize this framework to evaluate the economic implications of conservation actions before implementation. By doing so, they can make informed decisions about which conservation actions to pursue based on their expected economic outcomes.

Furthermore, researchers and practitioners can use the framework to track costs and benefits incurred after implementation, facilitating the reporting of projects or outcomes. This post-implementation assessment allows for the evaluation of the actual economic impacts of conservation actions, enabling stakeholders to adjust their strategies as needed and learn from past experiences. Overall, the proposed framework serves as a valuable tool for improving decision-making in conservation efforts by providing a systematic approach to assessing the economic costs and benefits associated with various conservation actions. It empowers stakeholders to make more informed choices and enhances accountability and transparency in conservation practices.

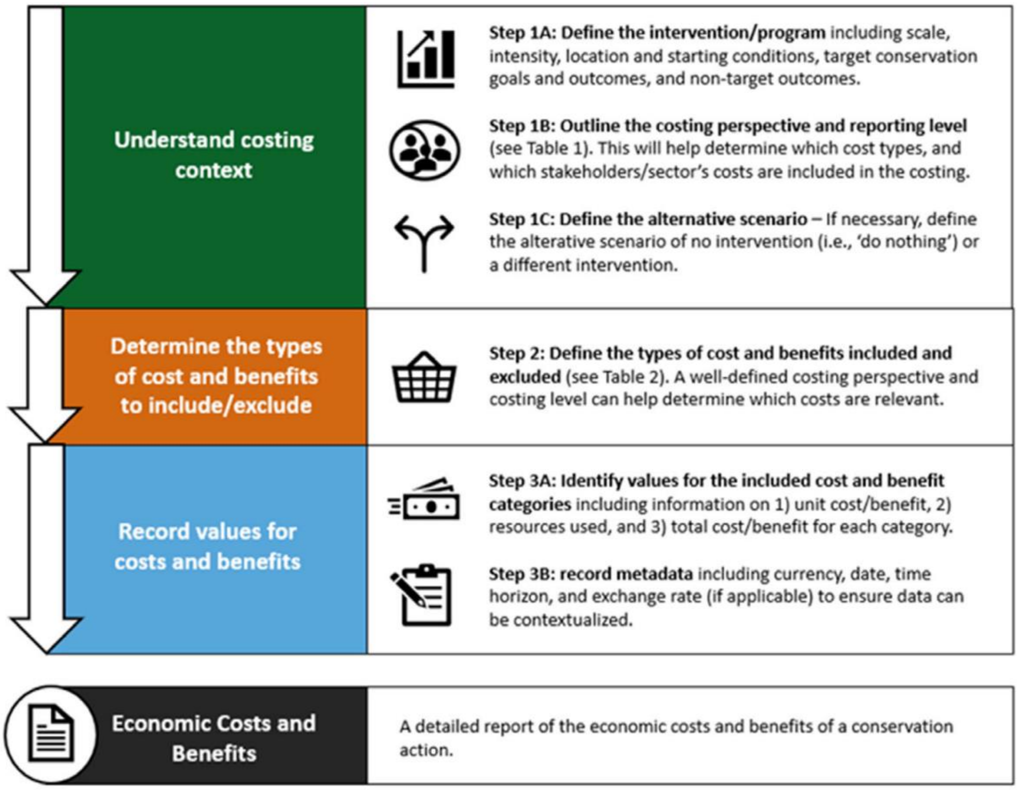

Figure 10.2 Steps for recording and reporting on the economic costs and benefits of conservation interventions
Source: White et al. (2022)

The framework is split into three main steps: (i) definition of the costing context, (ii) determination of the types of costs and benefit, and (iii) obtainment of values for costs and benefits.

Step 1. Define the costing context

Step 1A involves defining the intervention, its objectives, and outcomes in the context of biodiversity conservation. This step is crucial for accurately identifying and measuring costs associated with the intervention. Here's a breakdown of the key components to consider (Iacona et al., 2018; Murphy et al., 2021):

– Intervention definition: clearly define the conservation intervention being implemented. This includes describing the specific activities, strategies, or measures undertaken to achieve biodiversity conservation goals.

– Objectives: outline the overarching objectives of the intervention. These objectives should be clearly linked to biodiversity conservation goals and may include targets for ecosystem extent, species population size, or reduction of threatening processes.

– Outcomes: specify the desired outcomes or results expected from the intervention. These outcomes can be directly related to biodiversity objectives, such as increases in ecosystem extent or improvements in species populations. Additionally, consider indirect outcomes, such as improvements in water quality or carbon storage, which may result from the intervention.

– Environmental and social outcomes: recognize that conservation interventions may have multiple environmental and social outcomes beyond biodiversity conservation. For example, a reforestation project aimed at enhancing bird species richness may also impact agricultural production, water quality, and carbon storage. Documenting these additional outcomes is essential for comprehensive cost assessment.

– Social and economic context: provide information on the social and economic context surrounding the intervention. Factors such as location, starting conditions, intensity, scale, and timing of the intervention can influence the magnitude of costs incurred. Documenting these contextual details helps ensure that cost estimates are relevant and accurate for different contexts.

By defining the intervention, its objectives, and outcomes in detail, stakeholders can better understand the scope and purpose of the conservation effort, facilitating transparent and accurate cost assessment.

Step 1B involves outlining the costing perspective and reporting level for the conservation intervention. This step is essential for understanding whose costs and benefits are considered and at what organizational level the costs are reported. Here's how to approach this (table 10.1):

1. Costing Perspective: determine whose costs and benefits are included in the analysis. This may vary depending on the stakeholder's perspective. Consider the following perspectives (Adams et al., 2010):

– Societal perspective: includes costs and benefits to all stakeholders, reflecting the broader societal impact of the intervention.

– Payer perspective: focuses on the direct costs borne by a specific organization or entity funding the intervention. This perspective may be adopted by NGOs, companies, or government agencies concerned with their own financial obligations.

– Beneficiary perspective: considers the costs and benefits experienced by the direct beneficiaries of the intervention, such as local communities or ecosystem users.

2. Reporting Level: define the types of costs and benefits considered in the analysis. This determines the granularity of the cost assessment and may include the following reporting levels (e.g., Murphy et al., 2021; Vickery et al., 1994):

– Total costs: includes all direct and indirect costs associated with the intervention, regardless of stakeholder perspective.

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Table 10.1 Costing perspectives and reporting levels for conservation projects, and examples of the costs included for each category

Perspective (i.e., whose costs / benefits?)		Reporting (i.e., which costs / benefits?)		
Type	Description	Intervention	Project	Organization
Payer	Costing is conducted from the perspective of the entity paying for the conservation action (e.g., farm, NGO, government agency).	The direct costs of the intervention and future management, above current expenditure on associated interventions. May exclude staff time, capital expenditure and overheads. Can include/exclude direct financial benefits that result from the intervention.	Intervention level costs plus the costs of required associated interventions, future management costs within the project budget, staff time spent on the intervention and project-specific overheads. May include capital expenditure. Opportunity costs that could result in changes in the payer's budget can be considered. Can include/exclude direct financial benefits obtained by the payer, and payer costs avoided because of the project.	Project level costs plus a proportion of wider overheads (e.g., office rent, etc.) necessary for the project to operate. Opportunity costs, avoided costs, or income that could result in changes in the payer's budget can be considered. Can include/exclude direct financial benefits obtained by the payer, and payer's organizational costs avoided because of the project.
Sector	Costing is conducted from the perspective of the wider conservation /environmental management sector.	As above but including future management costs and opportunity costs that will be incurred by the wider sector. This includes both within budget future management costs, and costs incurred by other conservation actors. Can include/exclude direct financial benefits obtained by the wider sector, and costs that may be avoided by the wider sector because of the intervention. May require exploration of distributional impacts (i.e., which parts of the sector lose or gain overall, and at what scale).		
Local societal	Costing is conducted from the perspective of the conservation sector, whilst including some financial and economic costs that may emerge to other key stakeholders (e.g., local communities).	As above, but also includes local opportunity costs (e.g., lost income) incurred by local stakeholders directly because of the intervention. Can include/exclude direct financial benefits obtained by the payer and key stakeholders, and costs that may be avoided by these actors because of the intervention. This may also include the valuation of local non-monetary ecosystem service values. May require exploration of distributional impacts (i.e., which stakeholders/sectors lose or gain overall, and at what scale).		
Global societal	Costing is conducted from the perspective of global society, including costs to all relevant stakeholders and sectors.	As above, but future management costs, and opportunity costs to multiple stakeholders should be assessed. Can include/exclude avoided costs (inc. the averted loss or the gains for ecosystem service value) or estimates of financial benefit (inc. direct financial benefits and estimates of gained local and global ecosystem service value). May require exploration of distributional impacts (i.e., which stakeholders/sectors who lose or gain overall, and at what scale).		

– Net costs: accounts for the difference between total costs and any financial benefits accrued from the intervention.

– Incremental costs: focuses on the additional costs incurred by implementing the intervention compared to the status quo or alternative scenarios.

– Cost-effectiveness: evaluates the cost per unit of biodiversity outcome achieved by the intervention, providing insights into the efficiency of resource allocation.

By clearly defining the costing perspective and reporting level, stakeholders can tailor the cost assessment to their specific interests and objectives. This ensures that the analysis accurately reflects the financial implications of the conservation intervention from different perspectives Step 1C involves defining the alternative scenario against which the costs and benefits of the conservation intervention will be compared. This step is crucial for accurately assessing the economic costs and benefits of the intervention. Here's how to define the alternative scenario (Maron et al., 2018; Davis et al., 2019):

– Select the counterfactual: identify the scenario that represents what would happen if the conservation intervention were not implemented. This serves as the baseline for comparison and helps quantify the incremental costs and benefits of the intervention.

– Consider likelihood: choose the alternative scenario that is most likely to occur in the absence of the intervention. This could involve comparing the intervention scenario to a scenario of no intervention, where biodiversity values may continue to decline or remain stagnant.

– Evaluate dynamic baselines: assess whether the alternative scenario should involve a fixed baseline (e.g., maintaining current biodiversity levels) or a dynamic baseline (e.g., continued decline without intervention). Dynamic baselines may better capture the evolving nature of biodiversity and its response to different management actions.

– Explore multiple scenarios: in some cases, it may be necessary to compare costs and benefits under multiple alternative scenarios to account for uncertainty or variability in future conditions. This could involve considering different management approaches or potential changes in external factors affecting biodiversity.

– Consideration of costs and benefits: ensure that the choice of alternative scenario aligns with the specific costs and benefits being assessed. Different scenarios may result in varying cost-effectiveness estimates and can influence decision-making regarding the implementation of conservation interventions.

By carefully defining the alternative scenario, stakeholders can effectively evaluate the economic implications of conservation actions and make informed decisions about resource allocation and intervention strategies.

Step 2. Determine the types of costs and benefits

In table 10.2, we outline the possible financial costs and benefits associated with conservation interventions across four main themes: ongoing costs, direct intervention costs, opportunity costs, and economic benefits. Here's a breakdown of each theme:

– Ongoing costs: these are recurring expenses that occur regardless of whether a conservation intervention is implemented. Examples include human resources (HR) costs, administrative expenses, and maintenance of headquarters. Ongoing costs are typically not included in full costings for specific interventions or projects unless they are directly related to the intervention.

– Direct intervention costs: these are the expenses directly associated with implementing the conservation intervention. They include costs such as materials, equipment, labor, training, and monitoring. Direct intervention costs are essential for assessing the financial feasibility and resource requirements of the intervention.

– Opportunity costs: opportunity costs represent the value of the next best alternative foregone when a decision is made. In the context of conservation interventions, opportunity costs may arise from allocating resources (e.g., time, money, land) to one project instead of another, or from the potential benefits lost by not using a resource for its next best alternative use.

Table 10.2 The economic costs and benefits of conservation interventions

(1) Ongoing costs	*Costs incurred independently of the project or intervention under consideration.*
Central administration	HR costs, construction/maintenance of buildings (e.g., office blocks, HQ, rents), project design. These costs are incurred regardless of the intervention being implemented.
Training and skill development	Costs of training and skill development of staff. These costs are incurred regardless of the intervention being implemented.
(2) Direct intervention costs	*Various explicit financial costs incurred as a result of implementing the intervention.*
Implementation Labor	Cost and amount of labor required to implement the intervention.
Capital	Capital required to implement the intervention (e.g., vehicles, extra office space, machinery).
Consumables	Items or commodities that are required, and used up, when implementing the intervention (e.g., equipment, supplementary food, etc.).
Access	Cost required to access the intervention (e.g. transport costs, does it require services that are not available on site). Access costs can sometimes be considered consumables.
Transaction	Cost associated with designing and planning the intervention or program.
Joint costs/overheads	Overhead costs shared between multiple interventions where only a proportion of the cost can be assigned to the specific intervention or project being studied (e.g., project planning, electricity bills, administration staff, etc.). These are distinguished from ongoing costs as the project being implemented does contribute to a portion of these costs.
Future management	Future management costs which would not otherwise have been incurred (e.g., monitoring, replacement, reoccurring management actions).
(3) Opportunity costs	*Implicit costs equivalent to what is given up in order to pursue an intervention.*
Opportunity costs / benefits Foregone	Market valuation – Financial income foregone as a result of an intervention (i.e. lower income crop harvests, reduced hunting revenues, excess burden of tax at societal scale). Nonmarket valuation – Unrealised benefits as a result of an intervention due to foregone ecosystem service provision in the alternative scenario (e.g. a loss of carbon storage potential, or esthetic value due to the conservation action).
(4) Economic benefits	*Economic benefits that may occur due to the outcomes of an action.*
Explicit benefits / extra benefits from Enhanced Environment	Market valuation – Financial income generated as a result of the enhanced environment (e.g., ecotourism). Non-market valuation – Economic gains associated with greater ecosystem service provision (e.g., flood protection, carbon sequestration, water purification).
Avoided costs/costs foregone	Market valuation – Financial costs avoided as a result of the intervention (e.g., fines, costs of human-wildlife conflicts). Non-market valuation – Averted economic loss associated with the gained ecosystem services in the intervention scenario (e.g., flood protection, carbon sequestration, water purification).

– Economic benefits: these are the financial gains or benefits resulting from the conservation intervention. Economic benefits may include increased revenue from ecotourism, enhanced ecosystem services (e.g., improved water quality, carbon sequestration), and avoided costs (e.g., reduced healthcare expenses due to improved air quality).

When using the framework, users should determine and report the types of costs and benefits they are including in their assessment, considering the costing perspective and reporting level. This helps ensure transparency and accuracy in evaluating the economic implications of conservation actions.

Reporting the direct costs required to implement conservation interventions is crucial for understanding the financial implications of these actions. These direct costs encompass various expenses and are typically the most frequently reported costs associated with conservation programs. Here's a breakdown of the components often included in direct costs (ASU, 2022; Wenger et al., 2018):

– Capital expenditures: these are one-time expenses for purchasing assets or equipment necessary for the conservation intervention. Examples include the cost of constructing infrastructure, buying vehicles, or installing monitoring equipment.

– Equipment and consumable costs: this category include the costs of equipment, tools, and consumable supplies needed to carry out the intervention. It encompasses items such as field equipment, sampling tools, and materials required for habitat restoration activities.

– Labor costs: labor costs involve the expenses associated with hiring personnel to perform tasks related to the conservation intervention. This includes wages or salaries, fringe benefits, and any additional compensation for labor.

– Overheads specifically associated with the intervention: while less frequently included, overhead costs directly tied to the intervention, such as project-specific administrative expenses or management fees, may also be reported as part of the direct costs.

– Future management costs: these are ongoing expenses required for the maintenance and monitoring of the intervention beyond its initial implementation phase. Examples include routine maintenance of infrastructure, monitoring of biodiversity indicators, and adaptive management activities.

– Access costs: in situations where accessing project areas presents challenges or additional expenses, such as remote or rugged terrain, access costs may be included. These costs cover expenses related to transportation, logistics, and overcoming barriers to access project sites.

When reporting direct costs, it's essential to provide transparency regarding the types of costs included and detail how these costs were calculated. This ensures clarity and allows for accurate assessment and comparison of conservation interventions across different projects and contexts.

Conservation interventions can yield explicit financial benefits, some of which can be easily quantified using market-based approaches. Examples include revenue generated from fisheries or ecotourism activities associated with protected areas. These benefits are tangible and directly contribute to economic value. However, there are also numerous benefits associated with conservation outcomes that are not easily captured through market transactions. These nonmarket benefits require alternative valuation methods to estimate their economic value. Here are some key points regarding the financial benefits of conservation interventions: market-based valuation, nonmarket valuation, challenges in valuation, lack of recognition, varied economic benefits (Dasgupta, 2021; Huveneers et al., 2017).

In summary, while some financial benefits of conservation interventions can be readily quantified using market-based approaches, many important benefits are not captured through traditional economic accounting methods. Adopting a broader perspective that incorporates both market and nonmarket valuation techniques is essential for fully understanding the economic implications of conservation actions.

Step 3. Obtain values for costs and benefits

Step 3A involves recording values for the cost and benefit categories included in the conservation intervention. Here's how to proceed (Franklin et al., 2019; ASU, 2022):

– Collate information: gather cost data from various sources such as published literature, project budget documents, or online databases of equipment and intervention costs. This information may include unit costs, resources or items used (e.g., specific equipment, consumables), hours of labor required, and any other relevant details.

– Identify relevant categories: determine which cost and benefit categories are relevant to your conservation intervention. These may include ongoing costs, direct intervention costs, opportunity costs, and economic benefits, among others.

– Document unit costs: record the unit costs for each resource or item used in the intervention. This could include costs associated with equipment, consumables, labor, or any other inputs required for the intervention.

– Calculate total costs: calculate the total cost for each relevant category by multiplying the unit cost by the quantity used or the total hours of labor required. This will provide a comprehensive overview of the financial investment required for the conservation intervention.

– Note non-monetary resources: make sure to note any resources used in the intervention that would have had a monetary cost in different contexts. For example, volunteer labor or donated materials may have a tangible value that should be accounted for in the cost assessment.

By following these steps, you can accurately record the values associated with the costs and benefits of your conservation intervention, providing valuable information for decision-making and evaluation purposes.

Step 3B involves recording metadata alongside reported values to provide context for costs and benefits. Here's how to do it (Pannell et al., 2013; Teh et al., 2015):

– Currency type: specify the currency in which the costs and benefits are reported. This helps ensure consistency and comparability across different interventions.

– Date and time horizons: record the date when the costs and benefits were incurred or projected to occur. Additionally, specify the time horizon over which the costs and benefits are assessed (e.g., one year, five years, etc.).

– Exchange rates: if costs and benefits are reported in a currency different from the local currency, provide the exchange rates used for conversion. This allows for accurate comparison and interpretation of financial data.

– Cost type: classify costs as fixed or variable. Fixed costs remain constant regardless of the scale of the intervention, while variable costs change with the intensity or scale of implementation.

– Recurrence: specify whether costs are one-off or recurring over a given timeframe. This helps in understanding the long-term financial implications of the intervention.

– Cost incurrence: note who will incur the costs associated with the intervention. This allows for the investigation of the distribution of costs and benefits among different stakeholders.

– Discount rates: if applicable, specify the discount rate used to convert future costs and benefits into present-day values. Carefully choose a discount rate that reflects the local context, and consider conducting sensitivity analyses to assess the robustness of results.

By recording this metadata alongside reported values, you can ensure that costs and benefits are appropriately contextualized and facilitate accurate interpretation and comparison of financial data across different interventions and contexts.

10.3 Case studies on global conservation initiatives

10.3.1 Leaping from extinction: Rewilding the relict leopard frog in Las Vegas, Nevada, USA

Introduction. The Springs Preserve (Preserve) is a 73 ha urban park known as the birthplace of Las Vegas, Nevada, USA. Historically, the Preserve contained three springs that flowed into riparian meadows. These spring systems were once inhabited by the Vegas Valley leopard frog (Rana fisheri), which was once presumed extinct but has persisted in central Arizona, USA. Today, the Preserve is privately-owned by the Las Vegas Valley Water District (LVVWD), the local municipal water purveyor. As part of ongoing restoration efforts, ponds were constructed at the Preserve to rewild the state-protected Relict leopard frog (Rana onca), a species considered Endangered by the IUCN. This frog species was once presumed extinct, but populations persisted along drainages of the Virgin and Colorado rivers in Arizona and Nevada, USA (Jaeger et al., 2001).

Since then, eight natural populations have been documented and 13 refugia sites established. In spring 2018, surveys at all known sites documented a total of 1,125 frogs; although, the actual number was likely several times larger. The establishment of a population at the Preserve further protects the species from stochastic events that can lead to extinction.

Goals:

– Obtain regulatory and legal agreements, permissions, and permits necessary for private landowners to conduct actions that may contribute to the recovery of species listed as endangered or threatened under the U.S. Endangered Species Act.

– Design and construct a pond mesocosm suitable for Relict leopard frogs.

– Establish a self-sustaining population of Relict leopard frogs.

– Increase geographic distribution and total population count to increase species resilience to stochastic events.

– Educate public about the plight of the Relict leopard frog and foster community support.

Success Indicators:

– Ratification of Landowner Cooperative Agreement with Nevada Department of Wildlife (NDOW).

– Establishment of pond mesocosm at designated site.

– Obtain and translocate Relict leopard frogs.

– Relict leopard frog population becomes self-sustaining.

– Implement public education programing on conservation efforts.

Project Summary

Feasibility: To assist with conservation of the Relict leopard frog, additional public education and refugia populations are required. The Preserve was identified as a potential translocation site because: 1) it is a secure property that will reduce the likelihood of illegal introductions of non-native species, 2) it hosts two museums that promote conservation and public education, and 3) it was historically inhabited by the extirpated Vegas Valley leopard frog.

The Preserve, however, encompasses a 44-ha operational groundwater well-field that provides water to meet Las Vegas' peak municipal demands. To maintain operations of the active well-field, while ensuring the safety of a Relict leopard frog population, a 15-year Landowner Cooperative Agreement was ratified in 2017 by LVVWD and NDOW under a programmatic Candidate Conservation Agreement with Assurances between the U.S. Fish and Wildlife Service (USFWS) and NDOW. The legally binding document spelled out the rights, responsibilities, and obligations of the parties (LVVWD & USFWS, 2017).

Implementation: The design and construction of a pond mesocosm suitable for Relict leopard frogs was potentially the most challenging part of the project. Two previously built ponds at the

Preserve had been negatively affected by decomposing leaves from overhead Cottonwood trees (Populus fremontii). Supplemental aeration and filtration were necessary in order to rectify water quality issues. Once funding and approvals were secured, a new low-maintenance pond mesocosm was designed in August 2016. This design included two interconnected concrete ponds with shared aeration systems (i.e., bubblers, waterfalls), and both natural filtration (i.e., emergent macrophytes) and mechanical filtration (i.e., high-capacity skimmer baskets, settling basin). The intricacies of the unique aeration and filtration systems were detailed in Wallace (2018).

Relict leopard frog eggs were collected in spring 2018 and 2019 from natural populations in Lake Mead National Recreation Area, Clark County, Nevada. Tadpoles were reared in a laboratory setting by biologists from the University of Nevada, Las Vegas. Once the ponds were working as designed in May 2018, 100 newly metamorphosed Relict leopard frogs were released into the ponds. An additional 101 tadpoles and 111 newly metamorphosed frogs were translocated from March to May 2019.

Post-release monitoring: Since the ponds can be visited regularly by staff, post release monitoring has occurred almost daily. Upon the release of the initial 100 young frogs in May 2018, a female Mallard duck (Anas platyrhynchos) was observed consuming several frogs as they floated on the surface of one of the ponds. These laboratory-raised frogs appeared to have not developed effective flight response, which was compounded by a lack of dense cover in the newly planted riparian areas. Few frogs were observed during subsequent diurnal visits.

A nocturnal visual encounter survey (VES) in July 2018 noted the presence of only six Relict leopard frogs. By October 2018, four (one male and three females) large adult-sized frogs were captured, and PIT tagged during a nocturnal survey.

Although little is known about the overwintering habits of this species, dataloggers revealed that water temperatures in the two ponds decreased to 0.5°C and 1.5°C, respectively, over the winter of 2018 – 2019. All extant natural populations of Relict leopard frogs inhabit geothermally influenced systems, where water temperatures can reach 30 - 55ºC at sources (Bradford et al., 2005). Nonetheless, refugia populations have been established at sites with colder water (Conservation Team, 2016).

In March 2019, a nocturnal survey revealed the presence of two adult Relict leopard frogs. A male was captured at that time and its identity confirmed via PIT tag. This male, released as a newly metamorphosed frog in May 2018, was calling prior to capture, and thus already sexually mature.

In April 2019, in situ reproduction was confirmed when hundreds of small tadpoles were observed in the ponds. Although no egg mass was observed, Relict leopard frog egg masses can contain up to 1,100 eggs (Conservation Team, 2016). Thereafter, tadpoles were observed regularly on sunny days resting on algae and vegetation but were noticeably absent on overcast days. These tadpoles began to undergo metamorphosis in July 2019, and by August 2019, a VES documented 195 frogs and one tadpole in the ponds. Six of the observed frogs were of adult size.

In October – November 2019, 214 Relict leopard frogs were captured and marked in the ponds. Twelve of these frogs were of adult size, including a very large PIT tagged female from the 2018 cohort. A subsequent recapture revealed that an estimated 424 frogs inhabiting the ponds (with a 95% Confidence Interval=308 – 540). Although most of the frogs were young and had not yet overwintered, the presence of so many frogs is promising in terms of their potential contribution to the overall status of this species.

Major difficulties faced:

– Prior to the addition of aeration and filtration systems, there was an unanticipated decline in water quality because of large quantities of decomposing leaves in the fall and winter. The 2012 International Swimming Pool and Spa code recently adopted by the City of Las Vegas requires any body of water built deeper than 46 cm to be surrounded by child-proof, unclimbable, security fences. After consultation with the City of Las Vegas, it was determined that the ponds met the code requirements of a man-made lake used for recreational, scenic, or landscape purposes; therefore, no pool fencing was required.

– In spring 2018, the density of native plants in the riparian zone did not provide the translocated frogs with sufficient cover from previously undocumented avian predators. Riparian plant growth by 2019 appeared sufficient to resolve this issue.

– In 2018, most of the lab-raised young Relict leopard frogs did not appear to exhibit a sufficient flight response upon release to avoid avian predation. The contrast in wariness was especially evident in 2019, as the young frogs that developed in situ, or from tadpoles released at the site, had pronounced flight responses.

– The mechanical aeration system (i.e., bubblers) had to be adjusted so that the bubbles did not prevent falling leaves from reaching two large skimmer baskets. Given the closed nature of the system, large quantities of decomposing leaves could still potentially lead to water quality issues.

Major lessons learned:

– Small pond mesocosms require supplemental aeration and filtration.

– In 2019, modifications to the translocation protocol were implemented in an attempt to reduce the impact of diurnal avian predators: 1) all translocations were scheduled at dusk to allow animals to acclimate prior to experiencing potential diurnal avian predation, and 2) large tadpoles were released in addition to the newly metamorphosed frogs.

– Although plant cover was substantial by 2019, cover was further enhanced in 2019 by placing several partially submerged large sandstone slabs in the riparian zone. These slabs were heavy enough that ducks could not dislodge them, with access only under the edges. Subsequent monitoring has documented numerous metamorphs and young frogs sheltered under these slabs.

– Survivorship of young frogs that developed from the eggs deposited in situ was probably higher than the translocated lab-reared young frogs.

– The rewilding of the Springs Preserve generated a surprising amount of positive local media coverage. This media coverage was leveraged to educate the public about the plight of imperiled amphibian species in the Mojave Desert.

Success of project

Highly Successful	Successful	Partially Successful	Failure

Reason(s) for success:

– The initial buy-in and subsequent commitment from partner agencies to see the project through, despite temporary setbacks, was critical to the success of the project.

– The pond was redesigned to be a low maintenance mesocosm that provided redundant natural and mechanical aeration and filtration systems.

– Enhanced riparian habitat with additional cover to mitigate for previously undocumented avian predation by ducks.

– The probability of success was increased by adjusting translocation protocols for the species.

– Public education followed a multifaceted approach, including interpretive panels, site tours, and public television. These activities resulted in additional reporting in local print and social media, generating even more public interest.

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10.3.2 Reinforcement of isolated Javan ebony langur populations in East Java, Indonesia

Introduction. The Javan ebony langur (Trachypithecus auratus), also known as Javan lutung, is endemic to Indonesia and is listed as Vulnerable on the IUCN Red List. Two subspecies are currently recognized; T. auratus mauritius has a restricted distribution in west Java, and T. a. auratus occurs in eastern Java and on the smaller islands of Bali, Lombok, Pulau Sempu and Nusa Barung. The use of land for economic activities has resulted in disturbance to forest security in the form of encroachment, illegal logging, forest and land fire, and illegal trade in plants and wildlife (MoEF, The State of Indonesia's Forests 2018), including live capture of Javan ebony langurs for the illegal wildlife trade (Nijman & Supriatna, 2008). This case study refers to two reinforcement projects of eastern Javan ebony langurs, in the highland Coban Talun and the lowland Kondang Merak Protected Forests. Langurs for release are sourced from the Javan Langur Rehabilitation Centre located on the edge of the Coban Talun forest. Most released langurs are rescued from the illegal pet trade in Indonesia, others are from the European captive population. The project is managed within the Javan Primates Conservation Programme (JPCP), run by the Directorate General for Conservation of Natural Resources and Ecosystem, Ministry of Environment and Forestry (KLHK), in partnership with The Aspinall Foundation (TAF) Indonesia Program.

Goals:

– To return confiscated and captive born Javan primates to their natural habitat.

– To reestablish viable populations of the Javan ebony langur in the Coban Talun and Kondang Merak Protected Forests, East Java, Indonesia.

– To raise public awareness, especially amongst the younger generation, about the importance of wildlife and habitat conservation.

– To provide opportunities for national students to participate in field-based conservation of primates.

Success Indicators:

– High post-release survival of released Javan ebony langurs.

– Reproduction by released Javan ebony langurs.

– Increased population of Javan ebony langurs in the release sites.

– Increased viability of the Javan ebony langur populations in the release sites, and in the long-term across the natural range of the species.

– Increased public awareness not to keep or trade Javan ebony langurs.

Project Summary

Feasibility: The release sites were selected following population and habitat surveys at numerous sites across East Java in 2010 and 2011 (Wedana et al., 2013). Following these surveys, the choice of the first release site was the Coban Talun Protected Forest, located within the Raden Soerjo Forest Park. Another survey was undertaken in March 2012 to conduct detailed studies of biodiversity, threat potentials and vegetation, including wild food abundance (Kurniawan, 2012). Coban Talun PF comprises approximately 250 ha of forest from Mount Pusungrawung to the eastern slope of Mt. Biru and is a form of highland rainforest ecosystem with evergreen trees. Elevation ranges from 1,300 – 2,200 m a.s.l. Coban Talun is managed by a stateowned forestry enterprise Perum Perhutani. According to information from local residents, the number of langurs previously in the 1980s and 1990s could reach hundreds of individuals. The number has decreased dramatically as a result of uncontrolled poaching, and only six groups were found in 2010 – 2012 with an average of 15 individuals per group. The carrying capacity of Coban Talun was estimated at approximately 15 groups.

The second release site selected was the Kondang Merak Protected Forest, a lowland rainforest located by the coast south of Malang covering ~1,500 ha but with only 28 langurs in four groups inventoried in 2011. All coastal rainforests in this region are severely damaged and fragmented, and langur populations are isolated and highly threatened (Wedana & Kurniawan, 2011). The Kondang Merak PF is also managed by the state-owned forestry enterprise Perum Perhutani.

Implementation: The pre-release phase is undertaken at the Javan Langur Rehabilitation Centre (JLRC) in East Java, located only 4 km from Coban Talun, and approximately 50 km from Kondang Merak. The average rehabilitation period for the langurs prior to release is 10 months, including three months of quarantine. All necessary pre-release procedures, such as final veterinary exams and behavioral observations, are undertaken during the pre-release phase. All langurs undergo extensive pre-release testing and preparation that follows a detailed disease risk analysis. Transport to the release site is in individual cages, either carried as a backpack for the 1 – 2 hour journey to Coban Talun, or driven to Kondang Merak and then carried to the release site. Simple cages are constructed at the release sites to allow a soft-release process. The first releases used wooden cages built high in the trees (Wedana et al., 2013), more recent releases have used net cages constructed from ground level to the mid-storey. During this habituation phase the langurs are introduced to natural leaves which will become their food in the forest. After about five days the langurs are released.

A total of 128 East Javan ebony langurs have been rehabilitated at the JLRC from 2011 to 2019. Of these a total of 93 langurs have been released, 32 at Coban Talun and 61 at Kondang Merak (table 10.3). Sixteen originated from Howletts and Port Lympne in the UK, two from Beauval Zoo in France, seven were captive born at JLRC, and the remaining 68 were rescued by KSDAE from the illegal wildlife trade in Indonesia.

Table 10.3 Summary of Javan ebony langurs released at Coban Talun and Kondang Merak between 2012 – 2019

Year	Langurs released (Coban Talun)	Langurs released (Kondang Merak)	Confirmed deaths	Reported births
2012	13	0	0	0
2013	0	0	0	2
2014	10	0	0	3
2015	0	14	2	2
2016	0	15	2	8
2017	0	18	0	10
2018	0	8	1	3
2019	9	6	0	2
Total	32	61	5	30

Post-release monitoring: Intensive monitoring of the released langurs is conducted by The Aspinall Foundation in collaboration with East Java BKSDA Forest rangers. Eighteen university students have also conducted field research at the sites. The monitoring team records movements and types of food consumed. Subcutaneous VHF-transmitters were used on a few langurs but were not very effective due to the density of the forest and the hilly terrain. Twentysix langurs have been monitored for over two years, including eight for over five years and another for over seven years. Many of the released groups associated with wild langurs. Some wild individuals joined released groups, and some released individuals joined wild groups. Home-range sizes for the released groups are estimated at between 6 – 21 ha, depending on the condition of the vegetation cover and the availability of natural foods. At least 121 species of plants have been observed to be consumed by released langurs in Kondang Merak, and at least 35 species at Coban Talun. Vegetation consumed includes trees, vines, epiphytes, and shrubs.

Of the first 70 langurs released, to the end of 2017, only four are confirmed dead, 40 were monitored for at least one year post-release, and 12 could not be monitored after only a short time post-release, giving a first-year survival rate between 69% and 93% (excluding the 12 langurs that were not monitored), and considered to be at the higher end of this range as all disappearances were due to difficulties of maintaining monitoring and recognizing individual langurs rather than any evidence of possible mortality.

A total of 30 births have been reported to 28 released female langurs to the end of 2019 (60% of females released to the end of 2017), with one female having three reported births, including five births to female langurs captive-born in the UK. One of the offspring of a UK-born female has also been reported to have successfully given birth. The estimated population size at Coban Talun has increased from 90 in 2010 to 135 in 2019.

Major difficulties faced:

– Limitations of tracking equipment for post-release monitoring.

– Identifying additional forest locations for releases.

– Difficulties in rehabilitating some individuals who have spent considerable time in unnatural or unsuitable captive situations.

Major lessons learned

– The pre-release socialization stage must be as natural as possible, considering the natural behavior of the species, including in the selection of foods and of enrichment. The pre-release phase is very important in determining the ability of individual langurs to survive in the wild.

– Javan ebony langurs live in groups with a simple hierarchical structure, namely one-male multi-female. If there are other males in a group, there are many potential problems. Therefore, the determination of group composition prior to release should adjust to the characteristics of wild langur groups, both in terms of the number of individuals and the sex ratio.

– Health testing is critical for good selection of individuals for release.

– In the absence of effective tracking devices post-release monitoring must be conducted intensively on a daily basis for the initial 1 – 2 months after release. Just one or two days without monitoring makes it very difficult to locate the langur again.

– The success of a rehabilitation and release program lies in the management of post-release monitoring.

Success of project

Highly Successful	Successful	Partially Successful	Failure

Reason(s) for success:

– Post-release survival of the Javan ebony langurs appears to be very high.

– Post-release reproduction has been observed frequently, and reproduction of the F1 generation has also been reported.

– Population estimates at the release sites have increased since the start of the reinforcement projects.

– The project is helping conserve the habitat of the release sites.

– The project is raising public awareness on curbing the illegal wildlife trade and on wildlife conservation, at local and national levels, including through participation in some releases and through national media.

10.3.3 Conservation and re-introduction of red horntail orchid, a nationally extinct orchid species in Singapore

Introduction. Bulbophyllum maxillare is a beautiful native species of Singapore. It has two common names, first is the Chinbone Bulbophyllum and the second is the Red horntail orchid. Recent taxonomic revision (Vermeulen, O'Byrne & Lamb, 2015) has put Bulbophyllum blumei, Bulbophyllum masdevalliaceum under Bulbophyllum maxillare. The warm growing epiphyte grows on trees from sea level up to 800 m. The ovoid pseudobulb is light green in color, up to 4 cm long by 1.5 cm in diameter, each bearing a single soft fleshy leaf, 8 – 15 cm long by 1.5 – 2.5 cm across. The flower measures 6 – 9 cm long by 2 – 2.5 cm across. The petals are reddish purple with light yellow edges. The lip is purple and yellow.

The species is distributed in West Malaysia, Sumatra, Borneo, the Philippines, Papua New Guinea, the Solomon Islands and Australia. In Peninsula Malaysia and Singapore, the species are found growing on old mangrove and near rivers. In Singapore, it was first collected at Kranji in 1890 and was last collected by Henry Ridley, from Kranji in 1892. Since it is nationally extinct, we propagated the species from nursery materials and the species was successfully reintroduced to many areas in Singapore.

Goals:

- To conserve the species by raising seedlings from seeds.
- To reintroduce the seedlings to its natural habitat, parks and roadside trees.
- To monitor the growth of reintroduced plants.

Success Indicators:

- To propagate the species from seeds effectively.
- To ensure the species are reintroduced successfully into the natural habitats, parks and roadside trees.
- To ensure the reintroduced plants continue to survive after the reintroduction.
- To find out the best conditions for reintroduction.

Project Summary

Feasibility: Bulbophyllum maxillare was first collected by J.S. Goodenough at Kranji in 1890 and was last collected by the director of the Botanic Gardens, Henry Ridley, from Kranji in 1892. Since then, the species has not been rediscovered and became nationally extinct. The species was propagated from seeds by using nursery materials from Peninsular Malaysia.

Implementation:

Seedling's culture: Propagation of seeds is the most effective way to conserve orchid species. A modified KC medium is used for the germination of seeds; once germinated, seedlings are transferred to a second medium (Arditti, 1977; Yam, 2013; Yam et al., 2013). Seedlings are grown to about 4 cm tall, which takes about 12 months. They are then ready to be transferred to the nursery.

Propagation of seedlings in nursery: Seedlings should generally be planted in groups of about 30 into community pots, using small charcoal pieces and brick chips. When the seedlings are well established, they are divided and planted individually on slab of wood. Plants are ready for reintroduction when each seedling has three to four new shoots and a healthy root system.

Reintroduction: The seedlings were planted on trees during the rainy season, from the beginning of October to December.

Time of planting: The best time for planting tropical orchid seedlings is before or during the rainy season. In Singapore, the rainy season starts around October and lasts until January. Most of our plantings have been carried out from late September through November. Seedlings planted during these periods have established themselves quickly, producing new shoots and roots. Once the roots of epiphytic species have attached themselves to the bark of the host tree, they can absorb water and nutrients directly from the environment.

Host trees: Trees that support more epiphytes tend to be better hosts than those with fewer epiphytic plants, as their presence indicates that conditions are suitable for epiphytic species. Of all roadside trees that are suitable for epiphytes, the rain tree fosters the most luxuriant growth of epiphytic plants. The most common epiphyte found on rain trees is Asplenium nidus (Bird's nest fern) and Dendrobium crumenatum is the most common orchid.

Planting: The seedlings were planted under the proper environmental conditions, for this species, they were planted on mature host trees with other epiphytes and with 30 – 50% shade. Slabs of wood with established seedlings were secured on tree trunks and/or branches with horticultural wires and/or nails. Seedlings were reintroduced to Sungei Buloh, Singapore Botanic Gardens, Telok Blangah Hill Park, Dairy Farm Nature Park, MacRitchie Reservoir, Pulau Ubin, Holland Road and Napier Road, Pasir Ris Park and several neighborhood parks throughout Singapore.

Post-release monitoring: Some of the reintroduced plants have grown for more than 10 years in various nature reserves, parks and on roadside trees. Some 80 - 90% of the plants planted under the optimal environmental conditions have survived, and most of them have flowered and fruited. Our hope is that these plants will be able to self-propagate by seed; in this way, our reintroductions can help to enrich the development of the ecosystems in which they have been planted. Their flowers may attract and support viable populations of pollinators, which may in turn allow the development of viable seeds. These seeds may be dispersed to nearby locations, and if mycorrhizal fungi are present, germination will be possible, allowing the recruitment of new native orchids into these habitats.

Major difficulties faced:

- Seedlings planted at exposed areas did not survive.
- Some of the seedlings were removed by monkeys.

Major lessons learned

- The species grow more vigorously in areas with 50 – 70% shade with high relative humidity.
- Plants that are grown under 50% shade flower more often than those that are grown under 70% shade.
- Trees that support more epiphytes tend to be better hosts than those with fewer epiphytic plants.
- The best time for planting is during the rainy season.

Success of project

Highly Successful	Successful	Partially Successful	Failure

Reason(s) for success:

- Seedlings were grown to a mature size in the nursery before reintroduction.
- Reintroduced plants were planted on the right host trees.
- Reintroduction were carried out just before or during the rainy reason to ensure the seedlings establish well after planting.
- More than 80% of the plants planted under the optimal environmental conditions have survived, and many of them have flowered and fruited.

Summary

Many conservation biologists believe the best ethical basis for conserving natural entities is their claimed intrinsic value, not their instrumental value for humans. But there is significant confusion about what intrinsic value is and how it could govern conservation decision making. After examining what intrinsic value is supposed to be, we argue that it cannot guide the decision-making conservation requires. An adequate ethical basis for conservation must do this, and instrumental value does it best.

Collating and publishing the costs of conservation interventions is crucial for transparency and informed decision-making. By following a standardized framework for reporting economic costs and assessing cost-effectiveness, researchers and practitioners can enhance the comparability and reliability of cost data across different interventions and contexts. This standardized approach can also facilitate the identification of cost-effective conservation strategies and the allocation of limited resources to maximize conservation impact.

Moreover, making cost data readily available allows for greater scrutiny and validation of cost estimates, promoting accountability and trust in conservation efforts. It enables stakeholders to assess the economic feasibility of proposed interventions and prioritize investments based on their cost-effectiveness.

Overall, adopting a systematic approach to reporting economic costs and assessing cost-effectiveness in conservation interventions can contribute to more efficient resource allocation, improved conservation outcomes, and ultimately, the sustainable management of natural resources.

Effective decision-making is not only about cost-effectiveness, and there is a need to consider wider societal and human values in decision-making. However, the continued decline of biodiversity requires drastic and urgent action across society, and efficient use of limited conservation funds. This efficiency can only be achieved if both effectiveness and cost are suitably measured and reported – including all relevant economic costs and benefits of conservation actions. This data will allow decision-making tools to incorporate cost datahelping individuals, organizations, and governments make evidence informed decisions based on effectiveness, values, and cost.

Discussion questions

1. What is intrinsic value?
2. Do any environmental entities (species, ecosystems, or organisms) possess intrinsic value?
3. Why does it matter for conservation biology whether species, ecosystems or organisms have intrinsic value?
4. What is the instrumental values of biodiversity?
5. What are some examples of values of biodiversity?
6. What are some reasons for global decline in genetic diversity?
7. What is a conservation cost?
8. What is the economic importance of conservation?
9. What steps for recording and reporting on the economic costs and benefits of conservation interventions do you know?

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CHAPTER 11: BEHAVIORAL ECONOMICS AND THE ENVIRONMENT

Behavioral economics offers a powerful lens through which to understand the human dimensions of environmental decision-making. By acknowledging the influence of cognitive biases, heuristics, and social factors, this field enhances our ability to design interventions that align with the intricacies of human behavior. As one strives to address pressing environmental challenges, integrating behavioral insights into policies and initiatives becomes essential for creating a more sustainable and harmonious relationship between humanity and the natural world. In unraveling the complexities of decision-making, behavioral economics provides a roadmap for fostering pro-environmental attitudes and behaviors, ultimately contributing to a more resilient and environmentally conscious society. Traditional economic models often assume that individuals make rational and utility-maximizing decisions when it comes to environmental choices. However, the field of behavioral economics challenges this assumption by recognizing the complexity of human decision-making processes, incorporating insights from psychology and social sciences. In the context of the environment, behavioral economics sheds light on how cognitive biases, heuristics, and social influences impact individuals' attitudes, choices, and behaviors, influencing their interactions with the natural world.

11.1 Understanding Human Behavior and Biases

Human behavior is a complex interplay of biological, psychological, and social factors, influencing how individuals perceive, decide, and act in various situations. Within this intricate web of interactions, biases play a pivotal role, shaping cognitive processes and affecting the quality of decisions made. This exploration delves into the fundamental aspects of human behavior, the cognitive biases that often cloud judgment, and the implications for decision-making across different domains. Human behavior is deeply rooted in biological mechanisms, with the brain serving as the epicenter of decision-making. Neural processes, neurotransmitters, and genetic predispositions all contribute to shaping responses to stimuli and influencing behavioral patterns. Evolutionary psychology suggests that certain behaviors have evolved as adaptive responses to environmental challenges, ensuring the survival and reproduction of the species. Cognition, emotion, and motivation are integral components of human psychology that significantly impact behavior. Cognitive processes involve perception, attention, memory, and reasoning, while emotions contribute to the subjective experience of individuals. Motivation, often driven by a combination of internal and external factors, propels individuals to act in pursuit of goals or desired outcomes. Human behavior is profoundly influenced by social interactions and cultural contexts. Social norms, expectations, and the desire for social acceptance shape individual choices and behaviors. The need for affiliation, belongingness, and the impact of social comparison all contribute to the intricate tapestry of human behavior within social frameworks.

11.1.1 Cognitive Biases: Navigating Mental Shortcuts

Cognitive biases are systematic patterns of deviation from norm or rationality in judgment, often leading to perceptual distortion, inaccurate interpretation, or illogical interpretation. These biases emerge because of mental shortcuts or heuristics that the brain employs to make quick decisions in the face of information overload (Thaler, 1985). While heuristics can be efficient, they can also introduce errors and inconsistencies in judgment. One prevalent cognitive bias is confirmation bias, where individuals tend to favor information that confirms their preexisting beliefs or values. This bias can lead to selective exposure, perception, and interpretation of information, reinforcing existing views and hindering objective assessment of new evidence. The availability heuristic is another common bias, where individuals rely on readily available information rather than seeking out all relevant data. This can lead to skewed perceptions of probability and risk, as events that are more vivid, recent, or easily recalled are given undue weight in decision-making (Tversky & Kahneman, 1974; Hossain, Morgan & Wenzel, 2016). Anchoring bias occurs when individuals rely too heavily on the first piece of information encountered (the "anchor") when making decisions. Subsequent judgments are often influenced by this initial anchor, even if it is irrelevant or arbitrary, resulting in systematic errors in estimation. Overconfidence bias involves individuals overestimating their own abilities or the accuracy of their judgments. This bias can lead to unwarranted optimism and excessive risk-taking, as individuals may underestimate the complexity of tasks or the likelihood of negative outcomes. Loss aversion, a key concept in behavioral economics, refers to the tendency of individuals to prefer avoiding losses over acquiring equivalent gains. The fear of loss can lead to risk aversion and conservative decision-making, even when objectively assessing the potential benefits. The sunk cost fallacy occurs when individuals continue investing resources (time, money, effort) into a project or decision simply because they have already invested in it, regardless of the likelihood of success. This bias can impede rational decision-making by focusing on past investments rather than future outcomes.

11.1.2 Implications for Decision-Making Across Domains

Cognitive biases significantly impact economic decision-making, influencing choices related to investments, consumption, and financial planning. Understanding biases like loss aversion and overconfidence is crucial for financial advisors, policymakers, and individuals navigating complex economic landscapes. In healthcare, biases can affect patient decisions, adherence to medical advice, and perceptions of risk (Sunstein, 2017). The framing of health information, availability of relevant data, and emotional responses to medical conditions can all be influenced by cognitive biases, shaping health-related behaviors. Cognitive biases can also play a role in legal and judicial processes. From jury decision-making to witness testimony, biases such as confirmation bias and the availability heuristic can impact the outcomes of legal proceedings, potentially leading to unjust results. Within organizational settings, biases can affect leadership decisions, team dynamics, and overall workplace culture. Understanding biases in hiring processes, performance evaluations, and conflict resolution is essential for fostering fair and effective organizational behavior. In the realm of public policy, cognitive biases can influence the design and implementation of laws and regulations. Policymakers must be aware of biases such as anchoring and the sunk cost fallacy to develop effective and unbiased policy solutions (Gillingham, Newell & Palmer, 2009)

11.1.3 Mitigating Biases: Strategies for Better Decision-Making

Enhancing awareness of cognitive biases is a crucial first step in mitigating their impact. Education and training programs that familiarize individuals with common biases can empower them to recognize and address these tendencies in their decision-making processes. The development and use of decision support tools can provide individuals with objective information and alternative perspectives, helping to counteract biases. These tools may include algorithms, simulations, or decision aids that promote more rational and evidence-based decision-making. Encouraging diversity in decision-making teams can help mitigate biases by incorporating a range of perspectives and experiences. Diverse teams are less prone to groupthink and are more likely to consider a broader array of information, leading to more well-rounded decisions. Implementing reflection and feedback mechanisms within decision-making processes allows individuals to reconsider their judgments and decisions. Regular feedback loops can help individuals identify and correct biases over time, fostering continuous improvement. Organizations and institutions can implement structural changes to minimize the impact of biases. This may include clear decision-making protocols, checks and balances, and the establishment of independent review mechanisms to ensure objectivity and fairness.

Understanding human behavior and biases is a multifaceted endeavor that requires a synthesis of insights from psychology, neuroscience, economics, and sociology (DellaVigna, 2009). The intricate interplay between biological, psychological, and social factors shapes the way individuals perceive, process information, and ultimately make decisions. While cognitive biases are inherent in the human cognitive apparatus, awareness and proactive strategies can help mitigate their impact, fostering more informed, rational, and equitable decision-making across various domains. As we continue to unravel the complexities of human behavior, the quest for effective strategies to navigate biases remains a crucial aspect of promoting individual well-being, organizational success, and societal progress (Gerarden, Newell & Stavins, 2017). Behavioral economics departs from the traditional economic paradigm by acknowledging that individuals do not always act in a purely rational manner. Rooted in the groundbreaking work of psychologists Daniel Kahneman and Amos Tversky, behavioral economics explores the psychological factors that shape decision-making. Kahneman's dual-system theory, distinguishing between the fast and intuitive System 1 thinking and the slower, more deliberate System 2 thinking, provides a foundation for understanding how individuals make choices in different contexts. In the realm of environmental decision-making, behavioral economics uncovers the intricacies of how people perceive and respond to environmental issues. Traditional economic models often assume that individuals have well-defined preferences, respond consistently to changes in environmental conditions, and accurately assess the long-term consequences of their actions. Behavioral economics, however, reveals a more nuanced picture, where cognitive biases and heuristics play a substantial role in shaping environmental attitudes and behaviors (Tversky & Kahneman, 1974).

11.2 Nudge Theory and Its Application to Environmental Issues

Nudge theory, developed by behavioral economists Richard Thaler and Cass Sunstein, proposes a novel approach to influencing people's choices by leveraging insights from behavioral psychology. The central idea is to design interventions that, without restricting choices or imposing mandates, subtly guide individuals toward making better decisions. This concept has gained prominence in various domains, and its application to environmental issues holds significant promise in promoting sustainable behaviors and fostering a collective commitment to environmental stewardship (Loewenstein & Prelec, 1992; Soman, 2001).

11.2.1 Foundations of Nudge Theory:

At the core of nudge theory is the concept of "choice architecture," which refers to the design of the decision-making environment. The premise is that the way choices are presented can significantly influence individuals' decisions (List & Haigh, 2005). Nudges operate on the principle of preserving freedom of choice while structuring the decision context to encourage positive behaviors. Nudge theory draws from the understanding of dual systems of thinking, as proposed by Daniel Kahneman in his dual-system theory. System 1, characterized by fast and intuitive thinking, often relies on heuristics and biases, while System 2 involves slower, more deliberate reasoning. Nudges are designed to work with the tendencies of both systems, aligning with intuitive processes to guide decisions toward desirable outcomes. Environmental decision-making is rife with behavioral biases, including temporal discounting, loss aversion, and the status quo bias. People may prioritize immediate benefits over long-term sustainability, resist changes that involve perceived losses, and prefer maintaining existing habits (Frey & Meier, 2004). Nudge interventions seek to address these biases and gently steer individuals toward more environmentally friendly choices. In the realm of resource conservation, nudges have been employed to promote energy efficiency, water conservation, and waste reduction. For example, providing real-time feedback on energy consumption or framing messages in terms of social norms can nudge individuals to reduce their ecological footprint without resorting to mandates or restrictions (Lanz & Provins, 2017P).

11.2.2 Nudge Strategies for Environmental Conservation:

Manipulating default options is a powerful nudge strategy. For instance, setting energy-efficient appliances as the default choice during purchases encourages their adoption. Individuals tend to stick with defaults due to the status quo bias, making this an effective way to promote environmentally friendly options. How information is framed can significantly impact decision-making. Nudges use positive framing to highlight the gains associated with sustainable behaviors. For example, presenting recycling as a way to "conserve resources" rather than "reduce waste" can evoke a more positive response. Highlighting social norms or providing descriptive feedback about others' environmentally friendly behaviors can create a sense of collective responsibility. Nudges tap into the human inclination to conform to perceived societal standards, fostering a community-driven approach to environmental conservation. To combat temporal discounting, nudges often emphasize the long-term benefits of sustainable actions. Presenting the delayed rewards of conservation efforts, such as reduced environmental degradation or enhanced quality of life for future generations, can counterbalance the tendency to prioritize short-term gains. Nudges often incorporate incentives or rewards to reinforce positive behaviors. This can include gamification strategies, where individuals earn points or recognition for environmentally friendly actions, creating a sense of achievement and motivation (Thaler & Sunstein, 2008).

11.2.3 Success Stories and Real-world Applications:

In several regions, nudge interventions have been applied to energy consumption. Opt-out renewable energy programs, where individuals are automatically enrolled in green energy plans but can choose to opt out, have significantly increased the adoption of renewable energy sources. Studies have shown the effectiveness of social norm nudges in promoting conservation behaviors. Providing individuals with information about the average energy consumption in their neighborhood, along with positive feedback for below-average consumers, has led to substantial energy savings. Nudges have been successfully employed in recycling initiatives. Simplifying recycling processes, providing clear instructions, and emphasizing the positive impact of recycling on the community have proven to increase recycling rates. Nudge interventions raise ethical questions related to autonomy and paternalism. Critics argue that nudges may infringe on individual freedom by guiding choices in a way that may not align with everyone's preferences. Striking a balance between promoting sustainable behaviors and respecting autonomy is a key challenge. The effectiveness of nudges can vary, and their impact may not always align with intended outcomes. Additionally, there is a risk of unintended consequences or backlash if nudges are perceived as manipulative or coercive. Rigorous evaluation and ethical scrutiny are essential in designing and implementing nudge interventions.

Nudge theory offers a nuanced and versatile approach to addressing environmental challenges by acknowledging and working with the complexities of human decision-making. By steering individuals toward sustainable choices through subtle interventions, nudges have the potential to play a pivotal role in building a more environmentally conscious society (Kahneman, 2011). As we navigate the path towards a sustainable future, the integration of nudge strategies into environmental policies and initiatives can serve as a powerful tool for inspiring positive change and fostering a collective commitment to environmental conservation.

11.3 Case Studies: Single – Use Plastics, Water Conservation

11.3.1 Single-Use Plastics: A Global Menace

Single-use plastics have emerged as a global environmental menace, contributing significantly to pollution and adversely affecting ecosystems, wildlife, and human health. Governments, businesses, and individuals worldwide are grappling with the challenges posed by the pervasive use of items like plastic bags, bottles, and packaging materials. Examining case studies from various regions provides insights into the multifaceted efforts to address the single-use plastics crisis.

European Union's Ambitious Directive:

In a landmark move, the European Union (EU) has been at the forefront of tackling single-use plastics through its directive that came into effect in July 2021. The directive targets the ten most commonly found single-use plastic items on European beaches, including plastic cutlery, straws, and cotton swabs. EU member states are required to implement measures to reduce the consumption of these items, such as introducing bans or levies. The directive has spurred a wave of actions across member states. Many have implemented bans on single-use plastics, while others have introduced innovative alternatives. The legislation has also prompted manufacturers to rethink packaging designs and invest in sustainable alternatives. Early indicators suggest a reduction in the use of targeted items, leading to cleaner beaches and reduced plastic pollution.

Kenya's Bold Ban on Plastic Bags:

In 2017, Kenya took a bold step by imposing one of the world's strictest bans on plastic bags. The ban criminalizes the production, sale, or use of plastic bags and carries hefty fines and potential imprisonment for violations. This move was driven by the recognition of the severe environmental impact of plastic bags, particularly on marine life and agriculture. Kenya's ban has led to a significant reduction in plastic bag litter. While challenges in enforcement persist, the ban has fostered a shift in consumer behavior and increased awareness about the environmental consequences of single-use plastics. Additionally, the government has actively promoted alternative eco-friendly bags made from materials such as cloth and sisal (Allcott & Mullainathan, 2010).

The Role of Corporate Initiatives: Starbucks' Commitment to Sustainability:

Global corporations are increasingly recognizing their role in addressing the plastic crisis. Starbucks, one of the world's largest coffeehouse chains, pledged to eliminate plastic straws from its stores by 2020 as part of its broader sustainability goals. The company also committed to promoting recyclable, straw less lids and exploring innovative materials for its iconic cold beverage cups. Starbucks' initiative highlights the potential influence of corporate actions on consumer behavior. The move away from plastic straws reduces the company's environmental footprint and sets a precedent for other major players in the food and beverage industry. While challenges exist in sourcing sustainable alternatives, Starbucks' commitment represents a step towards corporate responsibility in mitigating single-use plastic pollution.

11.3.2 Water Conservation: Balancing Supply and Demand

Water scarcity is a pressing global issue exacerbated by climate change, population growth, and inefficient water management practices. Case studies in water conservation highlight diverse approaches to address this challenge, ranging from technological innovations to community-driven initiatives.

Israel's Pioneering Water Management:

Israel, a country with arid and semi-arid regions, has become a global leader in water management through a combination of technological innovation and policy measures. The adoption of advanced drip irrigation systems treated wastewater reuse, and the implementation of pricing mechanisms to encourage conservation are key components of Israel's comprehensive approach to water sustainability. Israel's water management strategies have significantly increased water use efficiency, allowing the country to meet its water needs despite challenging climatic conditions. The reuse of treated wastewater for agriculture has not only conserved freshwater resources but has also enhanced agricultural productivity. Israel's success underscores the importance of holistic, integrated approaches to water conservation (Bernauer & Koubi, 2009).

Singapore's NEWater: Embracing Wastewater Reuse:

Singapore, facing water scarcity and dependence on neighboring countries for water supply, developed the NEWater initiative. NEWater involves treating wastewater to a high standard, making it safe for consumption. The treated water is blended with freshwater supplies and distributed for domestic and industrial use. NEWater has significantly increased Singapore's water resilience by diversifying its water sources. Public acceptance was a crucial aspect of its success, achieved through extensive public education about the treatment process and rigorous water quality standards. The initiative serves as a model for other water-scarce regions seeking to maximize water reuse.

Community-Led Conservation: The Case of Rajasthan, India:

In the arid state of Rajasthan, India, community-led water harvesting initiatives have been instrumental in addressing water scarcity at the grassroots level. Villagers participate in building and maintaining traditional water harvesting structures such as check dams, ponds, and wells. These structures capture and store rainwater, replenishing groundwater and providing a sustainable water source for agriculture and daily needs. Community-led water conservation efforts in Rajasthan have transformed local landscapes, leading to increased vegetation cover, improved groundwater levels, and enhanced resilience to drought. The participatory nature of these initiatives fosters a sense of ownership and community cohesion, demonstrating the importance of involving local communities in sustainable water management (Hossain, Morgan & Wenzel, 2016).

The Challenges of Urban Water Conservation: Cape Town's Water Crisis:

Cape Town, South Africa, faced a severe water crisis in 2018, reaching a point where "Day Zero," the day when the city would run out of water, seemed imminent. The crisis was attributed to a combination of drought, population growth, and insufficient water management strategies. In response, the city implemented strict water restrictions, public awareness campaigns, and infrastructure improvements. Cape Town's water crisis underscored the vulnerabilities of urban water systems and the need for proactive measures. While the city averted "Day Zero" through collective efforts, the crisis highlighted the importance of integrated water resource management, early intervention, and long-term planning to ensure urban water sustainability. The case studies of single-use plastics and water conservation illustrate the diverse strategies and interventions employed globally to address pressing environmental challenges. From policy-driven bans to corporate commitments and community-led initiatives, these cases underscore the importance of multifaceted approaches that consider technological, regulatory, and behavioral aspects. As the global community navigates the complexities of environmental conservation, these case studies provide valuable insights and lessons that can inform future efforts to create a more sustainable and resilient world (Carattini, Baranzini & Lalive, 2017).

Summary

Behavioral economics, an interdisciplinary field blending insights from psychology and economics, has emerged as a powerful lens through which to understand and address environmental challenges. At its core, behavioral economics recognizes that individuals often deviate from traditional economic models, making decisions that are influenced by cognitive biases, heuristics, and social factors. When applied to environmental issues, this perspective unveils the intricate interplay between human behavior and ecological sustainability. The foundational principles of behavioral economics, rooted in the work of scholars like Daniel Kahneman and Richard Thaler, challenge the assumption of purely rational decision-making. Instead, it acknowledges the existence of two thinking systems – System 1, characterized by fast and intuitive thinking, and System 2, involving slower and more deliberate reasoning. Understanding these dual systems becomes crucial when exploring how individuals interact with and impact the environment. In the realm of environmental decision-making, behavioral economics reveals a multitude of cognitive biases that shape human behavior (Ayres, Raseman & Shih, 2012). From temporal discounting, where individuals prioritize short-term gains over long-term sustainability, to loss aversion and the status quo bias, these biases influence choices related to resource consumption, waste management, and overall environmental stewardship. Various case studies showcase the practical application of behavioral economics to address environmental issues. The European Union's directive on single-use plastics exemplifies the use of nudges, subtly guiding individuals toward more sustainable choices without imposing strict mandates. Kenya's ban on plastic bags illustrates the power of bold policy decisions in reshaping consumer behavior and reducing plastic pollution. Corporate initiatives, such as Starbucks' commitment to eliminating plastic straws, showcase how businesses can leverage behavioral insights to foster environmentally friendly practices. In the realm of water conservation, behavioral economics informs strategies that go beyond traditional economic incentives. Case studies from Israel and Singapore demonstrate the effectiveness of technological innovations and policy measures in optimizing water use efficiency. Community-led initiatives in Rajasthan, India, underscore the importance of involving local communities and tapping into social norms to drive sustainable water management.

The success of behavioral interventions in these cases is attributed to a nuanced understanding of human behavior. Strategies such as framing information positively, manipulating default options, and leveraging social norms align with the natural tendencies of individuals, making sustainable choices more attractive and accessible. However, challenges and ethical considerations arise in the application of behavioral economics to environmental issues. Balancing the need for intervention with respect for individual autonomy poses a significant ethical dilemma. Moreover, ensuring the effectiveness of nudges and addressing unintended consequences requires continuous evaluation and refinement of strategies. The behavioral economics offers a holistic and nuanced approach to addressing environmental challenges. By understanding the cognitive biases that shape decision-making, policymakers, businesses, and communities can design interventions that resonate with human behavior. The synthesis of insights from psychology and economics provides a robust framework for fostering sustainable practices, ultimately contributing to a more harmonious relationship between humanity and the environment. As we navigate the complexities of environmental conservation, the integration of behavioral economics becomes a crucial tool for promoting positive and lasting change.

Discussion questions

1. How do cognitive biases, such as temporal discounting and loss aversion, influence individual decisions related to environmental conservation?
2. In what ways can the principles of behavioral economics be applied to design effective interventions for reducing single-use plastic consumption?
3. How do social norms play a role in shaping environmental behaviors, and how can they be leveraged for positive change using behavioral economics?
4. What are the key challenges and ethical considerations associated with implementing nudges to encourage sustainable practices in the context of water conservation?
5. How can behavioral economics contribute to the development of innovative strategies for promoting renewable energy adoption and reducing carbon footprints?
6. To what extent do default options and framing impact individuals' choices regarding environmentally friendly products and services?
7. How can behavioral economics inform the design of educational campaigns to enhance public awareness and engagement in environmental conservation efforts?
8. What role can behavioral economics play in addressing the "tragedy of the commons" and promoting collective action for shared environmental resources?
9. In the context of environmental policies, how can policymakers balance the need for intervention with the ethical considerations of preserving individual autonomy?
10. How might behavioral economics be utilized to encourage sustainable behaviors in urban settings, considering the unique challenges of densely populated areas?

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CHAPTER 12: SUSTAINABILITY AND DEVELOPMENT: INTEGRATING ECONOMICS, ENVIRONMENT, AND SOCIETY

In the ever-evolving landscape of global development, the pressing need to integrate economic growth with environmental sustainability and societal well-being has never been more critical. Chapter 12 delves into the intricate dynamics of sustainability and development, presenting a nuanced exploration of how economic activities intersect with environmental objectives and social equity. This chapter unfolds against the backdrop of the Environmental Kuznets Curve hypothesis, which provides a foundational understanding of the relationship between economic development and environmental quality. As we traverse through various sections, the chapter sheds light on the multifaceted challenges and opportunities presented by sustainable development goals (SDGs), emphasizing the indispensable role of innovative decision-making and policy intervention.

At the heart of this discourse lies the imperative to bridge the gap between economic ambitions and the pressing need to preserve our planet for future generations. The chapter meticulously examines strategies for achieving a delicate balance between economic growth, environmental protection, and social equity, underscored by real-world examples and empirical insights. From the transformative potential of zero-emission vehicle regulations to the pivotal role of carbon emissions trading, the narrative navigates through the complexities of transitioning towards a sustainable future.

Furthermore, this chapter not only highlights the critical importance of global cooperation and policy frameworks but also showcases the pioneering efforts of nations like Thailand in embedding sustainability into their development agendas. Through an in-depth analysis of economic tools, financing strategies, and the transformative impact of technology, this introductory section sets the stage for a profound journey into understanding the essence of sustainability in the context of contemporary economic and social development.

As we embark on this journey, it is our collective responsibility to forge pathways that lead to a harmonious coexistence between human aspirations and the natural world. Chapter 12 serves as a beacon of knowledge, guiding us through the challenges and opportunities that lie ahead in our quest for a sustainable, equitable, and prosperous future for all.

12.1 The Environmental Kuznets Curve hypothesis

The environmental Kuznets curve (EKC) posits a theoretical correlation between diverse measures of environmental degradation and per capita income. During the initial phases of economic development, pollution emissions rise, and environmental quality deteriorates. However, beyond a certain threshold of per capita income (which varies for different indicators), this pattern reverses. At elevated income levels, economic growth becomes associated with environmental improvement. This suggests that environmental impacts or emissions per capita follow an inverted U-shaped trajectory relative to per capita income. EKC is named after Simon Kuznets, who proposed that income inequality initially increases and then decreases with advancing economic development. The EKC explores the connection between various indicators representing environmental pollution and per capita income. While environmental pollution tends to rise during the initial phases of economic growth, the hypothesis suggests that as income levels increase, economic growth contributes to environmental improvement. Therefore, the EKC hypothesis posits a relationship between GDP and environmental pollution resembling an inverted U shape (See Figure 12.1) (Stern, 2003).

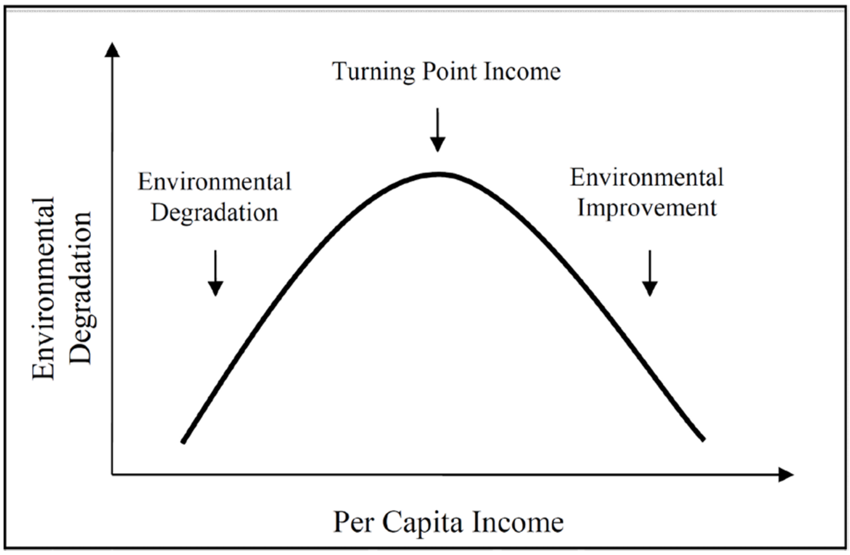

Figure 12.1 Environmental Kuznets Curve
Source: Yandle, Bhattarai, and Vijayaraghavan (2004)

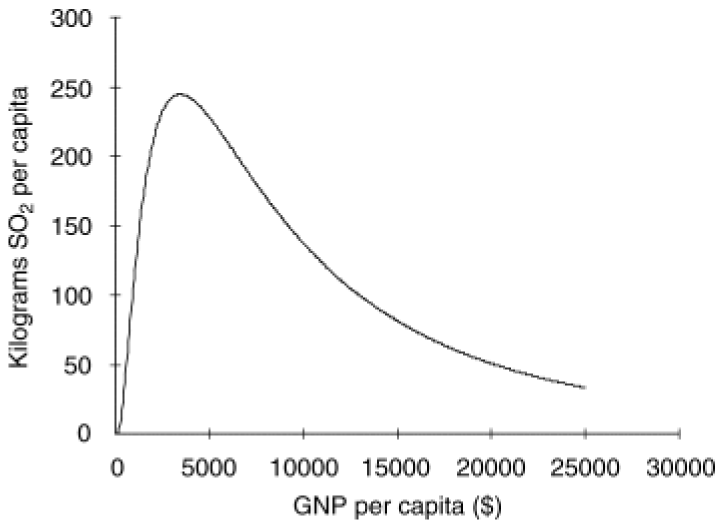

Figure 12.2 Environmental Kuznets curve for sulfur emissions.
Source: Stern (2024)

Figure 12.2 illustrates the emissions of different pollutants, including carbon dioxide, sulfur, and nitrogen oxides, are closely linked to energy consumption. Consequently, the EKC serves as a model depicting the interconnected dynamics among energy utilization, economic expansion, and environmental impact. The EKC has emerged as the primary approach used by economists to model both ambient pollution concentrations and aggregate emissions since its introduction by Grossman and Krueger in 1991. Despite being rooted in empirical observations, many estimates of EKC models lack statistical robustness. While certain local pollutants have demonstrably decreased in developed nations, there has been a noticeable increase in the emissions of various pollutants. Studies investigating the connection between per capita emissions and income, while attempting to navigate statistical challenges, indicate that per capita emissions generally rise with increasing per capita income when keeping other factors constant. However, changes in these other factors could effectively mitigate pollution. In rapidly growing middle-income countries, the impact of growth often outweighs these mitigating effects. Conversely, in wealthier nations with slower growth, efforts to reduce pollution can offset the growth effect. These econometric findings are consistent with the evidence that pollution concerns are indeed being addressed in developing economies.

12.2 Sustainable development goals and their economic implications and role of decision – making

The global prioritization of implementing the Sustainable Development Goals (SDGs) underscores the importance of economic tools and viable financing strategies in addressing the associated costs of realizing the 2030 agenda. Bridging funding gaps for socioeconomic and environmental challenges is crucial, as highlighted in the literature. A significant focus has been placed on sustainable financing and investments, with diverse instruments playing a pivotal role. Examples include private investments, foreign direct investments, funding avenues for sustainable development, sustainable bonds, and capital from various local, federal, and international sources. Furthermore, economic and policy instruments, such as taxes, tax exemptions, and auctions, offer avenues to mitigate negative externalities, contributing to the transition towards a more sustainable society. For a comprehensive overview of recent country-specific endeavors in green and sustainable financing, refer to Table 12.1 (Filho et al., 2022).

Table 12.1 Examples of countries that integrated sustainable development in action

Country/sector	References	Description
G7 countries	(Yang, Du, Razzaq, & Shang, 2022)	Green finance is recognized as a crucial factor influencing sustainable performance, which is assessed using indicators related to Environment, Social, and Governance (ESG).
United Nations	(United Nations, 2022a)	The report suggests taking immediate measures to address funding shortfalls and the increasing risks of debt, in order to align financial flows with sustainable development and enhance transparency in information.
European Council	(European Council, 2021)	The European Union's dedication to the Sustainable Development Goals involves an unparalleled goal of directing 30% of the overall budget towards combating climate change through green expenditures.

Source: (Filho et al., 2022)

The Zero-Emission Vehicle Regulation

The Zero-Emission Vehicle requirement was initially implemented by the California Air Resources Board (CARB) in 1990 as a component of the Low-Emission Vehicle regulation. Over the past three decades, the Zero-Emission Vehicle regulation has undergone adjustments to align with technological advancements. Amendments made in 2012, coupled with the implementation of the other two Advanced Clean Car Regulations, have positioned California on a trajectory towards the commercialization of zero-emission vehicles. This evolution enables automotive manufacturers to provide reasonably priced zero-emission vehicles to consumers. The Zero-Emission Vehicle Regulation aims to fulfill the state's long-term emission reduction objectives by enhancing the criteria for zero-emission vehicles. This involves elevating the standards for zero-emission vehicle sales and implementing measures to encourage widespread adoption and usage of such vehicles. The requirements outlined in ACC II mandate that new vehicles attain a 100% zero-emission and clean plug-in hybrid-electric status in California by the 2035 model year. As of now, zero-emission vehicle technologies primarily encompass battery electric vehicles and hydrogen fuel cell electric vehicles. Additionally, the regulation incorporates innovative provisions related to charging infrastructure and zero-emission vehicle assurance. These encompass requirements such as zero-emission vehicle warranties, durability standards, serviceability criteria, and battery labeling mandates. These measures are designed to facilitate consumers in successfully transitioning from conventional vehicles to new or used zero-emission and plug-in hybrid electric vehicles within California households. The ultimate goal is to meet their transportation needs while preserving the emission reduction benefits of the program. This comprehensive approach ensures that zero-emission vehicles play a permanent role in reducing and displacing emissions from conventional vehicles (California Air Resources Board, 2023).

Electric Vehicles Are Not Zero Emissions

At the point of CARB's decision, there was a widespread anticipation that Zero-Emission Vehicles (ZEVs) would operate on battery power, although other potential zero-emission systems were not explicitly excluded. On initial inspection, CARB's decision might seem like a triumph for the environment against traditional car and truck manufacturers and dealers. However, a more thorough examination unveils an inconvenient truth—the mandate is poised to worsen air quality in California rather than improve it in the foreseeable future. The introduction of the electric car mandate is expected to marginally decrease emissions from the typical new car purchased in California. Nevertheless, this initiative is anticipated to result in heightened prices for both electric and non-electric new vehicles across the state. This price increase stems from companies aiming to recoup expenses incurred in the development and production of electric vehicles, along with the subsidies necessary to incentivize consumer adoption. The ultimate impact on emissions hinges on how Californians respond economically to these elevated prices, potentially turning the well-intentioned efforts of CARB into additional emissions (Gruenspecht, 2001).

EV car decision making

Transportation-related carbon emissions represent the largest contributor to carbon emissions in the United States, constituting a significant 29%. The imperative now lies in the United States reducing transportation emissions to adhere to the targets set by the Paris Climate Accords—specifically, a 50% reduction from the 2017 emission levels. While the COVID-19 pandemic temporarily mitigated some of these emissions in 2020, the persistent trend reveals a failure to make substantial progress in curbing transportation-related emissions, which have remained nearly constant for the past 15 years.

Failing to address climate change and the emissions associated with gas vehicles poses severe consequences. Implications include mass species die-offs, an escalation in natural disasters, the depletion of fisheries, pervasive air pollution, conflicts over water resources, and a myriad of other pressing issues. Given that a substantial 82% of US emissions in 2018 originated from road vehicles, it is evident that a strategic reduction in emissions from cars is paramount. The key lies in swiftly removing combustion engine vehicles from the roads. While electric cars have gained popularity as a solution to this challenge, it is argued that relying solely on electric vehicles does not go far enough in addressing the magnitude of the issue (Bronsdon, 2022). Renewable energy decision making China's "Renewable Energy Law," implemented in 2006, advocates for the robust exploration and development of renewable energy resources. The "Medium and Long Term Development Plan for Renewable Energy," issued by the China Development and Reform Commission in 2007, establishes a goal for renewable energy consumption to constitute 15% of total energy consumption by 2020 [6,7].

In recent years, the prevalence of haze in numerous provinces and cities has underscored the imperative of transitioning to renewable energy to supplant traditional fossil fuels. Consequently, there has been a growing emphasis on renewable energy by both the government and the public(Zhao & Guo, 2015). Over the past decade, the Chinese government has actively provided subsidies to promote the development of renewable energy power [8]. By the end of 2013, the on-grid installed capacity for wind power, solar PV power, and biomass power had surged to 77.16 million kW, 14.79 million kW, and 12.23 million kW, respectively(Zhao & Guo, 2015). Carbon Emissions Trading (CET) plays a pivotal role in driving the transition to low-carbon power systems. Globally, 36 countries and over 20 regions, states, and cities have instituted carbon emission trading markets, encompassing 3.7 billion tons of carbon dioxide equivalent and constituting 13% of the annual global greenhouse gas emissions. Notably, the EU emissions trading system holds a prominent position among these markets. The Chinese government has implemented a comprehensive set of carbon emission trading policies, culminating in the official inauguration of the national carbon market on July 16, 2021. The initial traded products include carbon emission quotas (spots) and Chinese Certified Emission Reductions (CCER). By December 31, 2021, the trading volume for carbon emission quotas has reached 179 million tons, with a corresponding monetary volume of 7.661 billion yuan. The role of the carbon market in the power sector is to compel power plants to conserve energy or reduce emissions by engaging in transactions related to carbon reduction targets. The government's commitment to emission reduction, as manifested in the form of emission reduction pressure (ERP), directly influences power plants through a series of carbon emission trading policies (Wang & Li, 2022).

12.3 Strategies for achieving a balance between economic growth, environmental protection, and social equity

The foundations of sustainability are intricately linked, with actions in one sphere influencing others through spillover effects. The environmental and economic realms exhibit a robust interconnection, wherein sound environmental practices, such as responsible resource management, become crucial for preserving economic stability and the very fabric of the food supply chain. Moreover, certain sustainability strategies, like transitioning to a low-carbon economy and embracing sustainable practices, not only contribute to environmental well-being but also generate economic opportunities, spur innovation, and enhance the competitiveness of businesses. The social sphere is likewise intertwined with both the environmental and economic dimensions. A society characterized by equity and inclusion, marked by reduced inequalities, fosters social cohesion, active citizen engagement, and a foundation for a sustainable and resilient economy. It is evident that the health and well-being of individuals are intimately tied to the quality of the environment in which they reside, underscoring the holistic nature of sustainability. Environment, Social, and Governance (ESG) integration is an investment strategy that takes into consideration a company's environmental, social, and governance aspects. This method employs non-financial indicators to evaluate the performance of businesses and organizations. ESG integration involves collecting information about a company's policies, practices, and performance concerning environmental issues (such as environmental impact and resource utilization), social issues (such as management of employee and community relations), and governance issues (such as governance structure and transparency). The aim is to promote sustainable investments that generate long-term financial returns, considering the social and environmental consequences of economic activities while emphasizing transparency and corporate responsibility. For instance, Enel took a pioneering step in 2019 by introducing a bond linked to its ESG performance, signifying a significant move in this direction. It is crucial for companies to establish a measurable sustainability policy to foster transparency and accountability to all stakeholders, ranging from shareholders and employees to suppliers and local communities. This ensures that the implemented measures genuinely contribute to a positive impact (Enel Group, 2023).

Thailand strategies towards sustainable development

Thailand has historically struggled to demonstrate a robust commitment to climate change initiatives and sustainability goals, as indicated by assessments from the Climate Action Tracker, a research group monitoring global efforts to address climate change. Despite well-intentioned aspirations, the country has often fallen short in terms of dedication. Notably, at the 2021 UN Climate Change Conference in Glasgow, the Thai government set the target of achieving carbon neutrality by 2050 and a net-zero greenhouse gas emission goal by 2065, positioning it among nations considered slow to act. Notably, it refrained from signing an agreement to halt deforestation by 2030. Recent developments, however, suggest a shifting landscape with an increasing sense of urgency. Factors such as the spike in oil and gas prices due to the conflict in Ukraine and political instability in Myanmar, a crucial supplier of natural gas to Thailand, have underscored the need to enhance renewable energy sources. Additionally, environmental concerns have gained prominence. During 2022, a notable shift in policy was observed, with a stronger focus on ambitious targets and the promotion of sustainable practices. In November of the same year, Thailand presented its second revised nationally determined contribution, outlining a more ambitious objective to reduce greenhouse gas emissions by 30-40% from projected business-as-usual levels by 2030. Additionally, the government introduced a modified version of its Long-Term Low Greenhouse Gas Emissions Development Strategy, putting forward heightened initiatives to address emissions. The model of the bio, circular, and green economy (BCG), which has been in effect since 2021, aims to reinforce public commitment to addressing climate change risks and promoting sustainability, addressing previous international criticisms of perceived inaction by Thailand. This strategy gained prominence as a central economic policy during the Asia-Pacific Economic Cooperation summit in November 2022. Under the BCG initiative, government efforts are concentrated in four key economic sectors: food and agriculture, medical and wellness, energy, materials, and biochemicals, as well as tourism and the "creative" economy. The BCG policy integrates Thailand's sustainability goals with an investment promotion policy, aiming to attract interest in sectors where the country has competitive advantages. Another significant initiative indicative of an accelerated push for change is the draft form of the Climate Change Act (Economist Intelligence, 2023).

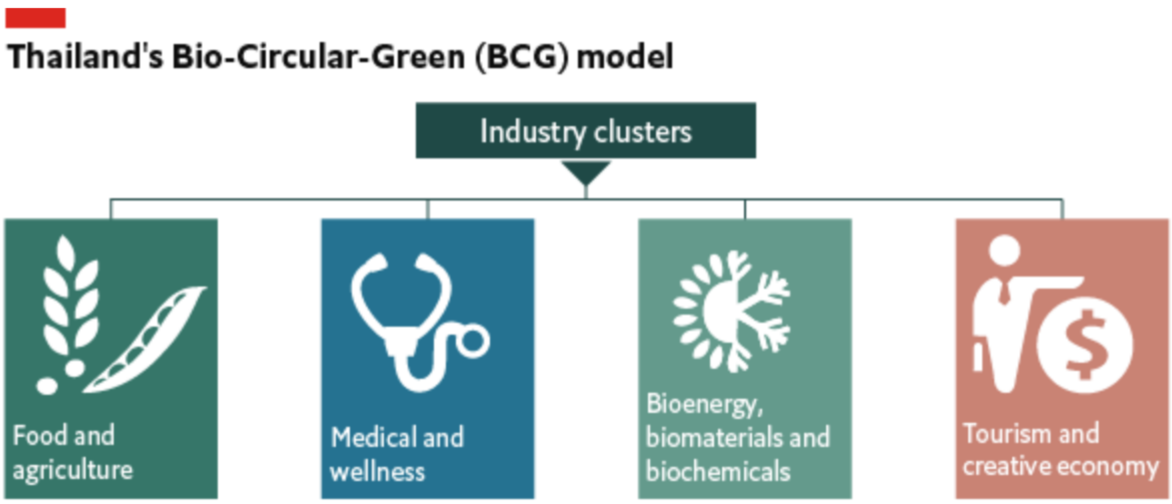

Figure 12.3 Bio-Circular-Green (BCG) model
Source: (Economist Intelligence, 2023)

In the financial sector, regulators are actively developing policies to support sustainable practices. The collaboration between the central bank, the Bank of Thailand, and the Securities

Exchange Commission involves the ongoing creation of the Thailand Taxonomy. This initiative involves standards designed to create a cohesive framework for a sustainable finance ecosystem. The primary objective is to facilitate the creation of products and financial services that adhere to the principles of green finance.

New opportunities will be concentrated in the renewable energy and low-emission transport sectors

Thailand has firmly embedded the Sustainable Development Goals (SDGs) into its developmental framework through the 20-Year National Strategy, serving as a cornerstone for the country's progress. The National Committee for Sustainable Development (CSD), under the leadership of the Prime Minister, serves as the pivotal entity driving advancements across all 17 Goals. To facilitate comprehensive SDG implementation, the CSD has appointed dedicated government focal points for each of the 169 targets. Additionally, the CSD operates through four sub-committees, each playing a vital role in specific aspects of SDG endeavors—namely, the application of the Sufficiency Economy Philosophy for the SDGs, monitoring and evaluation, and environmental assessments (United Nations, 2022b).

Achieving carbon neutrality and net-zero targets presents a formidable challenge that necessitates unwavering political determination. In the long run, strategic measures are crucial for the power sector, the primary emitter, to transition away from natural gas—already reduced from coal over the years—towards renewables, especially solar and wind. The development of new infrastructure, encompassing energy storage, efficiency enhancements, and advanced grid management, becomes essential to facilitate this transition.

Summary

Thailand's export-centric manufacturing sectors and heavy industries are urged to enhance energy efficiency and consider electrification to reduce reliance on fossil fuels for direct consumption. Addressing the transport sector's emissions entails improving public transport efficiency and promoting electrification through incentives and the establishment of charging infrastructure.

Over time, Thailand must also confront emissions from the agriculture sector by implementing offsetting strategies like carbon sinks, involving activities such as reforestation, and exploring technologies like carbon capture and storage. In the short to medium term, opportunities are anticipated to focus on electric vehicles (EVs), supported by robust government backing and substantial investment flows, alongside the promotion of renewable energy initiatives (Economist Intelligence, 2023).

Discussion questions

1. How do you define sustainability, and why is it important to integrate economic, environmental, and social considerations in sustainable development?
2. What are the key challenges in achieving sustainable development, particularly in balancing economic growth with environmental protection and social equity?
3. How can education and awareness-raising efforts promote a shift towards more sustainable lifestyles and consumption patterns?

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GLOSSARY

Adaptation- Strategies to adjust to the impacts of climate change, such as building seawalls or implementing drought-resistant crops.

Biodiversity – the variety of life in all its forms, and at all levels, including genes, species, and ecosystems. The CBD defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Bioeconomy- an economic system in which renewable biological resources, such as plants, animals, and microorganisms, are used to produce goods, services, and energy.

Biomass – the total mass of living biological material in a given ecosystem at a given time.

Circular Economy- An economic system aimed at minimizing waste and maximizing the reuse, recycling, and regeneration of materials and resources.

Climate change – the change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Climate Policy- Government regulations, incentives, or actions aimed at addressing climate change, including emission reduction targets and renewable energy subsidies.

Cognitive Biases – are systematic cognitive dispositions or inclinations in human thinking and reasoning that often do not comply with the tenets of logic, probability reasoning, and plausibility. These intuitive and subconscious tendencies are at the basis of human judgment, decision making, and the resulting behavior.

Conservation – an action taken to promote the persistence of ecosystems and biodiversity.

Conservative Strategy – necessitates investment in the safest short-term instruments, such as Treasury bills and certificates of deposit.

Contingent Valuation –a stated preference (survey) method in which respondents are asked to state their preferences in hypothetical or contingent markets

Cost-Benefit Analysis (CBA)- A systematic approach to evaluating the potential costs and benefits of a proposed project or policy-In environmental decision making, CBA helps quantify and compare the economic impacts, both positive and negative, alongside the environmental effects.

Decision Criteria- The criteria used to evaluate and compare different alternatives in environmental decision making. These criteria often include economic efficiency, environmental sustainability, social equity, and legal compliance, among others. CBA provides a structured framework for assessing alternatives based on these criteria.

Discount Rate- The rate used to discount future costs and benefits to their present value. In CBA, a discount rate is applied to account for the time value of money and to compare costs and benefits occurring at different points in time.

Economic evaluation – the Review uses the term "economic evaluation" to refer to two processes required for managing a society's portfolio of assets: 1) assessing whether economies achieve "progress" over time (sustainability assessment) and 2) assessing whether an investment, policy or plan will contribute to "progress" (policy analysis). The Review shows that the index for both is an inclusive measure of wealth.

Environmental Decision Making- The process of making choices or taking actions that affect the environment. It involves assessing various factors such as ecological impact, social implications, and economic considerations to arrive at decisions that balance environmental protection with other societal needs and goals.

Environmental Justice- The fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, in the development, implementation, and enforcement of environmental laws, regulations, and policies.

Environmental Kuznets Curve- a hypothesized relationship between environmental degradation and economic development.

Environmental Sustainability—This definition of sustainability is fulfilled if the physical stocks of designated resources do not decline over time.

Equity- The principle of fairness in the distribution of benefits and burdens, ensuring that all individuals and communities have access to resources and opportunities needed for a healthy environment and quality of life.

Externalities –a cost or benefit that is caused by one party but financially incurred or received by another. Externalities can be negative or positive. A negative externality is the indirect imposition of a cost by one party onto another.

Externality—The welfare of some agent, either a firm or household, depends on the activities of some other agent. The externality can take the form of either an external economy or external

Free-Rider Effect—When a good exhibits both the consumptive indivisibility and non-excludability properties, consumers may enjoy the benefits of goods purchased by others without paying anything themselves. (For example, countries that decide not to take any steps to control global warming can "free ride" on the steps taken by others.)

Functional diversity – the variety and number of species that fulfil different functional roles in a community or ecosystem.

Green economy- an economy that promotes sustainable development, environmental stewardship, and social equity.

Hotelling's theory, or Hotelling's rule, posits that owners of nonrenewable resources will only produce basic commodities if doing so can yield more than could be earned from available financial instruments, such as U.S. Treasury or other similar interest-bearing securities. The theory assumes that markets are efficient and that the owners of the nonrenewable resources are motivated only by profit.

Loss Aversion - Loss aversion is the notion that people hate losses more than they enjoy gains.

Market Economy—An economic system in which resource allocation decisions are guided by prices that result from the voluntary production and purchasing decisions by private consumers and producers.

Market Failure—An inefficient allocation produced by a market economy.

Market Failure—An inefficient allocation produced by a market economy.

Market Valuation – also known as OMV, or "open market valuation") is the price an asset would fetch in the marketplace, or the value that the investment community gives to a particular equity or business.

Market-Based Instruments- Economic mechanisms that use market forces to address environmental issues, such as emissions trading schemes.

Maximum Economic Yield (MEY) is the yield level that aligns with the harvest or effort level that maximizes the sustainable net returns from fishing activities. Achieving a MEY harvest is desirable because it represents the catch level that allows society to optimize the utilization of the resources provided by nature.

Mitigating Biases – Each type of bias can be interrupted or mitigated with different strategies. Interruption strategies are those that prevent the bias from being enacted. Mitigation strategies reduce the effects of the bias.

Mitigation- Actions aimed at reducing greenhouse gas emissions to lessen the severity of climate change.

Natural capital – the stock of renewable and non-renewable natural assets (e.g. ecosystems) that yield a flow of benefits to people (i.e. ecosystem services). The term "natural capital" is used to emphasise it is a capital asset, like produced capital (roads and buildings) and human capital (knowledge and skills).

Net Present Value (NPV)- A financial metric used in CBA to calculate the difference between the present value of benefits and the present value of costs associated with a project or policy. A positive NPV indicates that the benefits outweigh the costs.

Non-Market Valuation- Methods used to estimate the economic value of goods and services not traded in markets, such as clean air or biodiversity.

Non-renewable resources are natural resources that exist in fixed amounts and can be used up. Examples include fossil fuels such as petroleum, coal, and natural gas. These fuels formed from the remains of plants over hundreds of millions of years. We are using them up far faster than they could ever be replaced. At current rates of use, petroleum will be used up in just a few decades and coal in less than 300 years. Nuclear power is also considered to be a nonrenewable resource because it uses up uranium, which will sooner or later run out. It also produces harmful wastes that are difficult to dispose of safely.

Paris Agreement—It is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.

Property Rights—A bundle of entitlements defining the owner's rights, privileges, and limitations for use of the resource.

Public Good—A resource characterized by non-exclusivity and indivisibility.

Public Goods -a commodity or service that every member of a society can use without exhausting the supply of it that is available to others.

Rate of return – the rate of return on an asset (as opposed to the asset's own rate of return) is its yield plus the capital gains it enjoys over a unit of time.

Regulatory Approach- Environmental policies that rely on laws, regulations, and enforcement mechanisms to establish standards and requirements for pollution control and resource management.

Renewable resources are those resources that continue to exist despite being consumed or can replenish themselves over a period even as they are used.

Resilience – the magnitude of disturbance that an ecosystem or society can undergo without crossing a threshold to a situation with different structure or outputs i.e., a different state. Resilience depends on factors such as ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Sensitivity Analysis- An analytical method used to test the robustness of CBA results by assessing how changes in key variables or assumptions affect the outcome. Sensitivity analysis helps identify the most critical factors influencing the cost-benefit balance and the uncertainty associated with the analysis.

Social Marginal Cost—The cost of producing an additional unit of the resource that is borne by society at large. Generally includes private marginal costs plus external marginal costs.

Sustainability—The fairness of allocations of resources among generations. Generally requires that resource use by any generation should not exceed a level that would prevent future generations from achieving a level of well-being at least as great.

Sustainable forest management is the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.

Temporal Discounting – the cognitive phenomenon of preferring more immediate rewards over future benefits. Also known as hyperbolic discounting, it can lead to poor financial decisions, unhealthy lifestyle choices, and even societal issues like climate change.

Trade-offs- In environmental decision making, trade-offs refer to the compromises or sacrifices made between competing objectives or values, such as economic growth and environmental conservation. CBA-helps quantify and evaluate these trade-offs to inform decision making.

Tragedy of Common - an economic problem where the individual consumes a resource at the expense of society.