12

DEVELOPMENT AND THE ENVIRONMENT*

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* This chapter has been written by our colleague, Professor Iain Fraser.

Introduction

The environment is vital to supporting life, absorbing waste and providing inputs for production. Since the 1960s, there has been increasing concern about the effects of economic activity on the environment. In particular, it has been argued that economic growth has caused serious environmental damage and that the current state of the environment will constrain future economic development. For example, it is now widely, but not universally, accepted that recent economic development has led to climate changes, and that changes will, unless adapted to, seriously disrupt economic activity and society in the future. The poor in developing countries are often dependent on the natural environment for their livelihood and even their continued existence. Thus, damage to the environment and the relationship between the environment and the economy are often thought to be of more importance to developing than developed countries.

Table 12.1 shows how a range of selected environmental indicators vary by economic regions globally. For example, there are significant differences between Africa and Europe in terms of forest net change and access to sanitation. This chapter provides an introduction to the economic analysis of the relationship between the environment (including the climate), development and the economy.

A simple model is developed that explains the services the environment provides for economic activity and the effects of the economy on the environment. Next, the market-based approach to analysing the interactions of the environment and the economy is examined. This approach emphasizes the efficient use of the environment and considers market failures to be the main, and perhaps the only, cause of market economies' difficulties in allowing for environmental concerns in economic development. It is shown how this approach can be used to provide valuations of environmental services and improve the efficient use of the environment. The neoclassical analysis of equity within and between generations is considered and its importance in the context of the environment is examined.

The concept of **sustainable development** is then explained. This idea defines forms of development that meet the needs of the present generation while maintaining the potential to meet the needs of future generations. This is followed by a discussion of the recent **Stern Review on climate change** and the effect of climate change on the poor. Finally, there is a brief review of how environmentalists, economists and international agencies have approached the analysis of the environment, climate change and the economy.

A model of the environment and economic activity

There are many different models of the relationship between the environment and the economy. The model depicted in Figure 12.1 illustrates the four functions of the environment in supporting economic activity and the effects of this activity on the environment. (This discussion of the relationships between the environment and the economy is very general and simple; see Tarbuck et al. (2008) for an introduction to earth sciences and the interaction of humans and the environment.) These four functions are life support, supply of natural resources, absorption of waste products, and supply of amenity services. The economy is represented in Figure 12.1 by households consuming goods and services, and firms producing, using natural resources provided by the environment, and labour and man-made capital provided by households.

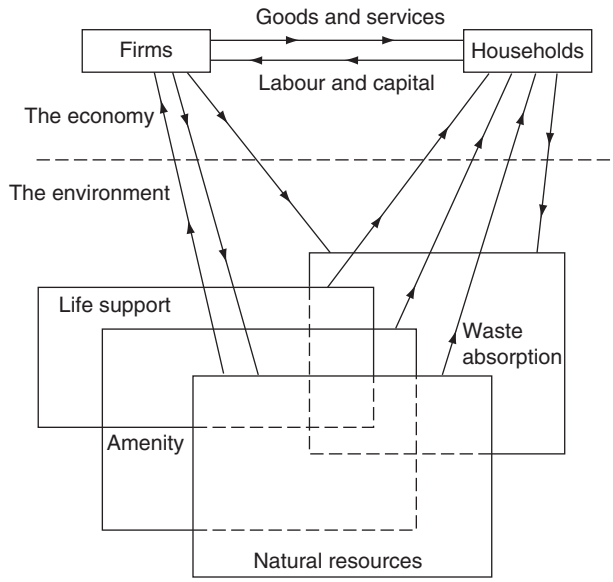
The environment provides a **biological**, **chemical and physical system** that enables human life to exist. This life support system includes the atmosphere, river systems, the fertility of the

Table 12.1 Key environmental indicators data

Key environmental indicator	Latest year on record	World	Africa	Asia and the Pacific	Europe	Latin America and the Caribbean	North America	West Asia	Unit of measurement
Consumption of ozone-depleting substances	2010	43 292	2 559	29 971	103	5 199	2 165	3 295	Million tonnes ODP
HFCs emissions – all gases	2008	651 748	2 146	237 395	140 251	14 882	255 602	1 471	Gigagrams
Carbon dioxide emissions	2008	32.11	1.14	13.69	6.61	1.65	6.01	1.04	Billion tonnes of CO_2
Carbon dioxide emissions per capita	2008	4.8	1.2	3.5	8.0	2.9	17.4	8.3	Tonnes of CO_2 per capita
Forest net change	2005–2010	5.6	-3.4	0.5	0.9	-3.9	0.4		Million hectares per year
Area protected to maintain biological diversity to surface area	2010	12.0	10.1	9.9	10.2	19.3	9.5	17.1	Per cent of total territorial area
Municipal waste collection	2000–2007			271.2	537.9	130.8		20.2	Million tonnes
Total water footprint per capita of national production – blue	1996–2005	167	94	181	109	110	380	345	m^3 per year per person
Total water footprint per capita of national production – green	1996–2005	1 087	1 167	780	1 259	1 924	2 689	426	m^3 per year per person
Access to sanitation	2010	61.0	39.9	57.4	90.9	80.1	100.0	78.3	Per cent of total population
Number of certifications of the ISO 14001 standard	2010	251 000	1 700	131 700	103 700	7 231	5 500	1 200	Number of certifications

Source: UNEP, 2012.

Figure 12.1 A simple model of the relationship between the economy and the environment



soil, and the diversity of plant and animal life. These environmental services are consumed by households and are essential to life. Large reductions in these services, for example through major climate change, would have catastrophic consequences for life.

The environment provides **raw materials and energy** for economic production and household activity. These natural resources are either renewable, as in forests and fisheries, or non-renewable, as in minerals. Renewable resources can be used in a sustainable manner, although excessive use or mismanagement can result in the complete loss of the resources, for example desertification following deforestation. The ability to use renewable resources sustainably and increase the stock of renewable resources is represented in Figure 12.1 by the flow from firms to natural resources. However, the use of a non-renewable resource reduces the finite stock of the resource forever.

The **waste products** of economic and household activity are absorbed by the environment. This waste absorption function allows some of such waste to be disposed of safely. However, there are certain wastes that are difficult or impossible for the environment to dispose of safely. For example, the global warming gas carbon dioxide (CO_2) is captured through the growth of forests and absorption in the oceans. Deforestation and physical limits to absorption in the oceans mean that the absorptive capacity of these processes has been reduced. Consequently, because of the effect of rising levels of carbon dioxide on climate change, it has been argued that the world economy has to change through reducing carbon dioxide emissions, seeking alternative means of capturing these emissions and adapting to climate change.

The environment also provides **amenity services**, such as natural beauty and space for outdoor pursuits, which are consumed, but are not crucial to the continued existence of life.

Parts of the environment may serve more than one function. The oceans, for example, are important in determining the life support systems provided by the global climate and microclimates, they are sources of many minerals and other resources, they assimilate many different wastes, and they provide the space and opportunity for marine pastimes. Thus, in Figure 12.1 above, the four blocks representing the different functions of the environment overlap. The functions of the

environment may be competitive; excessive discharges of waste materials into the oceans will, for example, reduce their capacity to provide a habitat for fish stocks. Alternatively, environmental functions can be complementary; as when appropriate forestry policies can provide a sustainable source of timber (a natural resource function), reduce soil erosion (an improvement in the life support function) and capture CO_2 emissions (a waste absorption function).

The market-based approach to environmental analysis

The market-based approach to environmental analysis has probably been the dominant view of the relationship between the environment and the economy (for an introduction to this subject, see Common, 1996). In particular, many environmental policies and much analysis are based on the view that markets may not function efficiently with regard to the environment and that the state has a duty to intervene and correct market failures. The underlying assumptions of the market-based approach are examined and various applications to the environment are considered.

The market or neoclassical approach to economics is concerned with how scarce resources are allocated in a market economy (explanations of the neoclassical approach to economics can be found in most intermediate microeconomics textbooks: see Varian, 2005). Allocation is assumed to take place on the basis of consumers' preferences, the distribution of economic assets and the costs of production. It is assumed that each consumer is rational and decides to purchase goods and services on the basis of prices and economic assets, which include labour income. It is assumed that the value a consumer places on additional units of consumption declines with increasing consumption. Economic rationality dictates that consumption of a good continues up to the point at which the value placed on an additional unit is just equal to the price. Further expenditure on the good would be inefficient as greater value could be obtained from using the additional expenditure to purchase more preferred goods and services. Similarly, less expenditure is inefficient, as greater value could be obtained by purchasing more of the good and fewer less preferred goods and services. Thus, the neoclassical model assumes that economic rationality gives efficiency in consumption.

The neoclassical view also assumes that firms are profit maximizers. This implies that firms minimize costs. This gives efficiency in production. Finally, it is assumed that competition among firms forces them to charge prices that are equal to their marginal costs of production. As consumption decisions are based on prices, the equality between prices and marginal costs means that these decisions are based on the marginal costs of production. This ensures efficiency between consumption and production.

The neoclassical view has various important implications for the analysis of the relationship between the environment and the economy:

1. It is implicitly assumed that the value of consumption is determined by the individual consuming the good. The value of consumption is not determined by the state or some other authority. Additionally, it is assumed that individual consumers and producers do not consider the effects of their decisions on other economic agents. Consequently, there is no difference between private and social costs or private and social benefits.
2. Economic rationality implies that the value of the marginal consumption of a good or service can be measured by price.
3. The neoclassical analysis of the market is based on considering small changes in consumption and production. This extends to the neoclassical view of the environment.

4. The outcome of a market economy, in terms of prices, quantities and the distribution of economic welfare, depends on the initial distribution of economic assets. Different distributions or reallocations of assets give different outcomes. It is frequently pointed out that under certain conditions, the operation of the market may be efficient, but it may not be equitable. It may be possible to assess the efficiency of a market economy in an objective manner, but evaluation of the equity of a market outcome is a value judgement.

Externalities

The idea of externalities can be used to analyse many, but not all, types of environmental degradation. Externalities occur when the actions of one economic agent affect other economic agents and the actions are not controlled through the operation of the market. Externalities have two related causes: lack of individual property rights, and jointness in either production or consumption (Baumol and Oates, 1988). Individual property rights are exercised over goods, services and factors of production and allow markets to function efficiently. With a complete set of individual property rights, all the effects of an action are controlled by the market, since consumption of a good or service and use of a factor require payment to the owner. Beneficial or positive externalities are likely to be undersupplied by a market, and negative externalities are likely to be oversupplied. For an externality to continue to exist, it is usually presumed that jointness in either production or consumption is involved.

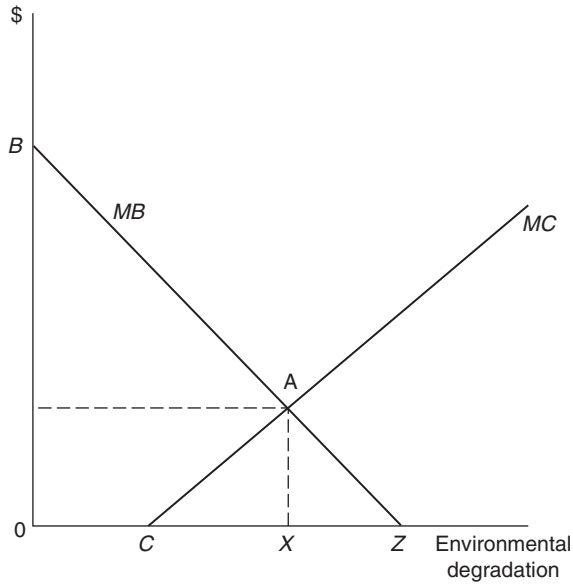
An example of negative environmental externalities and economic development can be seen in the building and operation of the Manantali and Diama hydroelectric dams in Mali (see Bond et al. (2001) for details and evaluation of the external effects of these hydroelectric dams). These dams generate cheap electricity, which has been distributed to Mali, Senegal and Mauritania since 2001. Downstream from the dams, the annual floods have been reduced and this has decreased agricultural productivity. Additionally, the elimination of salt water intrusion through the building of these dams has led to an increased incidence of bilharzia and other health problems. Thus, the building and operation of these hydroelectric dams has imposed external costs on those living and working downstream of the dams.

These (negative) externalities are caused by jointness in production of electricity. At the same time as electricity is being generated, the water system is being altered and this causes health and productivity effects. The economic cause of the externalities is that no markets exist in the management of water systems. In particular, there are not clear, legally enforceable rights to the ownership and services of the water system downstream. A simple model is developed in Figure 12.2 of the interests of the electricity generators and the downstream population.

The downstream environmental degradation by the generators produces a benefit to the economy as it allows the production of electricity. This is denoted by the marginal benefit *MB* curve (measured in dollars) and is assumed to be downward sloping. The downward slope can be justified by a lower price being obtained for the sale of electricity as more is produced. The environmental effects are mostly negative and are represented by an upward sloping curve, the marginal cost *MC* of environmental degradation. There is a threshold effect below which there is no environmental damage as the environment can absorb a minor change in the water system without any cost. The curve then slopes upwards as the environment has difficulty in coping with the increased environmental degradation.

The neoclassical view is that there is an optimal level of environmental degradation at which the marginal benefit is equal to the marginal cost, point *X* in Figure 12.2. Whether this level of degradation is small or large depends on the shape of the marginal benefit and cost functions. This conclusion considers environmental effects purely from the point of view of efficiency. However,

Figure 12.2 Marginal benefits and environmental costs of a dam



it should be remembered that outcome *X* may be efficient, but if the costs imposed on the inhabitants are relatively large, the resulting distribution of welfare may not be desirable.

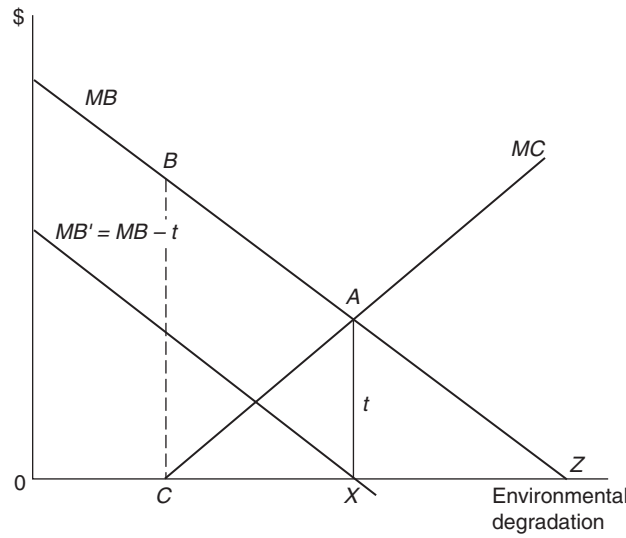
The operation of a market economy is unlikely to lead to an efficient outcome. The downstream inhabitants' environment is being degraded by the actions of the generators. In an economy with a complete set of individual property rights over all economic assets, the inhabitants or the generators would own the property rights to the environment. If the inhabitants owned the rights, the generators would have to pay to be allowed to degrade the environment. In the case of the generators owning the rights, the inhabitants would have to pay the generators to restrict environmental degradation. In reality, such property rights are likely to be ill-defined, particularly across national boundaries. It might be expected that no market controls this environmental degradation. Generators are likely to continue to degrade the environment until the marginal benefit to them of degradation is zero, point *Z* in Figure 12.2.

This analysis is one of **market failure**. A conventional reaction to market failure is to suggest the intervention of the state to secure a more efficient outcome. There are four feasible policies that have been suggested as solutions to this type of externality problem: **Pigovian taxes and subsidies**, named after A.C. Pigou, well-known Cambridge economist; **Coasian bargains**, named after Ronald Coase, Nobel Prize-winning economist; **marketable permits**; and **administrative action and legislation** (see Perman et al., 2011).

The **Pigovian tax solution** imposes an environmental use tax on the generators of the value of the marginal cost of degradation at the point of the optimal outcome *X*. This forces the generators to take account of the costs they impose on the inhabitants. This is shown in Figure 12.3, where the generators face a new marginal benefit *MB'* of environmental degradation schedule that includes the tax (t).

Generators will, out of self-interest, choose the efficient level of degradation. Examples of Pigovian taxes have recently been observed in several countries that have started to charge for plastic shopping bags in an effort to reduce the associated pollution caused by plastic in the environment.

Figure 12.3 Taxation, marginal benefits and costs of a dam



A Pigovian subsidy could alternatively be given to generators to reduce environmental degradation and a similar solution occurs. An example of such a subsidy is the payment made to generators of carbon emissions in Australia under the Emissions Reduction Fund introduced in 2014.

When attempting to increase the supply of positive externalities, it has become widely accepted that payments to correct market failure are legitimate. In this case, the **provider gets principle** as opposed to the **polluters pay principle** is applied. An example of this approach that has gained much attention by policy-makers is the **payment for ecosystem services** approach (Pagiola et al., 2005). This policy mechanism rewards farmers and landowners for maintaining and producing environmental goods and services that are typically undersupplied because of classic market failure. However, the Pigovian solution suffers from a number of problems.

Let us consider the dam example again. First, it is difficult to quantify and value the costs and benefits of environmental degradation (this point is returned to later). The benefits and costs are not likely to be uniform across different dams, which implies the complication of different tax rates. Second, many of the downstream inhabitants are not part of the cash economy and the state is unlikely to be able to tax and regulate generators or afford the cost of subsidies.

The **Coasian bargain solution** assumes that individual property rights are established and economic agents bargain an efficient outcome. If individual property rights over the environment are given to inhabitants, then generators have an incentive to bargain and pay to be allowed the right to degrade the environment, as their marginal benefit exceeds inhabitants' marginal cost at the origin in Figure 12.3 above. The potential efficiency gains of this bargaining are represented by the area *ABC*. Similarly, if the generators are given the property right, there are incentives for the inhabitants to pay the generators to reduce degradation from the point *Z*. The Coasian solution suffers from the major problem of how property rights are established. Additionally, there are incentives for individuals to **free ride** on the contributions that others make to reduce externalities. It is difficult to see how bargains can be enforced when there are many inhabitants. Finally, in many cases, the transaction costs of negotiating a Coasian bargain may be high and are likely to prevent such solutions from emerging.

In the real world, it is rare for Coasian bargains to occur as solutions to environmental problems. The **Global Environment Facility** (**GEF**, www.thegef.org), which was established in 1991, could be interpreted as such an example. The GEF is a partnership of many countries and international organizations that addresses global environmental issues, and receives donations from many sources, including countries, research institutions and so on. The GEF provides grants to countries to address global problems such as climate changes and pollution of international waters, and was charged with funding mechanisms to help achieve the three Rio Conventions (climate change, biodiversity and desertification) of the 1992 Rio Earth Summit.

The issuing of **marketable permits** that give the bearers the right to pollute is a potentially elegant and efficient means of solving the problem of pollution and externalities such as global warming and gas emissions. The size of the issue of permits directly controls the level of total pollution. Potential polluters have to decide whether to reduce their pollution or use their own or purchased permits. This should result in the set level of pollution being obtained at the least cost. Tietenberg and Johnstone's review (2004) shows that the use of different types of tradable permit schemes have increased and are often regarded as a valuable policy tool. A tradable permit 'cap and trade' scheme lay behind the operation of the **Kyoto Protocol** to reduce global warming gas emissions, and it is also an available policy instrument for the new global policy approach that is attempting to reduce carbon emissions. The operation of tradable permit schemes does not have universal support. There has been little investigation of the use of schemes by developing countries, and experience suggests problems with their operation and outcomes; for example, in 2008 the European Commission responded to criticism of the EU Emissions Trading Scheme (EU ETS) by implementing major changes. However, as policy-makers continue to gain experience, the introduction of tradeable permit-type schemes has increased; one important example being California's Cap-and-Trade Program, which began in 2013, and is second in size after the EU ETS. Ellerman et al. (2016) provide an overview of how the EU ETS has evolved and attempted to deal with the various challenges it has faced in practice.

The fourth solution to the externality problem is **command and control**. This approach takes action to ensure that the externality is reduced to a lower level. The usual examples of this solution are fixed standards backed up by legal sanctions, for example maximum allowable levels of environmental degradation. The actions taken by the Mali government to deal with the environmental problems caused by the previously mentioned Manantali energy project have taken many forms. The government enforced standards and monitored the building of the project. A reservoir management plan was developed to help irrigate downstream areas, affected land was purchased, people were resettled, and health programmes were implemented. These measures are practical, but do not have the theoretical elegance of the three previous solutions.

The one major problem facing all solutions to the problem of dealing with externalities is assessing their physical nature and calculating their economic value. This is discussed later in the section on the Stern Review (Stern, 2006) on the costs and benefits of preventing climate change. In particular, the uncertainties surrounding environmental effects and their economic value are discussed.

Common property rights

The common ownership of a renewable resource is likely to lead to an important externality. Such circumstances are frequently referred to as the **tragedy of the commons**. However, Dasgupta (1982) has forcefully argued that there has been considerable confusion over the economic

analysis of this problem. In many cases, the confusion stems from describing something as being common property when, in fact, it is open access. With open access, anybody can access the resource in question. An example would be the oceans. In contrast, 'common property' refers to a situation in which a closed group of individuals have access to a resource, such as a grazing common or an area of forestry. The analysis is frequently considered in terms of the example of cattle farmers grazing their animals on commonly owned land. The rational individual farmer will use common land without regard to the cost this use imposes on all other farmers. This behaviour is a negative externality and is inefficient. The cost imposed on other farmers is the exhaustion of the fertility of the soil. This effect will decrease the future value of the resource to farmers. In this sense, the problem of the commons is an **intertemporal externality**. However, it is not the case that use of the common property resource of grazing land necessarily destroys the usefulness of the land. The extent of overgrazing depends on the private cost of rearing animals, their market value, and the ability of the land to support a large number of animals. Nevertheless, appropriate cooperative action by farmers to reduce overgrazing would increase the economic welfare of the farmers as a group.

The negative implications that stem from the tragedy of the commons were challenged by Elinor Ostrom (1990). The importance of her work resulted in her being awarded the Nobel Prize for Economics in 2009.

Elinor Ostrom

Born 7 August 1933. Died 12 June 2012. Taught for most of her life at the University of Indiana, USA, where she established, with her husband, the Workshop in Political Theory and Policy Analysis to study how institutional arrangements affect behaviour and policy outcomes in diverse settings, particularly the efficient management of natural resources. Awarded the Nobel Prize in Economics in 2009 for showing how the problem of the tragedy of the commons can be 'solved' by appropriate action.

Ostrom's analysis of common property resources was based on a series of studies that explained that the tragedy of the commons did not always result simply because of an absence of property rights. (see Case example 12.1 for an example of such an institutional arrangement). This was because, as she identified, in many different circumstances, a set of institutional arrangements can emerge that allow the common property to be efficiently managed and, as a result, the negative externalities that are forecast to remain are nothing but a theoretical possibility. Her work also showed that voluntary arrangements, that is, institutional structures that do not need the direct involvement of the state, could bring about these alternative forms of resource management, such that voluntary management yields a more sustainable resource management outcome than that achieved by state intervention. In addition, her research also explained when the necessary conditions for the voluntary arrangements will begin to unravel and potentially fail. In particular, she identified that voluntary arrangements struggle to work when confronted with ever-increasing numbers of parties, when there is lack of social capital that exists between the economic parties, such that trust cannot be taken as a given (see Ostrom, 2000).

Case example 12.1

The tragedy of the commons: southern bluefin tuna

The phrase 'tragedy of the commons' can be traced back to Hardin (1968) and his classic paper on the inappropriate management of many types of natural resource. Fisheries in the open oceans are an example, as there are an unconstrained number of potential fishers that have no limits on access to the resource and the rate at which the resource is harvested. In such a world, no one fisher has an incentive to reduce effort as somebody else will simply harvest the fish that are not taken.

A well-documented example of this problem is the impact of open access fishing on the southern bluefin tuna. Tuna in general and this species in particular have been heavily overfished by a number of countries. Southern bluefin tuna are a migratory species of pelagic (live in the open oceans) fish that attract a high price because of demand from the Japanese sashimi market. As anticipated by Hardin, the value attached to this species and the fact that they are pelagic have led to excessive fishing that resulted in serious population decline, especially in mature adult fish. In an effort to manage these effects, the existing voluntary management arrangement between Australia, Japan and New Zealand was formalized in 1993 by, first, the Convention for the Conservation of Southern Bluefin Tuna and then, in 1994, the Commission for the Conservation of Southern Bluefin Tuna (www.ccsbt.org). Since 1994, more countries have agreed to abide by the management rules implemented by the commission; for example, South Africa joined in 2016.

Although the spawning biomass of the southern bluefin tuna is very low by historical levels, estimates in 2014 indicated a small improvement compared to 2011. This shows that the problems of resource management identified by Hardin can be resolved if economic agents are willing to cooperate and not simply view a natural resource as an asset to be used without thought for the future.

The discount rate

The degradation of the environment reduces the supply of environmental services in the future. Economic analysis of the environment requires a means of comparing the benefits and costs of environmental effects in the present and the future. This comparison is usually made through a weighting device called the **discount factor**. The practice of discounting environmental costs and benefits has caused much confusion and dispute.

In a neoclassical model of the behaviour of individual economic agents with finite lives, the discount rate is simply the market rate of interest. The level of the market rate of interest is the outcome of the preferences of individuals for present consumption over future consumption and the physical possibilities of transforming present consumption into future consumption. However, even with a set of perfect capital markets, the resulting intertemporal allocation of resources is unlikely to be socially efficient for a number of reasons.

First, the outcome of perfect capital markets reflects the preferences and actions of those presently alive. All individuals will eventually die and presumably value their own consumption more highly than that of their descendants. This implies the market outcome may underweight the consumption of future generations. It might be argued that the state should decide on a distribution of economic welfare over time that favours future generations more. Alternatively, it has been argued that technical progress will increase future incomes, and fairness requires redistribu-

tion from future generations to the present. However, it is unclear how the state can easily decide which distribution should be preferred (see Pearce et al., 2006).

Second, even with regard to the preferences of the present generation, the market outcome may be inefficient. The present generation may wish to save for the benefit of future generations. This can lead to two types of market failure, the **assurance problem** and the **isolation paradox** (Sen, 1967). Both phenomena are examples of externalities. The assurance problem concerns saving by one individual for future generations, which benefits all other individuals in the present who place a value on the consumption of future generations. Thus, the market aggregate level of saving is inefficient and the market rate of interest undervalues future consumption. Aggregate saving would be increased if individuals were assured that their additional savings would be matched by other altruistic individuals.

The isolation paradox concerns the value individuals place on their descendants' consumption compared with that of the rest of future generations. If the return from saving for the benefit of future generations cannot be captured entirely by an individual's descendants, then it is likely that even perfect capital markets will provide an inefficient level of saving.

Imperfections in the capital market are widespread and there is no unique interest rate or discount rate. Instead of the use of an observed market interest rate, the 'social opportunity cost of capital' has been used as a measure to discount the future. The social opportunity cost of capital measures the social value of a loss of one unit of capital in the economy to fund the proposed investment. If resources to fund a project displace other investments, rather than consumption, the social opportunity cost of capital is the correct measure of the cost of capital. However, there are practical difficulties in calculating the social opportunity cost of capital.

The effect of the discount rate on environmental degradation is unclear. A low discount rate weights future consumption more heavily and might be thought to give a better future environment than a higher rate. However, most investments have costs at the beginning of their life and benefits thereafter. Thus, a lower discount rate will make these investments appear more attractive as weighted future benefits will increase relative to present costs. Increased investment and the consequent economic growth may lead to more environmental degradation.

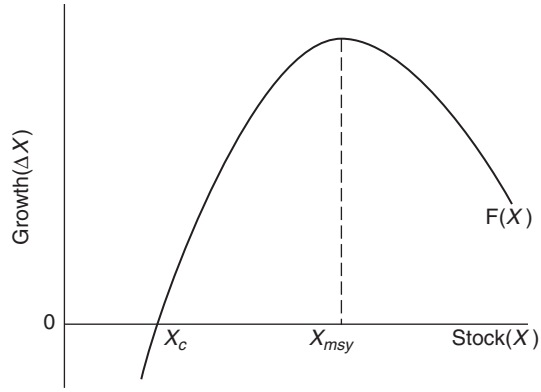
The harvesting of renewable resources

Renewable resources are those whose stock is capable of growth as well as depletion. Renewable resources are usually thought of as experiencing growth and regeneration through a biological process. Fisheries, forests and the previous example of common pasture land are all examples of renewable resources. The neoclassical analysis of renewable resources considers efficient harvesting, while biologists are often concerned with the **maximum sustainable yield** (MSY) that can be obtained from the resource. These two ideas are examined in the context of a fisheries example.

The growth of the stock of fish, ΔX, depends on the stock, X. This relationship is shown in Figure 12.4. Below a critical level, X_c, the stock is in danger of terminal decline as it is not capable of replication. The existence of a critical level may be explained by difficulties in reproduction. Above this level, growth is positive. Eventually, the growth declines because of competition for food supplies or the effects of predators. The MSY occurs at the point of greatest absolute growth.

The efficient use of the fish stock is examined by considering a simple model in which harvesting is costless. The objective is to maximize the social value of the stock over time. The social gain is examined in connection with reducing the harvesting of fish and allowing the present stock to increase by one unit. The present marginal social value of one unit of fish is denoted by v.

Figure 12.4 Relation between the growth and stock of a renewable resource



The marginal productivity of the stock, $F'(X)$, represents the change in growth from increasing the stock by one unit. The social value of this gain is $\nu F'(X)$. The marginal social value of an additional unit of fish in the second period is $(\nu + \Delta\nu)$, where $\Delta\nu$ is the change in social value between the first and second periods. With a discount rate of r, the present value of an additional unit of stock in the next period is:

$$\frac{\nu F'(X) + (\nu + \Delta\nu)}{1 + r} \tag{12.1}$$

The marginal social value of consuming one unit of fish in the present period is ν. Thus, if equation (12.1) exceeds ν, an increase in social welfare can be obtained by reducing the level of harvesting. This condition can be written more simply as:

$$F'(X) + \Delta\nu/\nu > r \tag{12.2}$$

This condition has a simple interpretation. If the marginal productivity of the stock plus the proportionate gain in the value of the stock over time exceeds the discount rate, then it is efficient to reduce harvesting. A reduction in the harvest increases the stock, which is likely to decrease $F'(X)$ (see Figure 12.4). A reduction in the harvest means consumption will fall and the marginal social value of present compared with future consumption will increase. These two effects may be expected eventually to give equality in equation (12.2), and thus efficiency.

Equation (12.2) has two important implications. First, the efficient outcome is not the same as the MSY, as the latter is given by $F'(X) = 0$. Second, for species that have a low marginal productivity of stock and whose value does not increase appreciably with decreasing stock, extinction may be an efficient outcome.

The present analysis is concerned with maximizing the social value of the fish stock over time. It is appropriate to consider whether the efficient outcome can be achieved through a market system. The fisheries example is another case of common property rights. In the discussion of common property rights, it was seen that it can be difficult to establish individual property rights for renewable resources such as fisheries, forests and pasture land. Thus, the market use of such renewable resources is likely to be inefficient.

If the property rights for the resource are given to a few individuals, this will affect the distribution of economic welfare and will result in monopoly power. Private monopoly control

of a renewable resource may result in its inefficient use, as marginal (private) revenue rather than social value would appear in equation (12.2) and, in order to maximize profits, the monopolist may restrict the use of the resource below the efficient level (see Hanley et al., 2013).

Non-renewable resources

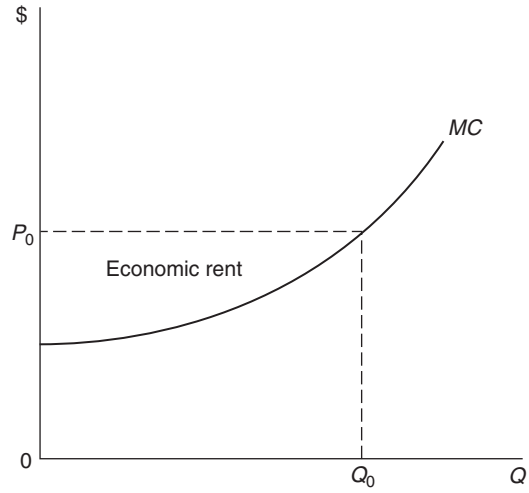
Non-renewable resources cannot be regenerated over time. The present use of one unit of such a resource prevents it from being used in the future. The finite levels of these resources means that they are often referred to as 'exhaustible resources'. This suggests that non-renewable resources should be used with care.

There are many estimates of the stocks of non-renewable resources. Calculation of the known reserves of a non-renewable resource has to be made in the context of the extraction cost and the price of the resource. It is considered inappropriate to include in estimates of reserves sources for which the cost of recovery exceeds the current price or for which there is no proven extraction technology. 'Proven reserves' refer to those sources that are presently known. It is likely that there are sources yet to be discovered. However, uncertainty means that it is difficult to calculate meaningful estimates for unproven reserves.

The depletion of a non-renewable resource can be analysed in terms of the objective of maximizing the social value of the stock. Figure 12.5 considers a one-period model and the maximization of the economic rent from extracting a mineral that has a price *P*. The economic rent is the area between the price and the marginal cost curve. If the price is equal to the marginal social value of consumption, a perfectly competitive industry will extract the resource up to the point Q_0, which is a socially efficient outcome. A monopoly faced with a downward sloping demand curve is likely to restrict output below Q_0, which is inefficient.

The **optimal depletion** of a non-renewable resource over time can be analysed in a similar manner to the harvesting of a renewable resource. Again, the objective is maximization of the social value of the stock over time. The decision to extract a non-renewable resource is simpler, in

Figure 12.5 Economic rent and the use of a non-renewable resource



that there is no marginal productivity of the stock to consider. It is assumed that the extraction of the resource is costless. The resource should be further conserved if:

$$\frac{\Delta v}{v} > r \tag{12.3}$$

Equation (12.3) has a simple interpretation. If the relative appreciation of the social value of the resource is greater than the discount rate, then more of the resource should be saved for the future.

For an efficient outcome, the social value of marginal consumption should be increasing at the rate r. This implies (through integration) that v is given by the function $v_0 e^{rt}$, where v_0 is the social value at time zero. If a constant marginal cost of extraction (mc) is introduced into the analysis, the efficient outcome gives the equation:

$$v(t) = mc + v_0 e^{rt} \tag{12.4}$$

Equation (12.4) reflects the optimal depletion path. It is possible for a perfect market to give this outcome. In this case, the optimal price path is given by:

$$p(t) = mc + r_0 e^{rt} \tag{12.5}$$

The $r_0 e^{rt}$ term is referred to as the **discounted rental premium**. It may be interpreted as the social cost of consuming the resource in the present rather than in the future.

As before, if the price is equal to the marginal social value of consumption, a perfectly competitive market will maximize social welfare across time. A monopoly may restrict the use of the resource below the efficient level and the price path will be inefficient (see Hanley et al., 2013).

It has been pointed out by Kay and Mirrlees (1975) that, for reasonable discount rates, one would expect the optimal price to be close to marginal cost for most of the lifetime of a non-renewable resource.

Other environmental values

It is a central tenet of neoclassical economics that prices should reflect the marginal costs of production. In a competitive economy, prices may reflect private marginal costs, but there are a number of other types of social costs that should be taken into consideration (see Garrod and Willis, 1999). First, the external costs imposed on other individuals should be taken into account. (The remaining values could strictly be classified as private or external costs, but for the purpose of exposition they are separated into different categories.)

Second, the economic rent in the use of non-renewable resources should be included in social marginal costs. As noted before, the economic rent may be regarded as a premium that has to be paid for the use of the resource in the present rather than in the future.

There are four other types of value that have not yet been considered: **option**, **quasi-option**, **existence** and **bequest values**:

1. An **option value** is the value placed on an option that allows use to be made of the environment in the future. Option values depend on attitudes to uncertainty, such as risk averseness. The option is not necessarily taken up, but it gives value. An example of an option value is

biodiversity. The protection of species of animals and plants may be desired in order to allow possible future uses of these species as inputs to production, and because many individuals may wish to have the opportunity of seeing these species in the future.

2. **Quasi-option values** are the values placed on an option given an expectation that there will be increases in knowledge. For example, the value of certain plant species may depend on the development of knowledge of new uses of the plants.
3. **Existence value** is the value placed on a good or service independent of any actual or possible future consumption. This value is different from the other types of value in that it is unrelated to use. An example of existence value is the concern expressed by many individuals for the preservation of elephants, even though they are unlikely ever to see them at first hand, or use this resource.
4. **Bequest value**, as the name suggests, is when an economic agent wishes to pass on resources to members of future generations.

Thus, the total social cost comprises seven components:

$$\begin{aligned}\text{social cost} = {} & \text{private cost} + \text{external cost} + \text{rental premium} + \\ & \text{option value} + \text{quasi-option value} + \text{existence value} + \text{bequest value}\end{aligned} \tag{12.6}$$

Efficient allocation requires consideration of all seven components of social costs.

Measuring environmental values

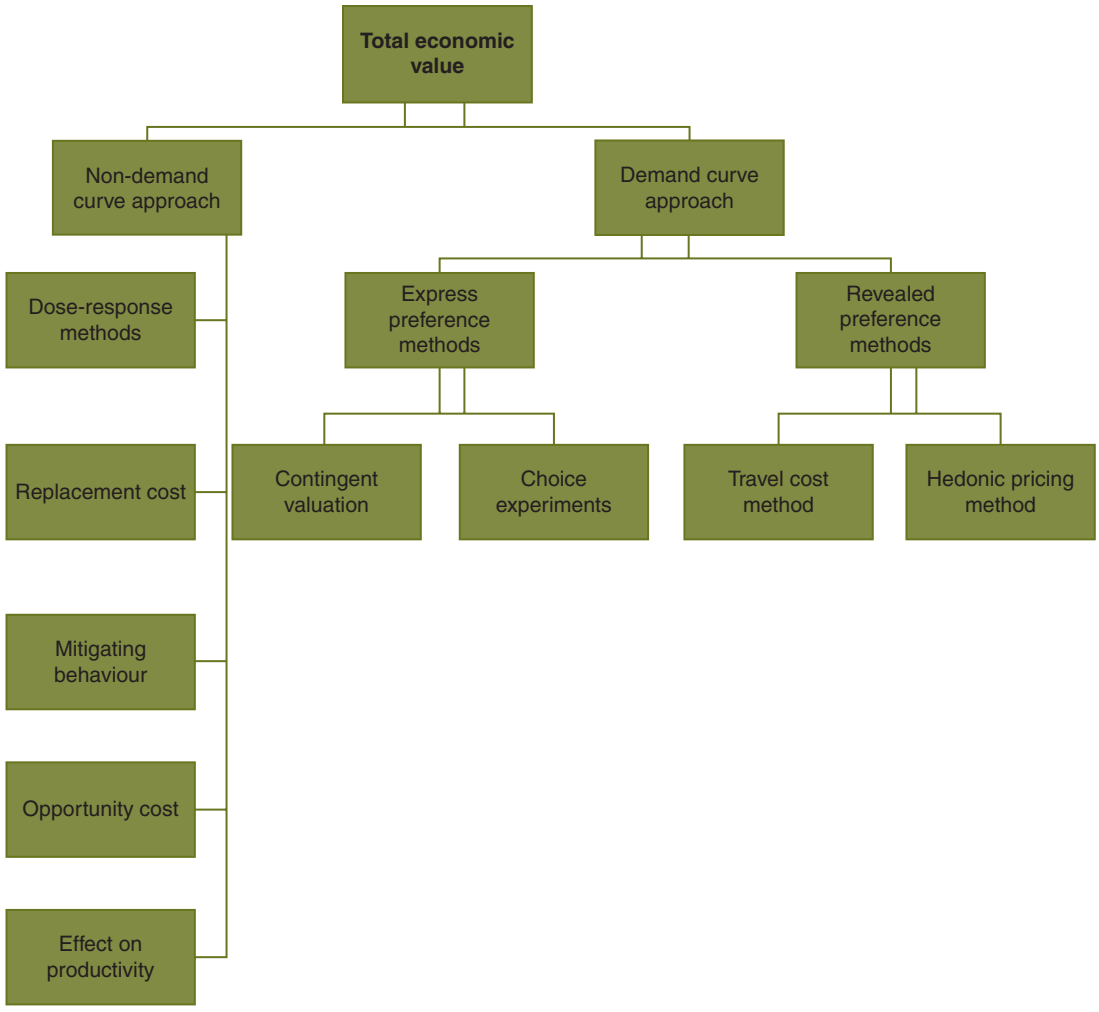
The analysis of this chapter suggests that a market economy will not value all aspects of the environment appropriately. This view is widely held and has led to much intellectual and practical effort being applied to the problem of how to introduce appropriate environmental values into economic decision-making. The following discussion considers the introduction of environmental considerations into social cost–benefit analysis and national income accounting.

Appraisals of many investment projects in developing countries now include **environmental impact assessments** (EIAs) that estimate the environmental effects of the projects. This should be the first stage of the introduction of the environmental effects of a project into social cost–benefit analysis. Often, it is very difficult to assess a project's physical effects on the environment. For example, the British government argued that the Stern Review (Stern, 2006) had underestimated the physical impacts of climate change. EIAs can rarely firmly establish the type and extent of environmental effects of projects. Thus, the introduction of previously unconsidered environmental effects into economic decision-making should take account of this uncertainty.

Once the environmental effects of a project have been estimated, there are four approaches to placing economic values on the effects (more precise details and discussion of economic valuation can be found in Garrod and Willis, 1999). First, the basic valuation technique in social cost–benefit analysis is to use market prices. This is justified by the neoclassical assumption that prices reflect the social value of goods and services. In the case of environmental effects in developing countries, markets and prices may not exist for many of the effects that require valuation. For large environmental effects, the project may actually alter prices. In this case, the changes in the values placed on environmental effects should be modelled. In practice, this is often impossible.

If we are unable to employ market prices, then it is necessary to employ one or more of the large number of valuation methodologies developed by economists. These methodologies have been developed using varying degrees of economic theory and statistical methods. Figure 12.6

Figure 12.6 An overview of economic valuation methodologies



gives an overview of these methods. In this context, economic value is referred to as 'total economic value', which can be estimated in part or full by either employing non-demand (a theoretical) curve approaches or demand (theoretically consistent) curve approaches.

Thus, the second approach calculates the value of environmental effects indirectly through observed economic behaviour; this set of methods is shown on the left-hand side of Figure 12.6. Within this approach, there are a number of different techniques. One is the **mitigating behaviour approach**, which takes the expenditure that people are prepared to undertake to prevent degradation as a measure of the value of the environmental effects. Another is the **replacement cost technique**, which estimates the expenditure people are prepared to undertake to restore the environment to its previous state after degradation has occurred. (These expenditures and costs may be difficult to observe and both techniques often require experts to estimate them.) The full long-term consequences of environmental effects may not be understood. Not all environmental effects can be fully offset by preventive expenditure and the environment cannot always be restored after degradation. Such problems may be particularly important for large changes in the environment,

for example changes in the ecology of a large watershed, and climate change. The ability of individuals to fund these expenditures may be limited by imperfect capital markets. For these reasons, it is usually thought that the two techniques may underestimate environmental costs.

The **production function approach** (or **effect on productivity approach**) values environmental impacts by their effects on production. Thus, part of the environmental impact of a change in climate conditions could be valued through the effects on agricultural output. Another example is the valuation of environmental health effects by estimating changes in the productivity of affected individuals. This implies that the value of life is only determined by production and there are no psychic costs to ill health and early death.

The third approach is typically referred to as the **revealed preference approach** and these methods are shown on the right-hand side of Figure 12.6. Why revealed preference? In the absence of a market for an environmental effect, it is sometimes possible to derive the value placed on the effect by the prices paid for other goods and services that implicitly value the effect. For example, property values vary with location, and this may, in part, reflect differences in the environment. The **hedonic prices method** can produce estimates of the contribution of differences in the environment to the prices of property. This can be used to give an estimate of the implied value of certain environmental qualities. In developing countries, there are often significant imperfections in markets, for example rent controls, which affect the validity of the technique. The hedonic price method requires large amounts of data. It is often difficult to measure the environmental quality that is being considered. The importance of the environmental variable may not be properly understood by individuals. These problems limit the usefulness of this technique, particularly in developing countries.

In contrast, the **travel cost method** values the time and costs that people are willing to incur in travelling to areas with more pleasant environments. Thus, the method gives an implied value of environmental quality. The formal assumptions of the model and its applicability to developing countries have been criticized (see Garrod and Willis, 1999). The method implicitly considers the environment in terms of the provision of recreational services rather than basic life support services.

The fourth approach to valuing environmental effects is referred to as the **stated** or **expressed preference approach** and these methods are shown in the middle of Figure 12.6. In this case, survey instruments are developed that are used to directly ask the public how much they might be willing to pay for a specific environmental outcome. The original stated preference approach is **contingent valuation**. A subset of the population is surveyed and asked for their valuation of the environment. There are two ways in which this question can be asked. Individuals can be asked about either their willingness to pay for an environmental benefit or their willingness to accept compensation for a loss of environmental quality. Economic theory suggests that the answers to the two types of question should be similar. In many surveys, willingness to accept compensation questions receive much higher responses. The questions asked are hypothetical and those surveyed may not be familiar with the environmental effect/resource being surveyed. Respondents may respond to questions strategically, and there is evidence of other forms of bias in the replies to surveys. The responses of individuals may reflect the context of the survey question. Thus, for example, individuals could, with appropriate questions, be induced to respond as citizens concerned with the public interest rather than as consumers pursuing their own self-interest. It is not always clear how to gross up the response from a survey to represent the general population's valuation of an environmental effect.

More recently, **choice experiments** have become a popular stated preference methodology. Like contingent valuation, they also make use of a survey but they do not directly ask what a specific environmental good or service is worth. Instead, by drawing on Lancaster's (1966) theory

of demand, they frame economic choices in terms of the attributes of a good or service that a consumer will consider when making a choice (Hensher et al., 2015).

Finally, **benefit transfer** is an alternative approach to all the above. As the name implies, benefit transfer takes existing benefit estimates and uses them in related or similar contexts. In recent years, this practice has become much more straightforward with the development of databases containing the results of many earlier valuation studies, such as the Environmental Valuation Reference Inventory (www.evri.ca). This approach can be useful if primary valuation research has not or cannot be conducted. However, there are potentially many biases that can occur in undertaking this approach and, as such, much of the research and application of this approach is directed at attempting to minimize biases that can occur in practice.

In summary, the valuation of environmental benefits and costs is essential to improving economic decision-making on the environment, and social cost–benefit analysis has developed various techniques to this end. However, there remain theoretical and practical problems with the use of all these techniques (IPCC, 2014a).

National income accounting

The neoclassical approach to economic analysis assumes that consumption in its widest sense is, and should be, the objective of economic activity. The ethical issues concerning whose consumption should be considered were examined in Chapter 8. The conventional approach is to measure economic welfare in terms of per capita income. This approach has been widely criticized and alternative measures have been proposed, many of which emphasize the importance of accounting for the environment.

Measures of economic welfare have to be judged in terms of their theoretical definition and practical application. The most obvious measure of current economic welfare is per capita current consumption. Current consumption can be increased by reducing investment and thus future consumption. This suggests that economic welfare in one period should be defined relative to a fixed capital stock. So, additions to capital stock, although not increasing current consumption, should be reflected in a measure of economic welfare as they allow increases in future consumption. This idea underlies the conventional definition of income (see Hicks, 1946): 'A person's income is what he can consume during the week and still expect to be as well off at the end of the week as he was at the beginning.'

There are many conceptual and practical problems with the definition of income, so only those directly concerned with accounting for the environment are examined here. Environmental degradation can be mitigated by the actions of economic agents, for example soil erosion can be reduced by planting forests. In national income accounts, such **defensive expenditures** are taken as giving rise to increases in economic welfare rather than as attempts to maintain the environment. It is commonly argued that these expenditures should be excluded from measures of economic welfare and account be taken of the environmental effects that give rise to these expenditures.

Environmental degradation affects economic welfare as individuals directly consume environmental services, for example unpolluted air. As there is not always a market in such services, or only an indirect one, they are not recorded in national income accounts. Degradation also reduces the productive potential of the environment, for example non-natural causes of soil erosion and reductions in the ability of the environment to absorb waste products. Reductions in the productive potential of the environment are examples of the depreciation of the stock of natural capital. These types of change are not recorded in national income accounts.

The use of non-renewable resources, for example fossil fuels, is not allowed for in a correct manner in national income accounts. These resources are part of the natural capital of the environment. Their use in the present reduces the supply available for future generations. National income accounts consider the use of non-renewable resources as a simple productive activity. It should also be considered as a depreciation of natural capital. (A similar analysis applies in the case of renewable resources, as regeneration can require time and investment, and thus present consumption of renewable resources can impose costs on future generations.)

At the international level, there is the London Group on Environmental Accounting, a UN research group that has attempted to update and modify the System of National Accounts (SNA) to take account of environmental issues in a manner consistent with the SNA. The result was the development in 1993 of the System of Environmental-Economic Accounting (SEEA) (unstats.un.org/unsd/envaccounting/seea.asp). The SEEA has adopted some of the ideas that have been developed by economists to extend the SNA but there are limits to the modifications that are considered, as there is the need to maintain consistency with the SNA.

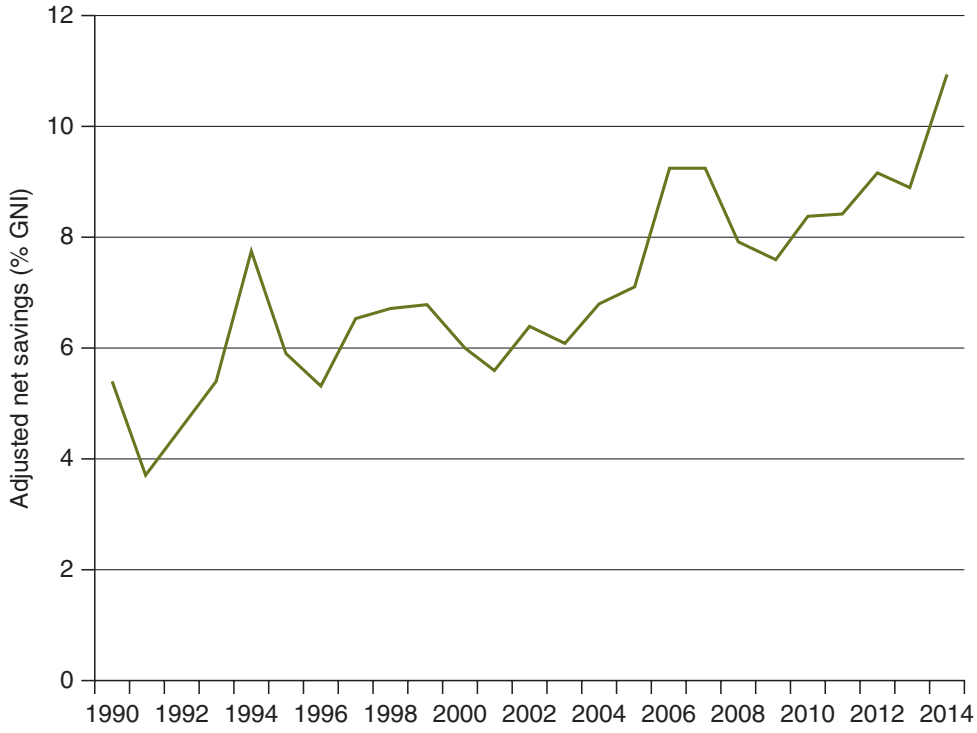
There have been four general responses to the failure of national income measures to account for the environment, some of which have been adopted within the SEEA, but many of which have not and go far beyond the modifications considered by the London Group. The first method follows Nordhaus and Tobin's (1972) calculations of **measures of economic welfare**, which attempt to recalculate national income accounts to allow for environmental effects. Progress on developing measures of national income that allow for the use of natural capital and environmental degradation has been slow for most developing countries, although the World Bank now reports the value of natural capital in many developing countries. A report in *Nature* (1998) suggested that adjusting for environmental effects may have reduced national income for Brazil, India and Indonesia by 12–17% in the mid-1990s, but a more recent estimate using World Bank data on adjusted national income for Taiwan suggests a reduction of only 1%. Allowing for the environment can often give quite different estimates of economic welfare and economic growth.

The second method of accounting for the environment follows the weak sustainability view that total capital should be at least maintained. In this approach, the level of saving is calculated and the depreciation of natural, man-made and other forms of capital is deducted. If the resulting number is negative, this may be taken as evidence of unsustainable development. The method is explained in World Bank (2002). **Genuine savings** (or adjusted net saving allowing for changes in environmental capital stocks) are reported for many developing countries and are sometimes negative. At the global level, genuine savings do not tend to evolve in a linear or constantly increasing manner. Figure 12.7 indicates that there is a rising trend in genuine savings globally but there can be significant year-on-year variations that indicate the problems faced in constantly being able to achieve even weak sustainability.

A third method of accounting for the environment in economic growth is to construct *physical*, rather than monetary, accounts of the environment. These accounts divide up the environment into different sectors and estimate the changes that have taken place over time. For example, the use and discovery of mineral and energy resources would be recorded. The World Bank (2011) has argued for the collection of physical indicators across time of the effect of human activities on the environment and the effect of the environment on human activities (see www.worldbank.org).

A fourth set of methods starts with national accounts and then makes a series of modifications, many of which remove the underlying theoretical consistency of the accounts. However, the motivation for making these changes is not to remain consistent with national accounting procedures but to yield a measure of economic activity that better reflects economic, environmental and societal policy objectives. An example that has attracted much attention is the **ecological**

Figure 12.7 Global genuine savings, 1990–2014



Source: World Bank staff estimates based on World Bank, 2011.
Note: Adjusted net savings equals net national savings plus education expenditure minus energy depletion, mineral depletion, net forest depletion and carbon dioxide and particulate emissions damage.

footprint method. This approach has proved popular with environmentalists who do not feel comfortable with simply relying on monetary measures of sustainability. The ecological footprint has also proved useful as a way for environmentalists to highlight what they consider to be excessive levels of human consumption and use of the environment. For example, Edward O. Wilson (2002), in his book *The Future of Life*, observes that if all individuals consume resources at the same level as the average individual in the USA, then with the current state of technology, we will require four additional planets. This powerful statistic is arrived at by converting all forms of consumption into a land use equivalent measure. Unsurprisingly, it has added another dimension to the ongoing debate about whether or not current levels of consumption are sustainable.

Importantly, the four methods of accounting for the environment are not substitutes. The monetary approach of the first of the two methods also requires the calculation of physical accounts. Physical environmental accounts are useful for considering ecological and environmental issues. Monetary environmental accounts are useful as they reduce all effects to a common measure and estimate a net figure for the use of the environment. However, because of the difficulty of doing this, they have been criticized on theoretical and practical grounds (see Perman et al., 2011).

Risk and uncertainty

Risk exists where there is doubt about a future outcome and it is possible to estimate objective probabilities of the occurrence of different possible future outcomes. The outcome of a throw of a dice is an example of risk. Uncertainty exists where there is doubt about the outcome and it is not possible

to estimate probabilities of the occurrence of the different possible future outcomes. It is difficult to analyse uncertain events and most environmental analysis that considers risk and uncertainty assumes, either explicitly or implicitly, that it is possible to estimate probabilities with some degree of objectivity, that is, the circumstances are assumed to be those of risk rather than uncertainty.

Uncertainty about the relationship between the environment and the economy complicates analysis. As previous examples have shown, there is scientific dispute about many important environmental effects. In the analysis of environmental policies, it is possible to distinguish two approaches to managing this uncertainty.

First, the different possible outcomes of a policy are predicted. Then probabilities are estimated for these different outcomes, although these probabilities are necessarily subjective. It could be argued that the notion of estimating probabilities for events such as global warming is not appropriate, as they cannot be considered as repeated probabilistic events like the throwing of a dice. However, recent studies have attempted to provide probability estimates of different levels of global warming and Stern (2006) suggests that there is a 63–99% chance of warming exceeding 2^0C after a doubling of greenhouse gas concentrations. Notwithstanding this, policy analysis could proceed by selecting the most preferred policy on the basis of the probabilities of the different outcomes of the policies. If society is averse to taking risks, it can be shown that uncertain costs should be given more weight than the expected value of costs, and uncertain benefits should be given less weight than their expected value.

The alternative procedure is to select the mean estimates of the effects of different environmental policies. These estimates are then used to decide the most preferred policy. This procedure is often used. The choice of the mean estimates is highly subjective. More importantly, this approach does not take account of either risk or uncertainty.

The potential importance of uncertainty in the area of environmental economics has been highlighted by Pindyck (2007), who argues that the uncertainty society faces in the area of environmental economics is far more complicated than in any other area of economics for three reasons:

1. The cost and benefit functions that describe the relationship between the economy and the environment might be highly nonlinear, meaning that we struggle to understand the consequences of our actions.
2. It is highly likely that there are important irreversibilities that exist in terms of policy choices and decisions as well as environmental damages.
3. Many of the most important environmental issues we confront have long time horizons, which conventional project and policy appraisal techniques do not deal with very well.

Economic growth and the environment

Figure 12.1 above indicates that the environment is essential for economic activity and growth, and shows the importance of the effects of economic growth on the environment. Environmentalists have argued that unconstrained economic growth will lead to the exhaustion of non-renewable resources and to levels of environmental degradation and climate change that will seriously affect economic production and the quality and existence of life (Meadows et al., 1972; Forrester, 1971). Economists who believe in the effectiveness of market-based policy instruments have responded to these arguments (see Sterner, 2003).

If markets operate effectively, the increased scarcity of non-renewable resources will increase their prices. These higher prices will give incentives for changes in economic behaviour:

- The direct consumption of these resources may fall: for example, lower consumption of scarce fossil fuels.

- There will be incentives to search for new supplies of these resources: for example, the level of exploration for new oilfields will increase.
- The use of higher priced non-renewable resources in production will decline through substitution with production techniques that are less intensive in these inputs: for example, production will become less fossil fuel-intensive.
- Higher prices will encourage the development of new technologies that provide substitutes for scarce resources: for example, non-fossil fuels such as 'biomass' or wind power – or utilize it more efficiently: for example, fuel-efficient cars.

Thus, efficient markets may provide a solution to the running down of non-renewable resources.

Supporters of economic growth often argue that its contribution to environmental degradation has been overestimated. Alternatively, there is a common view of the existence of opportunities for simultaneous economic development and improvement in the environment, as argued by the World Bank (2001). However, the pursuit of these twin goals is usually assumed to require the state to intervene and improve the operation of markets with regard to the environment.

It has been argued by Grossman and Krueger (1995) that in the early stages of economic development, the level of environmental degradation increases, but after this phase, the environment improves with economic development, but it is important to note that CO_2 emissions increase with the level of development (see Table 12.1 above). This proposition is in line with the World Bank (1992) and the results that are reported at the beginning of this chapter. However, there is an extensive debate on the relationship between the environment and economic growth and development. In particular, the relationship has been characterized by an inverted U-shaped relationship, referred to as the **environmental Kuznets curve** (see Hanley et al., 2013). The shape of this relationship between the environment and economic activity could be explained by changes in the mix of output at different levels of development, changes in the demand for the environment at different levels of income and the policy responses to these demands, and the availability and use of more environmentally friendly technologies in developed countries.

All the different views of economic growth and environmental degradation considered here are likely to be true in part. It is unlikely that the debates on the relationships between the environment and the economy can be resolved through exhaustive scientific and economic investigation. Economic and environmental policies have to be formulated and carried out on the basis of existing uncertain and disputed evidence.

Sustainable development

Much of the vast literature on the environment and the economy could be interpreted as a response to the concern that present patterns of economic growth may seriously degrade the environment and may be unsustainable, as the environment cannot support economic growth forever. This proposition may or may not be substantially true. At its heart lies the view that past and present economic policies have usually been concerned with providing the conditions for equilibrium economic growth, as measured by standard national accounting methods. Many environmentalists are concerned that these policies have not attempted to ensure 'the existence of ecological conditions necessary to support human life at a specified level of well-being through future generations' (Lele, 1991). This concern is of major importance in the concept of **sustainable development**. Sustainable development has perhaps become the most important approach to considering the environment and development.

There is a wide range of definitions and interpretations of the meaning of 'sustainable development'. The term first came to prominence in the *World Conservation Strategy*, presented in 1980 by the International Union for the Conservation of Nature and Natural Resources (IUCN/UNEP/WWF, 1980). It was popularized by the World Commission on Environment and Development's study *Our Common Future* (UN WCED, 1987), which is also known as the Brundtland Report, named in honour of its chairperson, the Norwegian prime minister. These and other studies have defined sustainable development in different ways. The most frequently quoted definition comes from the latter study: '**Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability of future generations to meet their own needs.**'

This definition would appear uncontroversial and is remarkably similar to the neoclassical definition of income given earlier by Hicks (1946). However, the interpretation differs in that *Our Common Future* examined how sustainable development can be achieved (UN WCED, 1987). This inevitably requires making value judgements that link the definition and the operational objectives, which, it has been suggested, will result in the attainment of sustainable development. For this reason, there has been criticism of the connection between the definition and the operational objectives. The objectives are increasing economic growth, meeting basic needs, involving more of the population in decision-making and development, controlling population growth, conserving and improving the environment, accounting for the environment in economic decision-making, changing technology, managing risk, and changing international economic relationships.

The concept of sustainable development has gained wide acceptance and has become a standard model for thinking about the environment, development and the economy. Most countries that attended the Rio Earth Summit in 1992 accepted the general idea of sustainable development, as enshrined in the *Agenda 21* process agreed at that summit (UN, 1993). The UN 2005 World Summit: 'reaffirmed [its] commitment to achieve the goal of sustainable development [and its] three components ... economic development, social development and environmental protection' (UN, 2005). However, as observed above, what the concept of sustainable development should imply for economic and environmental policies is disputed. In particular, the concern for equity between and within generations is central to most interpretations of the concept, but it is unclear how the welfare of individuals can be compared. One of the major controversies concerning the approach of the Stern Review (Stern, 2006) is the low discount rate used to compare costs and benefits for different generations. This is a central problem in neoclassical economics and the concept of sustainable development does not appear to provide a solution to the problem.

The new **Sustainable Development Goals (SDGs)**, which superseded the Millennium Development Goals (MDGs) in 2015, are an important set of policy objectives across a wide range of economic, environmental and social contexts (see Chapter 1). In particular, efforts to deal with climate change are a specific SDG (Goal 13) that articulate several important policy targets. Specifically, this goal argues for the need to integrate climate change policy actions into all national policy decisions. In addition, there is a commitment by all parties to the **UN Framework Convention on Climate Change (UNFCCC)** to have an annual fund of $100 billion by 2020 to ensure that the necessary policy actions are realized. The $100 billion target can be viewed as an explicit test of the willingness of richer nations to help poorer nations tackle climate change. The UNFCCC, which entered into force in 1994, is very important as it provides the primary international intergovernmental forum where global negotiations take place that attempt to deliver policy solutions to issues such as climate change and biodiversity loss.

Natural capital, equity and environmental values

In defining the notion of sustainable development, it is common to require that the stock of capital be non-declining through time. A constant or increasing stock of capital allows consumption levels to be maintained or increased. However, there are major differences of opinion over the capital stock that must be held constant or increased. The weak sustainability view considers all the different forms of capital – man-made, human, natural and social – to be substitutes, which can be aggregated into total capital. Thus, for example, degrading the natural fertility of the soil can be compensated for by using fertilizers and the methods of agricultural science to maintain crop yields. In this example, human capital and man-made capital are used to substitute for natural capital.

The alternative view of strong sustainability takes the position that it is only natural capital that needs to be held constant or increased. In this view, the focus is often on critical natural capital, which is either required for human survival or cannot be substituted for with other forms of capital. Thus, one might take atmospheric global warming gas levels as critical natural capital, as higher levels cannot be offset by other capital. For an economic comparison and analysis of weak and strong sustainability, see Hanley et al. (2013). However, it might be argued that some of the effects of climate change resulting from higher global warming gas levels can be adapted to by additional sea defences and migration of population (see the discussion of the Stern Review later in the chapter).

Underlying the analysis of the environment and development, and the importance of natural capital, are views about environmental values. The study of environmental values suggests three possible ways in which these values could be generated. First, the preferences of individuals give rise to values that with a complete set of perfect markets are reflected in the prices of goods and services. This is the neoclassical approach to valuation, and examples of market failure have already been examined. Market failures suggest that the environment will not be adequately accounted for in the operation of market economies.

The second source of environmental values is that of social preferences. Sagoff (1988) suggested that individuals are capable of considering issues, in particular those concerning the environment, from the point of society. It is not clear how such values could be established in the psyche of individuals. A possible explanation is a sociobiological one, in that individuals behave as social organisms for the benefit of the species (Dawkins, 1976). Environmental choices are so complex that even if social preferences exist, it is difficult to assume that, apart from in a tautological sense, they will result in decisions that improve social welfare. However, it has been suggested that the poor in developing countries are the most dependent on the environment. Thus, if social preferences are to give weight to the circumstances of the poor, the environment should be given greater weight than would occur from simple aggregation of the individual values placed on the environment.

The third source of environmental values follows from the belief that ecological systems have an intrinsic value independent of any value placed on them by humans (see Booth, 1994; Common and Stagl, 2005). The individual preferences basis for values considers only human beings to have rights. The ecological view represents the extension of rights to other species. How these rights can be measured is a difficult problem. The ecological values view suggests that greater weight should be attached to the environment than would be given by taking just social values or simple aggregation of individual values.

Preserving or increasing the stock of natural capital has important effects on intergenerational equity. If it is believed that present levels of environmental degradation and resource use

will substantially alter future human economic welfare, then intergenerational equity may be improved by the constraint that the stock of natural capital should be preserved. This is the strong sustainability view. However, the substitution of this constraint by a more flexible approach that allows some use of natural capital could conceivably increase economic welfare measured across all present and future generations. This is the weak sustainability view.

The use of a positive discount rate weights future environmental effects less heavily than those occurring in the present. This has been criticized as underestimating the importance of environmental degradation and resource use. This criticism is misplaced. If the arguments are accepted for the social preference of the present compared with the future, then discounting is appropriate. If it is felt that too little weight is being attached to future environmental effects, their estimated values should be adjusted, but not the discount rate.

Many environmental effects are irreversible, for example the extinction of a species. Irreversibility has been used as an argument for maintaining the natural capital stock. However, the dislike of irreversible losses in natural capital can be captured by the concepts of option, quasi-option and existence values.

The resilience of an ecosystem is its ability to maintain its normal functions after an external disturbance (Common and Stagl, 2005). It has been suggested that the larger the stock of natural capital, the more resilient an ecosystem is likely to be. This argument is justified on the basis of the idea that the diversity of the ecosystem increases its resilience. However, the notion of resilience and the related concept of stability have been criticized, as no ecosystem is likely to be globally stable and constant through time. This implies that the size of the external disturbance is important (Norton, 1987).

As discussed earlier, uncertainty is crucial to the analysis of the relation between the environment and the economy. A possible policy response to such uncertainty is to adopt policies that provide insurance against possibly disastrous future outcomes. This risk-averse strategy of emphasizing the worst possible outcome might be justified by, say, the worst forecasts of the disastrous outcomes of global warming. This argument supports the setting of a constraint that keeps the stock of natural capital fixed. Alternatively, it has been argued (see Lomberg, 2001) that the vast expenditure necessary to reduce global warming, the long period before such effects become important, and the lack of absolutely clear scientific proof of the size of these effects suggest that a conservative approach ought to be adopted. It is unclear how uncertainty should be included in environmental decision-making, but it *is* clear that the treatment of uncertainty has a very important effect on the actual decisions that have been or will be taken.

Arguments about weak and strong sustainability, sources of environmental values, discounting, irreversibility, uncertainty and resilience suggest that perhaps a higher value should be placed on the environment than the operation of a market economy would give. Strictly, this is not the same as suggesting that the stock of natural capital should be maintained. However, the complexity of decision-making on the environment might require an approximate constraint on the use of the environment, such as preserving the stock of natural capital.

This critical discussion of the concept of sustainable development suggests that the environment has an important role in economic development and this may not have been fully understood in the past. The concept of sustainable development has won many academic and political adherents. However, there are differences in opinion whether natural capital deserves special protection in economic development or whether it can be traded off against man-made and human capital. These differences are important in determining how the environment enters into economic decision-making.

There are also practical difficulties with the implementation of a constraint that keeps the stock of natural capital fixed. The environment is made up of many different resources and services. Constancy of the stock of natural capital could be interpreted as constancy of all types of natural capital. This interpretation implies that any positive use of non-renewable resources would not be compatible with sustainable development and is difficult to justify.

The alternative interpretation is to consider a single measure of natural capital that appropriately weights the different types of natural capital. The obvious weights are the values of the various types of natural capital. These values may not only reflect the ideas considered in equation (12.6), but also the distributional views that are often associated with the idea of sustainable development. However, placing values on the different types of natural capital would appear to deny the special role of such capital. If different forms of natural capital can be valued so as to give a single measure, this suggests that it can be traded off against man-made and human capital and requires no special protection in the process of development.

It may be the case that a single measure of most types of natural capital would be desirable, with individual measures for the remaining critical types of natural capital, for example atmospheric levels of greenhouse gases.

If the view is taken that the environment must be preserved, then a social cost–benefit analysis of a project should be carried out, subject to the additional constraint that the net effects on the environment are zero or positive. The strength of this additional constraint can be weakened by adding environmentally friendly investments to the project that allow the constraint to be met. If it is considered necessary to preserve the different types of natural stock, then there must be an additional constraint for each type of natural capital.

The constraint of preservation of all aspects of the environment implies that national income accounting methods cannot be altered to allow the calculation of one measure of economic welfare that includes environmental effects. Thus, it has been suggested that measures of economic welfare be presented alongside a set of indicators of the state of the environment.

The less restrictive interpretation of the concept of sustainable development allows substitution between different forms of capital and the simple inclusion of the environment in social cost–benefit analysis and national income accounting (see www.worldbank.org). The inclusion of the environment simply requires the correct valuation of environmental effects.

Economic thought and the environment[1]

Classical economists, such as Malthus ([1798]1983), Ricardo ([1817]1992) and Mill ([1856]1986), were generally pessimistic about the possibility of continued economic progress (see also Chapter 4). These economists assumed that there were diminishing returns to factors of production and the supply of land was fixed. The growth in population, and thus the labour force, would lead to reductions in the marginal product of labour and a declining average product of labour. Malthus and Ricardo assumed a constant technology, with the inevitable result that average agricultural production per unit of labour would decline. Mill considered that technical progress could offset the effect of diminishing returns to a factor, but was unlikely to do so in the long run. Marshall (1890) invented the idea of an externality, which was developed by Pigou (1920). However, in general, environmental externalities were considered to be unimportant.

The start of the debate about the environment and the economy is usually attributed to Rachel Carson and her book *Silent Spring* (1962). Other early contributions to the environmental debate were made by Boulding (1966), Ehrlich and Ehrlich (1970), Goldsmith et al. (1972),

Forrester (1971), Schumacher (1973) and Commoner (1972). A most influential environmental publication was *The Limits to Growth* by Meadows et al. (1972). The basic point of this study was that there is a number of non-renewable resources whose present levels of consumption are such that the known reserves will be exhausted in the not so distant future. The study was heavily criticized for not allowing for the effects of the price mechanism to reduce consumption and provide incentives to explore for new reserves and develop new technologies. A useful summary of the early developments of environmental economics is provided by Sandmo (2015).

These environmental contributions to the debate stimulated economic interest in the relation between the environment and the economy. Barnett and Morse (1963) could find little evidence of resource scarcity in the US economy in the period 1850–1957. Dasgupta and Heal (1979) provided a rigorous neoclassical analysis of the depletion of exhaustible natural resources. Kneese et al.'s (1970) development of the **materials balance approach** changed the view that some economists had of how the economic system dealt with the environment's waste absorption function. This simple principle states that all resources that flow into an economic system must eventually end up as waste products.

The debate about the environment and the economy has changed public views, and, in particular, the views of international agencies have changed.

Climate change, the Stern Review and predicting the future

Climate change occurs because the earth absorbs energy from the sun and re-emits this energy. Some of this energy is absorbed by greenhouse gases and warms the earth. The existence of the greenhouse effect and the warming of the planet since the middle of the twentieth century are universally agreed. The extent of the contribution to climate change from man-made greenhouse gas emissions, however, has been disputed by some scientists and is difficult to prove beyond doubt.

The impacts on nature of global warming are sea level rises, loss of land and species, ecosystem changes in agriculture, relocation of forests and fisheries, changes in water availability and in local climates, and more unpredictable weather episodes. The impacts on humans are increased mortality and morbidity from climate-related diseases, lack of food, air pollution, and weather-related disasters. Climate change also increases costs to society related to human migrations, changes in economic activity, adaptation to climate changes, and measures to reduce greenhouse gas emissions. The **World Meteorological Organization** and the **UN Environment Programme** set up the **Intergovernmental Panel on Climate Change (IPCC)** (www.ipcc), which reports on the scientific and economic research literature on climate change. These reports (including the current 6th report) suggest that global temperatures will rise by 1–6^{0}C during the twenty-first century. The variation in the estimates is due to the differing assumptions concerning the complex mechanisms and feedback systems that cause global warming.

The 2006 **Stern Review** on the economics of climate change was commissioned by the UK government to review the possible impacts of global climate change, to investigate the costs of these impacts, and to advise on policy actions. This review is the most widely quoted report on the economic effects of climate change, and possible policy responses. The review concludes on the scientific evidence that climate change is a serious threat, with many of the impacts being irreversible, and requires an urgent global response. The review estimates that with a 'business as usual' scenario, the overall costs of climate change will be in the region of 5% of GDP for each year over the next two centuries. Stern suggests that with alternative modelling assumptions, the costs may be as high as 20% of GDP for each year.

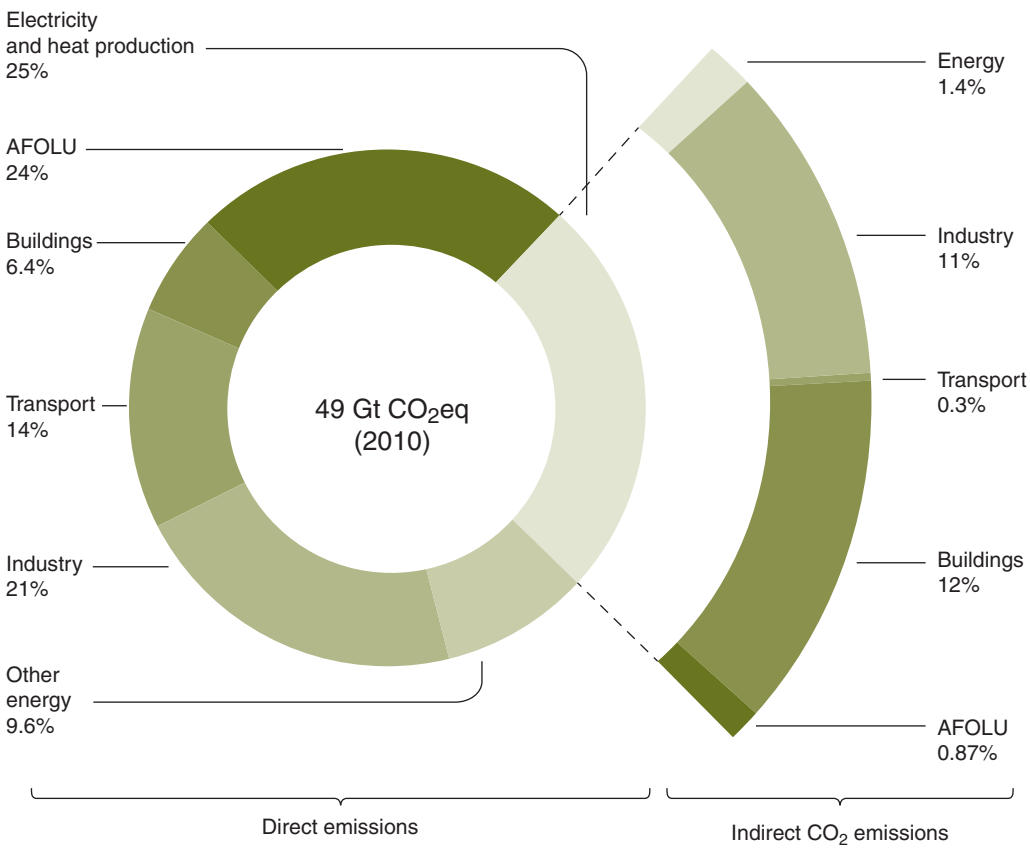
Stern calculated that a 2°C rise in global temperatures would cost about 1% of GDP. Subsequently, Stern (2008) has increased this estimate to 2% of GDP because of faster than expected climate change. The *World Development Report 2010: Development and Climate Change* puts the cost to Africa at 4% of GDP and India 5% (World Bank, 2010). The Stern Review estimates that greenhouse gas emissions need to be stabilized at 20% of current levels. It argues that the majority of these cuts must be borne by developed countries, but developing countries must also take significant action. It is suggested that such policies can help promote growth and development and, in particular, '[do] not cap the aspirations for the growth of poor countries' (Stern, 2006).

The different sources of global greenhouse gas emissions measured as CO_2 equivalents in 2014 are given in Figure 12.8. As can be seen in Figure 12.8, the biggest polluters are power generators and industry. We can also consider regional estimates of the use of energy and emission of greenhouse gases per capita and per $1,000 of GDP, as shown in Table 12.2.

It is clear from Table 12.2 who are the big energy users and where greenhouse gases come from. The USA uses by far the most energy per capita and is the biggest polluter per capita. Developed countries produce five times more CO_2 emissions per capita than developing countries. This is why poor countries think it is unfair that they should bear as much of the burden of adjustment to global warming as rich countries.

However, energy use and greenhouse gas emission measured relative to GDP are slightly higher for developing countries compared to developed countries, with transition economies

Figure 12.8 Greenhouse gasses by economic sector, 2014



Source: IPCC, 2014a.

Table 12.2 Energy use and CO_2 emissions, 2006

	Energy use per capita (tons of oil equivalent)	Energy use per $1,000 GDP	CO_2 emissions per capita (tons)	CO_2 emissions per $1,000 GDP
World	1.80	0.20	4.4	0.5
Developed countries	4.70	0.18	10.9	0.4
Europe	3.49	0.15	7.6	0.3
Japan	4.13	0.15	9.5	0.3
United States	7.74	0.21	15.2	0.5
Transition economies	3.87	0.48	8.1	1.3
Developing countries	0.97	0.21	2.3	0.5
Africa	0.66	0.28	1.0	0.4
Latin America	1.17	0.15	2.2	0.3
West Asia	2.76	0.36	6.8	0.9
Other Asia, excl. China	0.63	0.17	1.3	0.4
India	0.51	0.15	1.1	0.3
China	1.44	0.21	4.3	0.6

Source: UNCTAD, 2009.

faring the worst. This suggests that economic development is associated with energy and emission-intensive economic activity, which is most apparent in the intermediate and later stages of economic development. Thus, while the higher per capita use of energy and emissions in developed countries indicates that they should bear the major burden of reducing CO_2 emissions, developing and transition economies also need to take significant action to become more energy-efficient.

The Stern Review (Stern, 2006) believes that emissions can be reduced through the trading of emission permits, the pricing of carbon, the development and use of low-carbon technologies such as carbon capture, and action to reduce deforestation. Throughout the review, it is emphasized that the poorest countries are the most vulnerable to climate change. It concludes that it is the duty of rich countries to bear the majority of the emission reductions and provide technical and financial assistance to developing countries to reduce their emissions and adapt to climate change.

The Stern Review has received strong support from a number of experts, including five Nobel Prize-winning economists: Kenneth Arrow, Robert Solow, James Mirrlees, Amartya Sen and Joseph Stiglitz. But it has also been criticized for overestimating the costs of climate change, underestimating the costs of reducing emissions, and, conversely, underestimating the costs of global warming to the environment. These criticisms are important, and, as the range and variety of views in the debate show, it is difficult to evaluate the weight of evidence on this complex subject.

A more technical, but important, criticism of the Stern Review is its use of a low discount rate over time for estimating the present value of the costs of climate change (see Nordhaus, 2007; Dasgupta, 2007). As discussed earlier, the choice of discount rate is a complex technical and ethical issue concerning how to value the future relative to the present. The low values taken by the Stern Review result in greater estimated costs of global warming than may be found in less pessimistic studies (e.g. Nordhaus, 2007).

The Stern Review is undoubtedly the most important report on probably the most pressing economic issue that faces the world in the future. It has many detractors and as many supporters. Either way, the importance of climate change to future economic development requires expensive decisions to be made by the world economic community in the short term. The World Bank (2010) calculates that to keep global warming down to an increase of 2^0C by 2050 will cost developing countries alone a minimum of US$140 billion a year (compared with $8 billion they are currently receiving for climate change mitigation). The cost of adapting to global warming (as opposed to trying to stop it) would be $75 billion, compared to the $1 billion now available.

However, it needs to be understood that all these estimates, as well as those contained in the 5th IPCC report (IPCC, 2014b), are generated by complex models that combine science and economics. As recently argued by Stern (2013), many of these models appear to seriously underestimate the risks, which means that achieving the 2°C target is unlikely and that temperature rises of 4°C are potentially plausible. As Stern (2013, p. 839) clearly explains:

> The economic models add further underassessment of risk on top of the underassessment embodied in the science models, in particular because they generally assume exogenous drivers of growth, only modest damages from climate change and narrow distributions of risk.

Therefore, we should treat all the cost estimates presented in the literature with a great deal of caution and be prepared for unanticipated economic shocks that may well result from the impact of climate change in the future.

Climate change and the poor

It is now widely acknowledged that climate change is taking place in a serious way, and that poorer countries are most vulnerable to the impacts of such change (Stern, 2006; World Bank, 2003, 2010; Greenstone and Jack, 2015). This vulnerability results from the close dependence of poor countries and poor people on the natural environment and their limited human, institutional and economic capacity to respond to the effects of climate change. The World Bank (2010), in its *World Development Report 2010: Development and Climate Change*, gives four major reasons why the poor are more vulnerable to climate change than the rich:

1. Natural disasters, such as hurricanes and floods, hurt them more because of poor housing, poor health and inadequate healthcare. In the early 1980s, fewer than 500 million people required international disaster assistance. In the early 2000s, the number was 1.5 billion.
2. Related to the above, global warming increases the chances of catching life-threatening diseases such as malaria, meningitis, dengue fever and diarrhea. It is estimated that by 2030, 90 million extra people in Africa alone may be exposed to malaria as the temperature rises.
3. Poor countries are particularly prone to flooding. Of the fifteen largest cities in the developing world, ten are in low-lying coastal areas, including cities such as Shanghai, Dhaka and Cairo, all with over 10 million inhabitants.
4. Climate change affects agriculture and fishing on which many poor countries still rely for everyday living. The climate, by becoming more extreme, with more drought and more flooding, is starting to affect agricultural productivity. In the short term, some countries may benefit from being able to grow new products, but for most developing countries, agricultural productivity is predicted to fall as a result of climate change. This is likely to lead to greater hunger and famine. The number of malnourished children could rise by 25 million. Warren et al. (2006)

estimate an additional 600 million people in poor countries are at risk from starvation by 2050 if nothing is done. The IPCC (2007) predicts that yields in agriculture may fall by up to 50% by 2050, and the price of staples such as wheat and rice could more than double. Africa is regarded as the most vulnerable continent because of climate variability and its weak capacity to adapt.

As a consequence of the vulnerabilities faced by the poorest nations, it has been suggested that it is critical that developing countries adapt to the consequence of climate change (see Nyong, 2009; Brainard et al., 2009). This adaptation includes increased foreign financial and technical assistance, improved governance, better planning and information, the sharing of information between similar regions and countries, and increasing the resilience of the present types of economic activity and infrastructure to climate change. A particular concern is that climate change will result in substantial migration of population within and between countries and increased pressure on scarce natural resources such as water. Their impacts are likely to result in increased conflict between and within countries (see Bushby (2009) for an analysis of the security implications in developing countries of climate change).

One policy to mitigate fossil fuel CO_2 emissions is to grow biomass (e.g. maize or oil crops) that can be converted into liquid fuels (see IPCC, 2014a). An effect of the shift in the use of land to biomass production can, however, be a reduction in food production, resulting in reductions in supply and finally price increases, especially for the poor. Indeed, it was argued by some that such policy induced changes brought about the price spikes observed in food commodities in 2007/8. Yet, as observed by Wright (2014), biofuel policies adopted in the West are not the typical sources pointed to as causing the price spikes by many of the research agencies that have an agricultural development agenda. Also, Wright (2014) observes that the price increases during this period are far from unprecedented within recent times.

Despite these important policy implications, the IPCC (2014b) has once again argued that agriculture and forestry could become important sectors in mitigating CO_2 emissions via the deployment of bioenergy. If this is to be achieved, it will involve significant adaptation within many farming and forest management systems that will require significant international efforts. And, more importantly, such a policy proposition needs to be sensitive to potential real market effects of government policy, which have, in the past, been ignored by the policy-makers (Wright, 2014).

Of potentially most importance for policy-makers attempting to understand and cope with the issues that arise for the poor as a result of climate change are the Sustainable Development Goals (SDGs). The SDGs of eradicating extreme poverty and hunger and ensuring environmental sustainability are closely linked. Unfortunately: 'the plight of the poor is directly linked to natural resources around them [and as] total emissions continue to grow … the expected repercussions of climate change will affect [them]' (UN, 2005). As previously noted, given the obvious challenges faced, the SDGs have an explicit action (Goal 13) to deal with climate change and an associated set of targets. It remains to be seen if the SDGs are more successful than the MDGs in helping the poor to deal with the potentially huge impacts that may result from climate change.

Finally, despite the obvious relationship between environmental quality and associated health and productivity consequences, the value that households in many developing countries place on the environment remains low (Greenstone and Jack, 2015). This puzzle has led to more research that attempts to address the following question: Why is environmental quality so poor in developing countries? Greenstone and Jack (2015) identify four possible answers:

1. Society places a low value on environmental quality (this argument is related to the environmental Kuznets curve).
2. The costs of achieving improvements in environmental quality are high so there is a lack of effort.

3. The political economy can be such that the environment is undervalued.
4. There may well be a large number of market failures that have not been corrected and, as such, cause a simple misallocation of resources and economic activity.

This clearly indicates that the nexus between the environment and development is and will remain a key area of research for many years to come.

International agencies, agreements and the environment[2]

Since 1990, international agencies have begun to accept the importance of allowing for the environment in economic development and have started to change their practices.

The World Bank (1992) has accepted that the environment is directly relevant to its mission of supporting development and supports the sustainable development view. There are various aspects to its new policy view. First, it is accepted that there is a need for appropriate valuation of environmental effects. Since 1989, the World Bank has formally required environmental assessments of all projects that are expected to have a significant adverse environmental impact. However, there have been criticisms of whether these assessments contribute to actual project decision-making (see Lawrence, 2003). The World Bank (2001) has also recognized that 'the environment has yet to be fully mainstreamed in to the Bank's operations', but argues that the environment has a 'core task in supporting development and poverty reduction'.

Second, poverty is seen as a major cause of environmental damage and the poor are regarded as being heavily dependent on the environment (see earlier section on climate change and poverty).

Third, it is argued that high-income countries must accept financial responsibility and take the initiative for dealing with major worldwide environmental problems. However, it is also clear that the World Bank disagrees with the view that economic development should take place under the constraint that the stock of natural capital should not be depleted. It does now lend explicitly for environmental projects, and through the Global Environment Facility (GEF) makes grants to protect the environment. (Although the World Bank helped set up the GEF in 1991, at the Earth Summit in 1992, it was restructured to be a separate institution.) To date, the GEF has provided $US14.5 billion in grants and another $US75.4 billion in financing environmental projects (for details, see www.thegef.org). However, the benefits to the environment and native peoples of this lending have been disputed in the past (World Bank, 2001). There are also examples of other international sources of funding directly linked to climate change, such as the Green Climate Fund (see Case example 12.2).

Case example 12.2 **International funding of environmental projects: the Green Climate Fund**

The Green Climate Fund sits within the 2015 Paris Agreement on how to deal with climate change and is an example of a financial mechanism that aims to help support the achievement of the main objectives of the Paris Agreement, especially with regard to developing nations.

An example of the type of funding provided by the fund is the support of vulnerable communities in the Maldives to manage climate change-induced water shortages. In the Maldives, the outer islands are frequently short of water during the dry season. This has an obvious hard impact on the affected communities, in which more than 25% live below the US$2 per day poverty line. This means that some 105,000 people are affected and the majority of these are vulnerable households.

continued overleaf

Case example 12.2 **International funding of environmental projects** – *continued*

The proposed funding to be provided will enable three outcomes to be achieved by:

1. Increasing the scale of the water supply system to include vulnerable households.
2. The adoption and use of cost-effective dry water supply systems.
3. Improvements in groundwater use and management to ensure longer term environmental resilience.

To enable this to happen, the proposed project has a five-year duration, and a budget of almost $US30 million.

Source: www.greenclimate.fund/home.

Similarly, the IMF has slowly begun to recognize the need to take account of the environment in its structural adjustment programmes (SAPs) (see www.imf.org). The IMF has been criticized for only making token and superficial changes in policy (see Friends of the Earth website, www.foe.co.uk). Both the World Bank and the IMF are large international agencies where change is difficult to implement, and whether there is a commitment to implement changes in policies properly to protect the environment and the most disadvantaged persons in developing countries remains to be seen.

The World Trade Organization (WTO, www.wto.org) exists to promote the liberalization of world trade. The WTO's position is that sustainable development and environmental protection are important goals of the organization. WTO rules allow for trade-related measures to be adopted in order to protect the environment. However, the WTO believes that such measures are best managed through multilateral environmental agreements. Although the WTO has a dispute settlement procedure, it has not been used to deal with fundamental environment issues such as climate change. An important environment and trade issue is when developed countries reduce their production of goods that generate high levels of global warming gases and instead import such goods from developing countries. This helps developed countries meet their UN climate change obligations but it is likely to increase total global warming gas emissions. This complex and important subject is only just beginning to be considered by the WTO (see www.wto.org for details). The WTO believes that it is not appropriate for it to set environmental policies and standards. It believes that such issues should be considered by specialist and international negotiation. However, the WTO supports the objective of sustainable development and has been involved in assisting multilateral environmental agreements and increasing the awareness of links between trade and the environment (see Stokke and Thommessen, 2003).

The UN has been responsible for the two reports – *World Conservation Strategy* (IUCN/UNEP/WWF, 1980) and *Our Common Future* (UN WCED, Brundtland Report, 1987) – that have greatly influenced world opinion in favour of sustainable development. The UN Framework Convention on Climate Change (UNFCCC) was signed in June 1992 at the Rio Earth Summit, with the specific objective of stabilizing greenhouse gas concentrations at levels low enough to prevent serious change to the climate system. Subsequently, the Kyoto Protocol of 1997 established legally binding commitments to reduce greenhouse gas emissions. The intention was to reduce by 2012 emissions of industrial countries to an average 5.2% below 1990 levels (the exact targets varied between countries). China, India and other developing countries were not given targets by the Kyoto Protocol but

were expected to take responsibility for reducing emissions of greenhouse gases, while their share of global emissions would be allowed to rise in order for them to meet their development needs.

There is general agreement on the Rio Declaration on Environment and Development's support of sustainable global development, and *Agenda 21* considers specific programmes to achieve sustainable development in the twenty-first century (UN, 1993). However, the Rio Earth Summit was criticized for its failure to secure a binding commitment to increase aid, reduce debt and fundamentally shift resources from rich to poor countries. But, since then, the UN has linked the goal of sustainable development to the goal of eradicating extreme poverty and hunger. However, for this to happen, it is necessary for governments and international organizations to intervene and improve the operation of markets with regard to the environment, in particular the impacts of climate change on developing countries.

Finally, the most recent global agreement on how to deal with climate change was achieved by 195 countries at the Paris climate conference (COP21) in 2015, which has become known as the **Paris Agreement**. It builds on the UNFCCC, in that it aims to improve the global response to the potential dangers from climate change, with a specific target of keeping temperature increases to less than 2^0C of pre-industrial levels. Furthermore, there is a stated intention to help and support developing nations deal and cope with the challenges that climate change will bring.

The Paris Agreement was reached by the implementation of a novel solution to the complex coordination problem that this issue faces. Specifically, every nation (party to the UNFCCC) was required to submit its proposed best set of activities and efforts to deal with climate change, both domestically and, in some cases, linked to policies that support developing economies' efforts, called **nationally determined contributions (NDCs)**. Importantly, the NDCs make explicit reference to the use of market-based instruments that use economic incentives to change and modify behaviour. In total, by April 2016, there were 161 intended NDCs from 189 parties. Thus, not all parties have provided their intended NDCs but the 161 accounts for 96% of all the parties to the UNFCCC, which covers almost 99% of all global emissions.

Although the Paris Agreement is an important achievement in terms of efforts to deal with climate change, serious questions exist in relation to the NDCs and the ability to limit the temperature increase identified. Current research suggests that the NDCs will reduce global average per capita emissions, but to achieve the temperature target, additional efforts will be required. Thus, although the Paris Agreement is a ground-breaking policy mechanism, the current level of intended actions are insufficient. For this reason, the Paris Agreement, signed in December 2015 and likely to come into effect by 2017, is only the start of global efforts to deal with the consequences of climate change.

Summary

- Economic development in the past has caused serious environmental damage and the current state of the environment will constrain further economic development in developing countries. The environment provides four major functions for the economy and society: life support, amenity, natural resources and waste absorption.
- The neoclassical view of the economy is that markets allocate scarce resources efficiently. Many environmental economists argue that markets fail to allocate efficiently and fairly, and the state should intervene to correct these market failures.
- Externalities occur when the action of one economic agent affects other economic agents and the actions are not controlled through the operation of the market. The burning of fossil fuels and the release of global warming gases is an example of an externality. The effects of

externalities and, in particular, pollution can be corrected to an extent by taxation, subsidization, bargaining, marketable permits and regulation.

- Economic analysis of the environment requires the comparison of the costs and benefits of environmental effects in the present and future, and this is achieved using the device of the discount rate.
- The efficient use of renewable and non-renewable resources across time depends on their social value, the growth of renewable resources, the reserves of non-renewable resources, and the discount rate. The market will not necessarily use renewable and non-renewable resources efficiently.
- Economic analysis of market failures suggests that they can be corrected for in environmental decision-making by estimating and allowing for additional environmental values: external costs, a premium on the prices of non-renewable resources such as oil; value placed on the existence of environmental goods and services by the present generation and its wish to pass on the environment to future generations, and impact of uncertainty on the environment.
- The World Bank and other agencies have attempted to adjust measures of national income for environmental degradation caused by economic activity. The relation between economic development and the environment is complex and the subject disputed.
- The major idea of sustainable development has emerged since the 1980s, in which the well-being of future generations is not compromised by meeting the material needs of the present generation. This idea emphasizes the natural environment supporting economic activity and suggests that the world should be very cautious in depleting natural capital.
- The mitigation of climate change, and global warming, is a major challenge in the twenty-first century.
- The Stern review (2006) is the most comprehensive analysis to date of the costs of climate change and the costs of mitigation.

Chapter 12 Discussion questions

1. What are the functions of the environment in supporting economic activity?
2. What are the different possible solutions to externalities?
3. Explain the causes of 'the tragedy of the commons'.
4. What conditions determine the efficient use of renewable and non-renewable resources?
5. What are the different types of economic value that should be included in social costs?
6. How might one allow for environmental effects in social cost–benefit analysis and national income accounting practices?
7. Define and explain the idea of sustainable development.
8. What are the arguments for and against keeping the stock of natural capital fixed?
9. What are the physical and economic impacts of climate change?
10. How are the poor in developing countries affected by climate change?
11. How have international organizations responded to the ideas of sustainable development and the economic importance of the environment?

Notes

1. See Barbier (1989) for a good survey of the history of economic thought on the environment and development.
2. For a clear summary of the objectives and activities of most international agencies working in the environmental and development fields, see Stokke and Thommessen (2003).

Websites on the environment

International Institute for Environment and Development www.iied.org
World Watch Institute www.worldwatch.org
World Resources Institute www.wri.org
United Nations Environment Program www.unep.org
UN Sustainable Development Knowledge Platform https://sustainabledevelopment.un.org
World Bank www.world bank.org.
Friends of the Earth www.foe.org
Environmental Democracy Index www.environmentaldemocracyindex.org
World Trade Organization www.wto.org
International Monetary Fund www.imf.org