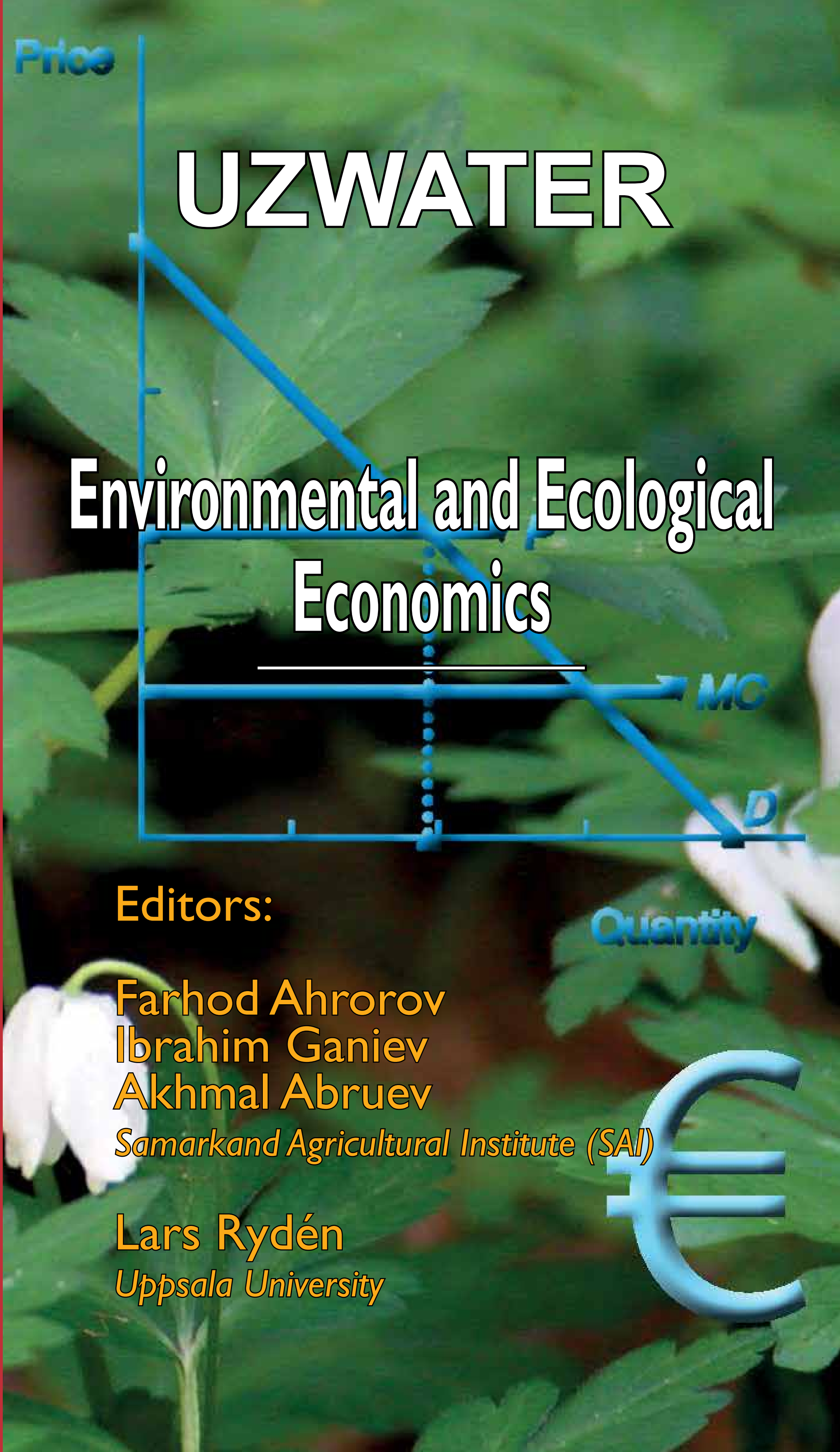

UZWATER

Environmental and Ecological Economics

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Theory and Tools of Environmental and Ecological Economics

Chapter 1
Environmental Challenges and Central Asia

1.1 Uzbekistan's environmental problems

Future societies will be confronted by both resource scarcity and accumulating pollutants. Many specific examples of these broad categories of problems are discussed in detail in the following chapters. This section provides a flavour of what is to come by illustrating the challenges posed by one pollution problem (climate change) and one resource scarcity problem (water accessibility).

Uzbekistan's main environmental problems are soil salinity, land pollution, and water pollution. In 1992, Uzbekistan had the world's 27th highest level of carbon dioxide emissions, which totalled 123.5 million metric tons, a per capita level of 5.75 metric tons. In 1996, the total dropped to 94.9 million metric tons. Chemicals used in farming, such as DDT, contribute to the pollution of the soil. Desertification is a continuing concern.

The nation's forestlands are also threatened and continue to dwindle. Between 1990 and 1995 deforestation occurred at an annual average rate of 2.65%.

The country's water supply also suffers from toxic chemical pollutants from industrial activity as well as fertilizers and pesticides. Uzbekistan has 16.3 km^3 of renewable water resources, with 94% used for farming and 2% used for industrial purposes. The Aral Sea has been drying up and, as a result, pesticides and natural salts in its water have become increasingly concentrated. The nation's cities produce an average of 45.8 million tons of solid waste per year.

As of 2001, only 1.8% of Uzbekistan's total land area is protected. In 2001, 7 mammal species and 11 bird species were threatened with extinction. Threatened or rare species include the markhor, the Central Asian cobra, Aral salmon, slender-billed curlew, and Asiatic wild dog.

1.2 Climate change

Energy from the sun drives the earth's weather and climate. Incoming rays heat the earth's surface, radiating energy back into space. Atmospheric "greenhouse" gases (water vapour, carbon dioxide, and other gases) trap some of the outgoing energy.

Figure 1.1. Map of Uzbekistan. Encyclopedia Britannia. http://kids.britannica.com/elementary/art-66919/Uzbekistan.

Without this natural "greenhouse effect," temperatures on the earth would be much lower than they are now, and life as we know it would be impossible. It is possible, however, to have too much of a good thing. Problems arise when the concentration of greenhouse gases increases beyond normal levels, thus retaining excessive heat somewhat like a car with its windows closed in the summer.

Since the Industrial Revolution, greenhouse gas emissions have increased considerably. These increases have enhanced the heat-trapping capability of the earth's atmosphere. According to the Intergovernmental Panel on Climate Change's Fifth Assessment Report (2014), "Warming of the climate system is unequivocal . . .". That study concludes that most of the warming over the last 50 years is attributable to human activities.

As the earth warms, extreme heat conditions are expected to affect both human health and ecosystems. Some damage to humans is caused directly by increased heat, as shown by the heat waves that resulted in thousands of deaths in Europe the hot summer 2003.

Human health can also be affected by pollutants, such as smog, that are exacerbated by warmer temperatures. Rising sea levels (as warmer water expands and previously frozen sources such as glaciers melt), coupled with an increase in storm intensity, are expected to flood coastal communities. Ecosystems will be subjected to unaccustomed temperatures; some will adapt by migrating to new areas, but others may not be able to adapt in time. While these processes have already begun, they will intensify slowly throughout the century.

Climate change also has an important moral dimension. Due to their more limited adaptation capabilities many developing countries that have produced relatively small amounts of greenhouse gases are expected to be the hardest hit as the climate changes.

Dealing with climate change will require a coordinated international response. That is a significant challenge to a world system where the nation-state reigns supremely and international organizations are relatively weak.

1.3 Impacts on water, land and biodiversity

Many of the environmental challenges in Central Asia are closely linked to regional water and energy issues. The massive diversion of water for irrigation has resulted in the widespread destruction of ecosystems, especially in the Aral Sea and the river deltas. Mismanagement of irrigation infrastructure has caused land salinization, swamping, desertification and declining ecosystems. Environmental changes such as deforestation and climate change are in turn affecting the formation of river flow and availability of water throughout the region. And environmental pollution aggravates water scarcity by making water resources unsuitable for agricultural or domestic use.

Similarly, extraction, transportation, transformation and use of all forms of energy have had significant environmental impacts, caused for example by oil drilling, coal mines, pipelines, dams and thermal power stations.

In a region where 60% of the population is engaged in agriculture, land has been a central component of development. Soviet policy was to bring more land into cultivation by extending the irrigated area by more than 70% between 1960 and 2000. Population growth largely negated this development, however, with per capita land availability actually decreasing by more than 40% over the same period. Land is in particularly short supply in the mountainous countries of Kyr-

Figure 1.2. Some old fishing boats in Moynaq, Aral Sea, Uzbekistan. Photo: Mr Hicks46. https://www.flickr.com.

gyzstan and Tajikistan, and in the densely populated regions of Uzbekistan (Samarkand and Khorezm Provinces, and the Fergana Valley).

Since 1991, *regional agricultural yields* have reportedly declined by 20 to 30%, causing annual losses in agricultural production of as much as $2 billion. A major contributing factor has been poor management of water. Between 1990 and 2000, the share of land in Central Asia with high groundwater levels increased from 25% to 35% of the total irrigated area. The area of salinized territories in the Amu Darya basin increased by 57% and in the Syr Darya basin by 79% from 1990 to 1999. More than 30% of irrigated land is salinized in Tajikistan and up to 40% in Kyrgyzstan. In addition, some 51% of agricultural lands are suffering from erosion in Kyrgyzstan and some 97% in Tajikistan.

In Central Asia, as elsewhere, people depend not only on cultivated land, but also on natural and semi-natural ecosystems for food and various other life support functions. Today, the useful productivity of such ecosystems is under significant threat, most notably in the degradation of the marine and coastal ecosystems of the Aral Sea. Other regionally important ecosystems – such as dry grasslands, river deltas and the mountains – are also declining at an alarming rate. Greatly impoverished saline deserts, *solonchaks*, have developed over an area of four million hectares affected by drainage waters. Flooded meadow soils in the deltas have dried up and transformed into takyr desert soils on over 1 million hectares.

In recent decades the area of natural lakes in the Amu Darya and Syr Darya deltas declined from 640 and 833 km^2 to 80 and 400 km^2, respectively, leading to the disappearance of once profitable fishing and musk-rat hunting and the complete loss of marshy areas for commercial use. In the Syr Darya delta, the biological productivity of commercially valuable reeds decreased by a factor of 30 to 35. Between 1970 and 1999, the area of old-growth tugai delta forests shrank by almost 90%. Whereas in 1960 more than 70 species of mammals and 319 species of birds (including the Khivin pheasant, raptors, the wild boar, the khangul or Bohara deer, and the reed cat) lived in river deltas, nowadays there are only 32 mammal and 160 bird species left.

Mountains are another category of regionally important ecosystems, occupying 93% of Tajikistan, 87% of Kyrgyzstan, 23% of Uzbekistan, 20% of Turkmenistan and 12% of Kazakhstan. More than 5.5 million people live in mountains in Central Asia. The main causes of mountain degradation include deforestation, overgrazing, unmanaged tourism and hunting, and poorly designed development projects. It is important that efforts to protect mountain ecosystems run concurrently with those to alleviate rural poverty.

Central Asia is also experiencing climate change, which affects water resources. In low-water years, the water flow in the Syr Darya basin can already be 37% less than average, and in the Amu Darya basin about 26% less than average. Many experts believe that the Central Asian climate will significantly warm up, resulting in major environmental, economic and social disruptions. Glaciers are already shrinking, which may eventually decrease water flows. From the 1950s to the 1990s, the Pamir-Alai glaciers lost 19% of their ice, with the process now gaining in intensity. For several decades, the area of glaciers in different regions of Tien Shan, Gissaro-Alai, Pamirs and Dzhungarskiy and Zailiyskiy Alatau has decreased at the average rate of about 1% per year. According to some model predictions, the availability of water in Syr Darya may decrease by up to 30% and in Amu Darya by up to 40%. Some other models do not predict such dramatic declines, but no scenario shows an increase in water flow; in all models, the demand for water grows faster than the natural supply.

Increasing occurrence of *droughts* and decreased grain productivity are also widely predicted. Given high uncertainties over these projections and the potentially serious consequences for human security and development in the region, it is necessary to constantly update and improve the knowledge (and its use in policy decisions) of natural processes in glaciers and mountain areas. No single country is capable of conducting such research on its own; as it stands, the last estimation of regional water resources using a common methodology was made 40 years ago.

While climate variations and changes in the mountain ecosystems seriously affect water quantity, environmental *pollution of the water* reduces its quality, often making it unsuitable for irrigation, drinking or commercial purposes. Since the 1960s, the water quality in Central Asia has drastically deteriorated. The main reason for this has been the discharge of heavily polluted water through drainage systems currently making up to 15% of the river flow volume of the Aral Sea basin. Effluent from municipal and industrial sewers and runoff from waste disposal sites and mining industries are other significant sources of pollution. The most visible result of pollution is the increasing salinity of water, especially in downstream areas. In the Republic of Karakalpakstan, for example, river water is unsuitable for drinking 10 months a year due to excessive mineral residues.

1.4 Water management in Uzbekistan – the historic background

The last years of the Soviet period witnessed increasing natural resource degradation due to massive irrigation and drainage system development as well as the conversion of vast tracts of deserts into irrigated agricultural land (Gleick, 2000). Downstream regions of Uzbekistan along the Syr-Darya and the Amu-Darya basins have exhibited increased trends in land and water degradation and declining crop yields as a result. This has threatened food security not only within the areas where degradation happens, but also in Central Asia as a whole (Klotzli 1994).

Since 1961, the water level of the Aral Sea has been declining progressively at the rate of 20 to 90 cm/yr. Accelerated salinization and desertification of land along with severe water pollution occur in the Amu-Darya and Syr-Darya deltas. The former bed of the Aral Sea is now an area of dust, pesticides, and salt. The decline of the Aral Sea also causes climate change in its basin. The water deficit is growing over time, especially in view of the population growth in Central Asia, increased water use by Afghanistan, and intensified desertification and climate change. Growth of water intake from the rivers into irrigation canals and losses in canals cause a flow reduction, and discharge of collector drainage water worsen its quality. Since the early 1960:s irreversible consumption of the river flow was doubled, and at present level it has increased four times in comparison with the 1930:s and 1940:s.

Deficit of water resources and their contamination is one of the most severe ecological problems within Uzbekistan. Water quality is an extremely important factor for all sectors of the economy and it plays a very important role in supporting ecological viability of water ecosystems and bio/hydro communities. Rivers, canals and reservoirs of the Republic are exposed to anthropogenic impact (including pollution), and its rate in many cases exceeds the self-purification capacities of natural water bodies. Water resources pollution caused by anthropogenic activities consists of: 1) pollution caused by agricultural activity; 2) pollution caused by industrial activity; 3) pollution caused by disposal of household and municipal wastes in urban and rural areas.

Irrigated agriculture is the basis of the socio-economic development of Uzbekistan. The country focused on agriculture during the Soviet period. A wide degradation of irrigated lands was observed under the conditions of the well-administrated irrigation system and state control of agricultural production. Uzbekistan`s excessive reliance on agriculture resulted in intensive land use and an excessive use of chemicals, which are detrimental for soil quality. This short term policy to achieve high productivity levels using chemicals and irrigation contradicts the long term goal of sustainability.

The last years of this period witnessed increasing natural resource degradation due to massive irrigation, drainage and the conversion of vast areas of deserts into irrigated agricultural land. Despite the benefits of irrigation to increase the agricultural productivity and to improve rural welfare, the practice also has negative impacts. In addition to high water use and low efficiency, the environmental problems are subject of concern. These include excessive waterlogging, soil salinization, water depletion and water quality degradation. Yield reductions of 20-30 % for cotton have been reported at medium salinity levels of the irrigated soils. About 54% of the land is polluted by pesticides, and over 80% has a high content of DDT, industrial pollutants (lead, cadmium, manganese, arsenic and zinc).

The use of low productive saline lands, disposal of untreated waste water in rivers, and inefficient wastewater treatment result in deterioration of water resource and an increase of water salinity. As a result of poor management by the former state-operated, large-scale irrigation systems the agricultural production is constrained by the decline of the quality of the soil and the water resources. Increasing water shortage already has an adverse effect on agricultural production. Mineralization of the available water increases. Accelerated salinization and desertification of land along with the severe degradation of water ecosystems occurs in the Amu-Darya and Syr-Darya deltas. Accelerated soil erosion reduces

Table 1.1 Available Water Resources of Uzbekistan (Average for 2002-2006). Source: MAWR, Ministry of Agriculture and Water Resources http://www.agro.uz 2008.

River basin	Intake from river			Underground water use	Collector drainage flow	Available water resources
	Trans-boundary	*Small rivers*	*Total*			
Syr-Darya	10,49	9,20	19,69	1,59	4,21	25,49
Amu-Darya	26,92	6,98	33,90	1,00	2,63	37,53
Total	37,41	16,18	53,59	2,59	6,84	63,02

soil fertility and stresses degradation of agricultural areas, which reduces crop production and worsens the environment.

1.5 Water resources and water accessibility

Another class of threats is posed by the interaction of a rising demand for resources in the face of a finite supply. Water provides a particularly interesting example because it is vital to life.

According to the United Nations, about 40% of the world's population lives in areas with moderate-to-high water stress. ("Moderate stress" is defined in the U.N. Assessment of Freshwater Resources as "human consumption of more than 20% of all accessible renewable freshwater resources," whereas "severe stress" denotes consumption greater than 40%.) By 2025, it is estimated that about two-thirds of the world's population – about 5.5 billion people – will live in areas facing either moderate or severe water stress.

This stress is not uniformly distributed around the globe. For example, in the United States, Mexico, China, and India, groundwater is being consumed faster than it is being replenished and aquifer levels are steadily falling. Some rivers, such as Colorado River in western United States and Yellow River in China, often run dry before they reach the sea. Formerly enormous lakes, such as the Aral Sea and Lake Chad, are now a fraction of their once historic sizes. Glaciers that feed many Asian rivers are shrinking.

According to U.N. data, Africa and Asia suffer the most from the lack of access to sufficient clean water. Up to 50% of Africa's urban residents and 75% of Asians lack adequate access to a safe water supply.

The availability of potable water is further limited by human activities that contaminate the finite supplies. According to the United Nations, 90% of sewage and 70% of industrial wastes in developing countries are discharged without treatment.

Figure 1.3. Amu-Darya close to Urgench and border to Turkmenistan. Photo: by stefan_fotos. https://www.flickr.com/.

Some arid areas have compensated for their lack of water by importing it via aqueducts from more richly endowed regions or by building large reservoirs. Regional and international political conflicts can result when the water transfer or the relocation of people living in the area to be flooded by the reservoir is resisting. Additionally, aqueducts and dams may be geologically vulnerable.

The Republic of Uzbekistan and the majority of the neighbouring countries are situated in the Aral Sea drainage basin, trans-boundary waters of which are in shared use for economic and environmental needs. The fresh waters of the rivers, lakes and reservoirs are used for irrigated farming, industrial and public utility sector needs. Water resources of the Republic of Uzbekistan are formed from renewed surface and underground water. Volumes of natural mean annual flow of the rivers are 123 km^3/year including 81.5 km^3 in Amu-Darya basin, and 41.6 km^3 in Syr-Darya basin. Volumes of actually available water resource of the Republic of Uzbekistan by sources of formation are given in Table 1.1. The table shows that about 60% of the available water is trans-boundary, which is subject to political controversy. 10.8 % of water has collector drainage source with a high level of mineralization and pollution.

Box 1.1 Solar electric power stations in Uzbekistan

The Scientific-Introduction Centre "ECO- ENERGIA has rich experience in projecting and building plants for the renewable energy sources such as power of the sun, biomass, small water flows and wind. Annually, the Centre puts into operation tens of the RES plants. For example, photoelectric solar stations were set up by the Centre's staff in the Navoi, Khorezm, and Kashkadaria Provinces in October 2009.

Four solar electric power stations for cattle-breeders and fish-breeders were set up in the Tomdi, Konimekh, and Nurata districts of the Navoi Province. Solar power is used for different purposes – desalination, drying and cooling. It helps to receive electric power, heat and hot water that raise the efficiency of cattle and fish breeding production. With the electric power the rural workers got uninterrupted access to mass media (TV, radio).

Solar power station appeared in the Bogot district of the Khorezm Province. In the Kashkadaria Province, a solar power station was also installed for a farming entity. The Scientific-Introduction Centre "ECO – ENERGIA" set up solar photoelectric stations at the village health care points and other medical facilities of the Termez district of the Surkhandaria Province, at the Kamashi and Chirakchi districts of the Kashkadaria Province, at the Izbazkan district of the Andijan Province, at the Jomboy district of the Samarkand Province and at the Uchkurgan district of the Namangan Province.

Strengthening of the material and technical base and power supply of the medical and preventive treatment institutions accompanied by the simultaneous raising of medical workers qualification provide the possibility to improve the quality of health services.

Source: O.Kis. Modernization of the Tashkent thermoelectric power plant, prospects and capabilities. JOOMLA, Open Source Content Management. 26.09.2014. http://eng.econews.uz/index.php/journal/115-eco-energy-will-help-the-village

In drought years these parameters are reduced up to 54.2 km^3. National renewed water resources of Uzbekistan make 11.5 km^3/year or 18,4% from total quantity of water consumption or 457 m^3 per capita/year. From 55.1 km^3 of average total water consumption 49.7 km^3 or 90.2% is used for irrigation purposes (MAWR, 2008).

Environmental conditions and sustainability of the national economy, in particular of the agricultural sector, greatly depends on water availability in a given region. Climatic peculiarities, that is strong continental climate, high evaporating capacity (up to 1700 mm a year), insignificant and irregular seasonal patterns of precipitation (on average 150-200 mm), as well as high summer temperatures (up to 50°C) have led to the development of irrigated farming. The arid climate and high level of natural soil salinity has resulted in salt accumulation in the soil. Use of low productivity saline lands for agricultural production, in-stream disposal of collector drainage waters and inefficient wastewater purification systems results in deterioration of water resource quality and an increase in water salinity (UNDP, 2008).

1.6 Energy resources in Uzbekistan

Energy consumption is an indispensable condition of human existence. The Republic of Uzbekistan possesses large reserves of fuel raw materials, but one should remember that their use is connected to two very serious problems. First the reserves are entirely non-renewable fossil coal, oil and gas may be exhausted in the long run. Secondly they give rise to carbon dioxide emission when they are used and thus cause climate change. Thus, they need to be used carefully and efficiently, and in finally not at all. In the long run Uzbekistan need to develop renewable sources for production of power, such as wind, solar etc..

Uzbekistan is one of the few countries which are fully self-sufficient in energy resources. It is the second largest of the Caspian gas producers (after Turkmenistan) and its abundant natural gas resources are used both for domestic consumption and export. Oil and natural gas comprise 97% of the country's energy balance. Primary energy shares consist of 86.3% gas, 1.9% hydro, 2.5% coal and peat, and 9.3% crude oil. Uzbekistan is the largest electricity producer in Central Asia. Total national electricity capacity is 12.6 GW, of which 88.5% is provided by thermal power plants and 11.5% by hydropower plants.

The national electrification rate is 94.4%, but electricity supply to rural areas is unreliable and of low quality. There are often power blackouts that last many hours per day. Renovating the power transmission networks is one of the energy sectors priorities.

The Republic has a great capacity of using renewable energy sources and further development of the alternative production of power. At present, however, only hydropower of natural and artificial water-currents brings an appreciable share into Uzbekistan's energy balance. Other renewable sources are used insignificantly.

Introduction and practical application of the renewable energy sources (RES) in the rural area is especially important. It will help to raise living standards in the remote areas. Uzbekistan possesses a significant potential of renewable energy. The highest potential in Uzbekistan has solar energy, which is estimated in approximately 51 thousand million toe (tons of oil equivalent) technically – in 177 million normalized tons. Solar energy is accessible anywhere throughout the country's territory, and its inclusion into energy balance can promote a most rapid solution of the problems of providing the population with access to electric and thermal energy, especially in the remote regions.

The Scientific-Introduction Centre "ECO- ENERGIA" attached to the State Committee for Nature Protection of the Republic of Uzbekistan in 2005, actively continues to introduce and duplicate new technologies in the field of the RES.

The Centre is engaged in the searches and introduction in practice use of the resources of renewable energy sources with the purpose of environment protection and saving of mineral fuel resources.

High start-up costs, low gas and electricity prices, and the lack of renewable energy promoting policies are reasons for the limited use of renewable energy sources. Nonetheless, a law "On Renewable Energy Sources" has been drafted. The national strategy on the development of RES is being formulated with the assistance of UNDP. Due to its abundance of energy, the development of renewable energy is not a high priority for the Government of Uzbekistan, except hydro power. Uzbekistan has 18 large hydroelectric stations.

Uzbekistan's climate conditions favour solar energy. There are 250 sunny days per year and the technically feasible potential of solar energy is 177 million toe (2 million GWh), which is much more than the national annual consumption. However, this potential energy source remains largely untapped due to high start-up costs.

Uzbekistan also has a high potential for biomass energy generation as it is the fourth largest producer of cotton in the world. Wood is not a prospective option for energy production because Uzbekistan has very little forest coverage.

Compared with traditional energy systems, renewable power engineering can serve the individual users in a so-called distributed energy system. It is possible to install photoelectric solar stations on every roof and every building. Biogas can be received at every farm. Thus instead of operating an enormous energetic system serving millions and millions of people; it is possible to develop a system, in which millions of power generation facilities working for the benefit of the millions and millions of people. And this is the choice of the future.

1.7 Meeting the environmental challenges

As the scale of economic activity has proceeded steadily upward, the scope of environmental problems triggered by that activity has transcended geographic and generational boundaries. The nation-state used to be a sufficient form of political organization for resolving environmental problems, but is that still the case?

Whereas each generation used to have the luxury of being able to satisfy its own needs without worrying about the needs of generations to come, intergenerational effects are now more prominent. Solving problems such as poverty, climate change, ozone depletion, and the loss of biodiversity requires international cooperation. Because future generations cannot speak for themselves, the current generation must speak for them. Current policies must incorporate our obligation to future generations, however difficult or imperfect that incorporation might prove

Figure 1.4. Desert storm near Nawoiy Vilayat in Uzbekistan bordering Kazakhstan and Karakalpakstan and also the provinces Samarkand and Buchara. Photo: Mariusz Kluzniak. https://www.flickr.com/

to be. International cooperation is by no means a foregone conclusion. Global environmental problems can result in very different effects on countries that will sit around the negotiating table. While low-lying countries could be completely submerged by the sea level rise predicted by some climate change models, arid nations could see their marginal agricultural lands succumb to desertification.

Other nations may see agricultural productivity rise as warmer climates in traditionally intemperate regions support longer growing seasons. Countries that unilaterally set out to improve the global environmental situation run the risk of making their businesses vulnerable to competition from less conscientious nations. Industrialized countries that undertake stringent environmental policies may not suffer much at the national level due to offsetting increases in income and employment in industries that supply renewable, cleaner energy and pollution control equipment. Some specific industries facing stringent environmental regulations, however, may well face higher costs than their competitors, and can be expected to lose market shares accordingly. Declining market shares and employment resulting from especially stringent regulations and the threat to outsource production are powerful influences. The search for solutions must accommodate these concerns. The market system is remarkably resilient in how it responds to challenges. As we shall see, prices provide incentives not only for the wise use of current resources but also for promoting innovations that can broaden the menu of future options.

Yet, as we shall also see, market incentives are not always consistent with promoting sustainable outcomes. Currently, many individuals and institutions have a large stake in maintaining the status quo, even when it involves environmental destruction. Fishermen harvesting their catch from an overexploited fishery are loath to reduce harvests, even when the reduction may be necessary to conserve the stock and to return the population to a healthy level. Farmers who depend on fertilizer and pesticide subsidies will give them up reluctantly.

Despite a high demand for irrigation water, Uzbekistan has a limited direct ability to influence the timing and volume of cross-border water inflows because it is located midstream. In the short term, its best policy option is to cooperate over water and energy. Uzbekistan has followed this strategy in the past by participating in the annual barter agreements, although in recent years it has taken a decisive unilateral stance in not agreeing to these. Uzbekistan has objected to the Kyrgyz notion that water is a commodity that should be paid for and has referred to relevant international water agreements. Furthermore, Uzbekistan is trying to achieve self-sufficiency in water by constructing new regulating dams on its own territory. These dams could provide additional storage of about 2.5 billion m^3 within the next few years, which could replace the equivalent additional discharge from Toktogul in winter and summer in years of normal water flow. Though they alleviate Uzbekistan's problems in low-water years, albeit at considerable costs, the reservoirs do not appear to be sufficiently large enough to achieve Uzbek self-sufficiency in irrigation water.

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Chapter 2
Modelling the Environment and the Economy together

2.1 A conceptual model of the environment and the economy

A basic building block of economic theory is the standard "circular flow" model of an economic system. As illustrated in Figure 2.1, this model shows the exchange of goods, services, and factors of production between two types of economic actors, consumers (households) and producers (firms). However, the environment and the natural resources which make economic production possible do not appear in the usual version of this model.

When a good or service is purchased, two kinds of flow occur: the good moves from the firm to the household and a corresponding payment moves from the household to the firm. Similarly, when firms purchase factors of production, a payment of money for the use of these factors accompanies the flow of factor

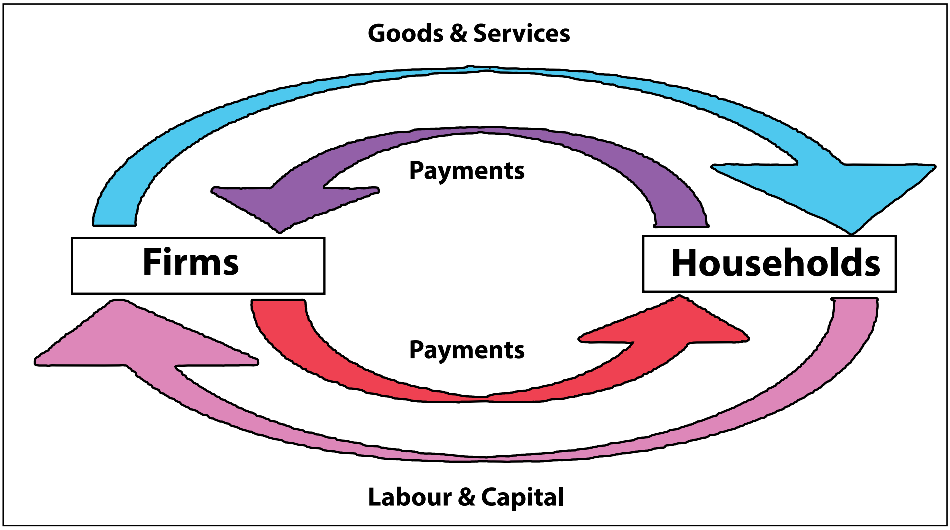

Figure 2.1. The Standard Circular Flow Model. Source: Main text Jonathan M.Harris and Anne-Marie Codur Macroeconomics and the Environment. Copyright © 2004 Global Development And Environment Institute, Tufts University. http://ase.tufts.edu/gdae.

services from households to firms. These transactions are symbolized on the graph above by the arrows going in both directions – from firms to households and vice versa. We distinguish between the two kinds of flows, real economic flows and the monetary flows which are their counterpart. The former are called "real" as they correspond to transfers of tangible things: goods and services flowing from firms to households; factors of production flowing from households to firms.

Can we locate the environment or natural resources in this picture? Certainly natural resources are essential to production: agriculture requires productive soils, industry requires fuels, water, and minerals. Consumers need drinking water, and many environmental resources, such as beaches and woodland, are in high demand. How is all this reflected in the circular flow?

Factors of production, which are also called inputs for the production process, have traditionally been divided into three categories: *land, labour, and capital*. "Land" is the term which is used by economists to represent all natural resources used in economic production, including soils, water, forests, species, minerals, fossil fuels, and other such resources. The first thinkers who studied economic mechanisms during the eighteenth and nineteenth centuries recognized the importance of land in the production process, and emphasized the existence of natural constraints on economic growth. These theorists included the Physiocrats such as Quesnay, who developed the first circular flow approach in 1758, and the Classical Economists of the late eighteenth and nineteenth centuries, including Adam Smith and David Ricardo.

Later, in the second half of the 19th century, economists focused increasingly on the two other factors of production, capital and labour, which were essential in the growth of the industrial sector, as rapid industrialization became the major economic phenomenon of these times. The eclipse of natural resources in economic thought lasted more than a century. Only recently, with the increasing urgency of environmental and resource problems at local, national, and global levels, have economists once again focused on the issues of natural resource constraints and the issue of what has come to be called *natural capital*. Natural capital includes all natural resources as well as the environment. It is essentially an updated interpretation of the classical economic concept of "land".

Using the term "natural capital" emphasizes the importance of these natural factors to the production process. It also indicates that what we ordinarily call "capital" is really *manufactured capital*. Both types of capital are essential to the productive process, and both contribute to society's wealth.

2.2 Dealing with natural capital

Returning to the circular flow model from Figure 2.1, let's consider whether the simple diagram deals adequately with natural capital. Economic models of the circular flow are usually presented as totally self-contained. But who or what ultimately provides households with the factors of production which will become inputs for the production sphere?

It is fairly clear that labour and manufactured capital is regenerated through the circular flow model in Figure 2.1. The provision of food and other necessities makes more labour possible, and investment builds up manufactured capital over time. But what about the first factor of production, natural resources?

Obviously, households and firms do not "create" energy, minerals, soils, water, forests, species, and all the diverse elements which form the broad category of natural capital. They may "own" them – if the legal system adequately defines private property rights to these different resources – but they cannot generate them, or replace them if they are used up. The "hidden" provider of these amenities, whether you call it Nature, Planet Earth or the *biosphere*, needs to be reintroduced in the picture as a major actor – or perhaps better as the stage – without which the whole economic "show" could not take place.

How can we introduce the biosphere into the circular flow? We need to show the complete picture of its relationship with economic activity: as a provider of natural resources and also as the receptor of various undesirable outputs of the production/consumption processes (pollution and wastes).

Since the sphere of economic activity (we will call it the "economic sphere") is embedded in the biosphere, we can replace the previous graph by a more complete one that represents the diverse flows of inputs and outputs between the biosphere and the economic sphere as well as inside the economic sphere. This is shown in Figure 2.2.

We must also take into account the fact that some of the wastes and pollution rejected in the biosphere are naturally recycled through biological processes and geophysical processes. For instance, wetlands play an essential role in purifying polluted waters. A few of the wastes of the production process are also recycled through the industrial system itself (including some paper, glass, and metals) and re-injected into the production process as raw material.

This means that we have to do some rethinking of standard economic concepts such as gross national product and economic growth. If we take the full circular flow into account, we will need to revise the standard ways of measuring economic wealth and income, and also to reconsider the effects of continual economic growth on human well-being.

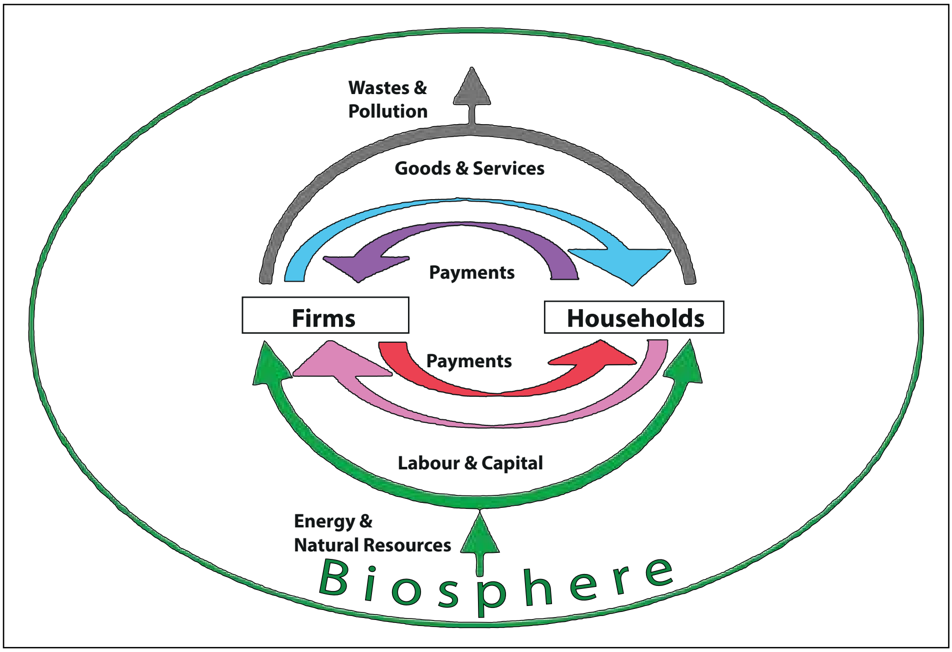

Figure 2.2. Conceptual model of the Environment and the Economy. Source: Main text Jonathan M.Harris and Anne-Marie Codur Macroeconomics and the Environment. Copyright © 2004 Global Development and Environment Institute, Tufts University. http://ase.tufts.edu/gdae.

2.3 Externalities

One job of policymakers is to understand how resources can be utilized most efficiently in order to accomplish the desired goals by weighing the costs of various alternatives to their potential benefits. In competitive markets, information exists about how much consumers value a particular good because we know how much they are willing to pay. When natural resources are involved in the production of that particular good, there may be other factors – scarcity issues, the generation of pollution – that are not included in its production cost. In these instances, scarcity issues or pollution become *externalities*, costs that are external to the market price of the product. If these full costs were included, the cost of the good may be higher than the value placed on it by the consumer.

A classic example of an externality is discussed in Garrett Hardin's Tragedy of the Commons, which occurs in connection to public commons or resources – areas that are open and accessible to all, such as the seas or the atmosphere. Hardin observed that individuals will use the commons more than if they had to pay to use them, leading to overuse and possibly to increased degradation.

It was Alfred Marshall (1842-1924) who first observed that the results of an activity often do not limit themselves to what is deliberately intended. They are accompanied by external effects or externalities, e.g. when the welfare level of other people, who do not take direct part in the activity, is affected. If the external impact causes loss of welfare, then it is called a negative externality, if it gives rise to increased welfare it is a positive externality. An important feature of an externality is that neither corresponding costs nor benefits are borne or received by the agent causing the externality. Thus, private costs or benefits of the activity differ from its social costs or benefits. Social costs or benefits refer to all effects of the activity, both the direct ones, appropriated by the involved party, and the externalities, borne by others.

The basic concept of the market mechanism, the famed "invisible hand," is based on the notion that each of the economic agents – producers and consumers alike – is pursuing individual self-interest and try to maximise his/her private surplus of benefits over costs. The very existence of externalities as the difference between private and social effects means that the market forces can induce private decisions which, while being rational from the point of view of individual self-interest, may be inefficient from the point of view of society as a whole.

This impotence of the "invisible hand" is called market failure. Arthur C. Pigou (1877-1959), who cited pollution as a classical example of a negative externality, searched for ways "to cure" market failures and proposed that they should be internalised, i.e. making them part of the undertaken economic decisions. Pigou argued that agents should be made responsible for the external costs of their actions via the introduction of an appropriate tax (Pigouvian tax) proportional to the size of externality. He also gave theoretical proof that such tax is, in principle, able to correct market failures.

There are three general schools of thought associated with reducing or eliminating environmental externalities. Most welfare economists believe that the existence of externalities is sufficient justification for government intervention, typically involving taxes. Market economists tend to advocate the use of incentives to reduce environmental externalities, rather than command-and control approaches, because incentives allow flexibility in responding to problems rather than forcing a singular approach on all individuals. Free market economists focus on eliminating obstacles that prevent the market from functioning freely, which they believe would lead to an optimal level of environmental protection and resource use. The key objective of environmental economics is to identify those particular tools or policy alternatives that will move the market toward the most efficient allocation of natural resources. It was the analysis of market mechanisms that brought neo-classical theory to discover externalities and market failures, both of cardinal importance for the development of environmental economics.

2.4 Ecosystem services

In economics, the environment is viewed as a composite asset that provides a variety of services. It is a very special asset, to be sure, because it provides the life- support systems that sustain our very existence, but it is an asset nonetheless. As with other assets, we wish to enhance, or at least prevent undue depreciation of, the value of this asset so that it may continue to provide aesthetic and life-sustaining services.

The environment provides the economy with raw materials, which are transformed into consumer products by the production process, and energy, which fuels this transformation. Ultimately, these raw materials and energy return to the environment as waste products (Figure 2.3).

The environment also provides services directly to consumers. The air we breathe, the nourishment we receive from food and drink, and the protection we derive from shelter and clothing are all benefits we receive, either directly or

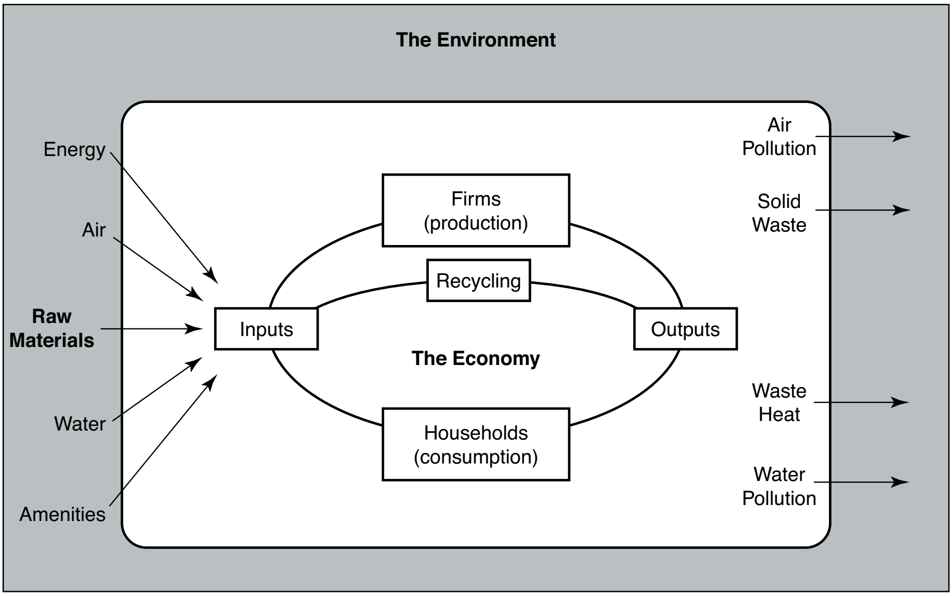

Figure 2.3 The human environment relationship. The Economic System and the Environment. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 17.

indirectly, from the environment. In addition, anyone who has experienced the exhilaration of white-water canoeing, the total serenity of a wilderness trek, or the breath-taking beauty of a sunset will readily recognize that the environment provides us with a variety of amenities for which no substitute exists.

If the environment is defined broadly enough, the relationship between the environment and the economic system can be considered a closed system. For our purposes, a closed system is one in which no inputs (energy or matter) are received from outside the system and no outputs are transferred outside the system. An open system, by contrast, is one in which the system imports or exports matter or energy.

So what are Ecosystem Services?

Nature is priceless, but it is worth a lot. Although ecosystems underpin all human life and activities, people are often not aware of the benefits they receive from nature nor of their value. A good understanding of ecosystem services can lead to win-win situations. Studies for the Scheldt estuary e.g. show that floodplains can provide a cheaper protection against flooding than the construction of higher dikes only. In a famous study by Robert Constanza the monetary value of global ecosystems services was estimated to 33 trillion USD per year, more than the total global GDP. The costs of deteriorating ecosystem from 1997 to 2011 due to land use change were estimated to 4.3–20.2 trillion USD per year, an enormous sum.

Lack of knowledge on ecosystem services (ESS) and their value can lead to wrong decisions and even catastrophes. The overexploitation of the Aral Lake in Kazakhstan and Uzbekistan has reduced this once largest inland water mass with 90%, leaving a desert and causing large economic losses and illness to the surrounding population. Many more examples in the TEEB study are the benefits people obtain from ecosystems illustrate of the importance of ESS. (The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on making nature's values visible, to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. See www.teebweb.org)

The Millennium Ecosystem Assessment, a large UN project to assess the conditions of ecosystems, studied the conditions of ecosystems all over the world. It shows ecosystems services in four different groups.

- provisioning services, e.g. food production
- regulating services, e.g. regulating climate
- cultural services, enjoying being in nature, and
- supporting services maintaining the conditions for life on Earth, like nutrient cycling and photosynthesis.

In 2005 Millennium Ecosystem Assessment reported that 60 % of ecosystems are deteriorating. The report, MA 2005, called for a continuing study of the ecosystems in parallel to the IPCC, the UN Panel on Climate Change. Such a work has started and the new platform called *Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES)* was established in 2012.

The ecosystems and biodiversity of Uzbekistan provide a wide variety of essential services to residing population, such as reliable and clean flows of water, productive soil, healthy forests, clean air, recreation opportunities, and climate regulation, amongst many others. Biodiversity is one among these services. There are more than 26 thousand wildlife species in Uzbekistan, including 15 thousand plants and 11 thousand animals. Important ecosystem services include the water ecosystems, which provide crucial services towards land management, forests and water for drinking, grazing and irrigated agriculture purposes. Present nature use practices and human activities are not always sustainable and lead in many places to ecosystem degradation. This often results in diminishing biodiversity, desertification, salinization, degradation of the natural landscape, diminishing water quality, frequent water shortages downstream, and many other issues.

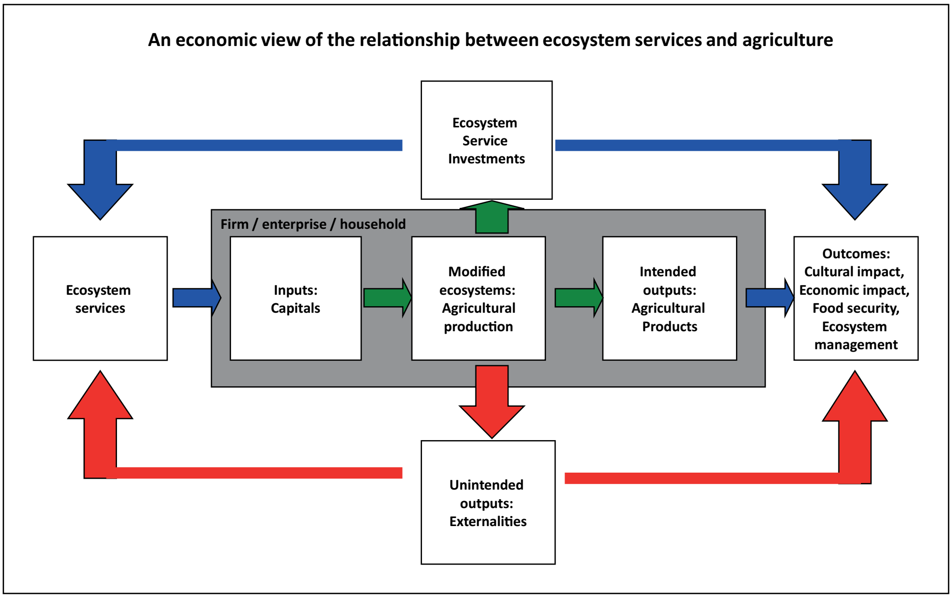

Figure 2.4 An economic view of the relationship between ecosystem services and agriculture.
Source: Farhod Ahrorov and Akmal Abruev.

Payment for Ecosystem Services (PES) represents a market-based tool for the more efficient ecosystems management and biodiversity protection to complement the command-and-control measures. A definition of PES states that Payments for Ecosystem Services is a contractual transaction between a buyer (e.g. farmer, timber logger, tourist, village or city resident) and a seller (e.g. farmer association, forest service, local government, private company) for an ecosystem service or a land use/management practice to conserve the ecosystems.

2.5 The environment as an open system

If we restrict our conception of the relationship in Figure 2.1 to our planet and the atmosphere around it, then clearly we do not have a closed system. We derive most of our energy from the sun, either directly or indirectly. We have also sent spaceships well beyond the boundaries of our atmosphere. Nonetheless, historically speaking, for material inputs and outputs (not including energy), this system can be treated as a closed system because the amount of exports (such as abandoned space vehicles) and imports (e.g., moon rocks) are negligible. Whether the system remains closed depends on the degree to which space exploration opens up the rest of our solar system as a source of raw materials.

The treatment of our planet and its immediate environs as a closed system has an important implication that is summed up in the first law of thermodynamics: energy and matter can neither be created nor destroyed. The law implies that the mass of materials flowing into the economic system from the environment has either to accumulate in the economic system or return to the environment as waste. When accumulation stops, the mass of materials flowing into the economic system is equal in magnitude to the mass of waste flowing into the environment.

Excessive wastes can, of course, depreciate the asset; when they exceed the absorptive capacity of nature, wastes reduce the services that the asset provides. Examples are easy to find: air pollution can cause respiratory problems; polluted drinking water can cause cancer; smog obliterates scenic vistas; climate change can lead to flooding of coastal areas.

The relationship of people to the environment is also conditioned by another physical law, the second law of thermodynamics. Known popularly as the *entropy* law, this law states that "entropy increases." The capacity for energy to do work is called *energy*. Even if energy is not lost its quality may be lost and energy decreases. Some energy is always lost during a conversion, and the rest, once used, is no longer possible to use for further work. The second law also implies that in the absence of new energy inputs, any closed system must eventually use up its available energy. Since energy is necessary for life, life ceases when useful energy flows cease.

We should remember that our planet is not even approximately a closed system with respect to energy; we gain energy from the sun. The entropy law does remind us, however, that the flow of solar energy establishes an upper limit on the flow of available energy that can be sustained. Once the stocks of non-renewable stored energy (such as fossil fuels and nuclear energy) are gone, the amount of energy available for useful work will be determined solely by the solar flow and by the amount that can be stored (through dams, trees, and so on). Thus, in the very long run, the growth process will be limited by the availability of solar energy and our ability to put it to work.

2.6 The economic approach

Two different types of economic analysis can be applied to increase our understanding of the relationship between the economic system and the environment: *Positive economics* attempts to describe what is, what was, or what will be. *Normative economics*, by contrast, deals with what ought to be. Disagreements within positive economics can usually be resolved by an appeal to the facts. Normative disagreements, however, involve value judgments.

Both branches are useful. Suppose, for example, we want to investigate the relationship between trade and the environment. Positive economics could be used to describe the kinds of impacts trade would have on the economy and the environment. It could not, however, provide any guidance on the question of whether trade was desirable. That judgment would have to come from normative economics, a topic we explore in the next section.

The fact that positive analysis does not, by itself, determine the desirability of some policy action does not mean that it is not useful in the policy process.

A rather different context for normative economics can arise when the possibilities are more open-ended. For example, we might ask, how much should we control emissions of greenhouse gases (which contribute to climate change) and how should we achieve that degree of control? Or we might ask how much forest of various types should be preserved? Answering these questions requires us to consider the entire range of possible outcomes and to select the best or optimal one. Although that is a much more difficult question to answer than one that asks us only to compare two predefined alternatives, the basic normative analysis frame-work is the same in both cases.

Also in the study of environment and economics there is a long term development of the subject. Originally we were dealing with *Environmental economics*. During this period the focus was on subjects such as costs for pollution, environmental taxes, charges and fees for services, such as water and waste management, and sometimes so-called green budgets. It remained much within traditional economics and the concepts used in national economy.

Especially from the 1990s *Ecological economics* has developed dramatically, with researchers such as Robert Constanza. It sees the environment and economy as a single system and argued that all economy finally depended on the environment and natural resources. Ecological economics developed the concepts of externalities, and the value of ecosystem services. It is dominated by such concepts as resource use, dynamic efficiency, intergenerational equity, valuation methods etc. This book is to a large extent using the concepts from ecological economics, as clearly developed in this chapter. Ecological economics is contributing to the development of a society and an economy for sustainable development.

From some years into the present decade the concept of *Green economy* has come into focus. Green economy was strongly promoted at the UN Rio+20 conference in Rio de Janeiro in 2012. Green economy focus on developing concepts useful for sustainable development. It is seen in contrast to the conventional, sometimes called brown, economy. In green economy concepts such as cyclic economy, bio-economy, and sharing economy (common use of resources) have developed. Green economy challenges some aspects in the conventional economy, such as using the Gross Domestic Product, GDP, as a measure of success, and wants to replace it with a measure of welfare. It also challenges the conventional growth economy, as it is too dependent on resource flows. Instead it has developed models for a non-growth economy. Green economy will be described and discussed later in the book.

Of course the concepts from all three of the main directions of economics and environment are used and essential for economists dealing with the environment. But it should be pointed out environmental economy is insufficient for working with sustainable development, and the green economy is developing many of the practical tools needed for approaching sustainable development of our societies.

Chapter 2 sources:

Sections 2.1 and 2.2 from Jonathan M.Harris and Anne-Marie Codur *Macroeconomics and the Environment*. Chapter 1. The circular flow model and the Biosphere. http://www.ase.tufts.edu/gdae/education_materials/modules/macroeconomics_and_the_environment.pdf. Copyright © 2004 Global Development and Environment Institute, Tufts University (http://ase.tufts.edu/gdae.

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Section 2.4 - 2.6 by Farhod Ahrorov and Akmal Abruev. These sections includes parts from Tietenberg, T., Lewis, L. (2012) *Environmental & Natural Resource Economics* 9th Ed. https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf Chapter 2 "The Economic Approach: Property Rights, Externalities, and Environmental Problems", with citations from p. 17 in Section 2.4, p. 18 in Section 2.5, and p. 19 in Section 2.6.

Chapter 3
Environmental Problems and Economic Efficiency

3.1 Environmental problems and economic efficiency

Before examining specific environmental problems and the policy responses to them, it is important that we develop and clarify the economic approach, so that we have some sense of the forest before examining each of the trees. By having a feel for the conceptual framework, it becomes easier not only to deal with individual cases but also, perhaps more importantly, to see how they fit into a comprehensive approach.

We develop the general conceptual framework used in economics to approach environmental problems. We begin by examining the relationship between human actions, as manifested through the economic system, and the environmental consequences of those actions. We can then establish criteria for judging the desirability of the outcomes of this relationship. These criteria provide a basis for identifying the nature and severity of environmental problems, and a foundation for designing effective policies to deal with them.

Throughout this chapter, the economic point of view is contrasted with alternative points of view. These contrasts bring the economic approach into sharper focus and stimulate deeper and more critical thinking about all possible approaches.

The chief normative economic criterion for choosing among various outcomes occurring at the same point in time is called *static efficiency*, or merely efficiency. An allocation of resources is said to satisfy the static efficiency criterion if the economic surplus derived from those resources is maximized by that allocation. Economic surplus, in turn, is the sum of consumer's surplus and producer's surplus.

Consumer surplus is the value that consumers receive from an allocation minus what it costs for them to obtain it. Consumer surplus is measured as the area under the demand curve minus the consumer's cost. The cost to the consumer is the area under the price line, bounded from the left by the vertical axis and the right by the quantity of the good. This rectangle, which captures price times quantity, represents consumer expenditure on this quantity of the good.

Why is this area thought of as a surplus? For each quantity purchased, the corresponding point on the market demand curve represents the amount of money some person would have been willing to pay for the last unit of the good. The total willingness to pay for some quantity of this good – say, three units – is the sum of the willingness to pay for each of the three units. Thus, the total willingness to pay for three units would be measured by the sum of the willingness to pay for the first, second, and third units, respectively. It is now a simple extension to note that the total willingness to pay is the area under the continuous market demand curve to the left of the allocation in question. For example, in Figure 3.1 the total willingness to pay for Q_d units of the commodity is the shaded area, were Q is the quantity of demanded good. Total willingness to pay is the concept we shall use to define the total value a consumer would receive from the five units of the good. Thus, total value the consumer would receive is equal to the area under the market demand curve from the origin to the allocation of interest. Consumer surplus is thus the excess of total willingness to pay over the (lower) actual cost.

Meanwhile, sellers face a similar choice (Figure 3.2). Given price P^*, the seller maximizes his or her own producer surplus by choosing to sell Q_s units.

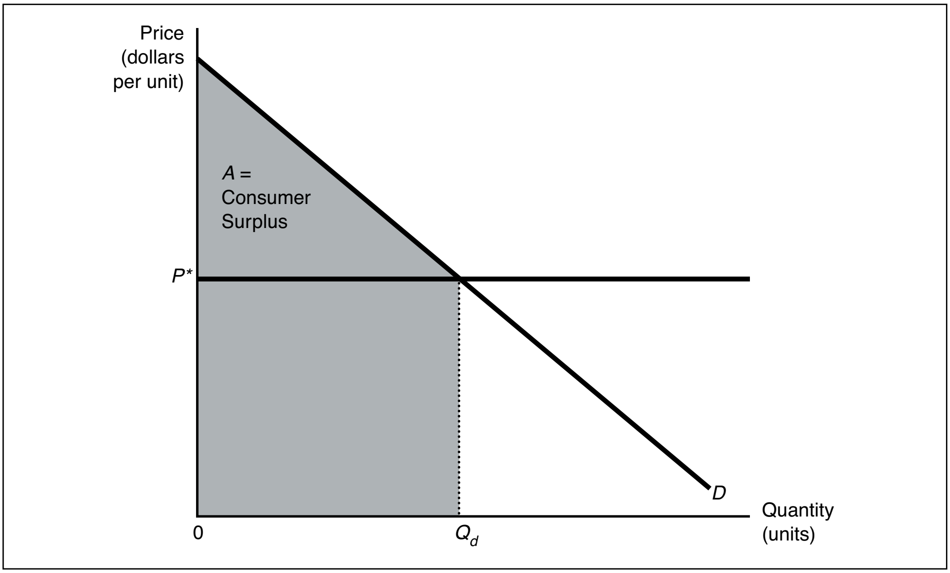

Figure 3.1 Consumers choice. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 21.

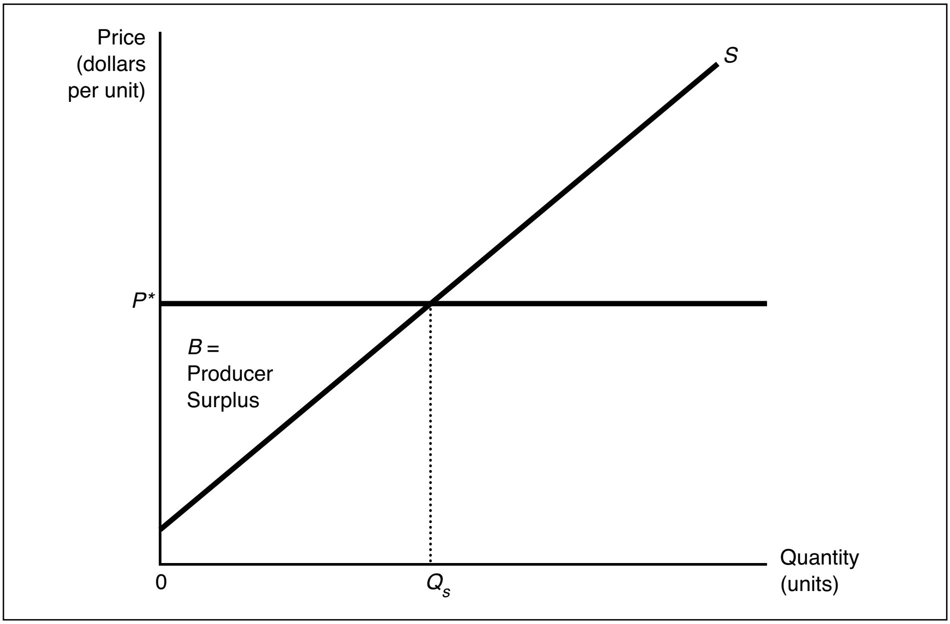

Figure 3.2 Producers choice. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 22.

The producer surplus is designated by area B, the area under the price line that lies over the marginal cost curve, bounded from the left by the vertical axis and to the right by the quantity of the good.

3.2 Property rights and efficient market allocations

The manner in which producers and consumers use environmental resources depends on the property rights governing those resources. In economics, property right refers to a bundle of entitlements defining the owner's rights, privileges, and limitations for use of the resource. By examining such entitlements and how they affect human behavior, we will better understand how environmental problems arise from government and market allocations.

These property rights can be vested either with individuals, as in a capitalist economy, or with the state, as in a centrally planned socialist economy. How can we tell when the pursuit of profits is consistent with efficiency and when it is not?

Let's begin by describing the *structure of property rights* that could produce efficient allocations in a well-functioning market economy. An efficient structure has three main characteristics:

1. *Exclusivity* – All benefits and costs accrued as a result of owning and using the resources should accrue to the owner, and only to the owner, either directly or indirectly by sale to others.
2. *Transferability* – All property rights should be transferable from one owner to another in a voluntary exchange.
3. *Enforceability* – Property rights should be secure from involuntary seizure or encroachment by others.

An owner of a resource with a well-defined property right (one exhibiting these three characteristics) has a powerful incentive to use that resource efficiently because a decline in the value of that resource represents a personal loss. Farmers who own the land have an incentive to fertilize and irrigate it because the resulting increased production raises income. Similarly, they have an incentive to rotate crops when that raises the productivity of their land.

When well-defined property rights are exchanged, as in a market economy, this exchange facilitates efficiency. We can illustrate this point by examining the incentives consumers and producers face when a well-defined system of property rights is in place. Because the seller has the right to prevent the consumer from consuming the product in the absence of payment, the consumer must pay to receive the product. Given a market price, the consumer decides how much to purchase by choosing the amount that maximizes his or her individual consumer surplus.

Is this allocation efficient? According to our definition of static efficiency, it is clear the answer is yes. The economic surplus is maximized by the market allocation and, as seen in Figure 3.3, it is equal to the sum of consumer and producer surpluses (areas A + B). Thus, we have established a procedure for measuring efficiency, and a means of describing how the surplus is distributed between consumers and producers.

This distinction is crucially significant. Efficiency is not achieved because consumers and producers are seeking efficiency. They aren't! In a system with well-defined property rights and competitive markets in which to sell those rights, producers try to maximize their surplus and consumers try to maximize their surplus. The price system, then, induces those self-interested parties to make choices that are efficient from the point of view of society as a whole. It channels the energy motivated by self-interest into socially productive paths.

Familiarity may have dulled our appreciation, but it is noteworthy that a system designed to produce a harmonious and congenial outcome could function effectively while allowing consumers and producers so much individual freedom in making choices. This is truly a remarkable accomplishment.

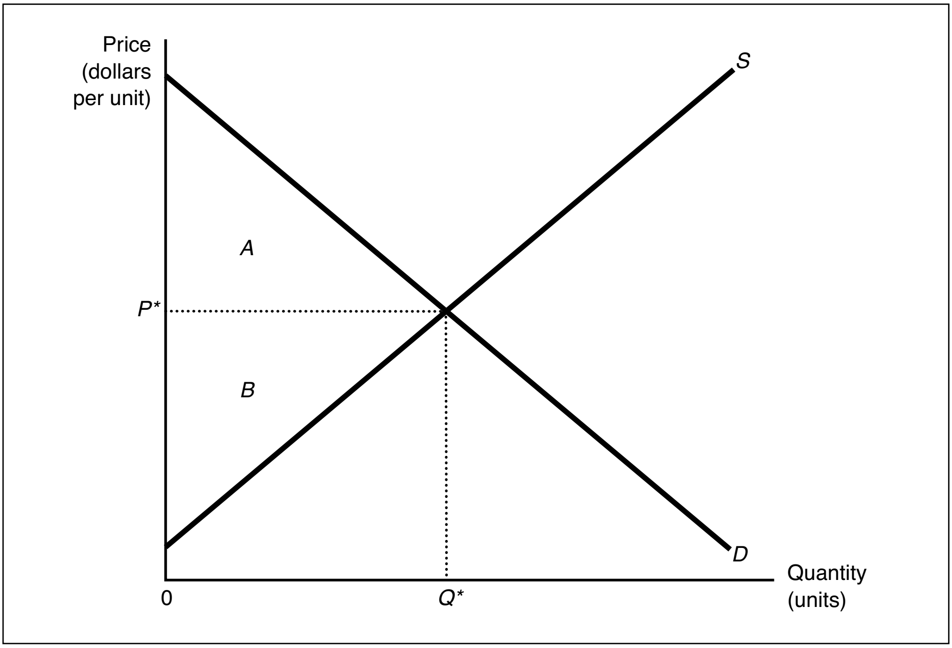

Figure 3.3 Market equilibrium. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 24.

Since the area under the price line is total revenue, and the area under the marginal cost curve is total variable cost, *producer's surplus* is related to profits. In the short run when some costs are fixed, producer's surplus is equal to profits plus fixed cost. In the long run when all costs are variable, producer's surplus is equal to profits plus rent, the return to scarce inputs owned by the producer. As long as new firms can enter into profitable industries without raising the prices of purchased inputs, long-run profits and rent will equal zero.

Most natural resource industries, however, do give rise to rent and, therefore, producer's surplus is not eliminated by competition, even with free entry. This producer's surplus, which persists in long-run competitive equilibrium, is called *scarcity rent*.

David Ricardo was the first economist to recognize the existence of scarcity rent. Ricardo suggested that the price of land was determined by the least fertile marginal unit of land. Since the price had to be sufficiently high to allow the poorer land to be brought into production, other, more fertile land could be farmed at an economic profit. Competition could not erode that profit because the amount of high quality land was limited and lower prices would serve only to reduce the supply of land below demand. The only way to expand production would be to bring additional, less fertile land (more costly to farm) into production; consequently, additional production does not lower price, as it does in a constant-cost industry. As we shall see, other circumstances also give rise to scarcity rent for natural resources.

3.3 Externalities as a source of market allocation

Externalities are unintentional side effects of an activity affecting people other than those directly involved in the activity. A *negative externality* is one that creates side effects that could be harmful to either the general public directly or through the environment. An example would be a factory that pollutes as a result of its production process. This pollution may pose health risks for nearby residents or degrade the quality of the air or water. Either way, the owner of the factory does not directly pay the additional cost to address any health issues or to help maintain the cleanliness of the air or water. In some cases, however, the harmed parties can use legal measures to receive compensation for damages.

A *positive externality*, on the other hand, is an unpaid benefit that extends beyond those directly initiating the activity. One example would be a neighbourhood resident who creates a private garden, the aesthetic beauty of which benefits other people in the community. Also, when a group voluntarily chooses to create a benefit, such as a community park, others may benefit without contributing to the project. Any individuals or groups that gain additional benefits without contributing are known as "free riders".

Traditionally, both negative and positive externalities are considered to be forms of *market failure*s – when a free market does not allocate resources efficiently. Arthur Pigou, a British economist best known for his work in welfare economics, argued that the existence of externalities justified government intervention through legislation or regulation. Pigou supported taxes to discourage activities that created harmful effects and subsidies for those creating benefits to further encourage those activities. These are now known as *Pigovian taxes and subsidies*.

Many economists believe that placing Pigovian taxes on pollution is a much more efficient way of dealing with pollution as an externality than government imposed regulatory standards. Taxes leave the decision of how to deal with pollution to individual sources by assessing a fee or "tax" on the amount of pollution that is generated. Therefore, in theory, a source that is looking to maximize its profit will reduce, or control, their pollution emissions whenever it is cheaper to do so. Other economists believe that the most efficient solution to externalities is to include them in the cost for those engaged in the activity. Thus, the externality is "internalized." Under this framework externalities are not necessarily market failures, which weaken the case for government intervention.

Many externalities (pollution, free rider benefits) can be internalized through the creation of well-defined property rights. Through much of his work, economist Ronald Coase showed that taxes and subsidies were typically not necessary as long as the parties involved could strike a voluntary bargain. According to Coase's theorem, it does not matter who has ownership, so long as property rights exist and free trade is possible. Two methods of controlling negative externalities loosely related to property rights include cap and trade and individual transferable quotas (ITQs).

The *cap and trade* approach sets a maximum amount of emissions for a group of sources over a specific time period. The various sources are then given emissions allowances which can be traded, bought or sold, or banked for future use, but – over the course of the specified period of time – overall emissions will not exceed the amount of the cap and may even decline. Therefore, individual sources, or facilities, can determine their level of production and/or the application of pollution reduction technologies or the purchase of additional allowances.

Individual transferable quotas are a market-based solution that is often used to manage fisheries. Regulators first determine a total annual catch that will preserve the health of the ecosystem, and then it is divided into individual quotas to prevent over-fishing. Each ITQ allows for a certain amount of fish to be caught in any given year. ITQs are transferable, which allows fishing vessel owners to buy and sell their quotas depending on how much they want to catch. The ITQ program also tries to create a commercial fishing industry that is more stable and profitable.

The options for dealing with externalities – positive or negative – are numerous, and often depend on the type of externality. The key is to identify the particular tool or policy alternative that will best move the market toward the most efficient allocation of resources.

3.4 Competition for a resource

Exclusivity is one of the chief characteristics of an efficient property rights structure. This characteristic is frequently violated in practice. One broad class of violations occurs when an agent making a decision does not bear all of the consequences of his or her action.

Suppose two firms are located by a river. The first produces steel, while the second, somewhat downstream, operates a resort hotel. Both use the river, although in different ways. The steel firm uses it as a recipient for its waste, while the hotel uses it to attract customers seeking water recreation. If these two facilities have different owners, an efficient use of the water is not likely to result. Because the steel plant does not bear the cost of reduced business at the resort resulting from waste being dumped into the river, it is not likely to be very sensitive to that cost in its decision making. As a result, it could be expected to dump too much waste into the river, and an efficient allocation of the river would not be attained.

This situation is an *externality*. An externality exists whenever the welfare of some agent, either a firm or household, depends not only on his or her activities, but also on activities under the control of some other agent. In the example, the increased waste in the river imposed an external cost on the resort, a cost the steel firm could not be counted upon to consider appropriately in deciding the amount of waste to dump.

The effect of this external cost on the steel industry is illustrated in Figure 3.4, which shows the market for steel. Steel production inevitably involves producing pollution as well as steel. The demand for steel is shown by the demand curve D, and the private marginal cost of producing the steel (exclusive of pollution control and damage) is depicted as MC_p. Because society considers both the cost of pollution and the cost of producing the steel, the social marginal cost function (MC_s) includes both of these costs as well.

If the steel industry faced no outside control on its emission levels, it would seek to produce Q_m. That choice, in a competitive setting, would maximize its private producer surplus. But that is clearly not efficient, since the net benefit is maximized at Q^*, not Q_m.

With the help of Figure 3.4 we can draw a number of conclusions about market allocations of commodities causing pollution externalities:

1. The output of the commodity is too large.
2. Too much pollution is produced.
3. The prices of products responsible for pollution are too low.
4. As long as the costs are external, no incentives to search for ways to yield less pollution per unit of output are introduced by the market.
5. Recycling and reuse of the polluting substances are discouraged because release into the environment is so inefficiently cheap.

The effects of a market imperfection for one commodity end up affecting the demands for raw materials, labour, and so on. The ultimate effects are felt through the entire economy.

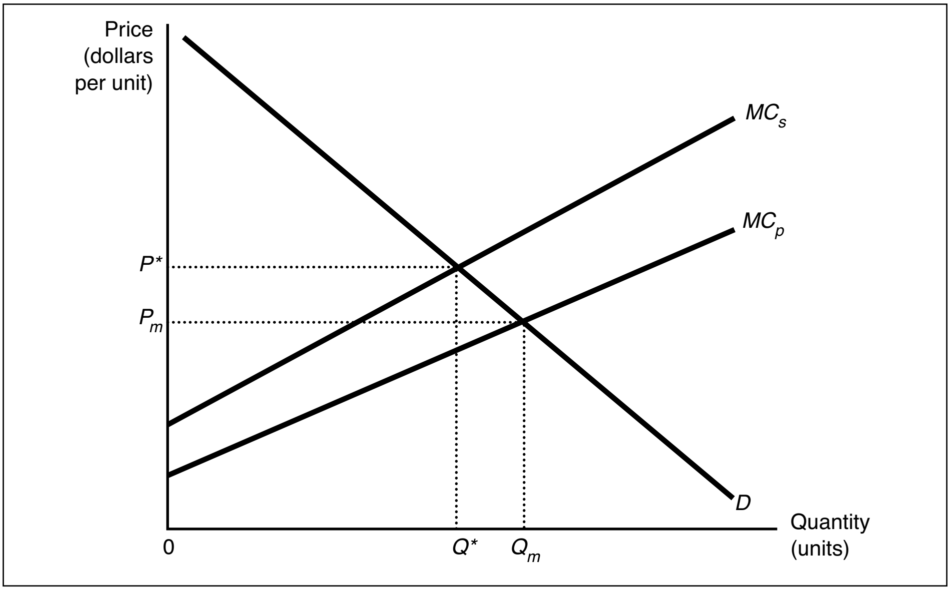

Figure 3.4 The market for Steel. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 26.

External economies are not hard to find, however. Private individuals who preserve a particularly scenic area provide an external economy to all who pass. Generally, when external economies are present, the market will undersupply the resources. One other distinction is important. One class of externalities, known as pecuniary externalities, does not present the same kinds of problems as pollution does. Pecuniary externalities arise when the external effect is transmitted through altered prices. Suppose that a new firm moves into an area and drives up the rental price of land. That increase creates a negative effect on all those paying rent and, therefore, is an external diseconomy.

3.5 An efficient role for government?

While the economic approach suggests that government action could well be used to restore efficiency, it also suggests that inefficiency is not a sufficient condition to justify government intervention. Any corrective mechanism involves transaction costs. If these transaction costs are high enough, and the surplus to be derived from correcting the inefficiency small enough, then it is best simply to live with the inefficiency.

Box 3.1 Shrimp Farming Externalities in Thailand

In the Tha Po village on the coast of Surat Thani Province in Thailand, more than half of the 1,100 hectares of mangrove swamps have been cleared for commercial shrimp farms. Although harvesting shrimp is a lucrative undertaking, mangroves serve as nurseries for fish and as barriers for storms and soil erosion. Following the destruction of the local mangroves, Tha Po villagers experienced a decline in fish catch and suffered storm damage and water pollution. Can market forces be trusted to strike the efficient balance between preservation and development for the remaining mangroves?

Calculations by economists Sathirathai and Barbier (2001) demonstrated that the value of the ecological services that would be lost from further destruction of the mangrove swamps exceeded the value of the shrimp farms that would take their place. Preservation of the remaining mangrove swamps would be the efficient choice.

Would a potential shrimp-farming entrepreneur make the efficient choice? Unfortunately, the answer is no. This study estimated the economic value of mangroves in terms of local use of forest resources, offshore fishery linkages, and coastal protection to be in the range of $27,264 – $35,921 per hectare. In contrast, the economic returns to shrimp farming, once they are corrected for input subsidies and for the costs of water pollution, are only $194 – $209 per hectare.

However, as shrimp farmers are heavily subsidized and do not have to take into account the external costs of pollution, their financial returns are typically $7,706.95 – $8,336.47 per hectare. In the absence of some sort of external control imposed by collective action, development would be the normal, if inefficient, result. The externalities associated with the ecological services provided by the mangroves support a biased decision that results in fewer social net benefits, but greater private net benefits.

Source: Suthawan Sathirathai and Edward B. Barbier. *Valuing Mangrove Conservation in Southern Thailand*, Contemporary Economic Policy Vol 19, No 2 (April 2001) pp. 109–122.

Consider, for example, the pollution problem. Wood-burning stoves, which were widely used for cooking and heat in the late 1800s in the United States, were sources of pollution, but because of the enormous capacity of the air to absorb the emissions, no regulation resulted. More recently, however, the resurgence of demand for wood-burning stoves, precipitated in part by high oil prices, has resulted in strict regulations for wood-burning stove emissions because the population density is so much higher.

As society has evolved, the scale of economic activity and the resulting emissions have increased. Cities are experiencing severe problems from air and water pollutants because of the clustering of activities. Both the expansion and the clustering have increased the amount of emissions per unit volume of air or water. As a result, pollutant concentrations have caused perceptible problems with human health, vegetation growth, and aesthetics.

Historically, as incomes have risen, the demand for leisure activities has also risen. Many of these leisure activities, such as canoeing and backpacking, take place in unique, pristine environmental areas. With the number of these areas declining as a result of conversion to other uses, the value of remaining areas has increased. Thus, the value derived from protecting some areas have risen over time until they have exceeded the transaction costs of protecting them from pollution and/or development.

The level and concentration of economic activity, having increased pollution problems and driven up the demand for clean air and pristine areas, have created the preconditions for government action. Can government respond or will rent seeking prevent efficient political solutions?

Chapter 3 sources:

Section 3.1 is cited from pp 16, and 20-22; **Section 3.2** on pp 25-27; **Section 3.4** on pp. 25-27; and **Section 3.5** on p. 42 in Tietenberg, T., Lewis, L. (2012) *Environmental & Natural Resource Economics* 9th Ed. (https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf). Chapter 2 “The Economic Approach: Property Rights, Externalities, and Environmental Problems”.

Section 3.3 by Farhod Ahrorov and Akmal Abruev.

Chapter 4
Methods for Valuing the Environment

4.1 Preference methods – the value of production

Two broad classes of methods can assess the economic value of environmental amenities and dis-amenities in the absence of explicit markets: behavioural or *revealed preference methods* and attitudinal or *stated preference methods*.

Revealed preference methods basically rely on how a product is valued in a market. In research one may develop natural experiments to estimate the demand function for an environmental good. Researchers look for cases where people face exogenous differences in environmental prices and the available quantity of goods; the relationship between price and quantity can be estimated by observing consumers' choices in these situations. However, because the experiments are usually not randomized, the methodologies must control undesired variation using a combination of carefully choosing experiments and controlling for remaining problems with statistical techniques. Some revealed preference techniques lean more heavily on structural statistical models, and their attendant assumptions, to estimate values. Other techniques, often called quasi-experimental methods, lean more heavily on the assumption that policy interventions are truly exogenous and have created something close to a randomized experiment in a natural setting.

Both approaches have strengths and weaknesses. Stated preference, or attitudinal, methods ask consumers how much they value environmental goods and services in carefully structured surveys. The approach has the appealing virtue that it can be used to value any environmental good or service as long as the good can be described. Because the approach is not tied to behaviour, it can be used to value some goods and services that revealed preference methods cannot value. However, in practice, the survey methods are more difficult than they appear.

Economists have a professional bias toward revealed preference approaches because economic science has developed around observing choices agents make in markets. The social sciences, in general, do not have this prejudice as sociologists, psychologists, and political scientists often apply attitudinal methods. However, as observed in social psychology, what people say they would do and what they actually do may differ. This raises several problems with stated preference methods, discussed below. Thus, economists generally rely primarily on revealed preference approaches to estimate use value and reserve stated preference methods for non-use value and to assess peoples' value for states of the world that do not exist (e.g., estimating the value of a piped water connection where there currently is none).

Revealed Preference Methods are often easy to calculate directly. Many environmental goods are inputs to production processes. Even if these inputs are not readily traded, their value can be calculated indirectly through market analysis. For example, the value of non-timber forest products, such as fruits, latex, and tropical medicines in a hectare of forestland, can be calculated by measuring the net revenues from collecting these goods per hectare.

Alternatively, the damage from sea level rise can be measured using the market value of land that is inundated plus the cost of constructing protective sea walls. One can also measure the value of environmental factors that cause the demand or supply of a market good to shift. For example, one can look at the impact of climate change on energy by observing how climate shifts demand functions for energy resources. Similarly, a shift in water supply can be valued using a demand model of water consumption in a watershed. The change in net consumer surplus across all users is the change in value.

4.2 Travel cost models – the value of recreation services

Although access to many environmental and resource amenities requires an entrance fee, that fee is often small compared to the expense of traveling to these sites. Harold Hotelling suggested the "travel cost method" of valuation that exploits the variation in travel cost to a site (an implicit price) that arises when people travel from different origins.

Exploiting the empirical relationship between travel cost and visitation rates permits the estimation of a demand function for recreation. The demand for any good or service is, in part, a function of the prices of substitutes and complements; this is also true of environmental goods and services.

Economists recognized shortly after the original travel cost model was developed that consideration of substitute sites would be important and introduced models involving systems of demand equations in which demand could be simultaneously estimated for multiple sites. The economic value of recreation at a site also depends on site characteristics, including environmental quality (e.g., water quality at a beach, air quality at a national park where scenic views are valued, and the average catch by anglers in a river).

One can use multiple site models to value site characteristics if the only difference between two sites is the characteristic in question. However, in practice, sites differ in many characteristics. Discrete choice methods model the choice of a site by a visitor as a function of site characteristics. People choose different sites to obtain different packages of site characteristics.

One can value site characteristics by seeing what travel costs people would pay to obtain different packages. Such models can be estimated using *random utility maximization (RUM) models*. Within this framework, the consumer chooses the recreational site (if any) that maximizes her utility, which is a function of income, the prices of the chosen site as well as those not chosen, and the characteristics of the site chosen and those not chosen. The researcher has many specification decisions to make regarding the definition of the limited choice set (i.e., which sites are appropriately considered substitutes), the structure of econometric error terms, the treatment of unobserved consumer heterogeneity (i.e., preferences), and many other factors.

Statistical development of the RUM travel cost models has given rise to one of the most active and prolific literatures in economic valuation. Travel cost models are among the most widely applied valuation methods and have become a very useful tool for estimating recreational demand, an important component of total value for many resource amenities.

But there are some challenges to these methods. Like all statistical models, they are vulnerable to the possibility that important factors have been omitted, which could bias the results. Other challenges stem from the fact that actual travel cost, or some portion of it, may be unobservable. One key unobserved cost is the opportunity cost of travel time. Some authors suggest assigning the wage rate to value time, but empirical evidence suggests that people enjoy traveling, suggesting a lower value. Researchers must also consider how to value time spent at the recreational site.

Another important issue concerns multipurpose trips. Some people travel just to visit a single recreational site. For trips with multiple purposes, however, an individual recreation site represents only a portion of the trip's value. If the analyst drops multipurpose trips, it will bias downward the site's value. Assigning proportional values to each destination or purpose is, unfortunately, arbitrary. Many of the assumptions of travel cost models can be dealt with through sensitivity analysis. Researchers can make a range of assumptions about the opportunity cost of time, which travel expenditures to include, and what portion of costs for a multipurpose trip should be attributed to an individual site. They can then observe how the recreational value of a site changes with these changes in assumptions.

4.3 Hedonic property models – the value of property

Hedonic models arise from the idea that the price of a good is really a sum of the implicit prices of each of its characteristics. For example, the price of a car comprises the implicit prices for characteristics including fuel efficiency, acceleration, passenger seating, and aesthetic appeal. Similarly, the price of a home depends on several groups of characteristics that determine its value: (a) physical structure, such as the number of bathrooms and bedrooms and square footage; (b) characteristics of the surrounding neighbourhood, e.g., the quality of public schools, proximity to jobs and transportation networks; and (c) environmental amenities, such as air and water quality or proximity to open space.

Hedonic property models collect data on the prices of home sales and housing characteristics, like those listed above, and then estimate the marginal implicit prices of the characteristics of interest. This captures the marginal value of an environmental amenity to homeowners at the amenity's current level of provision. Hedonic models have been used primarily to estimate the economic value of air quality. Other environmental applications include proximity to wetlands and open space and dis-amenities such as hazardous waste sites and airport noise.

Though valuable in many settings, hedonic property models have limitations. First, the researcher must assume that buyers and sellers have good information on the characteristics of all housing alternatives. Thus, the models are appropriate only for estimating the value of observable or known amenities and dis-amenities. Second, the models assume that people are mobile enough that current prices reflect their preferences. Although the hedonic methods readily estimate the marginal value of site characteristics, it has also been suggested that the technique can be used to estimate the demand for characteristics. Several authors have attempted to estimate the demand for characteristics using data from a single market.

Unfortunately, the variation in the observed prices in a single market is perfectly correlated with the variation in demand shift variables across people, so the demand functions cannot be estimated. Some authors have sought to overcome this by segmenting housing markets within a single city, but this approach requires strong assumptions. The unobserved characteristics of housing consumers cause people to self-sort into neighbourhoods on the basis of their preferences for environmental quality.

As with all natural experiments, unobserved factors can be spatially correlated with environmental quality, leading to biased estimates. For example, higher levels of air pollution may be observed in urban areas that also have more jobs. More jobs, in turn, can increase housing values. If one fails to adequately control for such factors, one may over- or underestimate the price of air pollution.

Another application of the hedonic property approach is the Ricardian model of agricultural land. Regressing farmland value on climate and other control variables, this approach can estimate the impact of climate on farmland value, using both cross-sectional and panel data.

4.4 Hedonic wage models – the value of life and a safe environment

Hedonic wage models share a similar theoretical basis with hedonic property models. In environmental economics, these models are used primarily to value mortality risk. Jobs are collections of characteristics: training, education, fringe benefits, prestige, and working conditions, including the risks of accidental death or injury. Regressing wages on job characteristics (controlling for worker characteristics) reveals their marginal implicit value. For example, the coefficient on the risk of a fatal accident reveals how much additional compensation a person requires to assume an additional small risk.

These estimated values of small risk reductions have been translated into the value of a statistical life (VSL). For example, imagine that 10,000 people are employed in a risky occupation, each faces a 1/10,000 risk of death, and each is willing to pay $500 to eliminate this risk. The total willingness to pay for risk reduction would be $5 million, which would prevent one statistical death, so this is the VSL. This technique does not estimate the compensation required for certain death or illness; it simply provides a measure of the rate at which workers are willing to trade fatal and nonfatal risk for monetary compensation.

Viscusi & Aldy review the economic literature on valuing risks to life and health. There are several challenges to this approach. As in the hedonic property models, omitted variables are a serious concern. For example, some people are insured by either private insurance or workers' compensation. They, or their heirs, consequently will receive a payment in case of their death or an accident. If this payment is not included, the hedonic wage approach could underestimate the value of risk. Omitted variables that are correlated with both wages and risk (such as unobserved characteristics of the worker, e.g., ease of work under pressure, or of the job, e.g., physical exertion) are particularly problematic. In addition, many jobs involve correlated risks of different types of injury, as well as fatality. Attempts to value small risk reductions for each of these occurrences must control appropriately for changes in the other risks, or estimates will be biased.

The "sorting" effects that have begun to be addressed in the hedonic housing models are also relevant to hedonic wage models. The hedonic wage approach can only estimate the value of changes in risks that workers perceive accurately.

The probability of injury or death on the job may not be accurate. For example, people might think that being a police officer or fire fighter is dangerous, but statistics show these jobs are quite safe. Researchers themselves may have trouble measuring mortality rates. For example, it may not be clear whether a heart attack on the job was actually caused by the job. There is evidence that the marginal value of risk may vary with age, across countries, and with the character of the risk, such as latency. For example, people may value the risk of cancer differently from the risk of a sudden car accident.

The hedonic wage literature tends to measure the value of reducing accidental deaths and not deaths associated with long-term chronic exposure to environmental contamination, but long-term chronic risks dominate the risk of accidental deaths on the job. Miners may die from black lung disease, bakers from white lung disease, and farmers from long-term exposure to particulates. These risks with long delays actually resemble the risks associated with pollution. Unfortunately, the literature is limited by the near absence of reliable estimates of long-term mortality risks by occupation.

4.5 Averting behaviour models – environmental debt

If people incur private expenditures to avoid the damages from pollution or other environmental disamenities, the sum of these incurred costs is at least a partial estimate of the value of these damages. In economic terms, these are "avoidance costs" or "averting expenditures." For example, if a groundwater source is contaminated, people may substitute bottled water. One can consider the medical costs a person incurs to treat any illness caused by pollution exposure in a similar way. Averting expenditures and "cost of illness" measures, however, are at best a lower bound on the value of damages from pollution because they do not capture the pain and suffering that cannot be avoided.

These costs are related to the *environmental debt* of environmental impacts caused by a previous activity. These may sometimes be very large. It is clear that to clean up the environment from a chemical, which has been polluting the environment during perhaps many years of previous activity, may be complex, expensive, and even impossible. It is most clear when a previous factory area has to be decontaminated due to planned housing projects. Very often the owner of the factory may not exist any longer. In addition it is not reasonable that the new owner should pay all costs. Thus large funds have been constructed to take care of costs for decontamination of polluted areas. These may be paid by the state or the industrialists or both. In the USA the so-called superfund, one of the largest

Box 4.1 Case study – Values of Environmental Amenities in Southold, Long Island.

The town of Southold, Long Island, New York, has coastlines on both the Peconic Bay and Long Island Sound. Compared to the rest of Long Island, it is a relatively rural area, with a large amount of farmland. However, population and housing density are rapidly increasing in the town, resulting in development pressures on farmland and other types of open space.

The Peconic Estuary Program is considering various management actions for the Estuary and surrounding land areas. In order to assess some of the values that may result from these management actions, a hedonic valuation study was conducted, using 1996 housing transactions.

The study found that the following variables that are relevant for local environmental management were had significant effects on property values in Southold:

Open Space: Properties adjacent to open space had, on average, 12.8% higher per-acre value than similar properties located elsewhere.

Farmland: Properties located adjacent to farmland had, on average, 13.3% lower per-acre value. Property values increased very slightly with greater distance from farmland.

Major Roads: Properties located within 20 meters of a major road had, on average, 16.2% lower per-acre value.

Zoning: Properties located within an area with two- or three-acre zoning had, on average, 16.7% higher per-acre value.

Wetlands: For every percentage point increase in the percent of a parcel classified as a wetland, the average per-acre value increased by .3%.

Based on the results of this study, managers could, for example, calculate the value of preserving a parcel of open space, by calculating the effects on property values adjacent to the parcel. For a hypothetical simple case, the value of preserving a 10 acre parcel of open space, surrounded by 15 “average” properties, was calculated as $410,907.

Source: Dennis M. King, Ph.D and Marisa J. Mazzotta, Ph.D. (2000) ecosystem Valuation Site. http://www.ecosystemvaluation.org/hedonic_pricing.htm#example

funds in the country, was established by industry and state together. In Sweden the financing of decontamination is typically a cooperation between local and state authorities. The operation most often involves the transportation of large amounts of soil, the decontamination of soil by chemical or physical methods or isolation of parts of the ground by impermeable barriers. These issues will be further treated in Chapter 6.

4.6 Stated preference methods or contingent valuation

Contingent Valuation Attitudinal methods use carefully designed surveys that ask consumers how much they value environmental goods and services. The survey creates a hypothetical market for the amenity so that responses can be evaluated in a manner similar to behaviour observed in markets. The basic architecture of a contingent valuation (CV) survey is (a) a description of the service/ amenity to be valued and the conditions under which the policy change is being suggested, (b) a set of choice questions that ask the respondent to place a value on the service/ amenity, and (c) a set of questions assessing the socioeconomic characteristics of the respondent that will help in determining what factors may shift that value.

Stated preference methods can be used to value any environmental good or service, even at levels of quality that are currently not in existence. They can also capture non-use value, which cannot be measured using revealed preference methods. Non-use values may be the largest, most important social values in some policy contexts, such as endangered species and wilderness preservation. Economists debate over whether such values should be included in economic analyses. We focus here on describing stated preference methods, rather than examining the validity of non-use value in economic theory. Nonetheless, there is an important paradox; some of society's most important values for natural resource amenities may be precisely the values that we have the least confidence in measuring.

In early attitudinal surveys, researchers simply asked people how much they were willing to pay for each amenity; this has become known as an "open-ended" question design. However, such open-ended valuation questions are limited in their ability to provide accurate results. Close-ended discrete choice questions, in which respondents offer a "yes or no" response when offered one or more specified prices for an environmental good or service, have largely replaced open-ended questions in CV studies. This newer format requires households to exercise the kind of judgment more familiar to them from typical purchases. CV survey respondents may lack market experience with the environmental good and not understand how to value it. Respondents sometimes express the same value for environmental goods of very different magnitudes. For CV: contingent valuation example, the valuation of responses to the loss of 2,000, 20,000, and 200,000 migratory waterfowl in the Central Flyway was essentially the same. In other cases, analysts have noted appropriate sensitivity to scope. It may be that such results, inconsistent with economic theory, are directly attributable to survey design problems and can be avoided in practice.

CV survey respondents may also be swayed by how a question is framed. For example, one can describe the impact of an oil spill on local fishermen in purely scientific terms by measuring the fish lost. Or one could choose to also convey the many precautions that the oil industry took to avoid a spill and that oil development was part of a national energy independence effort. Alternatively, one

Box 4.2 Case study – Water Over the Falls

The contingent valuation method (CVM) is used to estimate economic values for all kinds of ecosystem and environmental services. The Federal Energy Regulatory Commission (USA) faced a licensing decision where one important issue was how much water the utility company should allow to flow over the falls at a recreation area. Increasing the flow over the falls would result in less hydropower generated, but more water for recreation. The previous license required only a minimum instream flow of 50 cubic feet per second, which reduced the flow over the falls to a trickle. A contingent valuation survey was developed to determine how much visitors to the falls would be willing to pay for increased overflow levels. The survey instrument included pictures of the falls at four different flow levels and a series of valuation questions. It was mailed to a sample of previous visitors to the site. The key survey questions asked how much individuals would pay to visit the falls with each of the four flow levels depicted in the photos, and how many times they would visit each year at the four different flow levels.

Since both visitation and value per day were sensitive to flow, a statistical analysis of the survey results was used to estimate a total recreation benefit function. Using this function, the economic value of additional flows in each month was calculated, and compared to the economic value of the foregone hydropower required to allow the additional flows. The resulting optimum flow level during the summer months, when visitation was high, was calculated as 500 cubic feet per second, which was ten times larger then the existing minimum instream flow.

Source: Dennis M. King, Ph.D and Marisa J. Mazzotta, Ph.D. (2000) Ecosystem Valuation Site. http://www.ecosystemvaluation.org/contingent_valuation.htm

could mention that the captain of the vessel that caused the spill was drunk, the oil company was making huge profits, and the fishermen were poor. These details greatly influence responses, leading to very different values.

Respondents may also be affected by how they are asked to pay for the environmental good. For example, many respondents care whether the payment comes in the form of taxes, fees, or contributions. Respondents sometimes protest the question because they object to the payment method. They may provide “protest zeros,” even though they may actually have some positive value for the good. Although some studies simply drop observations that respond poorly to preliminary questions, it is better to control for protestors but still include them as part of the sample.

A final problem with attitudinal surveys is that the responses to willingness-to-accept (WTA) questions have generally been many times greater than the responses to willingness-to-pay (WTP) questions. This is especially true for non-use values. These large differences are difficult to justify, suggesting they are measurement problems. To help respondents understand the good, the report suggested an extensive unbiased description of the good. It also recommends the use of close-ended questions and the use of WTP questions rather than WTA questions.

In addition, experimental economics has contributed significantly to survey design in recent years. Well-designed CV surveys are, for now, the only tools available for estimating non-use value. They have also been used to estimate some types of use value; for example, they have been used in mortality risk valuation (in many cases obtaining estimates comparable to those from hedonic wage studies), as well as in estimating the value of improving piped water service coverage and increased provision of vaccines in developing countries.

Chapter 4 sources:

Section 4.1-4.6. Robert Mendelsohn and Sheila Olmstead (2009) The Economic Valuation of Environmental Amenities and Disamenities: Methods and Applications. Annual Review of Environment and Resources. Vol. 34: 325-347;

The comment on environmental debt in Section 4.5 by Lars Rydén

II

Dynamic Efficiency and Sustainable Economy

Chapter 5
Estimating the Value of the Environment

5.1 Valuing the environment

In this chapter it is explored how we can move from the general concepts of a value of an envionrmetnal benefit to the actual estimates of compensation required e.g. in a court process. A series of special techniques has been developed to value the benefits from environmental improvement or, conversely, to value the damage done by environmental degradation.

Special techniques were necessary because most of the normal valuation techniques that have been used over the years cannot be applied to environmental resources. Cost-benefit analysis requires the monetization of all relevant costs and benefits of a proposed policy or project, not merely those where the values can be derived from market transactions. As such, it is also important to monetize those environmental goods and services that are not traded in any market. Even more difficult to grapple with are those nonmarket benefits associated with passive-use or nonuse value, topics explored below.

Why value the environment? While it may prove difficult, if not impossible, to place an accurate value on certain environmental amenities, not doing so leaves us valuing them at 0, nothing. Will valuing them at 0 lead us to the best policy decisions? Probably not, but that does not prevent the controversy from arising over attempts to replace 0 with a more appropriate value.

Many govenrmental organizations require a cost-benefit analysis for decision making. Ideally, the goal is to choose the most economically desirable projects, given limited budgets.

Environmental benefits often have huge values. Pollination is one example of an ecosystem service with multiple benefits, including nonmarket impacts such as aiding in genetic diversity, ecosystem resilience and nutrient cycling, as well as direct economic impacts of increasing the productivity of agricultural crops. Many agricultural crops rely on bee pollination. Farmers who experiecence a lack pollinating insects understand the value of this particular ecosystem service.

Valuation can be a useful tool that aids in evaluating different options that a natural resource manager might face. Because our ecological resources and services are so varied in their composition, it is often difficult to examine them on the same level. However, after they are assigned a value, an environmental resource or service can then be compared to any other item with a respective value. Ecosystem valuation is the process by which policymakers assign a value – monetary or otherwise – to environmental resources or to the outputs and/or services provided by those resources. For example, a mountain forest may provide environmental services by preventing downstream flooding.

Environmental resources and/or services are particularly hard to quantify due to their intangible benefits and multiple value options. It is almost impossible to attach a specific value to some of the experiences we have in nature, such as viewing a beautiful sunset. Problems also exist when a resource can be used for multiple purposes, such as a tree – the wood is valued differently if it is used for flood control versus if it is used for building a house. The quantity of a resource must also be taken into consideration because the value can change depending on how much of a resource is available. An example of this might be in preventing the first "unit" of pollution if we have a pristine air environment. Preventing the first unit of pollution is not valued very highly because the environment can easily recover. However, if the pollution continues until the air is becoming toxic to its surroundings, the value of preserving clean air by preventing additional pollution is going to be increasingly valued.

Within economics, a value is generally defined as the amount of alternate goods a person is willing to give up in order to get one "additional unit" of the good in question. An individual's preference for certain goods may either be stated or revealed. In the case of stated preferences, the amount of money a person is willing to pay for a good determines the value because that money could otherwise be used to purchase other goods. However, a value may also be determined by simply ranking the alternatives according to the amount of benefit each will produce. Revealed preferences can be measured by examining a person's behaviour when it is not possible to use market pricing.

There is a series of methods used for valuing environmental benefits. They can be divided in two categories as there are typically two ways to assign a value to environmental resources and services – *use value and non-use value* – and there are approaches to measuring environmental benefits based on these defined values. When environmental resources or services are being used, it is easier to observe the price consumers are willing to pay for the conservation or preservation of those resources.

Market or opportunity cost pricing can be used when there are tangible products to measure, such as the amount of fish caught in a lake. Replacement cost can also be used, calculated based on any expenses incurred to reverse environmental damage. *Hedonic pricing* will measure the effect that negative environmental qualities have on the price of related market goods. When evaluating non-use value, *contingent valuation* is employed through the use of surveys that attempt to assess an individual's *willingness to pay* for a resource that they do not consume.

A cost-benefit analysis requires the quantification of possible impacts of a proposed project. The impacts could be physical or monetary, but both must be calculated and included since a financial analysis that requires assigning money values to every resource evaluated is also performed. The process of an environmental resource or service valuation provides a way to compare alternative proposals, but it is not without problems. All valuation techniques encompass a *great deal of uncertainty*: flaws can exist in the methods of assigning value accurately due to a wide number of variables and it is difficult to compartmentalize and measure environmental and natural resources and/or services within an ecosystem that functions as an interconnected web.

In summary, ecosystem valuation is a complex process by which economists attempt to assign a value to natural resources or to the ecological outputs and/or services provided by those resources. Although challenging, it allows policymakers to make decisions based on specific comparisons, typically monetary, rather than some other arbitrary basis.

5.2 Valuation of pollution damages on human health

While the valuation techniques we shall cover can be applied to both the damage caused by pollution and the services provided by the environment, each context offers its own unique problems. We begin our investigation of valuation techniques by exposing some of the difficulties associated with one of those contexts, pollution control.

The damage caused by pollution can take many different forms. The first, and probably most obvious, is the effect on human health. Polluted air and water can cause disease when ingested. Other forms of damage include loss of enjoyment from outdoor activities and damage to vegetation, animals, and materials. Assessing the magnitude of this damage requires

1. identifying the affected categories;
2. estimating the physical relationship between the pollutant emissions (including natural sources) and the damage caused to the affected categories;
3. estimating responses by the affected parties toward averting or mitigating some portion of the damage; and
4. placing a monetary value on the physical damages.

Each step is often difficult to accomplish. Because the data used to track down causal relationships do not typically come from controlled experiments, identifying the affected categories is a complicated matter. Obviously we cannot run large numbers of people through controlled experiments. If people were subjected to different levels of some pollutant, such as carbon monoxide, so that we could study the short-term and long-term effects, some might become ill and even die. Ethical concern precludes human experimentation of this type.

This leaves us essentially two choices. We can try to infer the impact on humans from controlled laboratory experiments on animals, or we can do statistical analysis of differences in mortality or disease rates for various human populations living in the area in question.

Statistical studies, on the other hand, deal with human populations subjected to low doses for long periods, but, unfortunately, they have another set of problems – correlation does not imply causation. To illustrate, the fact that death rates are higher in cities with higher pollution levels does not prove that the higher pollution caused the higher death rates. Perhaps those same cities averaged older populations, which would tend to lead to higher death rates. Or perhaps they had more smokers. The existing studies are often sophisticated enough to account for many of these other possible influences but, because of the relative paucity of data, are not able to cover them all.

The problems discussed so far arise when identifying whether a particular effect results from pollution. The next step is to estimate how strong the relationship is between the effect and the pollution concentrations. In other words, it is necessary not only to discover whether pollution causes an increased incidence of respiratory disease, but also to estimate how much reduction in respiratory illness could be expected from a given reduction in pollution.

The nonexperimental nature of the data makes this a difficult task. It is not uncommon for researchers analyzing the same data to come to remarkably different conclusions. Diagnostic problems are compounded when the effects are energistic – that is, when the effect depends, in a non-additive way, on what other elements are in the surrounding air or water at the time of the analysis.

Once physical damages have been identified, the next step is to place a monetary value on them. It is not difficult to see how complex an undertaking this is. Consider, for example, the difficulties in assigning a value to extending a human life by several years or to the pain, suffering, and grief borne by both a cancer victim and the victim's family.

5.3 Marginal cost function

Marginal costs and *marginal benefits* are essential information for economists, businesses, and consumers. Even if we do not realize it, we all make decisions based on our marginal evaluations of the alternatives. In other words, "what does it cost to produce one more unit?" or "what will be the benefit of acquiring one more unit?"

When necessary, individual and social marginal cost and benefit curves can be drawn separately in order to understand different effects that a given action or policy might have. In the case of pollution, the social cost is generally higher than the individual cost due to externalities. However, as a whole, an economic system is considered efficient at the point where marginal benefit and marginal cost intersect, or are equal. Similar to the production of goods and services, we can utilize the same information in order to analyse pollution abatement – in terms of the production or reduction of pollution – within the market. In order to assess environmental improvement, we must take cost into consideration. The cost of these improvements is often thought of as the direct cost of any action taken in order to improve the environment.

Marginal cost measures the change in cost over the change in quantity. For example, if a company is producing 10 units at $100 total cost, and steps up production to 11 units at $120 total cost, the marginal cost is $20 since only the last unit of production is measured in order to calculate marginal cost. Mathematically speaking, it is the derivative of the total cost. Marginal cost is an important measurement because it accounts for increasing or decreasing costs of production, which allows a company to evaluate how much they actually pay to 'produce' one more unit. Marginal cost will normally initially decrease through a short range, but increase as more is produced. Therefore the marginal cost curve is typically thought of as upward sloping. The marginal cost curve can represent a wide range of activities that can reduce the effects of environmental externalities, like pollution. The key point is that most environmental improvements are not free; resources must be expended in order for improvement to occur. For example, take an environment that has been polluted – while the initial unit of clean-up may be cheap, it becomes more and more expensive as additional clean-up is done. If clean-up is undertaken to point "Q", the total cost of the clean-up is P*Q the white and light grey areas on the graph in Figure 5.1.

Marginal benefit is similar to marginal cost in that it is a measurement of the change in benefits over the change in quantity. While marginal cost is measured on the producer's end, marginal benefit is looked at from the consumer's perspec-

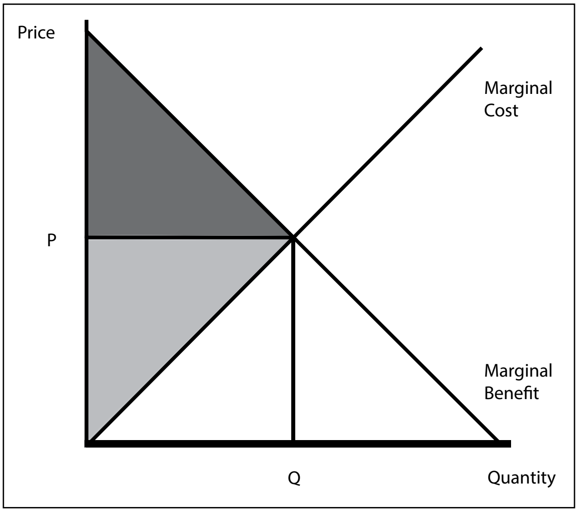

Figure 5.1 Marginal costs versus Marginal benefits. Source: Roger A. Arnold. (2014) Economics 11th Edition. South-Western, Cengage Learning.

tive – in this sense it can be thought of as the demand curve for environmental improvement.

The marginal benefit curve represents the trade-off between environmental improvement and other things we could do with the resources needed to gain the improvement. Again take an environment that has been polluted, the first unit of this pollution that is cleaned up has a very high benefit value to consumers of the environment.

Each additional unit that is cleaned up is valued at a somewhat lower level than each previous one because the overall pollution level continues to decrease. Once the pollution is reduced below a certain point, the marginal benefit of additional pollution control measures will be negligible because the environment itself is able to absorb a low level of pollution. Taking a look at the graph (Figure 5.1), the total consumer benefit that is represented as the dark grey area, the net benefit is greatest when the quantity "Q" reaches the marginal benefit curve. We could increase total benefit by adding pollution controls beyond Q, but only with marginal costs (MC) greater than marginal benefits (MB), so it is no longer efficient to further increase the benefits.

Oftentimes, benefits are more difficult to measure because they are not always monetary. In cases such as these the measurement may involve utilizing revealed preferences, through a survey or another mechanism, in order to discover the maximum price consumers are willing to pay for a particular quantity of a good. An average benefit is used when considering society as a whole because each individual's willingness to pay is different. Marginal costs and benefits are a vital part of economics because they help to provide the relevant measurement of costs and benefits at a certain level of production and consumption. If measured marginal costs and benefits are provided, it is much easier to calculate the ideal price and quantity. It is where the two intersect that will always be the most economically efficient point of production and consumption.

When considering environmental issues, the efficient point at which marginal costs and marginal benefits are equal is an important economic concept because it captures the essence of trade-offs. Often, environmental improvement concerns often revolve around whether we are above or below this point – whether any additional environmental improvement can provide more benefit than it will cost; this becomes an essential component in cost-benefit analysis.

5.4 Net value

Economists focus much of their analyses on a marketplace where supply and demand are based on the perceptions of present value and scarcity. However, when going beyond the simplicity of the short-term, particularly when costs and benefits occur at different points in time, it is important to utilize *discounting* to undertake longer-term analyses. Discounting adjusts costs and benefits to a common point in time. This approach can be useful in helping to determine how best to utilize many of our non-renewable natural resources. *Net present value (NPV)* is a calculation used to estimate the value – or net benefit – over the lifetime of a particular project, often longer-term investments, such as building a new town hall or installing energy efficient appliances. NPV allows decision makers to compare various alternatives on a similar time scale by converting all options to current dollar or euro figures. A project is deemed acceptable if the net present value is positive over the expected lifetime of the project.

The formula for NPV requires knowing the likely *amount of time* (t, usually in years) that cash will be invested in the project, the *total length of time* of the project (N, in the same unit of time as t), the *interest rate* (i), and the *cash flow* at that specific point in time (cash flow = cash inflow – cash outflow, C).

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

For example, take a business that is considering changing their lighting from traditional incandescent bulbs to fluorescents. The initial investment to change the lights themselves would be $40,000. After the initial investment, it is expected to cost $2,000 to operate the lighting system but will also yield $15,000 in savings each year; thus, there is a yearly cash flow of $13,000 every year after the initial investment. For simplicity, assume a discount rate of 10% and an assumption that the lighting system will be utilized over a 5 year time period. This scenario would have the following NPV calculations:

$t = 0$ NPV = $(-40{,}000)/(1 + .10)^0 = -40{,}000.00$
$t = 1$ NPV = $(13{,}000)/(1.10)^1 = 11{,}818.18$
$t = 2$ NPV = $(13{,}000)/(1.10)^2 = 10{,}743.80$
$t = 3$ NPV = $(13{,}000)/(1.10)^3 = 9{,}767.09$
$t = 4$ NPV = $(13{,}000)/(1.10)^4 = 8{,}879.17$
$t = 5$ NPV = $(13{,}000)/(1.10)^5 = 8{,}071.98$

Based on the information above, the total net present value over the lifetime of the project would be $9,280.22.

Once the net present value is calculated, various alternatives can be compared and/or choices can be made. Any proposal with a NPV < 0 should be dismissed because it means that a project will likely lose money or not create enough benefit. The clear choice is a project whose NPV > 0 or, if there are several alternatives with positive NPVs, the choice would be the alternative with the higher NPV.

With most societal choices, the *opportunity costs* are also considered when making decisions. Net present value provides one way to minimize foregone opportunities and identify the best possible options. The solution example, given above assumes that the interest rate does not change over time. Longer periods of time will often require separate calculations for each year in order to adjust for anticipated changes in the interest rate. When discounting is used it takes into account the fact that benefits in the future are not expected to be worth as much as in the present time. For example, $10 today may only be worth $9, $5, or even $1 in 2025. The rationale behind using a discount rate is two-fold: all things being equal, (1) individuals prefer to benefit now rather than later and (2) they tend to be risk averse, uncertain of what will occur in the future.

Net present value calculations can also help account for depreciation. Over time most assets depreciate, or lose value. Companies or individuals must be able to calculate a rate that includes depreciation for account balancing and tax purposes, as well to help predict replacement times for the asset in question.

NPV and depreciation calculations are extremely valuable in the world of economics; they tell us what projects and businesses are better investments and what outcomes we may expect in the future. However, while depreciation rates can be reliably estimated for most physical items, such as computer equipment or buildings, their application to natural resources and other environmental issues is more uncertain. Natural resources do not necessarily lose value over time. Thus, in most cases natural resources should not be depreciated when calculating resource NPVs. Also, since there is uncertainty about the future and external effects exist, it is much easier to predict what a company can do and what the reaction will be in the structured world of business than to accurately assess, say, the value of a forest to a local economy in future years.

Despite how helpful calculating NPV can be, using it to assess projects related to the environment will continue to be controversial. Ecosystem valuation is a complex process that does not always result in the assignment of accurate values to natural resources. And, while the use of discounting may make sense for money – being not as valuable in the future as it is today – it may be more difficult to use in assessing natural resources. Since many natural resources often increase in value, this type of evaluation method would need to recognize increased future resource values and/or that of other environmental services.

5.5 The value of non-market goods – the case of water

Nonmarket economic valuation can be defined as the analysis of actual and hypothetical human behaviour to derive estimates of the economic value (called accounting or shadow prices) of goods and services in situations where market prices are absent or distorted. Here we will, in order to illustrate the methods, analyse the value of provision of water for irrigation. Due to the prevailing lack of markets for water-related goods and services, accounting prices are an essential component of economic assessment of public water allocation and other policy choices. Both the theory and methods developed by economists for nonmarket valuation have been greatly expanded and improved over the last several decades and refinement in the field continues. The progress has occurred with the usual scholarly practice of confronting conceptual models with empirical evidence, and revising the former when it conflicts with the latter. Most of the effort towards a nonmarket economic valuation has focused on households' valuation of environmental public good uses of water, but producers' use of water is another important field.

It will be useful to begin with the point that most applied methods of water valuation fall into one of two broad categories that differ in the basic mathematical procedures and types of data employed in the valuation process. One type, which can be classed as hypothetical-deductive methods, or for simplicity just *deductive methods*, involves logical processes by an analyst to reason from general premises to particular conclusions. Applied to producers' valuation of water, deductive techniques commence with abstract models of human behaviour that are fleshed out with appropriate data to fit the case at hand. In addition to the behavioural postulates (e.g., profit maximization or cost minimization), the data to fit a deductive model will typically include assumptions about the relations between input levels and output (the "production function") plus forecasts of the relevant input and output prices.

The accuracy of the results of deductive reasoning depends on the validity of the behavioural and empirical premises, the appropriateness and detail of the model specification and the forecasts of the production function and prices. Examples of deductive techniques applied to valuing water in crop irrigation range from annual cost and return budgeting (via spreadsheets) of single products or an aggregate of multi-product firms to multi-period mathematical optimization models. Deductive techniques offer the advantage of flexibility. They can be constructed to reflect any desired future policies, economic and technological scenarios, and sensitivities of the results to varying assumptions.

The other broad group of valuation approaches are the *inductive methods.* They involve a process of reasoning from the particular to the general, or from real-world data to general relationships. Applied to producers' uses, inductive methods involve observation of prices from water rights or land and water rights transactions, responses to survey questionnaires, or from secondary data from government reports.

The accuracy of inductive techniques depends on several factors, including the representativeness and validity of the observational data used in the inference, the set of variables and the functional form used in fitting the data, and the appropriateness of the assumed statistical distribution.

A review of the previous literature on economic valuation of irrigation water suggests that valuations based on observed behaviour (inductive techniques) and those based on models of hypothesized farmer decisions (deductive techniques) are often inconsistent. Although my inference is not based on a formal meta-analysis, the large majority of behaviour-based (inductive) valuations in the literature appear to show a much lower valuation than do those grounded on the more common deductive models that relied on hypothesized producer actions.

A few econometric examples that show results much less optimistic for returns to public irrigation investments than do the deductive analyses commonly used for *ex ante* justification of such investments include: analyses of the contribution of irrigation to farm land values (see Torell et al 1990); studies of regional economic impacts of irrigation in the western US (Cicchetti et al 1975); econometric evaluations of factors (including investments in irrigation infrastructure) affecting regional long term economic growth in India and China (Fan and Hazell 2002); and *ex post* studies of public irrigation water investments in the western US (Wilson 1997). Further evidence is the general inability of governments to collect a significant part of the cost of public irrigation investments.

5.6 Analysis of the value of water

To analyse the issue of inductive versus deductive approaches, we begin with a conceptual framework grounded in production theory. Consider a multi-crop production function that expresses the maximum expected outputs of a set of crops associated with a package of known inputs:

$$Y = f(X_M, X_H, X_K, X_L, W)$$

Here Y refers to the quantities of outputs, and X to the quantities of various non-water inputs, and W is irrigation water. The subscripts refer to groups of inputs where

- materials, energy and equipment is M;
- human effort (e.g. labour, supervision) is H;
- capital is K;
- non-irrigated land is L.

The production function can apply to a single farm, or to broader geographical areas, such as a region. Both inductive and deductive approaches proceed from the production function to a measure of the value of irrigation water.

Inductive methods employ observational data and statistical (usually regression) methods to fit a production function, from which can be derived the input demand function for irrigation water, the producers' willingness to pay for alternative amounts of irrigation water. The most common deductive method applied to irrigation water valuation is called the residual method, which assumes optimizing producers who can forecast the production function and prices of outputs and inputs other than water.

The economic value of the unpriced scarce input (irrigation water) is derived as the net return to water; the expected revenues minus the expected non-water costs or cost of delivery of water per unit land area (e.g., ha). For a single crop for one year, this net return (denoted R_{W1}) represents the willingness to pay per ha for water delivered to the farm gate:

$$R_{W1} = YP_Y - (P_M X_M + P_H X_H + P_K X_K + P_L X_L) \qquad (1)$$

All estimated non-water costs of production are deducted from expected revenues (for if they were not, the residual would be correspondingly overestimated). The net return to water per ha is usually divided by the cubic meter of water delivered or consumed per acre to obtain an estimate of the unit value of water (e.g., USD/ha). Water demand functions derived via more rigorous methods (mathematical optimization models) are also classified as deductive analyses.

A significant premise is that there is no single "economic value" of water. Non-market economic valuation measures the net benefit (welfare change) associated with some policy-induced change in the attributes of the good or service. Thus, there are a number of benefit concepts, each applicable in specific decision contexts. To select the appropriate concept for measurement, it is important to clarify the specific attributes of the situation and decision in question.

It is worthwhile to differentiate between *at-site* and *at-source* value estimates. As with any economic commodity, the willingness of a user to pay for water depends on the place, form, and time for which the estimate is made. An at-site value refers to the value at the farm receiving point (head gate or well head). The at-source value, in contrast, refers to the value in the natural hydrologic system, at the point of withdrawal. Water for irrigation must be captured and transported from the point in a natural watercourse to the place of use.

Thus, value at site will exceed that at the source by the costs of transportation and storage, which can be expressed by subtracting acquisition or pumping costs from the net return in equation (1). Letting D represent the costs of delivery, an at-source value (R_{W2}) can be expressed as:

$$R_{W2} = R_{W1} - D \qquad (2)$$

Since the value estimates need to be comparable across sectors, and because instream values are at-source, at-source estimates are most appropriate for studies of inter-sectorial water allocation.

Because policy decisions relating to water entail a range of cases, from major long-lived capital investments to one-off allocations in the face of immediate events such as droughts, it is important to distinguish carefully between *long-run* and *short-run* values of irrigation water. The distinction relates to the degree of fixity of certain inputs. In the short run, where some inputs are fixed, the estimate of the increase in the net value of output can ignore the cost of the fixed inputs. But, in the long run, where all input costs must be covered, they cannot be ignored. Therefore, we would expect that for the same site and production processes, values estimated for a given supply for short-run contexts will be larger than values for the long run.

Another important distinction is between *periodic* and *capitalized* values. An annual or a periodic value estimate is, for convenience, the customary form of the value of water used in everyday discussion and planning. However, in some contexts (such as with prices of perennial or permanent water rights), observed prices represent the capitalized present value of a stream of periodic values (called asset or capitalized values). Asset values are, of course, much larger than the corresponding periodic price.

Finally, the perspective from which benefits and costs are accounted for in a specific economic evaluation is called the accounting stance, which can be either *private* or *public*. The private and public accounting perspectives differ as to how input and product prices are measured (market prices or social prices). A value estimate from a private perspective uses the prices faced by the producers in their decision-making. The public accounting stance adjusts prices of inputs and outputs to reflect society's perspective. For example, adjustments to a public viewpoint may remove government subsidies for certain crops, such as cotton or rice, thus lowering the net income (economic value) attributed to water.

What types of methods may be applied to reflect these distinctions? Inductive approaches to valuing irrigation water policies, in that they study actual farmer behaviour, universally reflect a private accounting stance. Some inductive approaches, such as observations on water rental markets, will represent both the short run and the periodic cases, but most, including hedonic property values and water rights markets, will represent both a long run and a capital asset value. Those inductive methods that measure net returns provide an at-source value (with delivery costs deducted), but production and cost function techniques provide at-site estimates. In contrast, the flexibility of deductive methods allow them to be used to estimate economic values either at-site or at-source, short-run or long-run, periodic or capitalized, and private or social accounting stances.

Chapter 5 sources:

Section 5.1 – 5.2. These sections includes parts from Tietenberg, T., Lewis, L. (2012) *Environmental & Natural Resource Economics* 9th Ed. (https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf). Chapter 4 "Valuing the Environment: Methods", with citations from pp 74-78 (Why value the Environment?) and pp 78-79 (Valuation).

Section 5.3-5.6 Roger A. Arnold. (2014) Economics 11th Edition. Cengage Learning.

Chapter 6
Who should Pay the Cost of Pollution?

6.1 The pollutants

Pollutants are chemical substances which cause damage in the environment, most often by being toxic to life, animals or plants or entire ecosystems. The environment has a certain capacity to deal with polluting substances, for example by oxidizing them or in other ways turning them into non-toxic products. Pollutants which are degraded in this way are called *biodegradable*.

In other cases the pollutants are not undergoing chemical changes and remain in the environment, or are removed only very slowly. These are called non-biodegradable or *persistent* pollutants. However many substances are slowly degraded and are not easily put into one or the other category.

Pollutants may either be emitted from an activity such as an industry, in gaseous form into the atmosphere, as water soluble substances in the waste effluents, or in solid from as part of solid waste.

A few categories of substances should be specially listed.

Heavy metals are metals which are toxic also in limited amounts. These are toxic in their metallic or ionic form, but especially as metal-organic compounds. Some of the most important are mercury, lead, cadmium and copper. Metals cannot be changed into anything else. They are removed slowly from the environment by mostly by being stored in the bottom sediments in lakes and streams.

Persistent Organic Pollutants, POP, are organic compounds which are not at all or very slowly broken down in nature. In this category we find several classical biocides, e.g. DDT toxic to insects, and several industrial chemicals, notably PCB, used for a very long time in electric equipment as a very stable and isolating oil, but also in many buildings. Both of these substances are today outlawed and not used in OECD countries. Other POPs are formed as side products in different chemical processes, e.g. the very toxic dioxins, which are formed in combustions. Other pollutants formed in combustion – most notably from cars – are polycyclic-aromatic substances, PAH, and volatile organic compounds, VOC.

Oxides of nitrogen and sulphur, NO_x and SO_x both form acids and thus contribute to acid rain. They are formed in combustion, and are found for examples in exhausts from cars. In limited amounts the environment can deal with these substances, but in larger amounts they can be very destructive.

Exhausts from waste streams from urban centers and, in general, human settlements, as well as from agricultural fields, contain *nutrients* which spur organic growth. If a recipient, e.g. a lake or a stream, receives too much of nutrients growth of e.g. algae will use up oxygen and create oxygen-free, dead, environments. This process is called eutrophication and the pollutants most often called just nutrients. A limited amount of nutrients are normal but too much of it is, as mentioned, destructive.

Carbon dioxide, which is an important greenhouse gases, is a normal component of the life of all ecosystems as it is used to build up green plants. Because of this it is not a pollutant. However its dramatically increased concentration in the atmosphere, causes an imbalance which leads to global warming and climate change. It is therefore treated as a pollutant and its emission regulated or taxed (or both). In the US it has been included in the clean air law and thus is formally a pollutant. This is not the case in the EU.

In American literature the persistent pollutants are referred to as *stock pollutants*, while the non-persistent biodegradable pollutants are referred to as *fund pollutants*.

Of course the emission of pollutants into the environment cause damage and thereby a cost for someone. It is sometimes very clear who and what is affected, e.g. when a forest produces less timber because of acidification or the health of inhabitants in a city decreases because of air pollution from cars. It may also be clear from where the pollution comes, e.g. a factory or, as in this case, the cars. In other cases it is less clear both who is the polluter and who is suffering from the consequences.

In any case the problem of who should bear the cost of pollution remains a central issue in environmental economics. We will deal with this issue in this chapter, and come back to the question in chapter 9, where environmental taxation is dealt with.

6.2 Cost-effective distribution of pollution-reduction duties

We begin our analysis with uniformly mixed gaseous and biodegradable pollutants, which analytically are the easiest to deal with. An example is sulphur oxide, SO_x. The damage caused by these pollutants depends on the amount entering the atmosphere. In contrast to non-uniformly mixed pollutants, the damage caused by uniformly mixed pollutants is relatively insensitive to where the emissions take place. Thus, the policy can focus simply on controlling the total amount of emissions in a manner that minimizes the cost of control. What can we say about the cost-effective allocation of control responsibility for uniformly mixed pollutants?

Consider a simple example. Assume that two emissions sources are currently emitting 15 units each for a total of 30 units. Assume further that the control authority determines that the environment can assimilate 15 units in total, so that a reduction of 15 units is necessary. How should this 15-unit reduction be allocated between the two sources in order to minimize the total cost of the reduction?

We can demonstrate the answer with the aid of Figure 6.1, which is drawn by measuring the marginal cost of control for the first source from the left-hand axis (MC_1) and the marginal cost of control for the second source from the right-hand axis (MC_2). Note that a total 15-unit reduction is achieved for every point on this graph; each point represents some different combination of reduction by the two sources. Drawn in this manner, the diagram represents all possible allocations of the 15-unit reduction between the two sources. The left-hand axis, for example, represents an allocation of the entire reduction to the second source, while the right-hand axis represents a situation in which the first source bears the entire

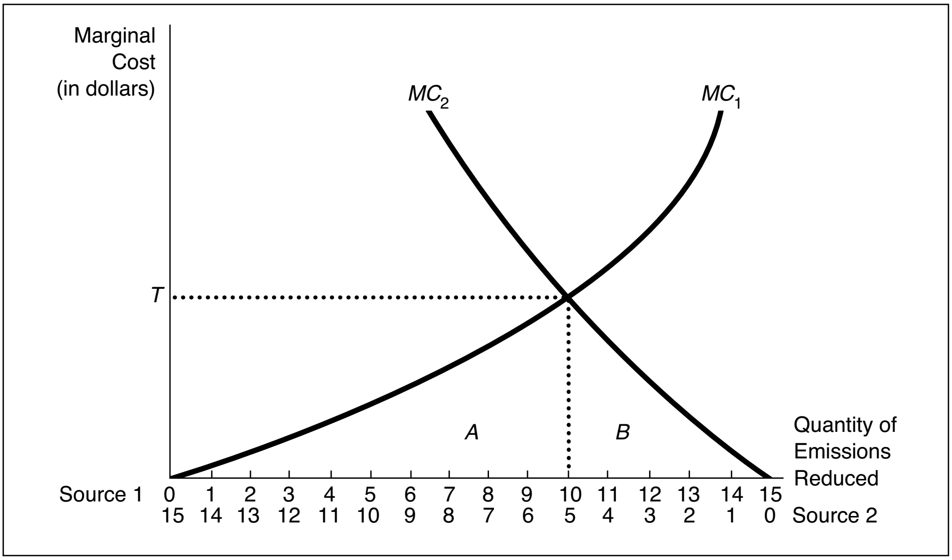

Figure 6.1 Cost-Effective Allocation of a Uniformly Mixed Fund Pollutant, Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Ed. p. 369 (https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf.)

responsibility. All points in between represent different degrees of shared responsibility. What allocation minimizes the cost of control?

In the cost-effective allocation, the first source cleans up ten units, while the second source cleans up five units. The total variable cost of control for this particular assignment of the responsibility for the reduction is represented by area A plus area B. Area A is the cost of control for the first source; area B is the cost of control for the second. Any other allocation would result in a higher total control cost. (Convince yourself that this is true).

6.3 Cost-effective pollution-control policies

This proposition can be used as a basis for choosing among the various policy instruments that the control authority might use to achieve this allocation. The authorities have a large menu of options for controlling the amount of pollution they allow the factories etc to emit into the environment. The cheapest method of control will differ widely not only among industries, but also among plants in the same industry. The selection of the cheapest method requires detailed information on the possible control techniques and their associated costs.

Generally, plant managers are able to acquire information on control options for the plants when it is in their interest to do so. However, the government authorities responsible for meeting pollution targets are not always likely to have this information. Since the degree to which these plants would be regulated depends on cost information, it is unrealistic to expect these plant managers to transfer unbiased information to the government. Plant managers would have a strong incentive to overstate control costs in hopes of reducing their ultimate control burden.

This situation poses a difficult dilemma for control authorities. The cost of incorrectly assigning the control responsibility among various polluters is likely to be large. Yet the control authorities do not have sufficient information at their disposal to make a correct allocation. Those who have the information – the plant managers – are not inclined to share it. Can the cost-effective allocation be found?

The answer depends on the approach taken by the control authority.

We start our investigation of this question by supposing that the control authority pursues a traditional legal approach by imposing a separate emissions limit on each source. In the economics literature this approach is referred to as the "command-and-control" approach. An *emissions standard* is a legal limit on the amount of the pollutant an individual source is allowed to emit. It is given to the industrial plant in the permit to run the factory. In our example it is clear that the two standards should add up to the allowable 15 units, but it is not clear how, in the absence of information on control costs, these 15 units are to be allocated between the two sources.

The easiest method of resolving this dilemma – and the one chosen in the earliest days of pollution control – would be simply to allocate each source an equal reduction. As is clear from Figure 6.1, this strategy would not be cost-effective.

While the first source would have lower costs, this cost reduction would be substantially smaller than the cost increase faced by the second source. Compared to a cost-effective allocation, total costs would increase if both sources were forced to clean up the same amount.

When emissions standards are the policy of choice, there is no reason to believe that the authority will assign the responsibility for emissions reduction in a cost-minimizing way. This is probably not surprising. Who would have believed otherwise?

Surprisingly enough, however, some policy instruments do allow the authority to allocate the emissions reduction in a cost-effective manner even when it has no information on the magnitude of control costs. These policy approaches rely on economic incentives to produce the desired outcome.

6.4 Cost-effectiveness analysis

What can be done to guide policy when the requisite valuation for benefit-cost analysis is either unavailable or not sufficiently reliable? Without a good measure of benefits, making an efficient choice is no longer possible. In such cases, frequently it is possible, however, to set a policy target on some basis other than a strict comparison of benefits and costs. One example is pollution control. What level of pollution should be established as the maximum acceptable level? In many countries, studies of the effects of a particular pollutant on human health have been used as the basis for establishing that pollutant's maximum acceptable concentration. Researchers attempt to find a threshold level below which no damage seems to occur. That threshold is then further lowered to provide a margin of safety and that becomes the pollution target.

Approaches could also be based upon expert opinion. Ecologists, for example, could be enlisted to define the critical numbers of certain animal species or the specific critical wetlands resources that should be preserved. Once the policy target is specified, however, economic analysis can have a great deal to say about the cost consequences of choosing a means of achieving that objective. The cost consequences are important not only because eliminating wasteful expenditures is an appropriate goal in its own right, but also to assure that they do not trigger a political backlash.

Typically, several means of achieving the specified objective are available; some will be relatively inexpensive, while others turn out to be very expensive. The problems are frequently complicated enough that identifying the cheapest means of achieving an objective cannot be accomplished without a rather detailed analysis of the choices.

In the example above it is assumed that the polluter by some process can remove the pollutant from the flue gases, so-called end-of-pipe cleaning. This is e.g. easily achieved for sulphur oxide emissions from a power plant using fossil coal, oil, or gas, or for that matter any sulphur-containing organic substance such as household waste, as fuel. The cleaning of the flue gases from SO_x is not very expensive and is the best alternative if there is high enough cost connected to the emission of the pollutant.

Cost-effectiveness analysis frequently involves an optimization procedure. An optimization procedure, in this context, is merely a systematic method for finding the lowest-cost means of accomplishing the objective. This procedure does not, in general, produce an efficient allocation because the predetermined objective may not be efficient. All efficient policies are cost-effective, but not all cost-effective policies are efficient.

Cost-effectiveness analysis can also be used to determine how much compliance costs can be expected to change if the authority, most often the Environmental Protection Agency of the country, EPA, chooses a more stringent or less stringent standard. The case study presented in the case above not only illustrates the use of cost-effectiveness analysis, but also shows that costs can be very sensitive to the regulatory approach chosen by the EPA.

6.5 Policy tools for charging the polluter

Which methods are used to regulate the cost of pollution? The two most common approaches are known as emissions charges and emissions trading.

A *charge* is a cost to be paid to the authorities for each gram or kilo or tonne of a pollutant emitted in flue gases or in the effluent or the solid waste from an activity. The charge is normally set to eventually reduce or even eliminate the pollutant. It is most often set to make the option of taking away the pollutant more attractive than to pay the charge. This is, as mentioned, e.g. the case for sulphur oxides. The company has then three options to deal with the issue. They may use a fuel with less sulphur, such as low sulphur oil; they may introduce end-of-pipe cleaning which removes the SO_x from the flue gas; finally they may introduce cleaner production methods to completely change the production process in such a way that the problem disappear, e.g. by introducing renewable source of energy in the company.

The word charge is used for several things. The cost for a municipality to provide water and energy is also called a *charge*, and a municipality is also charging for taking care of solid waste and waste water, which may be considered pollution.

An *environmental tax* is also a charge but often not with the intention to remove the taxed substance from the production. For example taxing resource use is not meant to remove the use of resources but often to make it more efficient and stimulate recycling (and provide an income, like a tax, to the authority). We say that a charge is an *elastic* measure, while a tax is less elastic.

Emission trading is used to distribute the cost of reducing a pollutant between two or several emitters in the most cost-efficient way. Emission trading has been used for several different pollutants emitted from flue gases, but is today most often used for reducing carbon dioxide and other GHG emissions. In this case the authorities define the total amount which can be emitted, the so-called *cap*, and a market is constructed to let the polluters deal with the reduction in the best way. Emission trading is therefore also called *cap and trade*.

We will come back to the policy tools in chapter 9.

6.6 Environmental and strategic impact analysis

What can be done when the information needed to perform a cost-benefit analysis or a cost-effectiveness analysis is not available? The analytical technique designed to deal with this problem is called impact analysis. An impact analysis, regardless of whether it focuses on economic impact or environmental impact or both, attempts to quantify the consequences of various actions.

In contrast to cost-benefit analysis, a pure impact analysis makes no attempt to convert all these consequences into a one-dimensional measure, such as dollars or euros, to ensure comparability. In contrast to cost-effectiveness analysis, impact analysis does not necessarily attempt to optimize. Impact analysis places a large amount of relatively undigested information at the disposal of the policy-maker. It is up to the policy-maker to assess the importance of the various consequences and act accordingly.

The environmental policy may be strong. In the United States the National Environmental Policy Act was implemented in 1970. This act, among other things, directed all agencies of the federal government to include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on

- the environmental impact of the proposed action,
- any adverse environmental effects which cannot be avoided should the proposal be implemented,
- alternatives to the proposed action,
- the relationships between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and
- any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

This was the beginning of the environmental impact statement, which is now a familiar, if controversial, part of environmental policy-making.

Current environmental impact statements are more sophisticated than their early predecessors and may contain a cost-benefit analysis or a cost-effectiveness analysis in addition to other more traditional impact measurements. Historically, however, the tendency had been to issue huge environmental impact statements that are virtually impossible to comprehend in their entirety.

The requirements in the National Environmental Policy Act are today answered by making an environmental impact analysis, or environmental impact assessment, EIA. An EIA is in EU legislation a requirement for all larger infrastructure projects, such as building a road or railroad, or for a factory or other production facility. In addition there is also a request for a strategic impact analysis, SIA. An SIA is in the EU legislation "a systematic process for evaluating the environmental consequences of proposed policy, plan or program initiative in order to ensure they are fully included and appropriately addressed at the earliest stage of decision-making on a par with social and economic considerations".

The best method for arriving at a comprehensive impact analysis is to use *Life Cycle Assessment*, LCA. In this method a complete mapping of the impact of a product or a process during its entire lifetime, from extraction of resources, production in a factory, use in society to end-of-life most often wasting, is assessed and summarised in a quantitative way. Several different impact categories are assessed separately, such as resource use, energy use, climate impact, emissions of toxic substances, acidifying substances, eutrophying substances, impact on human health etc. LCA requires large databases on the impacts of all different components used in a production process. Such databases have been developed and are used. LCA is presently the best method to answer the seemingly simple question: How environmentally friendly is this product or process?

6.7 The Polluter's Pays Principle

In environmental law, the Polluter Pays Principle, PPP, is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment. It is regarded as a regional custom because of the strong support it has received in most countries in the Organization for Economic Co-operation and Development (OECD) and European Union (EU).

The polluter pays principle (sometimes called the polluters' pay principle, assuming there are many polluters) underpins environmental policy such as an Eco tax, which, if enacted by government, deters and essentially reduces greenhouse gas emissions. Some eco-taxes underpinned by the polluter pays principle include: the Gas Guzzler Tax, in US, Corporate Average Fuel Economy (CAFE) – a "polluter pays" fine.

The PPP sounds excellent, is widely accepted but difficult to use in practice. Suppose you notice that a forest is damaged by acid rain. From where does this acid rain come? To find out requires a research project and in most cases the result is not more detailed than that a region or country may be identified, but not a specific company or factory. No one can then be charged for polluting the forest. The cost of reduced timber production, which may be large, is then in practice borne by the victim, not the polluter. Similarly for the air pollution in a city the situation is the same. You may not identify a particular car for causing the pollution and its costs.

In these cases other means have to be used to reduce the pollution. In the case of sulphur oxides and nitrogen oxides an international convention was established between the countries of the United Nations Economic Commission for Europe (UNECE), the *Convention on Long-Range Transboundary Air Pollution*. This convention, signed in 1979, has been very successful and especially for the sulphur oxides the levels a have decreased to some 10% of its values before the convention was implemented. For air pollution in cities it is today standard that cars *are requested to use catalytic converters* which reduce the emissions considerably. Urban planning may also come into the picture as car free streets and areas are typically expanding all over the world. In both these examples thus *regulation* or "command and control" is the measure used.

But there are also cases where the polluter is clearly identified, for example when the area around a factory is severely polluted and the pollution is limited to that area. For such cases we repeatedly see court cases for charging the polluter with the costs. In the longer term the permit or license to run the factory has to deal with this pollution and request from the factory to change its processes to reduce or eliminate it.

A category of cases which deserves special mention are the large international catastrophes or *accidents* which may cause very large damages for many countries. Well known are the Chernobyl disaster in Ukraine in 1986 and the effluent after a fire from a factory in Basel, Switzerland into River Rhine also in 1986. The two accidents caused very large costs for countries in all of Europe without any charges raised against the two responsible companies. On the contrary extensive measures were developed for control and early warning systems, thus increased international cooperation in the field of environmental protection.

6.8 Extended Producer Responsibility (EPR)

It is also possible to be proactive and from the beginning charge the producer with the responsibility to deal with its products over its entire life span. This is called Extended Producer Responsibility (EPR). This is a concept that was probably first described by Thomas Lindhqvist for the Swedish government in 1990. EPR seeks to shift the responsibility dealing with waste from governments (and thus, taxpayers and society at large) to the entities producing it. In effect, it internalizes the cost of waste disposal into the cost of the product, theoretically meaning that the producers will improve the waste profile of their products, thus decreasing waste and increasing possibilities for reuse and recycling.

OECD defines EPR as a concept where manufacturers and importers of products should bear a significant degree of responsibility for the environmental impacts of their products throughout the product life-cycle, including upstream impacts inherent in the selection of materials for the products, impacts from manufacturers' production process itself, and downstream impacts from the use and disposal of the products. Producers accept their responsibility when designing their products to minimize life-cycle environmental impacts, and when accepting legal, physical or socio-economic responsibility for environmental impacts that cannot be eliminated by design.

EPR is implemented in societies in different ways. If it deals with a specific product such as a car, when it is to be wasted, it is easy enough. The car has to be taken back by the factory, which is now typically the case. If it is something more general such as paper or glass containers it is more difficult. In Sweden this was solved by an agreement between the state and the industrial organisations by setting up a company responsible for collecting waste paper, glass and plastic containers from the households and sending them to recycling facilities. The cost for the collection and recycling is carried mostly by the industrial partner.

Another means of doing this is by refunding, using a *deposit-refund system*. In this case a bottle or can has a charge on it when the beverage is bought, and this charge is repaid when the empty container is returned to the shop. The system is quite efficient. In 2014 85% of aluminum cans and 91% of PET bottles were returned, while return of glass beverage bottles was 98% The figures are a little lower for other categories. In other countries in EU there is a system of return but not refund, which is much less efficient. This is used in Sweden for batteries, which is still returned for about 70%.

6.9 Who pays for restoration of brownfields?

Areas, polluted and not used but of interest for new uses, are commonly called *brownfields*. These are typically abandoned industrial sites. The costs for cleaning up may be substantial, if it includes removal and often treatment of contaminated soil, the transport of large amounts of sand, gravel etc. to allow for the development of housing areas, where no contamination is acceptable.

Who should pay for these large costs? It may seem obvious that the industries which were located there should bear the costs. However this is not often possible. The sites may have been abandoned since decades, the companies may have disappeared since many years or being in bankruptcy. In practice it is not quite reasonable that the new user, typically a housing company, should bear the costs either. In practice it is thus a question for the municipality or sometimes the region or the state to deal with such sites. This means in practice the taxpayers.

In some countries also the industries come into the picture. In the United States where it is less obvious that the state or federal agencies would accept to pay such costs, the industries have set up a very large fund – the *Superfund*, one of the largest in the country – to allow for the restoration of brownfields. The U.S. Superfund law requires polluters to pay for clean-up of hazardous waste sites, when the polluters can be identified, but as mentioned it is not often the case. In Western Europe it is more typically the municipalities which take responsibility for the cost of the clean-up. Here the municipalities also have a much larger part of tax money and are also responsible for the development of the cities.

Brownfield restoration is thus one more of the many cases where the polluter pays principle fails.

Chapter 6 sources:

Section 6.1 Lars Rydén

Sections 6.2 – 6.4. From Tietenberg, T., Lewis, L. (2012) *Environmental & Natural Resource Economics* 9th Ed. https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf. Chapter 14 "Economics of Pollution Control: An Overview", with citations from pp 368-370 (Section 6.2) and pp 370-375 (Section 6.3) (Cost- Effective Policies for Uniformly Mixed Fund Pollutants); and Chapter 14 "Economics of Pollution Control: An Overview" pp. 66-68 (Section 6.4) (Cost- Effective Policies for Uniformly Mixed Fund Pollutants).

Sections 6.5- 6.9 By Lars Rydén based on the following sources: *Environmental Science. Understanding, protecting and managing the environment in the Baltic Sea Region* Editors: Lars Rydén, Pawel Migula and Magnus Andersson. The Baltic University Programme, Uppsala University, 2003 Chapter 19. The Cost of Pollution – Environmental Economics. http://www.balticuniv.uu.se/index.php/boll-online-library/834-es-environmental-science *Environmental Policy – Legal and Economic Instruments*. Børge Klemmensen, Sofie Pedersen, Kasper R. Dirckinck-Holmfeld, Anneli Marklund, and Lars Rydén. Baltic University Press, 2007. Chapter 10. Economic Policy Instruments – Taxes and Fees http://www.balticuniv.uu.se/index.php/boll-online-library/826-em-1-environmental-policy-legal-and-economic-instruments- *Environmental Impact Assessment* E. Beimborn, University of Wisconsin-Milwaukee https://www4.uwm.edu/cuts/utp/impacppt.pdf *Polluter pays principle* Wikipedia https://en.wikipedia.org/wiki/Polluter_pays_principle

Chapter 7
Ethics – Applying Normative Criteria in Economic Decision-Making

7.1 Ethics and equity – intergenerational equity

Three key principles of justice dominate the discussion on the ethics of sustainable development.

- Justice towards future generations, inter-generational justice (or equity)
- Justice towards the present generations, intra-generational justice (or equity)
- Justice towards the rest of the living world, nature.

Intergenerational equity has a special role here as it emphasizes the long-term nature of sustainable development, and has been used as "definition" of sustainable development all the time since the Brundtland Commission did so in their 1987 report. In this chapter we will analyse this criterion in some detail. We will first look at how the distribution of resources between the present and future can be evaluated by economic means and then look at some examples.

We begin by considering a specific, ethically challenging situation – the allocation of a non-renewable resource over time. We shall trace out the temporal allocation of a non-renewable resource using the dynamic efficiency criterion and show how this allocation is affected by changes in the discount rate. To lay the groundwork for our evaluation of justice, we then turn to the task of defining what we mean by inter-generational equity. Finally, we consider not only how this theoretical definition can be made operationally measurable, but also how it relates to dynamic efficiency. To what degree is dynamic efficiency compatible with intergenerational equity?

A two-period model. Dynamic efficiency balances present and future uses of a non-renewable resource by maximizing the present value of the net benefits derived from its use. This implies a particular allocation of the resource across time. We can investigate the properties of this allocation and the influence of such key parameters as the discount rate with the aid of a simple numerical example. We begin with the simplest of models – deriving the dynamic efficient allocation across two time periods. Later we will show how these conclusions generalize to longer time periods and to more complicated situations.

Assume that we have a fixed supply of a non-renewable resource to allocate between two periods. Assume further that the demand function is constant in the two periods, the marginal willingness to pay is given by the formula $P = 8 – 0.4q$, and marginal cost is constant at $2 per unit (Figure 7.1). Note that if the total supply was 30 or greater, and we were concerned only with these two periods, an efficient allocation would produce 15 units in each period, *regardless of the discount rate.*

Thirty units would be sufficient to cover the demand in both periods; the consumption in Period 1 does not reduce the consumption in Period 2. In this case the static efficiency criterion is sufficient because the allocations are not interdependent.

Examine, however, what happens when the available supply is less than 30. Suppose it equals 20. How do we determine the efficient allocation? According to the dynamic efficiency criterion, the efficient allocation is the one that maximizes the present value of the net benefit. The present value of the net benefit for both periods is simply the sum of the present values in each of the two periods. To take a concrete example, consider the present value of a particular allocation: 15 units in the first period and 5 in the second. How would we compute the present value of that allocation?

The present value in the first period would be that portion of the geometric area under the demand curve that is over the supply curve – $45.00. The present

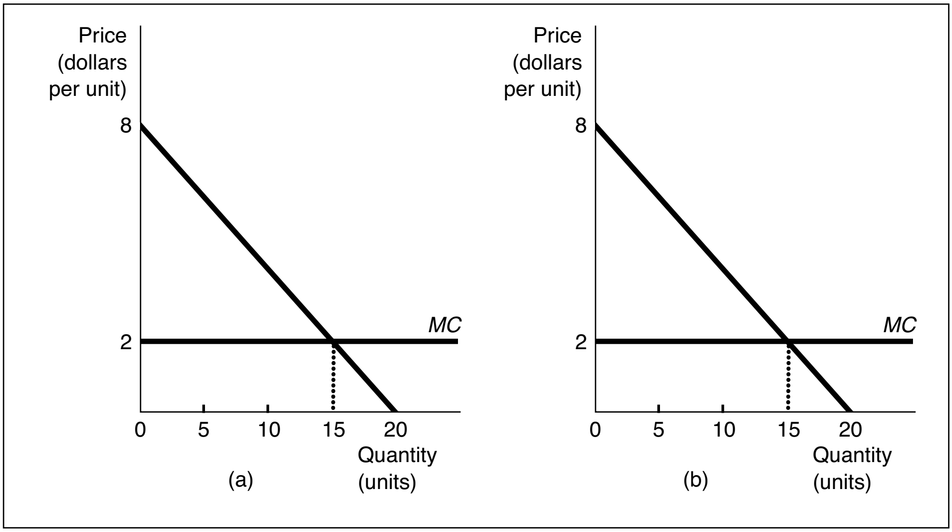

Figure 7.1 Allocation of a non-renewable resource over time. A Two-Period Model (source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 103.

value in the second period is that portion of the area under the demand curve that is over the supply curve from the origin to the five units produced multiplied by $1/(1 + r)$. If we use $r = 0.10$, then the present value of the net benefit received in the second period is $22.73, and the present value of the net benefits for the two years is $67.73.

Having learned how to find the present value of net benefits for any allocation, how does one find the allocation that maximizes present value? One way, with the aid of a computer, is to try all possible combinations of q_1 and q_2 that sum to 20. The one yielding the maximum present value of net benefits can then be selected. That is tedious and, for those who have the requisite mathematics, unnecessary.

The dynamically efficient allocation of this resource has to satisfy the condition that the present value of the marginal net benefit from the last unit in Period 1 equals the present value of the marginal net benefit in Period 2. Even without mathematics, this principle is easy to understand, as can be demonstrated with the use of a simple graphical representation of the two-period allocation problem.

Figure 7.2 depicts the present value of the marginal net benefit for each of the two periods. The net benefit curve for Period 1 is to be read from left to right. The net benefit curve intersects the vertical axis at $6; demand would be zero at $8 and the marginal cost is $2, so the difference (marginal net benefit) is $6. The

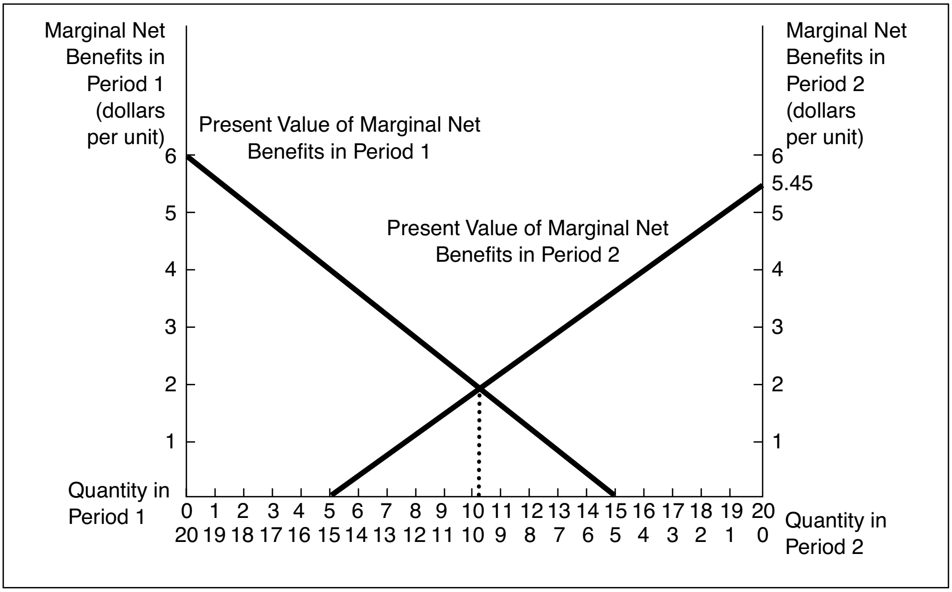

Figure 7.2. The Dynamically Efficient Allocation. A Two-Period Model (source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p. 105.

marginal net benefit for the first period goes to zero at 15 units because, at that quantity, the willingness to pay for that unit exactly equals its cost.

The only challenging aspect of drawing the graph involves constructing the curve for the present value of net benefits in Period 2. Two aspects are worth noting. First, the zero axis for the Period 2 net benefits is on the right, rather than the left, side. Therefore, increases in Period 2 are recorded from right to left. This way, all points along the horizontal axis yields a total of 20 units allocated between the two periods. Any point on that axis picks a unique allocation between the two periods.

Second, the present value of the marginal benefit curve for Period 2 intersects the vertical axis at a different point than does the comparable curve in Period 1. (Why?) This intersection is lower because the marginal benefits in the second period need to be discounted (multiplied by $1/(1 + r)$) to convert them into present value form since they occur one year later. Thus, with the 10 percent discount rate we are using, the marginal net benefit is \$6 and the present value is \$6/1.10 = \$5.45. Note that larger discount rates would rotate the Period 2 marginal benefit curve around the point of zero net benefit ($q_1 = 5$, $q_2 = 15$) toward the right-hand axis. We shall use this fact in a moment.

The efficient allocation is now readily identifiable as the point where the two curves representing present value of marginal net benefits cross. The total present value of net benefits is then the area under the marginal net benefit curve for Period 1 up to the efficient allocation, plus the area under the present value of the marginal net benefit curve for Period 2 from the right-hand axis up to its efficient allocation. Because we have an efficient allocation, the sum of these two areas is maximized. Since we have developed our efficiency criteria independent of an institutional context, these criteria are equally appropriate for evaluating resource allocations generated by markets, government rationing, or even the whims of a dictator.

7.2 Marginal user cost

While *any* efficient allocation method must take scarcity into account, the details of precisely how that is done depend on the context. Inter-temporal scarcity imposes an opportunity cost that we henceforth refer to as the *marginal user cost*. When resources are scarce, greater current use diminishes future opportunities. The marginal user cost is the present value of these forgone opportunities at the margin. To be more specific, uses of those resources, which would have been appropriate in the absence of scarcity, may no longer be appropriate once scarcity is present. Using large quantities of water to keep lawns lush and green may be wholly appropriate for an area with sufficiently large renewable water supplies, but quite inappropriate when it denies drinking water to future generations. Failure to take the higher scarcity value of water into account in the present would lead to inefficiency due to the additional cost resulting from the increased scarcity imposed on the future. This additional marginal value created by scarcity is the marginal user cost.

We can illustrate this concept by returning to our numerical example. With 30 or more units, each period would be allocated 15, the resource would not be scarce, and the marginal user cost would be zero.

With 20 units, however, scarcity emerges. No longer can 15 units be allocated to each period; each period will have to be allocated less than would be the case without scarcity. Due to this scarcity the marginal user cost for this case is not zero. As can be seen from Figure 7.2, the present value of the marginal user cost, the additional value created by scarcity, is graphically represented by the vertical distance between the quantity axis and the intersection of the two present-value curves. It is identical to the present value of the marginal net benefit in each of the periods. This value can either be read off the graph or determined more precisely, as demonstrated in the chapter appendix, to be \$1,905.

We can make this concept even more concrete by considering its use in a market context. An efficient market would have to consider not only the marginal cost of extraction for this resource but also the marginal user cost. Whereas in the absence of scarcity, the price would equal only the marginal cost of extraction, with scarcity, the price would equal the sum of marginal extraction cost and marginal user cost.

To see this, solve for the prices that would prevail in an efficient market facing scarcity over time. Inserting the efficient quantities (10.238 and 9.762, respectively) into the willingness-to-pay function ($P = 8 - 0.4q$) yields $P_1 = 3.905$ and $P_2 = 4.095$. The corresponding supply-and-demand diagrams are given in Figure 6.3. Compare Figure 6.3 with Figure 7.1 to see the impact of scarcity on price. Note that in the absence of scarcity, marginal user cost is zero.

In an efficient market, the marginal user cost for each period is the difference between the price and the marginal cost of extraction. Notice that it takes the value \$1,905 in the first period and \$2.095 in the second. In both the periods, the present value of the marginal user cost is \$1.905. In the second period, the actual marginal user cost is \$1,905$(1 + r)$. Since $r = 0.10$ in this example, the marginal user cost for the second period is \$2,095. Thus, while the present value of marginal user cost is equal in both periods, the actual marginal user cost rises over time.

Both the size of the marginal user cost and the allocation of the resource between the two periods is affected by the discount rate. In Figure 7.2, because of discounting, the efficient allocation allocates somewhat more to Period 1 than to

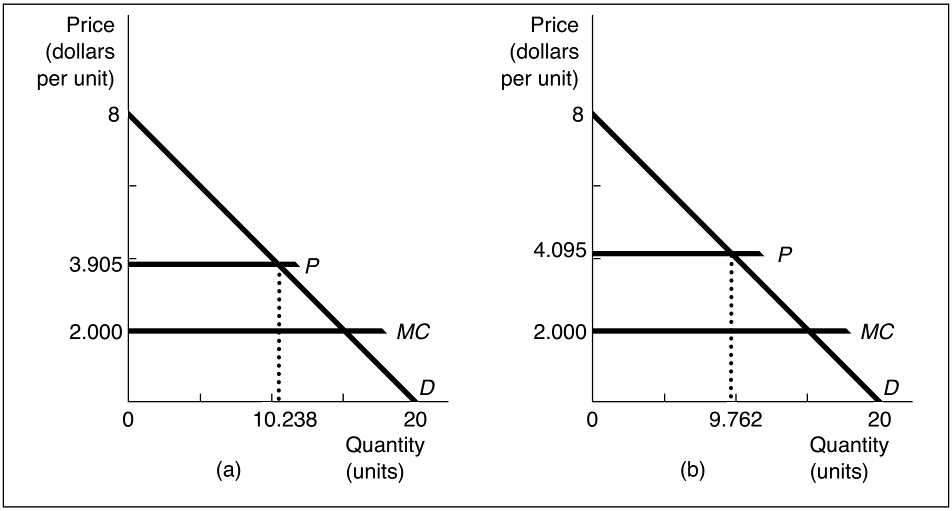

Figure 7.3. Efficient market allocation of a non-renewable resources. Dynamic Efficiency and Sustainable Development. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p.107.

Period 2. A discount rate larger than 0.10 would be incorporated in this diagram by rotating the Period 2 curve an appropriate amount toward the right-hand axis, holding fixed the point at which it intersects the horizontal axis (can you see why?). The larger the discount rate, the greater the amount of rotation required. The amount allocated to the second period would be necessarily smaller with larger discount rates. The general conclusion, which holds for all models we consider, is that higher discount rates tend to skew resource extraction toward the present because they give the future less weight in balancing the relative value of present and future resource use. The choice of what discount rate to use, then, becomes a very important consideration for decision makers.

7.3 Applying the sustainability criterion

One of the difficulties in assessing the justice of inter-temporal allocations using this version of the sustainability criterion is that it is so difficult to apply. Discovering whether the well-being of future generations is lower than that of current generations requires us not only to know something about the allocation of resources over time, but also to know something about the preferences of future generations (in order to establish how valuable various resource streams are to them). That is a tall (impossible?) order!

Is it possible to develop a version of the sustainability criterion that is more operational? Fortunately it is, thanks to what has become known as the "Hartwick Rule." In an early article, John Hartwick (1977) demonstrated that a constant level of consumption could be maintained perpetually from an environmental endowment if all the scarcity rent derived from resources extracted from that endowment were *invested in capital*. That level of investment would be sufficient to assure that the value of the total capital stock would not decline.

Two important insights flow from this reinterpretation of the sustainability criterion. First, with this version it is possible to judge the sustainability of an allocation by examining whether or not the value of the total capital stock is non-declining. That test can be performed each year without knowing anything about future allocations or preferences. Second, this analysis suggests the specific degree of sharing that would be necessary to produce a sustainable outcome, namely, all scarcity rent must be invested.

Let's pause to be sure we understand what is being said and why it is being said. Although we shall return to this subject later, it is important now to have at least an intuitive understanding of the implications of this analysis. Consider an analogy.

Suppose a grandparent left you an inheritance of $10,000, and you put it in a bank where it earns 10 percent interest. What are the choices for allocating that money over time and what are the implications of those choices? If you spent exactly $1,000 per year, the amount in the bank would remain $10,000 and the income would last forever; you would be spending only the interest, leaving the principal intact. If you spend more than $1,000 per year, the principal would necessarily decline over time and eventually the balance in the account would go to zero. In the context of this discussion, spending $1,000 per year or less would satisfy the sustainability criterion, while spending more would violate it.

What does the Hartwick Rule mean in this context? It suggests that one way to tell whether an allocation (spending pattern) is sustainable or not is to examine what is happening to the value of the principal (capital) over time. If the capital is declining, the allocation (spending pattern) is not sustainable. If the principal is increasing or remaining constant, the allocation (spending pattern) is sustainable. How do we apply this logic to the environment? In general, the Hartwick Rule suggests that the current generation has been given an endowment. Part of the endowment consists of environmental and natural resources (known as "natural capital") and physical capital (such as buildings, equipment, schools, and roads). Sustainable use of this endowment implies that we should keep the principal (the value of the endowment) intact and live off only the flow of services provided. We should not, in other words, chop down all the trees and use up all the oil, leaving future generations to fend for themselves. Rather we need to assure that the value of the total capital stock is maintained, not depleted.

The desirability of this version of the sustainability criterion depends crucially on how substitutable the two forms of capital are. If physical capital can readily substitute for natural capital, then maintaining the value of the sum of the two is sufficient. If, however, physical capital cannot completely substitute for natural capital, investments in physical capital alone may not be enough to assure sustainability.

How tenable is the assumption of complete substitutability between physical and natural capital? Clearly it is untenable for certain categories of environmental resources. Although we can contemplate the replacement of natural breathable air with universal air-conditioning in domed cities, both the expense and the artificiality of this approach make it an absurd compensation device.

Obviously intergenerational compensation must be approached carefully (see Example 7.1.). Recognizing the weakness of the constant total capital definition in the face of limited substitution possibilities has led some economists to propose a new definition. According to this new definition, an allocation is sustainable if

Box 7.1. Example Nauru: Weak Sustainability in the Extreme

The weak sustainability criterion is used to judge whether the depletion of natural capital is offset by sufficiently large increases in physical or financial capital so as to prevent total capital from declining. It seems quite natural to suppose that a violation of that criterion does demonstrate unsustainable behaviour. But does fulfilment of the weak sustainability criterion provide an adequate test of sustainable behaviour? Consider the case of Nauru.

Nauru is a small Pacific island that lies some 3,000 kilometres northeast of Australia. It contains one of the highest grades of phosphate rock ever discovered. Phosphate is a prime ingredient in fertilizers.

Over the course of a century, first colonizers and then, after independence, the Nauruans decided to extract massive amounts of this rock. This decision has simultaneously enriched the remaining inhabitants (including the creation of a trust fund believed to contain over $1 billion) and destroyed most of the local ecosystems. Local needs are now mainly met by imports financed from the financial capital created by the sales of the phosphate.

However wise or unwise the choices made by the people of Nauru were, they could not be replicated globally. Everyone cannot subsist solely on imports financed with trust funds; every import must be exported by someone! The story of Nauru demonstrates the value of complementing the weak sustainability criterion with other, more demanding criteria. Satisfying the weak sustainability criterion may be a necessary condition for sustainability, but it is not always sufficient.

Source: J. W. Gowdy and C. N. McDaniel, "The Physical Destruction of Nauru: An Example of Weak Sustainability." LAND ECONOMICS, Vol. 75, No. 2 (1999), pp. 333–338 it maintains the value of the stock of natural capital. This definition assumes that it is natural capital that drives future well-being, and further assumes that little or no substitution between physical and natural capital is possible.

To differentiate these two definitions, the maintenance of the value of total capital is known as the "*weak sustainability*" definition, while maintaining the value of natural capital is known as the "*strong sustainability*" definition.

A final definition, known as "environmental sustainability," requires that certain physical flows of certain key individual resources be maintained. This definition suggests that it is not sufficient to maintain the value of an aggregate. For a fishery, for example, this definition would require catch levels that did not exceed the growth of the biomass for the fishery. For a wetland, it would require the preservation of the specific ecological functions.

7.4 Implications for environment

In order to be useful guides to policy, our sustainability and efficiency criteria must be neither synonymous nor incompatible. Do these criteria meet that test? They do. Not all efficient allocations are sustainable and not all sustainable allocations are efficient. Yet some sustainable allocations are efficient and some efficient allocations are sustainable. Furthermore, market allocations may be either efficient or inefficient and either sustainable or unsustainable.

Do these differences have any policy implications? Indeed they do. In particular they suggest a specific strategy for policy. Among the possible uses for resources that fulfil the sustainability criterion, we choose the one that maximizes either dynamic or static efficiency as appropriate. In this formulation the sustainability criterion acts as an overriding constraint on social decisions. Yet by itself, the sustainability criterion is insufficient because it fails to provide any guidance on which of the infinite number of sustainable allocations should be chosen. That is where efficiency comes in. It provides a means for maximizing the wealth derived from all the possible sustainable allocations.

This combination of efficiency with sustainability turns out to be very helpful in guiding policy. Many unsustainable allocations are the result of inefficient behaviour. Correcting the inefficiency can either restore sustainability or move the economy a long way in that direction. Furthermore, and this is important, correcting inefficiencies can frequently produce win-win situations. In win-win changes, the various parties affected by the change can all be made better off after the change than before. This contrasts sharply with changes in which the gains to the gainers are smaller than the losses to the losers.

Win-win situations are possible because moving from an inefficient to an efficient allocation increases net benefits. The increase in net benefits provides a means for compensating those who might otherwise lose from the change. Compensating losers reduces the opposition to change, thereby making change more likely. Do our economic and political institutions normally produce outcomes that are both efficient and sustainable? Later we will provide explicit answers to this important question.

7.5 Three kinds of sustainable allocations

Efficiency and ethical considerations can guide the desirability of private and social choices involving the environment. Whereas the former is concerned mainly with eliminating waste in the use of resources (as complete as possible use of resources), the latter is concerned with assuring the fair treatment of all parties.

This chapter examines one globally important characterization of the obligation previous generations owe to those generations that follow and the policy implications that flow from acceptance of that obligation. The specific obligation examined in this chapter – sustainable development – is based upon the notion that earlier generations should be free to pursue their own wellbeing as long as in so doing they do not diminish the welfare of future generations. This notion gives rise to three alternative definitions of sustainable allocations:

1. *Weak Sustainability*. Resource use by previous generations should not exceed a level that would prevent subsequent generations from achieving a level of wellbeing at least as great. One of the implications of this definition is that the value of the capital stock (natural plus physical capital) should not decline. Individual components of the aggregate could decline in value as long as other components were increased in value (normally through investment) sufficiently to leave the aggregate value unchanged.
2. *Strong Sustainability*. According to this interpretation, the value of the remaining stock of natural capital should not decrease. This definition places special emphasis on preserving natural (as opposed to total) capital under the assumption that natural and physical capital offer limited substitution possibilities. This definition retains the focus of the previous definition on preserving value (rather than a specific level of physical flow) and on preserving an aggregate of natural capital (rather than any specific component).
3. *Environmental Sustainability*. Under this definition, the physical flows of individual resources should be maintained, not merely the value of the aggregate. For a fishery, for example, this definition would emphasize maintaining

a constant fish catch (referred to as a sustainable yield), rather than a constant value of the fishery. For a wetland, it would involve preserving specific ecological functions, not merely their aggregate value.

The views of sustainability attributed to the ecological economics vision are known in the literature as weak sustainability and strong sustainability, respectively. Environmental sustainability, as the term indicates, refers to abundance and genotypic diversity of individual species in ecosystems subject to human exploitation or, more generally, intervention (Gatto, 1995). Weak sustainability and strong sustainability, on the other hand, both have their roots in economics, which incorporates the concept of sustainability into the standard definition of income as "the maximum amount that a community can consume over some time period and still be as well off at the end of the period as at the beginning" (Hicks, 1946 in Daly, 1994:23). Therefore, in Hicksian terms, Brundtland may be saying no more than that we, the present generation, should consume within our income (Heal, 1996). The Hicksian, or economic, definition of sustainability, which aims at having the same capacity to produce the same income (or to meet the same needs) each year, requires that the capital stock be maintained intact. However, there are two ways to maintain total capital intact, and they relate to the difference between weak and strong sustainability. Weak sustainability refers to the maintaining intact of the sum of Natural Capital, Manufactured Capital and Cultural Capital on aggregate. Strong sustainability relates to the maintenance of each of the three capital stocks separately (Costanza and Daly, 1992; Daly, 1994).

It is possible to examine and compare the theoretical conditions that characterize various allocations (including market allocations and efficient allocations) to the necessary conditions for an allocation to be sustainable under these definitions. According to the theorem that is now known as the "Hartwick Rule", if all of the scarcity rent from the use of scarce resources is invested in capital, the resulting allocation will satisfy the first definition of sustainability.

In general, not all efficient allocations are sustainable and not all sustainable allocations efficient. Furthermore, market allocations can be:

1 efficient, but not sustainable;
2 sustainable, but not efficient;
3 inefficient and unsustainable; and
4 efficient and sustainable.

One class of situations, known as "win-win" situations, provides an opportunity to increase simultaneously the welfare of both current and future generations.

We shall explore these themes much more intensively as we proceed through the book. In particular we shall inquire into when market allocations can be expected to produce allocations that satisfy the sustainability definitions and when they cannot. We shall also see how the skilful use of economic incentives can allow policymakers to exploit "win-win" situations to promote a transition onto a sustainable path for the future.

7.6 Normative criteria for decision making

Normative choices can arise in two different contexts. In the first context we need simply to choose among options that have been predefined, while in the second we try to find the optimal choice among all the possible choices.

Evaluating Predefined Options can be done by using *cost-benefit analysis*. If you were asked to evaluate the desirability of some proposed action, you would probably begin by attempting to identify both the gains and the losses from that action. If the gains exceed the losses, then it seems natural to support the action.

That simple framework provides the starting point for the normative approach to evaluating policy choices in economics. Economists suggest that actions have both benefits and costs. If the benefits exceed the costs, then the action is desirable. On the other hand, if the costs exceed the benefits, then the action is not desirable.

We can formalize this in the following way. Let B be the benefits from a proposed action and C be the costs. Our decision rule would then be

If $B > C$, support the action.

Otherwise, oppose the action.

As long as B and C are positive, a mathematically equivalent formulation would be

If $B/C > 1$, support the action.

Otherwise, oppose the action.

So far so good, but how do we measure benefits and costs? In economics the system of measurement is anthropocentric, which simply means human centered. All benefits and costs are valued in terms of their effects (broadly defined) on humanity. As shall be pointed out later, that does not imply (as it might first appear) that ecosystem effects are ignored unless they directly affect humans. The fact that large numbers of humans contribute voluntarily to organizations that are dedicated to environmental protection provides ample evidence that humans place a value on environmental preservation that goes well beyond any direct use they might make of it. Nonetheless, the notion that humans are doing the valuing is a controversial point that was revisited and discussed in Chapter 4 along with the specific techniques for valuing these effects.

In cost-benefit analysis, benefits are measured simply as the relevant area under the demand curve since the demand curve reflects consumers' willingness to pay. Total costs are measured by the relevant area under the marginal cost curve.

It is important to stress that environmental services have costs even though they are produced without any human input. All costs should be measured as opportunity costs. As presented in Example 7.1, the opportunity cost for using resources in a new or an alternative way is the net benefit lost when specific environmental services are foregone in the conversion to the new use. The notion that it is costless to convert a forest to a new use is obviously wrong if valuable ecological or human services are lost in the process.

To firm up this notion of opportunity cost, consider another example. Suppose a particular stretch of river can be used either for white-water canoeing or to generate electric power. Since the dam that generates the power would flood the rapids, the two uses are incompatible. The opportunity cost of producing power is the foregone net benefit that would have resulted from the white-water canoeing. The marginal opportunity cost curve defines the additional cost of producing another unit of electricity resulting from the associated incremental loss of net benefits due to reduced opportunities for white-water canoeing.

Since net benefit is defined as the excess of benefits over costs, it follows that net benefit is equal to that portion of the area under the demand curve that lies above the supply curve.

Consider Figure 7.4, which illustrates the net benefits from preserving a stretch of river. Let's use this example to illustrate the use of the decision rules introduced earlier. For example, let's suppose that we are considering preserving a four-mile stretch of river and that the benefits and costs of that action are reflected in Figure 7.4. Should that stretch be preserved? Why or why not?

This example also illustrates the dilemma we face when considering the rights of future generations. It is entirely possible that future development will have other possibilities for the production of renewable electricity, and thus for them hydropower is not urgent. Future people, however, will not be able to restore the lost white water part of the river if it is used for hydropower now. From

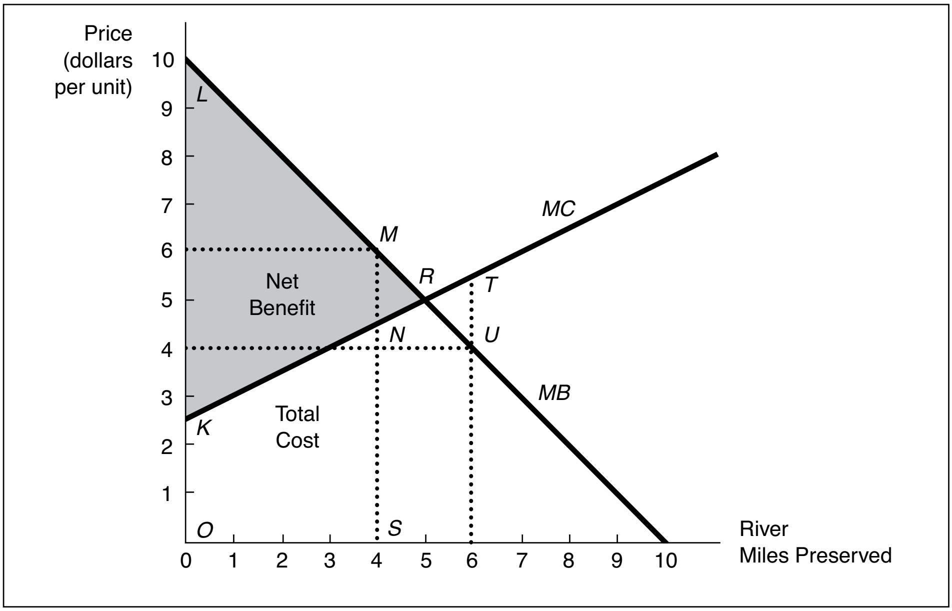

Figure 7.4. The Derivation of Net Benefits. Normative Criteria for Decision Making. Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition. p.49.

this point of view we should thus select to save the river for canoeing. In some cases this has also been accepted as rivers – for example in North Sweden, as decided by the parliament in 1968 – have been saved from exploitation for hydropower. Although the arguments for preservation were then dominated by beauty and scenery and fishing opportunities – for the present generations mostly!

When we address individual environmental problems, the normative analysis will proceed in three steps. First we will identify an optimal outcome. Second we will attempt to discern the extent to which our institutions produce optimal outcomes and, where divergences occur between actual and optimal outcomes, to attempt to uncover the behavioral sources of the problems. Finally we can use both our knowledge of the nature of the problems and their underlying behavioral causes as a basis for designing appropriate policy solutions. Although applying these three steps to each of the environmental problems must reflect the uniqueness of each situation, the overarching framework used to shape that analysis is the same.

To provide some illustrations of how this approach is used in practice, consider two examples: one drawn from natural resource economics and another from environmental economics. These are meant to be illustrative and to convey a flavor of the argument; the details are left to later.

Consider the rising number of depleted ocean fisheries. Depleted fisheries, which involve fish populations that have fallen so low as to threaten their viability as commercial fisheries, not only jeopardize oceanic biodiversity, but also pose a threat to both the individuals who make their living from the sea and the communities that depend on fishing to support their local economies.

How would an economist attempt to understand and resolve this problem? The first step would involve defining the optimal stock or the optimal rate of harvest of the fishery. The second step would compare this level with the actual stock and harvest levels. Once this economic framework is applied, not only does it become clear that stocks are much lower than optimal for many fisheries, but also the reason for excessive exploitation becomes clear. Understanding the nature of the problem has led quite naturally to some solutions. Once implemented, these policies have allowed some fisheries to begin the process of renewal.

Another problem involves solid waste. As local communities run out of room for landfills in the face of an increasing generation of waste, what can be done?

Economists start by thinking about how one would define the optimal amount of waste. The definition necessarily incorporates waste reduction and recycling as aspects of the optimal outcome. The analysis not only reveals that current waste levels are excessive, but also suggests some specific behavioral sources of the problem. Based upon this understanding, specific economic solutions have been identified and implemented. Communities that have adopted these measures have generally experienced lower levels of waste and higher levels of recycling.

7.7 Distribution of wealth and income

The distribution of wealth is a comparison of the wealth of various members or groups in a society. It differs from the distribution of income in that it looks at the distribution of ownership of the assets in a society, rather than the current income of members of that society.

Wealth in the context of this article is defined as a person's net worth, expressed as:

Wealth = assets – liabilities

The word "wealth" is often confused with "income". These two terms describe different but related things. Wealth consists of those items of economic value that an individual owns, while income is an inflow of items of economic value. The relation between wealth, income, and expenses is:

Change of wealth = income − expenses

The distribution of income is substantially different from the distribution of wealth. According to the International Association for Research in Income and Wealth, “the world distribution of wealth is much more unequal than that of income.”

If an individual has a large income but also large expenses, her or his wealth could be small or even negative.

The United Nations definition of inclusive wealth is a monetary measure which includes the sum of natural, human and physical assets.

There are many ways in which the distribution of wealth can be analysed. One example is to compare the wealth of the richest one percent with the wealth of the median (or 50th) percentile. In many societies, the richest ten percent control more than half of the total wealth.

Pareto Distribution has often been used to mathematically quantify the distribution of wealth, since it models a random distribution.

Wealth Over People (WOP) Curves are a visually compelling way to show the distribution of wealth in a nation. WOP curves are modified Distribution of Wealth curves. The vertical and horizontal scales each show percentages from zero to one hundred. We imagine all the households in a nation being sorted from richest to poorest. They are then shrunk down and lined up (richest at the left) along the horizontal scale. For any particular household, its point on the curve represents how their wealth compares (as a%) to the average wealth of the richest percentile. For any nation, the average wealth of the richest 1/100 of households is the topmost point on the curve (People = 1%, Wealth = 100%) or (p=1, w=100) or (1,100). In the real world two points on the WOP curve are always known before any statistics are gathered. These are the topmost point (1,100) by definition, and the rightmost point (poorest people, lowest wealth) or (p=100,w=0) or (100,0). This unfortunate rightmost point is given because there are always at least one percent of households (incarcerated, long term illness, etc.) with no wealth at all. Given that the topmost and rightmost points are fixed ... our interest lies in the form of the WOP curve between them. There are two extreme possible forms of the curve. The first is the “Perfect Communist” WOP. It is a straight line from the leftmost (maximum wealth) point horizontally across the people scale to p=99. Then it drops vertically to wealth = 0 at (p=100, w=0).

The other extreme is the “Perfect Tyranny” form. It starts on the left at the Tyrant’s maximum wealth of 100%. It then immediately drops to zero at p=2, and continues at zero horizontally across the rest of the people. That is, the tyrant and his friends (the top percentile) own the entire nation’s wealth. All other citizens are serfs or slaves. An obvious intermediate form is a straight line connecting the left/top point to the right/bottom point. In such a "Diagonal" society a household in the richest percentile would have just twice the wealth of a family in the median (50th) percentile. Such a society is compelling to many (especially the poor). In fact it is a comparison to a diagonal society that is the basis for the "Gini Values" used as a measure of the "Disequity" in a particular economy.

In many societies, attempts have been made, through property redistribution, taxation, or regulation, to redistribute wealth, sometimes in support of the upper class, and sometimes to diminish extreme inequality.

Examples of this practice go back at least to the Roman republic in the third century B.C., when laws were passed limiting the amount of wealth or land that could be owned by any one family. Motivations for such limitations on wealth include the desire for equality of opportunity, a fear that great wealth leads to political corruption, to the belief that limiting wealth will gain the political favour of a voting bloc, or fear that extreme concentration of wealth results in rebellion. Various forms of socialism attempt to diminish the unequal distribution of wealth and thus the conflicts and social problems (see image below) arising from it.

In the Outlook on the Global Agenda 2014 from the World Economic Forum the widening income disparities come second as a worldwide risk.

In addition to government efforts to redistribute wealth, the tradition of individual charity is a voluntary means of wealth transference. There are also many voluntary charitable organizations making concerted efforts to aid those in need.

Higher Gini coefficients signify greater inequality in wealth distribution, with 1 being complete inequality and 0 being complete equality. "The top 10 per cent owned 71 per cent of world wealth, and the Gini coefficient for the global distribution of wealth is estimated to be 0.804, indicating greater inequality than that observed in the global distribution of consumption or income."

7.8 Intra-generational equity

Intra-generational equity is concerned with equity between people of the same generation. This is separate from intergenerational equity, which is about equity between present and future generations. Intra generational equity includes considerations of distribution of resources and justice between nations. It also includes considerations of what is fair for people within any one nation.

Income distribution can be viewed as intra-generational equity. Traditional economic analysis accepts or at least does not question-existing income distribution. On the assumption that underlines cost-benefit analysis, a society will be economically efficient in its use of resources when net monetary social benefits

– that is the difference between total monetary benefits and total monetary costs, measured in socially desirable prices – are maximized.

Efficiency measured without regard to whom the benefits and costs accrue and irrespective of whether society considers the prevailing distribution of income to be desirable. If income distribution is of concern, as it is in most developing countries, then the distribution of costs and benefits must be considered in cost-benefit analysis. Projects/actions which will primarily benefit already wealthy individuals at expense of poorer individuals may be undesirable on distributional grounds, even if they show high benefit/cost ratios.

Three different approaches are commonly used to address distributional effects in an economic analysis: qualitative consideration, weighting, or the establishment of distributional constraints.

The simplest method of providing economic analysis is to estimate net benefits by income class, group or region as applicable. Similarly, adverse impacts or costs of project/action must be examined on which groups these burden will fall.

The controversial dispute on potential earthquake danger has been a major cause of international concern over the construction of Rogun Dam in Tajikistan. Benefits from Rogun Dam mostly gained Tajikistan. They are domestic and export electricity sales, avoided flood protection costs. Direct costs-construction, equipment, resettlement, O&M – are faced again by Tajikistan. But, indirect costs like lost agricultural production, danger of earthquake provoked flood are distributed between upstream and downstream countries like Tajikistan and Uzbekistan.

Construction of the Rogun Hydropower Project (Rogun HPP) began in 1980 and was then interrupted by political changes resulting from the independence of Tajikistan. Construction began again in 2008, but since 2012 only safety-related and maintenance activities have been carried out pending the completion of the assessment studies. The Rogun Hydropower Project (Rogun HPP) was first conceived in the Soviet Union in the 1950s and 1960s as part of the regional development of what are now several independent states. The original purpose of the Rogun project has evolved from supporting regional irrigation and hydropower generation, to the present plan, which calls for Rogun to serve as a hydropower project with additional benefits provided by the project relating to flood control and sediment management.

Chapter 7 sources:

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Section 7.4 (Implication for Environmental Policy) pp 114-115 (Section 7.5) (Summary of the book) and Chapter 3 "Evaluating Trade-Offs: Benefit-Cost Analysis and Other Decision-Making Metrics" with citations from pp. 46-50 (Section 7.6) (Normative Criteria for Decision Making). https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf.

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Chapter 8
Cost-Benefit Analysis and Dynamic Efficiency

8.1 Cost-benefit analysis

Many agencies are required to consider the distributional impacts of costs and benefits as part of any economic analysis. For example, the US EPA provides guidelines on distributional issues in its "Guidelines for Preparing Economic Analysis." According to the EPA, distributional analysis "assesses changes in social welfare by examining the effects of a regulation across different sub-populations and entities."

Distributional analysis can take two forms: *economic impact analysis* and *equity analysis*. Economic impact analysis focuses on a broad characterization of who gains and who loses from a given policy. Equity analysis examines impacts on disadvantaged groups or sub-populations. The latter delves into the normative issue of equity or fairness in the distribution of costs and benefits. Loomis (2011) outlines several approaches for incorporating distribution and equity into cost-benefit analysis.

Cost-benefit analysis (CBA) has been used to assess the desirability of efforts to control pollution. Pollution control certainly confers many benefits, but it also has costs. Do the benefits justify the costs? We will illustrate this question with one case from the USA.

In 1990 the U.S. Congress wanted the US Environmental Protection Agency (EPA) to evaluate the benefits and costs of the US air pollution control policy initially over the 1970-1990 period and subsequently over the 1990-2020 time period. In responding to this congressional mandate, the EPA set out to quantify and monetize the benefits and costs of achieving the emissions reductions required by US policy. Benefits quantified by this study included reduced death rates and lower incidences of chronic bronchitis, lead poisoning, strokes, respiratory diseases, and heart disease as well as the benefits of better visibility, reduced structural damages, and improved agricultural productivity.

Despite the fact that this study did not attempt to value all pollution damage to ecosystems that was avoided by this policy, the net benefits were still strongly positive. While presumably the case for controlling pollution would have been even stronger had all such avoided damage been included, the desirability of this form of control is evident even with only a partial consideration of benefits. An inability to monetize everything does not necessarily jeopardize the ability to reach sound policy conclusions.

Although these results justify the conclusion that pollution control made economic sense, they do not justify the stronger conclusion that the policy was efficient. To justify that conclusion, the study would have had to show that the present value of net benefits was maximized, not merely positive. In fact, this study did not attempt to calculate the maximum net benefits outcome and if it had, it would have almost certainly discovered that the policy during this period was not optimal. The costs of the chosen policy approach were higher than necessary to achieve the desired emissions reductions. With an optimal policy mix, the net benefits would have been even higher.

One of the most basic conflicts faced by environmental policy occurs when a currently underdeveloped but ecologically significant piece of land becomes a candidate for development. If developed, the land may not only provide jobs for workers, wealth for owners, and goods for consumers, but also it may degrade the ecosystem, possibly irreversibly. Wildlife habitat may be eliminated, wetlands may be paved over, and recreational opportunities may be gone forever. On the other hand, if the land were preserved, the specific ecosystem damages caused by development could be prevented, but the opportunity for increased income and employment provided by development would have been lost. These conflicts become intensified if unemployment rates in the area are high and the local ecology is rather unique.

One such conflict arose in Australia from a proposal to mine a piece of land in an area known as the Kakadu Conservation Zone (KCZ). Decision makers at that time had to decide whether it should be mined or preserved. One way to examine that question is to use the techniques above to examine the net benefits of the two alternatives

8.2 Issues in benefit estimation

The analyst charged with the responsibility for performing a cost-benefit analysis encounters many decision points requiring judgment. If we are to understand cost-benefit analysis, the nature of these judgments must be clear in our minds.

Environmental projects usually trigger both *primary and secondary consequences*. For example, the primary effect of cleaning a lake will be an increase in recreational uses of the lake. This primary effect will cause a further ripple effect on services provided to the increased number of users of the lake. Are these secondary benefits to be counted? The answer depends upon the employment conditions in the surrounding area. If this increase in demand results in employment of previously unused resources, such as labour, the value of the increased employment should be counted. If, on the other hand, the increase in demand is met by a shift in previously employed resources from one use to another, it is a different story. In general, secondary employment benefits should be counted in high unemployment areas or when the particular skills demanded are underemployed at the time the project is commenced. This should not be counted when the project simply results in a rearrangement of productively employed resources.

The *accounting stance* refers to the geographic scale at which the benefits are measured. Who benefits? If a proposed project is funded by a national government, but benefits a local or regional area, a cost-benefit analysis will look quite different depending on whether the analysis is done at the regional or national scale.

The "*with and without" principle* states that only those benefits that would result from the project should be counted, ignoring those that would have accrued anyway. Mistakenly including benefits that would have accrued anyway would overstate the benefits of the program.

Tangible benefits are those that can reasonably be assigned a monetary value. *Intangible benefits* are those that cannot be assigned a monetary value, either because data are not available or reliable enough or because it is not clear how to measure the value even with data. How are intangible benefits to be handled? One answer is perfectly clear: They should not be ignored. To ignore intangible benefits is to bias the results. That benefits are intangible does not mean they are unimportant. Intangible benefits should be quantified to the fullest extent possible. One frequently used technique is to conduct a sensitivity analysis of the estimated benefit values derived from less than perfectly reliable data. We can determine, for example, whether or not the outcome is sensitive, within wide ranges, to the value of this benefit. If not, then very little time has to be spent on the problem.

If the outcome is sensitive, the person or persons making the decision bear the ultimate responsibility for weighing the importance of that benefit.

8.3 Approaches to cost estimation

Estimating costs is generally easier than estimating benefits, but it is not easy. One major problem for both derives from the fact that cost-benefit analysis is forward-looking and thus requires an estimate of what a particular strategy will cost, which is much more difficult than tracking down what an existing strategy does cost. Two approaches have been developed to estimate these costs.

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

The *Engineering Approach* bypasses the source being regulated by using general engineering information to catalogue the possible technologies that could be used to meet the objective and to estimate the costs of purchasing and using those technologies. The final step in the engineering approach is to assume that the sources would use technologies that minimize cost. This produces a cost estimate for a "typical," well-informed firm. The engineering approach has its own problems. These estimates may not approximate the actual cost of any particular firm. Unique circumstances may cause the costs of that firm to be higher, or lower, than estimated; the firm, in short, may not be typical.

The frequently used *Combined Approach* circumvents these problems, as analysts use a combination of survey and engineering approaches. The survey approach collects information on possible technologies, as well as special circumstances facing the firm. Engineering approaches are used to derive the actual costs of those technologies, given the special circumstances. This combined approach attempts to balance information best supplied by the source with that best derived independently. In the cases described so far, the costs are relatively easy to quantify and the problem is simply finding a way to acquire the best information. This is not always the case, however. Some costs are not easy to quantify, although economists have developed some ingenious ways to secure monetary estimates even for those costs.

Take, for example, a policy designed to conserve energy by forcing more people to carpool. If the effect of this is simply to increase the average time of travel, how is this cost to be measured? For some time, transportation analysts have recognized that people value their time, and quite a literature has now evolved to provide estimates of how valuable time savings or time increases would be. The basis for this valuation is opportunity cost - how the time might be used if it weren't being consumed in travel. Although the results of these studies depend on the amount of time involved, individuals seem to value their travel time at a rate not more than half their wage rates.

8.4 The treatment of risk

For many environmental problems, it is not possible to state with certainty what consequences a particular policy will have, because scientific estimates themselves often are imprecise. Determining the efficient exposure to potentially toxic substances requires obtaining results at high doses and extrapolating to low doses, as well as extrapolating from animal studies to humans. It also requires relying upon epidemiological studies that infer a pollution-induced adverse human health impact from correlations between indicators of health in human populations and recorded pollution levels.

For example, consider the potential damages from climate change. While most scientists now agree on the potential impacts of climate change, such as sea level rise and species losses, the timing and extent of those losses are not certain. The treatment of risk in the policy process involves two major dimensions: (1) identifying and quantifying the risks; and (2) deciding how much risk is acceptable. The former is primarily scientific and descriptive, while the latter is more evaluative or normative.

Cost-benefit analysis grapples with the evaluation of risk in several ways. Suppose we have a range of policy options A, B, C, D and a range of possible outcomes E, F, G for each of these policies depending on how the economy evolves over the future. These outcomes, for example, might depend on whether the demand growth for the resource is low, medium, or high. Thus, if we choose policy A, we might end up with outcomes AE, AF, or AG. Each of the other policies has three possible outcomes as well, yielding a total of 12 possible outcomes. We could conduct a separate cost-benefit analysis for each of the 12 possible outcomes. Unfortunately, the policy that maximizes net benefits for E may be different from that which maximizes net benefits for F or G. Thus, if we only knew which outcome would prevail, we could select the policy that maximized net benefits; the problem is that we do not. Furthermore, choosing the policy that is best if outcome E prevails may be disastrous if G results instead.

When a dominant policy emerges, this problem is avoided. A dominant policy is one that confers higher net benefits for every outcome. In this case, the existence of risk concerning the future is not relevant for the policy choice. This fortuitous circumstance is exceptional rather than common, but it can occur. Other options exist even when dominant solutions do not emerge. Suppose, for example, that we were able to assess the likelihood that each of the three possible outcomes would occur. Thus, we might expect outcome E to occur with probability 0.5, F with probability 0.3, and G with probability 0.2. Armed with this information, we can estimate the expected present value of net benefits. The expected present value of net benefits for a particular policy is defined as the sum over outcomes of the present value of net benefits for that policy where each outcome is weighted by its probability of occurrence. Symbolically this is expressed as (8.1)

$$EPVNBj = \sum_{i=0}^{1} PiPVNBij, \quad j=1,\ldots\ldots..J \qquad (8.1)$$

where $EPVNB_j$ = expected present value of net benefits for policy j P_i = probability of the ith outcome occurring $PVNB_{ij}$ = present value of net benefits for policy j if outcome i prevails J = number of policies being considered, I = number of outcomes being considered.

The final step is to select the policy with the highest expected present value of net benefits. This approach has the substantial virtue that it weighs higher probability outcomes more heavily. It also, however, makes a specific assumption about society's preference for risk. This approach is appropriate if society is risk-neutral.

Risk-neutrality can be defined most easily by the use of an example. Suppose you were allowed to choose between being given a definite $50 or entering a lottery in which you had a 50%chance of winning $100 and a 50%chance of winning nothing. (Notice that the expected value of this lottery is $50 = 0.5($100) + 0.5($0).) You would be said to be risk-neutral if you would be indifferent between these two choices. If you view the lottery as more attractive, you would be exhibiting *risk-loving* behaviour, while a preference for the definite $50 would suggest *risk-averse* behaviour. Using the expected present value of net benefits approach implies that society is risk-neutral.

Is that a valid assumption? The evidence is mixed. The existence of gambling suggests that at least some members of society are risk-loving, while the existence of insurance suggests that, at least for some risks, others are risk-averse. Since the same people may gamble and own insurance policies, it is likely that the type of risk may be important.

Even if individuals were demonstrably risk-averse, this would not be a sufficient condition for the government to forsake risk-neutrality in evaluating public investments. One famous article (Arrow and Lind, 1970) argues that risk-neutrality is appropriate since "when the risks of a public investment are publicly borne, the total cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investments." The logic behind this result suggests that as the number of risk bearers (and the degree of diversification of risks) increases, the amount of risk borne by any individual diminishes to zero.

When the decision is irreversible, as demonstrated by Arrow and Fisher (1974), considerably more caution is appropriate. Irreversible decisions may subsequently be regretted, but the option to change course will be lost forever. Extra caution also affords an opportunity to learn more about alternatives to this decision and its consequences before acting. Isn't it comforting to know that occasionally procrastination can be optimal?

There is a movement in national policy in both the courts and the legislature to search for imaginative ways to define acceptable risk. In general, the policy approaches reflect a case-by-case method. Current policy reflects a high degree of risk aversion toward a number of environmental problems.

Box 8.1 Discounting – time and money

To many people, discounting future values is unfair and arbitrary. Yet without discounting, inter-temporal choices would be difficult to make. The rationale for discounting results from a so-called time preference. Let us assume that there is no inflation (which does not change the idea but makes the calculations more complex). Most people are not indifferent to getting either $1000 today or $1000 a year from now; they would prefer to have it sooner rather than later. But how about having $1000 now or $1500 a year from now? Most of us would probably prefer the latter option. But perhaps there is some amount of money $1000(1+r) between $1000 and $1500 that makes us indifferent to having either $1000 now or $1000(1+r) a year from now.

The number r which renders the two options equivalent is called the rate of time preference. It is a fundamental component of any discount rate used in order to compare costs and benefits accruing at different points in time. If r=0.025 (2.5%) then we would consider $1025 a year from now as equivalent to $1000 now and $1000 a year from now is equivalent to $1000/(1+r), that is, approximately $976 today.

It is easy to extend this concept to time intervals of any length. The present value of $1000 two years from now is $\$1000/(1+r)^2$ and so on. If a project requires costs of 1000, 100 and 200 now, a year from now and three years from now, respectively, then its discounted sum of costs is $\$1000 + \$100/(1+r) + \$200/(1+r)^3$. If it provides the investor with benefits of $300, $400, $400, and $300 after the first, second, third, and fourth year, respectively, its discounted sum of benefits is $\$300/(1+r) + \$400/(1+r)^2 + \$400/(1+r)^3 + \$300/(1+r)^4$. The net present value, NPV – a key concept used in cost-benefit analysis – is the difference between the discounted sum of benefits net of costs.

It is easy to check that substituting 2.5% for r in the example above would yield NPV = $33.35. Mere subtraction of (undiscounted) costs from (undiscounted) benefits would give the difference of $100. This can be interpreted as NPV with zero discount rate. Thus discounting with positive rates decreases the value of projects whose costs come earlier than benefits. The same example recalculated with 5% discount rate will demonstrate a negative NPV.

Source: A Sustainable Baltic Region 8 Tomasz Zylicz (ed.) Ecological Economics – Markets, prices and budgets in a sustainable society, Baltic University Programme. http://www.balticuniv.uu.se/index.php/boll-online-library/819-a-sustainable-baltic-region

8.5 Distribution of costs and benefits – choosing discount rates

The static efficiency criterion is very useful for comparing resource allocations when time is not an important factor. But how can we think about optimal choices when the benefits and costs occur at different points in time? The traditional criterion used to find an optimal allocation when time is involved is called dynamic efficiency, a generalization of the static efficiency concept already developed. In this generalization, the present-value criterion provides a way for comparing the net benefits received in one period with the net benefits received in another.

The *discount rate* can be defined conceptually as the social opportunity cost of capital. This cost of capital can be divided further into two components: (1) the riskless cost of capital and (2) the risk premium.

The *choice of the discount rate* can influence policy decisions. Recall that discounting allows us to compare all costs and benefits in current dollars, regardless of when the benefits accrue or costs are charged. Suppose, a project will impose an immediate cost of $4,000,000 (today's dollars), but the $5,500,000 benefits will not be earned until 5 years out. Is this project a good idea? On the surface it might seem like it is, but recall that $5,500,000 in 5 years is not the same as $5,500,000 today. At a discount rate of 5 percent, the present value of benefits minus the present value of costs is positive. However, at a 10%discount rate, this same calculation yields a negative value, since the present value of costs exceeds the benefits. Can you reproduce the calculations that yield these conclusions?

When the public sector uses a discount rate lower than that in the private sector, the public sector will find more projects with longer payoff periods worthy of authorization. And, as we have already seen, the discount rate is a major determinant of the allocation of resources among generations as well.

Traditionally, economists have used long-term interest rates on government bonds as one measure of the cost of capital, adjusted by a risk premium that would depend on the riskiness of the project considered. Unfortunately, the choice of how large an adjustment to make has been left to the discretion of the analysts. This ability to affect the desirability of a particular project or policy by the choice of discount rate led to a situation in which government agencies were using a variety of discount rates to justify programs or projects they supported.

One set of hearings conducted by US Congress during the 1960s discovered that, at one time, agencies were using discount rates ranging from 0 to 20 percent. During the early 1970s the US Office of Management and Budget published a circular that required, with some exceptions, all government agencies to use a discount rate of 10%in their cost-benefit analysis. A revision issued in 1992 reduced the required discount rate to 7 percent. This circular also includes guidelines for cost-benefit analysis and specifies that certain rates will change annually.

This standardization reduces biases by eliminating the agency's ability to choose a discount rate that justifies a predetermined conclusion. It also allows a project to be considered independently of fluctuations in the true social cost of capital due to cycles in the behaviour of the economy. On the other hand, when the social opportunity cost of capital differs from this administratively determined level, the cost-benefit analysis will not, in general, define the efficient allocation.

Earlier we concluded that producers, in their attempt to maximize producer surplus, also maximize the present value of net benefits under the "right" conditions, such as the absence of externalities, the presence of properly defined property rights, and the presence of competitive markets within which the property rights can be exchanged.

Now let's consider one more condition. If resources are to be allocated efficiently, firms must use the same rate to discount future net benefits as is appropriate for society at large. If firms were to use a higher rate, they would extract and sell resources faster than would be efficient. Conversely, if firms were to use a lower-than-appropriate discount rate, they would be excessively conservative.

Why might private and social rates differ? The social discount rate is equal to the social opportunity cost of capital. This cost of capital can be separated into two components: the risk-free cost of capital and the risk premium. The risk-free cost of capital is the rate of return earned when there is absolutely no risk of earning more or less than the expected return. The risk premium is an additional cost of capital required to compensate the owners of this capital when the expected and actual returns may differ. Therefore, because of the risk premium, the cost of capital is higher in risky industries than in no-risk industries.

One difference between private and social discount rates may stem from a difference in social and private risk premiums. If the risk of certain private decisions is different from the risks faced by society as a whole, then the social and private risk premiums may differ. One obvious example is the risk caused by the government. If the firm is afraid its assets will be taken over by the government, it may choose a higher discount rate to make its profits before nationalization occurs.

From the point of view of society – as represented by government – this is not a risk and, therefore, a lower discount rate is appropriate. When private rates exceed social rates, current production is higher than is desirable to maximize the net benefits to society. Both energy production and forestry have been subject to this source of inefficiency.

Another divergence in discount rates may stem from different underlying rates of time preference. Such a divergence in time preferences can cause not only a divergence between private and social discount rates (as when firms have a higher rate of time preference than the public sector), but even between otherwise similar analyses conducted in two different countries.

Time preferences would expected to be higher, for example, in a cash-poor, developing country than in an industrialized country. Since the two cost-benefit analyses in these two countries would be based upon two different discount rates, they might come to quite different conclusions. What is right for the developing country may not be right for the industrialized country and vice versa. Although private and social discount rates do not always diverge, they may. When those circumstances arise, market decisions are not efficient.

Box 8.2 A case of cost-effectiveness and impact analysis – the Qibray power plant

Even when benefits are difficult or impossible to quantify, economic analysis has much to offer. Policy-makers should know, for example, how much various policy actions will cost and what their impacts on society will be, even if the efficient policy choice cannot be identified with any certainty. Cost-effectiveness analysis and impact analysis both respond to this need, albeit in different ways.

One of the biggest thermoelectric power plants of Uzbekistan is being reconstructed at the moment in order to decrease consumption of combustible fuel and decrease the rate of noxious wastes discharged into environment. Tashkent thermoelectric power plant was established in 1963. The power plant is situated in Qibray district, 15 km north-east from the capital.

Its rated power is 1860 MW. The plant's primary equipment are 12 condensing units each presenting a power of 155 MW. The primary fuel is natural gas constituting 85 percent of the total fuel. Fuel-oil is a reserve one and constitutes 15 percent. Tashkent thermoelectric power plant provided capital with energy for many years.

The condensing units' lifetime is 40-48 years. Today we observe a decrease in efficiency of fuel-into-energy transformation. There's also a quantity increase of the used fuel because of the outdated machinery. Thus this situation hits the environment: the activity of the power plant will lead to emissions into the atmosphere, and waste dumping into the Boz-su channel.

Within flow of the years, necessity in energy increases proportionally to the growth of the city, old technologies are replaced by the latest and requirements of the environmental protection grow stricter. Concerning this situation, reconstruction of the Tashkent thermoelectric power plant is an obvious necessity today.

Taking in attention its own researches and the results of the Public hearings on that topic, Uzbekenergo decided to start a reconstruction. Uzbekenergo plans to install more efficient and modern machinery that will get over the problem of low efficiency and decrease emission of CO_2 into the atmosphere.

8.6 A critical appraisal of cost-benefit analysis

We have seen that it is sometimes, but not always, difficult to estimate benefits and costs. When this estimation is difficult or unreliable, it limits the value of a cost-benefit analysis. This problem would be particularly disturbing if biases tended to increase or decrease net benefits systematically. Do such biases exist?

In the early 1970s, Robert Haveman (1972) conducted a major study that shed some light on this question. Focusing on Army Corps of Engineers water projects, such as flood control, navigation, and hydroelectric power generation, Haveman compared the *ex-ante* (before the fact) estimate of benefits and costs with their *ex-post* (after the fact) counterparts. Thus, he was able to address the issues of accuracy and bias. He concluded that in the empirical case studies presented, ex-post estimates often showed little relationship to their ex-ante counterparts. On the basis of the few cases and the a priori analysis presented here, one could conclude that there is a serious bias incorporated into agency ex-ante evaluation procedures, resulting in persistent overstatement of expected benefits.

Similarly in the analysis of project construction costs, enormous variance was found among projects in the relationship between estimated and realized costs. Although no persistent bias in estimation was apparent, nearly 50%of the projects displayed realized costs that deviated by more than plus or minus 20%from ex-ante projected costs.

In the cases examined by Haveman, at least, the notion that cost-benefit analysis is purely a scientific exercise was clearly not consistent with the evidence; the biases of the analysts were merely translated into numbers. Does their analysis mean that cost-benefit analysis is fatally flawed? Absolutely not! It does, however, highlight the importance of calculating an accurate value and of including all of the potential benefits and costs (e.g., nonmarket values). It also serves to remind us, however, that cost-benefit analysis is not a stand-alone technique. It should be used in conjunction with other available information.

Economic analysis including cost-benefit analysis can provide useful information, but it should not be the only determinant for all decisions. Another shortcoming of cost-benefit analysis is that it does not really address the question of who reaps the benefits and who pays the cost. It is quite possible for a particular course of action to yield high net benefits, but to have the benefits borne by one societal group and the costs borne by another. This admittedly extreme case does serve to illustrate a basic principle – ensuring that a particular policy is efficient provides an important, but not always the sole, basis for public policy. Other aspects, such as who reaps the benefit or bears the burden, are also important.

In summary, on the positive side, cost-benefit analysis is frequently a very useful part of the policy process. Even when the underlying data are not strictly reliable, the outcomes may not be sensitive to that unreliability. In other circumstances, the data may be reliable enough to give indications of the consequences of broad policy directions, even when they are not reliable enough to fine-tune those policies.

Cost-benefit analysis, when done correctly, can provide a useful complement to the other influences on the political process by clarifying what choices yield the highest net benefits to society.

On the negative side, cost-benefit analysis has been attacked as seeming to promise more than can actually be delivered, particularly in the absence of solid benefit information. This concern has triggered two responses. First, regulatory processes have been developed that can be implemented with very little information and yet have desirable economic properties.

The second approach involves techniques that supply useful information to the policy process without relying on controversial techniques to monetize environmental services that are difficult to value.

8.7 Economic modelling of climate change impacts

The monetary cost of climate change is now expected to be higher than many earlier studies suggested, because these studies tended not to include some of the most uncertain but potentially most damaging impacts. Modelling the overall impact of climate change is a formidable challenge, involving forecasting over a century or more as the effects appear with long lags and are very long-lived. The limitations to our ability to model over such a time scale demand caution in interpreting results, but projections can illustrate the risks involved and policy here is about the economics of risk and uncertainty.

Most formal modelling has used as a starting point 2-3°C warming. In this temperature range, the cost of climate change could be equivalent to around a 0-3% loss in global GDP from what could have been achieved in a world without climate change. Poor countries will suffer higher costs. However, 'business as usual' (BAU) temperature increases may exceed 2-3°C by the end of this century. This increases the likelihood of a wider range of impacts than previously considered, more difficult to quantify, such as abrupt and large-scale climate change. With 5-6°C warming, models that include the risk of abrupt and large-scale climate change estimate a 5-10% loss in global GDP, with poor countries suffering costs in excess of 10%. The risks, however, cover a very broad range and involve the possibility of much higher losses.

Box 8.3 The Stern review on the economics of climate change
choosing discount rates

The Stern review is a 700-page report released for the British government in 2006 by economist Nicholas Stern, at the London School of Economics and also chair of the Centre for Climate Change Economics and Policy (CCCEP) at Leeds University. The report discusses the effect of global warming on the world economy. It is the largest and most widely known and discussed report of its kind.

The Review assessed a wide range of evidence on the impacts of climate change and on the economic costs, and has used a number of different techniques to assess costs and risks. From all of these perspectives, the evidence gathered leads to a simple conclusion: the benefits of strong and early action far outweigh the economic costs of not acting. Climate change will affect the basic elements of life for people around the world – access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms.

The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes.

Assessing the discount rate became a major difficulty in the work. As is intuitively clear, raising the pure time discount rate lowers loss estimates because the future is seen as less important. The authors argued that even a pure time discount rate of 0.5% should be regarded as too high in this context, from an ethical or probability of extinction perspective.

Yet assessing impacts over a very long time period emphasises the problem that future generations are not fully represented in current discussion. This throws the second rationale for 'discounting' future consumption mentioned above – pure time preference – into question. The report took a simple approach: if a future generation will be present, we suppose that it has the same claim on our ethical attention as the current one.

A further difficulty was that using only one discount rate was not quite possible. With many goods and many households, there will be many discount rates. For example, if conventional consumption is growing but the environment is deteriorating, then the discount rate for consumption would be positive but for the environment it would be negative. Similarly, if the consumption of one group is rising but another is falling, the discount rate would be positive for the former but negative for the latter.

The analysis described, together with a discussion of ethics in the Review, it can be seen that the standard welfare framework is highly relevant as a theoretical basis for assessing strategies and projects in the context of climate change. However, the implications of that theory are very different from those of the techniques often used in cost-benefit analysis. For example, a single constant discount rate would generally be unacceptable for dealing with the long-run, global, non-marginal impacts of climate change.

Source: Based on *The Stern Review: The Economics of Climate Change* http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

This underlines the importance of revisiting past estimates. Modelling over many decades, regions and possible outcomes demands that we make distributional and ethical judgements systematically and explicitly. Attaching little weight to the future, simply because it is in the future ('pure time discounting'), would produce low estimates of cost, but if you care little for the future you will not wish to take action on climate change. Using an Integrated Assessment Model, and with due caution about the ability to model, Stern (2006) estimates the total cost of BAU climate change to equate to an average reduction in global per capita consumption of 5%, at a minimum, now and forever. The cost of BAU would increase still further, were the model to take account of three important factors:

First, including direct impacts on the environment and human health ('non-market' impacts) increases the total cost of BAU climate change from 5% to 11%, although valuations here raise difficult ethical and measurement issues. But this does not fully include 'socially contingent' impacts such as social and political instability, which are very difficult to measure in monetary terms;

Second, some recent scientific evidence indicates that the climate system may be more responsive to greenhouse gas emissions than previously thought, because of the existence of amplifying feedbacks in the climate system. Our estimates indicate that the potential scale of the climate response could increase the cost of BAU climate change from 5% to 7%, or from 11% to 14% if non-market impacts are included. In fact, these may be only modest estimates of the bigger risks – the science here is still developing and broader risks are plausible;

Third, a disproportionate burden of climate change impacts fall on poor regions of the world. Based on existing studies, giving this burden stronger relative weight could increase the cost of BAU by more than one quarter.

Putting these three additional factors together would increase the total cost of BAU climate change to the equivalent of around a 20% reduction in current per-capita consumption, now and forever. Distributional judgements, a concern with living standards beyond those elements reflected in GDP, and modern approaches to uncertainty all suggest that the appropriate estimate of damages may well lie in the upper part of the range 5-20%. Much, but not all, of that loss could be avoided through a strong mitigation policy.

Developing countries are especially vulnerable to the physical impacts of climate change because of their exposure to an already fragile environment, an economic structure that is highly sensitive to an adverse and changing climate, and low incomes that constrain their ability to adapt. The effects of climate change on economies and societies will vary greatly over the world.

The circumstances of each country – its initial climate, socio-economic conditions, and growth prospects – will shape the scale of the social, economic and environmental effects of climate change. Vulnerability to climate change can be classified as 1) exposure to changes in the climate, sensitivity – the degree to which a system is affected by or responsive to climate stimulation and adaptive capacity and 2) the ability to prepare for, respond to and tackle the effects of climate change. Unless these vulnerabilities are overcome they are likely to increase the risk and scale of damaging impacts posed by climate change.

Agriculture and related activities are crucial to many developing countries, in particular for low income or semi-subsistence economies. The rural sector contributes 21% of GDP in India, for example, rising to 39% in a country like Malawi, whilst 61% and 64% of people in South Asia and sub-Saharan Africa are employed in the rural sector. The concentration of activities in one sector also limits flexibility to switch to less climate-sensitive activities such as manufacturing and services. The agricultural sector is one of the most at risk to the damaging impacts of climate change – and indeed current extreme climate variability - in developing countries.

Chapter 8 sources:

Sections 8.1-8.6. From Tietenberg, T., Lewis, L. (2012) *Environmental & Natural Resource Economics* 9th Ed. https://e4anet.files.wordpress.com/2014/09/tomtietenberglynnelewisenvironmentalandnaturalresourceseconomics2011.pdf. Chapter 3 "Evaluating Trade-Offs: Benefit-Cost Analysis and Other Decision-Making Metrics" Applying the Concepts of the book, with citations from p 54 (Section 8.1); p. 58 (Section 8.2); p 59 (Section 8.3); pp 59-60 (Section 8.4); pp 61-62 (Section 8.5); pp 65-66 (Section 8.6) (Divergence of Social and Private Discount Rates).

Section 8.7 and Box 8.3 were based on *The Stern Review: The Economics of Climate Change* http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf

III

The Macroeconomics of the Environment

Green Economy

Chapter 9
Policy and Policy Tools

9.1 The policy perspectives

The starting-point for a policy-making process is the appearance of a problem. However, as policy problems, environmental issues such as water pollution or global climate change are not objective conditions. Facts, conditions and situations may be interpreted differently by different people, which means that the same information may result in conflicting perceptions. Indeed, "policy problems are in the eye of the beholder" (Dunn, 1981). A policy problem can be seen as a situation where there is a gap between a normative standard and a perception of an existing or expected situation. In sum, a problem is not a given fact but a social construct.

Let us take climate change as an example. The first essential element of climate change policy is the use of *economic policy tools*, such as carbon pricing. Greenhouse gases are, in economic terms, an externality: those who produce greenhouse gas do not face the full consequences of the costs of their actions themselves. Putting an appropriate price on carbon, through taxes, trading or regulation, means that people pay the full social cost of their actions. This will lead individuals and businesses to switch away from high-carbon goods and services, and to invest in low-carbon alternatives. But the presence of a range of other market failures and barriers mean that carbon pricing alone is not sufficient.

Technology policy, the second element of a climate change strategy, is vital to bring forward the range of low-carbon and high-efficiency technologies that will be needed to make deep emissions cuts. Research and development, demonstration, and market support policies can all help to drive innovation, and motivate a response by the private sector.

Policies to remove the barriers to *behavioural change* are a third critical element. Opportunities for cost-effective mitigation options are not always taken up, because of a lack of information, the complexity of the choices available, or the upfront cost. Policies on regulation, information and financing are therefore important. And a shared understanding of the nature of climate change and its consequences should be fostered through evidence, education, persuasion and discussion.

The credibility of policies is key; this will need to be built over time. In the transitional period, it is important for governments to consider how to avoid the risks that long-lived investments may be made in high-carbon infrastructure.

9.2 The four stages of policy-making

The policy-making process can be divided into several distinctive stages. In sum, one studies first how policy problems arise and appear on the agenda of government decision-making, then how people formulate issues for action, next how legislative action follows, how administrators subsequently implement the policy, and finally at the end of the process, how policy is evaluated.

In the *first stage the agenda is set* which means that problems are selected, identified and defined. The fundamental question is whether or not there is a problem. Agenda building is the process by which demands of various groups are translated into items asking for the serious attention of public officials (Cobb et al., 1976). The model distinguishes between two agendas: the public agenda, consisting of issues which have achieved a high level of public interest, and the formal agenda, consisting of items that decision-makers have formally accepted for serious attention. However it is not always that the policy-making process ends with a decision. "Non-decisions" frequently occur in the policy-making process, especially in the agenda-setting phase. A non-decision is a decision that results in suppression of a challenge to the values or interests of the decision-makers.

The *second stage is focused on formal decision-making* in which a particular policy is adopted. Here, a formal setting intended to change behaviour is established. It is important to emphasize that this stage includes everything from policy documents, like White Papers, which are background reports or "paper tigers," to strictly binding laws.

It is noticeable that there is a much wider range of policy documents of varying degrees of legality in parliamentary systems in Western Europe than in the USA. The European Commission has a number of options from its Environmental Action Plans from about each 4th year to legal documents, so-called Directives and Regulations.

In the *third stage, implementation*, attempts are made to realize policy. According to Webster's Dictionary to implement means "to carry out: to accomplish, fulfil; to give practical effect to and ensure of actual fulfilment by concrete measures, to provide instruments or means of practical expression". In order to translate words into deeds it is necessary to have access to financial resources, personnel, organizational structure, etc. However, the activities undertaken in the implementation phase need not lead to the fulfilment of the policy objectives. As has been shown by ample literature on implementation, discrepancies between promise and performance frequently occur.

In the *fourth stage policy is evaluated*. In this phase the result of a public programme is assessed with respect to the intended and unintended effects. All sorts of activities undertaken during the policy-making process are evaluated. Mistakes are identified and explained and lessons for future policy-making are drawn.

However, the policy-making process is not necessarily linear. A major objection that has been raised to the stages model described above, is its view on implementation as a mere instrumental execution of earlier agreed policy. Instead it is argued that the shaping of a policy continues throughout the implementation phase (Bachratz and Baratz, 1970), and that the "real decisions" are rather taken when policy is realized, not when it is adopted or when policy-making occurs as bureaucrats attempt to implement vague legislation.

Problems, policies and politics may be seen as three independent streams which have their own dynamics and flow (Kingdon, 1984). Policy change is most likely to occur when the three streams are coupled. This tends to be the work of a policy entrepreneur who benefits from a short-term opportunity, a "policy window", to highlight a particular problem or solution.

Policy alternatives tend to be elaborated before the agenda is set (Kingdon, 1984). They may also occur in parallel. The "garbage can model" (Cohen et al., 1972) sees the decision-making process as an ad hoc mixture of problems and solutions. The model is based on the assumptions that the value function is ambiguous, knowledge about the choice situation is uncertain and decision rules are complex and symbolic. In addition the stages model has been criticized for not being a causal model, for neglecting the fact that evaluations of existing programmes often affect agenda-setting and for having a top-down bias which implies that so-called street-level bureaucrats and other actors are excluded from the analysis.

9.3 Policy instruments

Broadly speaking, policy instruments are tools used by the policy-makers in their attempts to alter society. They address societal processes to change them according to the intention of the policy-makers. Technically, policy instruments are a set of techniques used by the executive power of a country, the governmental authorities. By them governments "wield their power in attempting to ensure support and effect or prevent social change" (Vedung, 1995).

- Public policy instruments are generally divided into three classes:
- regulations,
- economic means, and
- information/moral suasion.

Regulation (also called command-and-control instruments) comprises a range of direct regulations such as standards, bans, permits, zoning use restrictions, etc. Direct regulations are institutional measures aimed at directly influencing the environmental performance of polluters by regulating processes or products used, by abandoning or limiting the discharge of certain pollutants, and/or by restricting activities to certain times, areas, etc. Within countries belonging to the OECD, regulation has traditionally been the most commonly used policy instrument in environmental protection.

The second approach is the application of *economic instruments* to create environmentally appropriate behaviour. The main economic instruments could be categorized as:

- charges and taxes (effluent charges, product charges, tax differentiation), subsidies,
- deposit-refund systems,
- market creation (emissions trading, liability), and
- financial enforcement incentives (non-compliance fines, performance bonds).

Economic policy instruments involve either the handing out or the taking away of material resources. In other words, economic instruments make it cheaper or more expensive to pursue certain actions.

The third approach is *information and moral suasion* aiming at changing an agent's behaviour on a voluntary basis. This could be accomplished via education, transfer of knowledge, training, persuasion, recommendation, and negotiation. One important instrument in this category is voluntary agreements between governmental agencies and private enterprises.

According to the OECD (1994), a shift towards prevention and sustainability will require governments to use instruments such as negotiation with stakeholders and joint agreement and action plans between sectorial ministries.

- Four central concepts in environmental policy are:
- effectiveness,
- efficiency,
- cost-effectiveness, and
- equity.

Effectiveness concerns the extent to which a measure, such as an investment, succeeds in reducing environmental impacts in relation to the set policy targets. Efficiency has to do with the extent to which the costs of a policy are justified in terms of its effects and if it maximizes the effects minus the costs (Semeniene and Zylicz, 1997). A cost-effective policy seeks the least costly method of attaining a specific environmental quality goal.

Equity relates to the balance between costs and benefits across the parties concerned. Hence, it has to do with burden-sharing and fairness. It is difficult (but not impossible) to design policies that combine the notions of effectiveness, efficiency, and equity. As Weale (1992) aptly observes, "no country ... has discovered how to combine technical effectiveness with political responsiveness and economic efficiency. The solution to that problem still awaits discovery."

9.4 Emission trading

One policy instrument which offers an interesting opportunity to achieve both effectiveness and efficiency is *emission trading* or *marketable permits*.

The use of pollution rights to be sold and bought on a market was first proposed in 1968 by the American economist Herman Daly. This arrangement became quite popular in the USA, in which several such markets have been established. It is mostly used for air pollutants. A condition is that it is not so important exactly where the pollutant is emitted.

The main idea behind emission trading is that firms with the lowest marginal abatement costs should abate their emissions more than firms with the highest marginal abatement costs. The first steps in an emission trading scheme are, in general, taken by the government which defines the emission levels - the cap or ceiling - for a particular region and then fixes an amount of permits which subsequently are either sold to the highest bidders at auctions or distributed for free, so-called grandfathering. At this stage the government opens up the game for the market forces. The polluters participating in the scheme start to sell and buy their permits. Emission permits will be bought by those firms which have the highest opportunity costs.

The maximum concentrations or amounts allowed according to the scheme set up by the authorities is the ceiling or cap. Emission trading is therefore often named *cap and trade*. The allowed amounts, the cap, is established at the beginning. Most often it is for a defined time period and for following time periods the cap is reduced.

The first European case seems to be that of the Polish city of Chorzow in Upper Silesia, where a trading scheme was market-based economic instruments established between just two industries. One steel mill was in bad economic conditions with many emissions, but where these could be reduced by rather inexpensive actions. The other factory was in good economic conditions, but the reductions of emission would be comparatively expensive. The common trading scheme was successful and dramatic reductions in emissions of particles, CO, SO_2, NO_X and VOC were achieved. The Polish scheme constituted a quite local so-called bubble.

The largest scale emission trading ever established is the EU carbon dioxide emission trading (EU ETS) under the Framework Convention on Climate Change, FCCC, signed during the UNCED Rio Conference in 1992 by 153 participating states. It entered into force in March 1994. Its intention was, and is, to stop climate change by reducing combustion of fossil fuels and the resulting greenhouse gas emissions, but exactly how to do it was then left to further developments.

A series of COPs (Conference of Parties) were staged, which, piece by piece, have formed one of the most efficient conventions ever created. The 3rd COP in Kyoto, Japan, in 1997 was especially fruitful since the levels for decreased emission of CO_2 for the so-called Annex 1 states, basically the industrialised countries, were detailed in its protocol. The Kyoto protocol stated that by 2010 (as the average of the 2008-2012 window), the parties should have decreased their CO_2 emission by an average of 5.2% as compared to the chosen base year of 1990. The first trading period entered into force on the 16th of February 2005 after the Russian Federation had ratified the protocol as one of more than 150 States. After much resistance from some countries a second trading period 2013-2020, with a different set of parties, was finally agreed. During this period parties committed to reduce GHG emissions by at least 18 percent below 1990 levels.

9.5 Harnessing markets for mitigation – the role of taxation and trading

Agreeing on a quantitative global stabilisation target range for the stock of greenhouse gases (GHGs) in the atmosphere is an important and useful foundation for overall policy. It is an efficient way to control the risk of catastrophic climate change in the long term. Short term policies to achieve emissions reductions will need to be consistent with this long-term stabilisation goal.

In the short term, using price-driven instruments (through tax or trading) will allow flexibility in how, where and when emission reductions are made, providing opportunities and incentives to keep down the cost of mitigation. The price signal should reflect the marginal damage caused by emissions, and rise over time to reflect the increasing damages as the stock of GHGs grows. For efficiency, it should be common across sectors and countries.

In theory, taxes or tradable quotas could establish this common price signal across countries and sectors. There can also be a role for regulation in setting an implicit price where market-based mechanisms alone prove ineffective. In practice, tradable quota systems – such as the EU's emissions-trading scheme, EU ETS – may be the most straightforward way of establishing a common price signal across countries. To promote cost-effectiveness, they also need flexibility in the timing of emissions reductions.

Both taxes and tradable quotas have the potential to raise public revenues. In the case of tradable quotas, this will occur only if some firms pay for allowances (through an auction or sale). Over time, there are good economic reasons for moving towards greater use of auctioning, though the transition must be carefully managed to ensure a robust revenue base.

The global distributional impact of climate-change policy is also critical. Issues of equity are likely to be central to securing agreement on the way forward. Under the existing Kyoto protocol, participating developed countries have agreed on binding commitments to reduce emissions. Within such a system, company-level trading schemes such as the EU ETS, which allow emission reductions to be made in the most cost-effective location – either within the EU, or elsewhere – can then drive financial flows between countries and promote, in an equitable way, accelerated mitigation in developing countries.

At the national – or regional – level, governments will want to choose a policy framework that is suited to their specific circumstances. Tax policy, tradable quotas and regulation can all play a role. In practice, some administrations are likely to place greater emphasis on trading, others on taxation and possibly some on regulation. The key question that arises from the previous section is how to combine a price instrument that allows flexibility about where, when and what emissions are reduced in the short term, with a long-term quantity constraint. In particular, the challenge is how to ensure that the short-term policy framework remains on track to deliver the long-term stabilisation goal. There are two important aspects to this:

having established the long-term stabilisation goal, the price of carbon is likely to rise over time, because the damage caused by further emissions at the margin - the social cost of carbon - is likely to increase as concentrations rise towards this agreed long-term quantity constraint;

short-term tax or trading policies will then need to be consistent with delivering this long-term quantitative goal. In the short-term, applying these principles to tax and trading, this means that in a tax-based regime, the tax should be set to reflect the marginal damage caused by emissions. Abatement should then occur up to the point where the marginal cost of abatement is equal to this tax.

In a tradable-quota scheme, the parameters of the scheme – notably the total quota allocation – should be set with a view to generate a market price that is consistent with the social cost of carbon (SCC). In practice – and within the time period between allocations in a tradable-quota system – the market price may be higher or lower than the SCC. This is because the actual market price will reflect both the quota-driven demand for carbon reductions and the marginal cost of delivering reductions in the most cost-effective location. Ex-post, the trading period will therefore deliver abatement up to where the marginal abatement cost equals the actual market price. In the case of either tax or trading, clear revision rules are therefore necessary to ensure that short-term policies remain on track to meet the long-term stabilisation goal. In particular, the short-term policy framework should be able to take systematic account of the latest scientific information on climate change, as well as improved understanding of abatement costs.

Both taxes and tradable quotas can be used to raise public funds. Carbon taxes automatically raise public revenues, but tradable-quota systems only have the potential to raise public revenue if firms have to purchase the quotas from government through a sale or auction. Carbon taxes automatically transfer funds from emitting industries to the public revenue. This transfer may be used to:

- enhance the revenue base;
- limit the overall tax burden on the industry affected through revenue recycling;
- reduce taxes elsewhere in the economy;

Revenue recycling to the industry can encourage emitters to reduce GHG emissions, without increasing their overall tax burden relative to other parts of the economy. The advantage of this approach is that it can ease the initial impact of the scheme for those industries facing the greatest increase in costs, and therefore ease the transition where carbon taxes are introduced. As the introduction of carbon pricing through taxation is a change to the rules of the game (which will affect shareholders in the short run), there is a case for some transitional arrangements. Over time, however, recycling may discourage or slow the necessary exit of firms from the polluting sectors. Monitoring and protecting the position of incumbents in this way could also reduce competition. Alternatively, revenue from carbon taxes can be used to reduce taxes elsewhere in the economy. In such circumstances, the revenue from the carbon tax is sometimes argued to generate a so-called 'double dividend' by allowing other distortionary taxes to be reduced.

At the global level, policymakers need both a shared understanding of a long-run stabilization goal, and the flexibility to revise short-run policies over time. At the national – or regional – level policy makers will want to achieve these goals in a way that builds on existing policies, and creates confidence in the future existence of a carbon price. In particular, they seek to assess how carbon pricing (through either taxation, tradable quotas or regulation) will interact with existing market structures and existing policies (for instance, to encourage the development of renewable energy or petrol taxes). Governments on their side seek to tailor a package of measures that suits their specific circumstances. Some may choose to focus on regional trading initiatives, others on taxation and others may make greater use of regulation. The key goal of policy should be to establish common incentives across different sectors, using the most appropriate mechanism for a particular sector. With market failures elsewhere, other objectives, and the costs of adjustment associated with long-lived capital, it will be important to look at both the simple price or tax options as well as quotas and regulation to see what incentives in particular sectors really work. Carbon pricing is only one element of a policy approach to climate change. The following two sections discuss the role of technology policy, and policies to influence attitudes and behaviours, particularly in regard to energy efficiency. All three elements are important to achieve lowest cost emissions reductions.

9.6 Accelerating technological innovation

Effective action on the scale required to tackle climate change requires a widespread shift to new or improved technology in key sectors such as power generation, transport and energy use. Technological progress can also help reduce emissions from agriculture and other sources and improve adaptation capacity. The private sector plays the major role in R&D and technology diffusion. But closer collaboration between government and industry will further stimulate the development of a broad portfolio of low carbon technologies and reduce costs. Co-operation can also help overcome longer-term problems, such as the need for energy storage systems, for both stationary applications and transport, to enable the market shares of low-carbon supply technologies to be increased substantially. Carbon pricing alone will not be sufficient to reduce emissions on the scale and pace required as:

- Future pricing policies of governments and international agreements should be made as credible as possible but cannot be 100% credible.
- The uncertainties and risks both of climate change, and the development and deployment of the technologies to address it, are of such scale and urgency that the economics of risk points to policies to support the development and use of a portfolio of low-carbon technology options.
- The positive externalities of efforts to develop them will be appreciable, and the time periods and uncertainties are such that there can be major difficulties in financing through capital markets. Governments can help foster change in industry and the research community through a range of instruments:
- Carbon pricing, through carbon taxes, tradable carbon permits, carbon contracts and/or implicitly through regulation will itself directly support the research for new ways to reduce emissions;
- Raising the level of support for R&D and demonstration projects, both in public research institutions and the private sector;
- Support for early stage commercialization investments in some sectors. Such policies should be complemented by tackling institutional and other non-market barriers to the deployment of new technologies.

These issues will vary across sectors with some, such as electricity generation and transport, requiring more attention than others. Governments are already using a combination of market-based incentives, regulations and standards to develop new technologies. These efforts should increase in the coming decades. Modelling suggests that, in addition to a carbon price, deployment incentives for low emission technologies should increase two to five times globally from current levels of around $33 billion. Global public energy R&D funding should double, to around $20 billion, for the development of a diverse portfolio of technologies. Policies to price greenhouse gases, and support technology development, are fundamental to tackling climate change. However, even if these measures are taken, barriers and market imperfections may still inhibit action, particularly on energy efficiency. These barriers and failures include hidden and transaction costs such as the cost of the time needed to plan new investments; lack of information about available options; capital constraints; misaligned incentives; as well as behavioural and organisational factors affecting economic rationality in decision-making. These market imperfections result in significant obstacles to the uptake of cost-effective mitigation, and weakened drivers for innovation, particularly in markets for energy efficiency measures.

Policy responses which can help to overcome these barriers in markets affecting demand for energy include:

- Regulation: Regulation has an important role, for example in product and building markets by: communicating policy intentions to global audiences; reducing uncertainty, complexity and transaction costs; inducing technological innovation; and avoiding technology lock-in, for example where the credibility of carbon markets is still being established.
- Information: Policies to promote: performance labels, certificates and endorsements; more informative energy bills; wider adoption of energy use displays and meters; the dissemination of best practice; or wider carbon disclosure help consumers and firms make sounder decisions and stimulate more competitive markets for more energy efficient goods and services.
- Financing: Private investment is key to raising energy efficiency. Generally, policy should seek to tax negative externalities rather than subsidise preferable outcomes, and address the source of market failures and barriers. Investment in public sector energy conservation can reduce emissions, improve public services, fostering innovation and change across the supply chain and set an example to wider society.
- Careful appraisal, design, implementation and management helps minimise the cost and increase the effectiveness of regulatory, information and financing measures. Energy contracting can reduce the costs of raising efficiency through economies of scale and specialisation. Fostering a shared understanding of the nature and consequences of climate change and its solutions is critical both in shaping behaviour and preferences, particularly in relation to their housing, transport and food consumption decisions, and in underpinning national and international political action and commitment. Governments cannot force this understanding, but can be a catalyst for dialogue through evidence, education, persuasion and discussion.

9.7 Policy responses for adaptation

Climate is a pervasive factor in social and economic development – one so universally present and so deeply ingrained that it is barely noticed until things go wrong. People are adapted to the distinct climate of the place where they live. This is most obvious in productive sectors such as agriculture, where the choice of crops and the mode of cultivation have been finely tailored over decades, even centuries, to the prevailing climate. But the same is true for other economic sectors that are obviously weather-dependent, such as forestry, water resources, and

Figure 9.1. A village in Uzbekistan adapts to climate change, and raises incomes Climate change has taken its toll on rural Uzbekistan, degrading pastureland and depleting livestock. However, one remote village has demonstrated that it can adapt to the effects of climate change – and even increase people's income at the same time.The inhabitants of Kyzyl Ravat, a remote village in the Kyzylkum desert of Uzbekistan, have employed a range of techniques to improve herding and breeding practices for their sheep and cattle. In the process, they raised the productivity of their cattle by 36% and increased their income by 32%. Photo courtesy UNDP. https://www.flickr.com/photos/undpeuropeandcis/6459055021

recreation. It is also evident in how people live their daily lives, for instance in working practices.

So far we have mostly discussed measures taken and policies used to reduce GHG emissions, called mitigation. But in reality much more efforts are made and money spent to adapt to climate change, *adaptation*, rather than to stop it from happening, address its causes.

Adaptation will be crucial in reducing vulnerability to climate change and is the only way to cope with the impacts that are inevitable over the next few decades. In regions that may benefit from small amounts of warming, adaptation will help to reap the rewards. It provides an impetus to adjust economic activity in vulnerable sectors and to support sustainable development, especially in developing countries. But it is not an easy option, and it can only reduce, not remove, the impacts. There will be some residual cost – either the impacts themselves or the cost of adaptation. Without early and strong mitigation, the costs of adaptation rise sharply.

Adaptation is crucial to deal with the unavoidable impacts of climate change to which the world is already committed. It will be especially important in developing countries that will be hit hardest and soonest by climate change. Adaptation can mute the impacts, but cannot by itself solve the problem of climate change. Adaptation will be important to limit the negative impacts of climate change. However, even with adaptation there will be residual costs. For example, if farmers switch to more climate resistant but lower yielding crops.

There are limits to what adaptation can achieve. As the magnitude and speed of unabated climate change increase, the relative effectiveness of adaptation will diminish. In natural systems, there are clear limits to the speed with which species and ecosystems can migrate or adjust. For human societies, there are also limits – for example, if sea level rise it will leave some nation states, small island nations, uninhabitable. Without strong and early mitigation, the physical limits to – and costs of – adaptation will grow rapidly. This will be especially so in developing countries, and underlines the need to press ahead with mitigation. Adaptation will in most cases provide local benefits, realised without long lag times, in contrast to mitigation. Therefore some adaptation will occur autonomously, as individuals respond to market or environmental changes. Much will take place at the local level. Autonomous adaptation may also prove very costly for the poorest in society. But adaptation is complex and many constraints have to be overcome.

Governments have a role to play in making adaptation happen, starting now, providing both policy guidelines and economic and institutional support to the private sector and civil society. Other aspects of adaptation, such as major infrastructure decisions, will require greater foresight and planning, while some, such as knowledge and technology, will be of global benefit. Studies in climate-sensitive sectors point to many adaptation options that will provide benefits in excess of cost. But quantitative information on the costs and benefits of economy-wide adaptation is currently limited.

In developed countries, adaptation will be required to reduce the costs and disruption caused by climate change, particularly from extreme weather events like storms, floods and heatwaves. Adaptation will also help take advantage of any opportunities, such as development of new crops or increased tourism potential. But at higher temperatures, the costs of adaptation will rise sharply and the residual damages remain large. The additional costs of making new infrastructure and buildings more resilient to climate change in OECD countries could range from $15-150 billion each year (0.05-0.5% of GDP), with higher costs possible with the prospect of higher temperatures in the future.

Markets that respond to climate information will stimulate adaptation amongst individuals and firms. Risk-based insurance schemes, for example, provide strong signals about the size of climate risks and encourage better risk management. In developed countries, progress on adaptation is still at an early stage, even though market structures are well developed and the capacity to adapt is relatively high. Market forces alone are unlikely to deliver the full response necessary to deal with the serious risks from climate change. Government has a role in providing a clear policy framework to guide effective adaptation by individuals and firms in the medium and longer term. There are four key areas:

- High-quality climate information will help drive efficient markets. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.
- Land-use planning and performance standards should encourage both private and public investment in buildings, long-lived capital and infrastructure to take account of climate change.
- Government can contribute through long-term polices for climate-sensitive public goods, such as natural resources protection, coastal protection, and emergency preparedness.
- A financial safety net may be required to help the poorest in society who are most vulnerable and least able to afford protection (including insurance).

Adaptation to mute the impact of climate change will be essential in the poorer parts of the world. The poorest countries will be especially hard hit by climate change, with millions potentially pushed deeper into poverty. Development itself is key to adaptation. Much adaptation should be an extension of good development practice and reduce vulnerability by:

- Promoting growth and diversification of economic activity;
- Investing in health and education;
- Enhancing resilience to disasters and improving disaster management;
- Promoting risk-pooling, including social safety nets for the poorest.

Putting the right policy frameworks in place will encourage and facilitate effective adaptation by households, communities and firms. Poverty and development constraints will present obstacles to adaptation but focused development policies can reduce these obstacles. Adaptation actions should be integrated into development policy and planning at every level. This will incur incremental adaptation costs relative to plans that ignore climate change. But ignoring climate change is not a viable option – inaction will be far more costly than adaptation. Adaptation costs are hard to estimate, because of uncertainty about the precise impacts of climate change and its multiple effects. But they are likely to run into tens of billions of dollars. This makes it still more important for developed countries to honour both their existing commitments to increase aid sharply and help the world's poorest countries adapt to climate change.

More work is needed to determine the costs of adaptation. Without global action to mitigate climate change, both the impacts and adaptation costs will be much larger, and so will be the need for richer countries to help the poorer and most exposed countries. The costs of climate change can be reduced through both adaptation and mitigation, but adaptation is the only way to cope with impacts of climate change over the next few decades.

9.8 Environmental organisations and the green political parties

The social movement to protect the environment has very deep roots. Early on they became a force in the societies where they were present with an agenda to protect the environment. This became considerably stronger after the Silent Spring debate in the early 1960s, when many environmental NGOs (Nongovernmental Organisations, also called Civil Society Organisations, CSOs) increased dramatically in size. Many became very efficient to influence the politics of the countries.

Soon thereafter environmental concerns formally entered the political landscape, when the first green political parties were formed. They quickly got representatives in local and regional assemblies in many countries in Europe. Some decade later they had become large enough to receive seats in the national par-

Figure 9.2. Participants at festival "Chimghan Echo 2014" in Uzbekistan. Source: http://www.eco.uz/

liaments. After the end of the Soviet Union in 1991 the Polish Ecological Club became very influential in Polish policy. The first green party to be part of a national government in Europe was the German Greens which governed in alliance with the Social Democrats 1998-2005. The Swedish Green Party became part of a government coalition in 2014. The European Green parties have since long a strong voice in the European Parliament.

The Ecological Movement of Uzbekistan was established on August 2, 2008 and registered by the Ministry of Justice of the Republic of Uzbekistan on September 20, 2008. It works as a political party and has a ten percent quota (15 seats) in the Legislative Chamber of Oliy Majlis. The governing bodies of the movement are the Republican Conference, the Central Kengash, the Executive committee and the Central control-revision commission.

The Republic of Karakalpakstan, the regions and Tashkent city have operating regional offices of the Ecological Movement of Uzbekistan.

The Movement aspires to mobilize all forces of a society for the further deepening of the transformations carried out in the country directed on realization and strict observance of the rights of the present and the future generations of citizens of Uzbekistan for a life in a favourable environment, improvement of health of the population, protection and rational use of the whole complex of natural resources. The main slogan of the Movement is

A healthy environment - A healthy person

The policy objectives of the Ecological Movement of Uzbekistan are:

- All-round activity of public participation in work on protection of environment and improvement of ecological conditions;
- Maintenance of the system to ensure the implementation of existing laws and other government documents for the protection of the environment and promoting the further improvement and development of the law in this area;
- Increasing the responsibility of public central and local authorities, public and other agencies for execution of the accepted instruments for the protection of the environment and ensure sustainable use of resources allocated for this purpose;
- Increasing environmental awareness, the development of environmental education;
- Development of international cooperation in the field of environmental protection;
- To facilitate that the environment has become a matter of the state and society, and every citizen;
- Coordination of activity of non-governmental non-commercial organizations (NGOs'), which are the collective participants of the Movement.

The Movement is called to unite the citizens of the country supporting ideas and wishing to participate actively in protection of the environment and health of the person, convinced that ecologically focused approach in carrying out of political, economic and social reforms is the most effective way of steady development of Uzbekistan.

Eco-movement is a co-founder of the social and political newspaper «Jamiyat» and the socio-economic newspaper «Ekohayot». For the purpose of educating the younger generation in the spirit of love and respect for the country, the formation of ecological knowledge and culture, ensuring continuous environmental education in Uzbek and Russian languages, they publish monthly the children's environmental magazine «Buloqcha» («Spring»).

The Ecological Movement aims to unite citizens of the country who support ideas and want to actively participate in environmental and public health protection, and are convinced that an environmentally focused approach in carrying out political, economic and social reforms is the most effective way for sustainable development of Uzbekistan.

The Ecological Movement seeks to mobilize all forces of society for further deepening of reforms carried out in the country, which are aimed at implementation and strict observance of the rights of present and future generations of Uzbekistan to a favourable environment life, improvement of public health, protection and rational use of all the complex of natural resources.

1 Considering "Healthy Environment – Healthy Human" as its main motto, the Ecological Movement sets the following program tasks for its implementation.
2 All-round increase of public participation activity in environmental protection and improvement.
3 Carrying out of systemic work to ensure implementation of already adopted laws and other state documents on environmental protection, and assistance to further perfection and development of the legislation in this field.
4 Raising of the responsibility of central and local authorities, public and other structures for executing adopted documents on environmental protection and ensuring rational use of resources allocated to these purposes.
5 Raising of ecological culture of the population, development of the system for ecological education and training.
6 Promotion of international cooperation in environmental protection. Assistance to that environmental protection would become a business of the government, society and every citizen.
7 Coordination of activities of non-governmental non-profit organizations acting in environmental protection

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Chapter 10
The Green Economy

10.1 Green economy: economics for people and the planet

During the last decade the concept of Green Economy (sometimes labelled Green Economics) have gained support as the main road to an economy capable of promoting sustainable development. Green Economy became a main concern at the Rio+20 World Conference in June 2012, where one of the main focuses was "Green economy policies, practices and initiatives". Green Economy is strongly promoted by several of the main global organisations for development and environmental protection, such as The United Nations Environment Programme, UNEP, OECD**,** the World Bank, and others. It is perceived as an economy for human wellbeing and environmental protection.

In a series of workshops with an international group of top researchers from many fields – economics, natural sciences, social sciences etc - organised by MISTRA in Stockholm in 2013-14 on a "Green Inclusive Economy" they noted that A *substantial consensus exists on a range of economic principles relevant to sustainable development*. They summarised:

"A transition to an inclusive green economy would require a systems perspective and the closest possible cross-disciplinary cooperation. Moreover, the global nature of the challenges will require the research to be truly *international*. The economy is a powerful engine for the development of society. If this engine does not work towards sustainable development, efforts for sustainability will always involve an uphill struggle. A green economy results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low-carbon, resource-efficient and socially inclusive"

The main differences between the current (brown) economy and a future, green, inclusive economy are summarized in Table 10.1 from the Mistra prestudy 2014.

10.2 Tools for transition to a green economy

Several of the means pointed out as necessary for achieving a Green Economy has been identified and discussed since long and several of them have been part of ecological economics. They include:

Table 10.1. Examples of contrasting aims and features (as expressed by UNEP, the OECD etc.) of the current economy and a green economy. Source: Mistra. Prestudy: The inclusive green economy, 2014

Current economy	Green economy
GDP growth: more economic activity the aim	'Beyond GDP': prosperity the aim
Focus on the near future (short-termism)	Long-termism
Maximisation of return s	Safeguarding of long-term income
Shareholder value	Stakeholder value: benefit to society
Extraction of natural resources	Management of natural resources
Linear production systems	Circular production systems
Short-life products for sale	Long-life services: the 'performance economy'
Efficiency measured in monetary terms (e.g. cost-benefit analysis, CBA)	Multidimensional efficiency (e.g. multi-criterion analysis, MCA)
Micro- and macrorationality highly divergent	Micro- and macrorationality highly congruent

- pricing externalities
- eliminating perverse subsidies
- enforcing regulatory standards
- redirecting investment flows
- promoting equity and social protection
- fulfilling oft-repeated pledges about international co-operation and assistance
- recognizing common but differentiated responsibilities

We have discussed externalities already in chapter 2, as well as in later chapters. The important part to stress here is that *all environmental costs* should be included in the price of a good or a service. The partner causing the impact should be responsible for this, thus the Polluter Pays Principle should be used. We have also learned that there are methods for converting these costs into monetary values. The key role of the state is also underlined. The state is most often acting to collect the payments.

Subsidies for supporting business which is not sustainable, mostly for using non-renewable energy, is enormous. An example is the fishing industry, which typically have a lower price on gasoline, than other sectors. The state does this for avoiding a collapse of the sector, since its economic situation is very tight. Another sector with much energy subsidies is agriculture. Subsidies for commuting, e.g. by reducing taxation for commuting to work or studies by car, is also large.

These kinds of subsidies conserve the use of *fossil fuels*. Summed up over the entire global economy subsidies for using coal, oil and gas is extreme. Fossil fuel subsidies reached $90 billion in the OECD and over $500 billion globally in

2011. Many of the world's richest countries continue to pour money into fossil fuel subsidies. The average spending is $112 per adult/year. In developing countries the majority of benefits from fossil fuel subsidies go to the richest 20% of households. According to the IEA the phase-out of fossil fuel subsidies would reduce greenhouse gas emissions by 10%. Presently it seems that financing of mitigation is smaller than subsidies for using fossil fuels.

Investments are the financing of projects to build the future of our societies. They are thus of key importance for the direction of development. Today we see large sums invested for e.g. new oil fields instead of renewable energy. In the Green Economy investments should support a sustainable development. Main investors are the states of course, but also risk capitalists, pension funds etc.

Recently large groups argue for *divestments*. Divestment means that capital is withdrawn from less sustainable business and used for better purposes. Last year a number of investors have publicly announced that they have withdrawn capital from oil companies and used it for renewable energy companies. These include several pension funds and others such as the Rockefeller Foundation. The reason for divestments is probably not only for contributing to sustainability but equally much since oil production becomes more risky, may suffer from carbon dioxide taxation or even regulated, while renewables, both wind and solar energy, becomes increasingly profitable.

10.3 Principles for a green inclusive economy

If we try to identify the main differences between the present conventional economy and the Green Economy, we will find that they are large, in fact, representing a new paradigm of social development.

Firstly the Green Economy looks at the *long-term development*, sometimes labelled long-termism. This contrasts to the present short term thinking in politics and economy. Politicians think in terms of election periods, most often 4 years. Companies report every year or even quarter of year. Banks and the stock market think in days or even shorter periods. Sustainable Development with its emphasis on care for future generations is really very different. Here the time perspective is decades or even centuries.

We have already mentioned that the market should not have free riders, that is, all costs should be included in the price. *External impacts must be internalised*, and anyone who pollutes the environment must pay for remediation.

The *capitalist economy* has inherent difficulties in a Green Economy and regulations are needed to deal with this. The distribution of incomes and ownership in society must be relatively even, that is intra generational equity should prevail, while unregulated capitalism concentrates wealth and ownership. A well-functioning market requires symmetrical information, i.e. both sellers and buyers must be fully informed about the content of transactions. Thus neither sellers nor buyers should be so large and dominant that they can themselves exercise strong influence on market prices.

There is a need for an institutional framework to reduce the difference between what is beneficial for the individual and society, i.e. economic benefit to businesses should result in economic benefit to society. Today the *Corporate Social Responsibility*, CSR, is increasing as a way for companies to relate to the society and this is a welcome shift to a new way to see the role of the private sector in social development. CSR is not a global management system but it still has an ISO standard 26 000. This standard is however only a guideline and not an agreed standard.

10.4.The green tax shift

The Green Tax Shift, more correctly called the ecological tax reform (ETR) is seen as one of the first steps to be taken to approach a Greener economy. The ETR is a different concept compared to environmental taxation. The latter is about using the taxation to make people act environmentally sensibly, i.e. use economic incentives to achieve the goals for the environment which the legislation has set up. The ETR is about a completely new and comprehensive taxation strategy, shifting taxation away from labour to natural resources. The aim is still environmental, i.e. a sustainable production and a sustainable society.

The higher taxation of natural resources, first of all energy resources, will put enormous pressure on industry, transportation and private households alike. The only solution will be higher energy and general resource efficiency, i.e. the introduction of innovation and savings. There is a strong relation between fuel prices and fuel efficiency.

The revenue should not be used for environmental protection. That is in principle delivered by the efficiency increase through innovation and savings, which is the expected outcome of the taxation itself. The revenue should be used to replace – wholly or to a great extent – the taxation of human activity, of labour. The concept is summarized in the following phrase: The Ecological Tax Reform (ETR) is about achieving “a wider use of labour and a wiser use of nature”. The source for the total state tax revenue should, in other words, to a much greater extent be natural resources instead of labour and other human activity.

There will be a need for compensation to a part of industry to allow for time to adapt. And there will be a need for social balancing towards people with low income and/or shortage of investment or mobility options.

The green tax shift has occurred in many countries but only to a limited extent. Thus fiscal economy relies on taxation of energy (fossil fuel, e.g. petrol for cars) carbon dioxide emissions, several metals, fertilizers etc, to some extent in several Nordic countries, Germany and the Netherlands. However to reduce resource flows a much more drastic reform is needed. This reform is also assumed to reduce unemployment as taxation of salaries is drastically reduced.

10.5 The dilemma of economic growth and GDP as a measure of progress

We live in a society in which economic growth has become a mantra for all policy makers and business people. Among the several factors behind growth energy stands out as the most important. The access to cheap fossil fuel has been closely linked to economic growth during over a long period. Easy access to energy made labour productivity rise by some 3-4% yearly over more than a century.

But where does a never ending economic growth take us? Suppose that all inhabitants should have the standard of a typical OECD country. This means another 15 times increase, and by the end of the century after further growth a 40 times bigger economy in the world. Is this possible? Obviously growth cannot go on forever. Still the “engine of growth” in market economies allows a company to gain a net profit, which is invested in a development that leads to more growth and jobs. In short it seems like modern economy has to choose between eternal growth and collapse, both of which are unsustainable. The growth dilemma may be the largest problem for the vision of a Green economy.

Growth measured as Gross Domestic Product, GDP, is today used as a measure of progress in almost all societies. It is clear that economic growth is crucial up to a point for quality of life, happiness, prosperity, education, health etc. But after that it appears that economic growth is not so important. In international studies life expectancy, infant mortality, education or happiness itself does not increase after a GDP of about 10,000 USD/capita (purchasing power parity using 1995 dollars). In investigations one finds that factors which are important to individual satisfaction and wellbeing do not cost much or cannot be bought at all, such as family, friends, leisure time, enjoying nature etc. Increased income however, is still a priority in all societies. Why do people rather get richer than happier?

Another road is green growth. This was a main theme at the 2012 Rio + 20 Conference. Green economy in short only refers to an economy where environmental concerns are taken into account. Here one component is that material flows become cyclic (recycle all components of products) so that they do not contribute to resource extraction or environmental loads. The economy needs to rely on renewable resources especially in energy sector. Obviously we need a green sector of the economy, but so far we have not seen it contribute to absolute decoupling. According to the Limits to Growth studies even very extreme assumptions about technical developments did not in itself solve the problem of limits to growth. They only pushed the peaks further into the future. We have to make life style changes.

As a response to mounting concerns about the growth dilemma the de-growth movement has developed as a protest against the all-embracing concern with material possessions. The de-growth movement want other ways to measure success. The common practice of using Gross Domestic Product, GDP, as a measure of the success of a country is therefore brought into question. GDP is just the sum of all economic transactions in a country (many of which may be very negative) and was never intended to be a measure of success. The de-growth movement want to focus on welfare, prosperity or even happiness.

10.6 The resource efficient society

Of the several ways to a green the economy three stands out:

- Resource efficiency
- Bio-economy
- Cyclic economy

Resource efficiency relates more than anything more to energy efficiency and the move from fossil fuel dependency to use of renewable energy resources. As is clear from the above leaving the fossil fuel economy is an essential part of the Green Economy. However here we will look at some cases on how energy efficiency can be achieved within the present system.

Heating (or air conditioning) houses is a major part of the economy of many countries. In Sweden it accounts for about 38% of the energy budget. Energy Performance Contracting (EPC) is a cooperation model for improved energy efficiency in the building sector in the European Union. Companies in the EPC are consultancies which offer house owners projects to reduce their energy consumption (and costs!). It is normally a three step procedure. First an investigation is made to review the possibilities in general. If house owners are interested a contract is signed to make a detailed investment plan and estimation of energy efficiency possibilities. Then then the project is carried out. 22% energy reduction

Box 10.1 Energy reductions in large Swedish companies

One of the participating industries Sandvik Materials Technology, Sweden. The company has 9,000 employees, and an economic turnover of 18 billion SEK (2 billion Euros). In the project they were conducting 52 projects during 2 years

Figure 10.1 Sandvik Materials Technology, Sweden,

Primary improvements

Temperature adjustments
Heat recovery
New valves
Insulation
Changed routines
New lighting
Toilets

Secondary improvements

Reduced water use
Decreased fire risks
Less air pollutants
Less noise

Results after 2 years

Accomplished 19 304 MWh /year
Under planning 32 942 MWh /year

Source: Swedish Energy Authority, Programme for Improving Energy Efficiency in Energy Intensive Industries (PFE) http://www.energimyndigheten.se/en/news/2009/companies-have-found-more-energy-savings-than-expected/

has been achieved in the apartment building sector and 55% reduction in industry buildings. Return of investment has been about 7 years.

In another project the Swedish Energy Authority invited large companies to take part in an Energy Efficiency project. In the first period 100 companies took part. All made a complete energy use mapping and introduced a certified energy management system. In these 100 companies 1247 projects were carried out which resulted in 1.47 TWh less electricity use annually. The investments were 708 MSEK while 400 MSEK less energy costs annually. Average return of investments was thus 1.5 year. Tax reductions 150 MSEK annually.

Also many municipalities have taken steps to green their economy. One well known case is the neighbourhood Vauban in Freiburg, Germany. According to its homepage there are about 1,500 green businesses employing about 10,000 people. Of those ten thousand, about 1,500 people are employed in the solar energy sector. About 50% of electricity is produced by co-generation units (CHPs) that also provide heat through district heating systems. In addition to larger co-generation units, there are about 90 small CHP units around the city. Solar energy is very visible around Freiburg. Currently 12.3 MW of solar capacity is in place, producing over 10 million kilowatt-hours annually. There are also five medium sized wind turbines installed on the hills around the city. They produce 14 million kWh every year, more than produced by all the solar PV panels.

Freiburg is accompanied by many larger and smaller cities. Sweden's largest green city district is to be developed in central Stockholm called Royal Seaport. It contains plans for 12,000 new residences and 35,000 new workspaces Wuppertal Institute for Climate, Environment, and Energy

Figure 10.2. Solar energy village Vauban in Freiburg. Source: http://convertnews.com/wp-content/uploads/2015/09/the-vauban-district-renewable-energy-sources.jpg

The literature on energy and resource efficiency, e.g. from the Wuppertal Institute in Germany and the Rocky Mountains Institute in the USA, points to considerable potentials to reduce resource and energy consumption in several industrial sectors, as well as in transport, urban planning and agriculture. If the economic incentives become large enough we are only in the beginning of this development. So far the automotive industry is the largest investor in green R&D. Renault / Nissan invests Euros 4 billion in zero-emission mobility and Volkswagen's invest 76.4 billion Euros on R&D of efficient vehicles and greening production by 2016.

The semiconductor sector is the second largest investor. Solar panel manufacturers have reached the milestone of silicon modules at a cost of $1 per watt of capacity. Large firms such as Samsung and Philips are investing billions in new LED lighting technology.

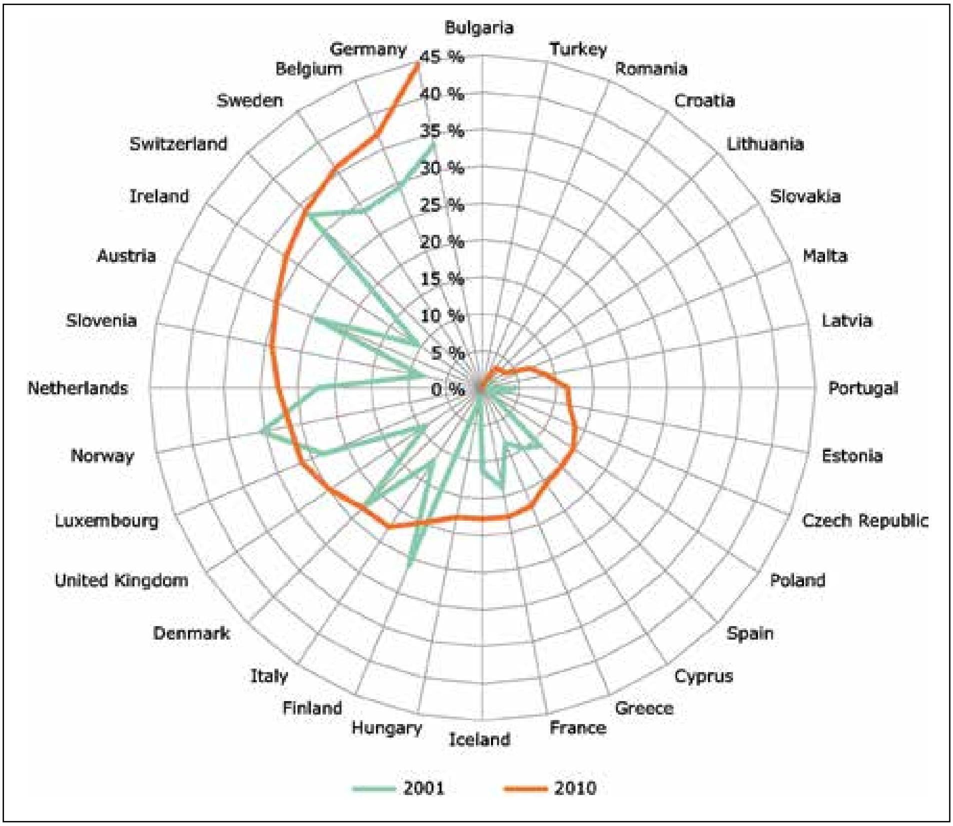

Figure 10.3 Material recycling as a percentage of municipal waste generation in 32 European countries, 2001 and 2010. http://ec.europa.eu/eurostat/statistics-

Out phasing fossils using renewable resources, recycling materials, eco design. Green chemistry and technologies;

10.7 The Bio-economy

In a bio-economy the resources used are all of biological origin. Of course biological resources have been with us all the time, but in the bio economy it will replace resources based on oil. In February 2012 the European Commission launched the Communication "Innovating for Sustainable Growth: a Bio-economy for Europe". The EU established a European Bio-Observatory to develop a Bio-economy Strategy and an accompanying Action Plan for promoting a more sustainable use of renewable biological resources within the European economy.

The reasons to promote a bio-economy include

- food security for the fast-growing global population and higher life expectancy, and the consequent rise of food and feed production and demand (according to Food and Agriculture Organization, plus 70% by 2050);
- the need of strengthening renewable energy security, which call for a more diversified supply option range;
- increasing demand of biological resources for bio-based products;
- increasing sustainability concerns (e.g. GHG emission reduction, moving towards a zero-waste society, environmental sustainability of primary production systems, increasing land use competition.

The estimated development of the market for bio-based products in the EU is expected to grow from 19 billion Euros in 2006 to 38 billion in 2020, and job market to more than double.

Also here there are many cases. One is how the town of Güssing in Austria, used forest products to produce all fuels needed and made their energy. From 1992 within eleven years, Güssing became self-sufficient with regards to electricity, heating, and transportation. In addition, more than 60 new companies and over 1,500 new "Green Jobs" were created and the share of commuters to other regions fell to 40%. Since Güssing generates more "green" energy than the region needs, the value added to the region is over $28 million per year. Finally, greenhouse gas emissions were reduced by over 80%.

An interesting sector is wooden houses. Wood is today starting slowly to successfully compete with concrete as building material. It is cheaper, the building project is faster and it is in fact also safer for fire. It is used for multi-story houses.

10.8 The circular economy

The most promoted phase of the Green Economy today is the *circular economy*. The circular economy is a generic term for an industrial economy that is, by design or intention, restorative. The materials flows are of two types, *biological nutrients*, designed to re-enter the biosphere safely, and *technical nutrients*, which are designed to circulate at high quality without entering the biosphere.

The reasons for a circular economy are obvious:

- Resources costs both financially and environmentally – resources should be used as well as possible
- Energy intensity reflects the resource use per economy (GDP) in a society
- Resource use is much improved by recycling and proper waste management – waste is a resource!
- Resource use in production is much improved by Cleaner Production (CP) measures

Already in the 1990s Michael Braungart, Hamburg and William McDonough, San Fransisco, developed the Cradle to Cradle (C2) Design model. It considers

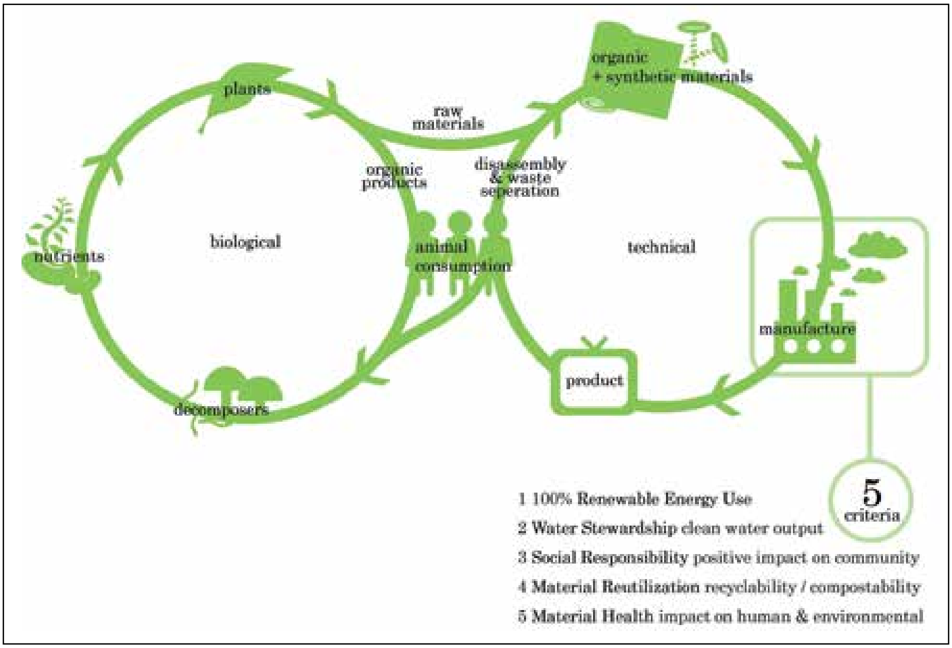

Figure 10.4 Cradle to Cradle design developed by Michael Braungart , Hamburg and William McDonough, San Fransisco. Source: https://en.wikipedia.org/wiki/Cradle-to-cradle_design

that all material involved in industrial and commercial processes can be seen as nutrients and be used again for new production. Today the concept is well accepted and hundreds of companies are certified according to the C2C concept, as reported by the Cradle to Cradle Products Innovation Institute.

A circular economy relies on a *good waste management* and resource management schemes. “Waste is a resource but on the wrong place” is an old saying. Recycling of all “waste” is thus a must in a circular economy and development of good waste regulation is necessary. In the EU presently several countries have more than 50% recycling, but there is still much to do to improve recycling.

Another important component in the circular economy is *industrial symbiosis*. In such a scheme several industries cooperate to make the waste from one plant becoming the resource of another. A very good example is the Danish town of Kalundborg, where seven industries and the municipality work together in a symbiotic scheme. For example a refinery sends all its surplus hot water and steam for district heating in the town, and its gypsum (calcium sulphate from

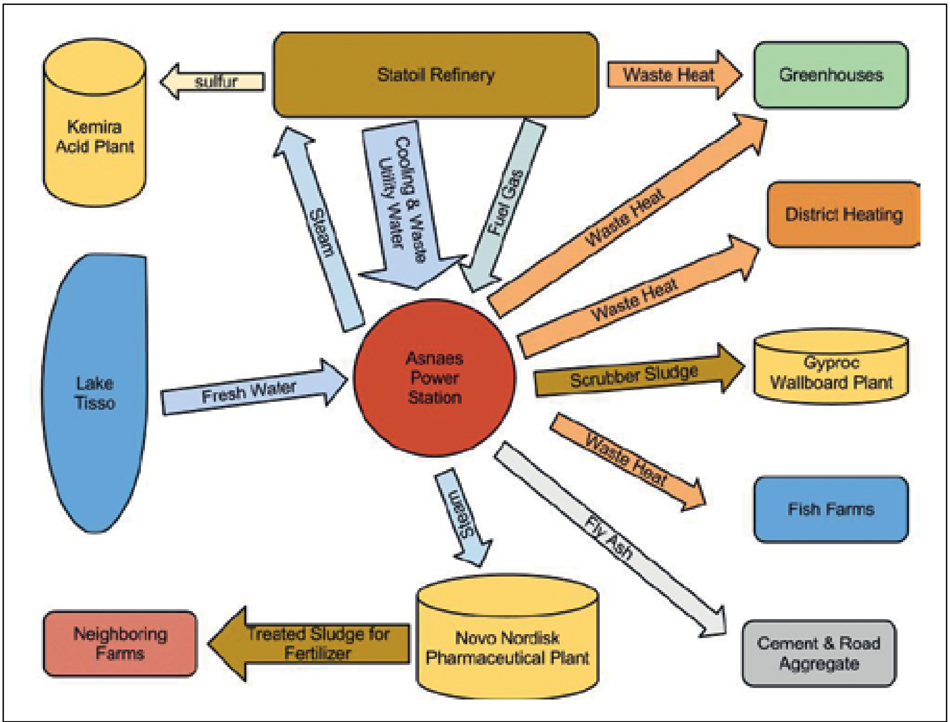

Figure 10.5. Kalundborg town in Denmark, a case of industrial symbiosis. http://www.symbiosis.dk/en and https://en.wikipedia.org/wiki/Kalundborg_Eco-industrial_Park

flue gas cleaning) to a board factory which produces building boards for export; a factory which produces an enzyme from yeast, sends its used yeast slurry to a chicken farm where it is used as chicken feed. Resource used for the entire system is greatly reduced, e.g. water by a factor of close to 10!

There are also several developments in civil society which is seen as part of a circular economy. One is the *economy of sharing*. Here a resource is used by several thereby reducing resource flows. We may mention the second hand business, which is growing in all of Europe. More developed schemes include car pools, where the individual users of cars are not owning the car but belong to the car pool which uses a set of cars together. Car pools in larger cities are increasing. Other examples are using music and films on the Internet instead of having your own copy. There are of course very established cases of sharing resources since very long, e.g. having common washing machines in a multi-apartment building, or having printer or copying machines together in a company.

Organic agriculture may also be included, since one aspect is that fertilisers are from the farm, not commercial fertilisers from outside. It is thus a case of recycling. It is also possible to use manure and sometimes together with a crop to produce biogas for energy purposes; then the residue becomes an excellent fertiliser.

10.9 Promoting the Green Economy

There are several efforts to promote the Green Economy.

Some Governments integrate green growth into their economic plans. These risk being exclusively focused on business development and technology; Frontrunners include Denmark, South Korea, UAE, Mexico and Germany.

On the business side Industry and private sector organisations pursuing market opportunities., eg. car industry and semiconductors.

A main missing 'link' in the transition to a green economy is 'green finance'. Ethical Markets see global investors redeploy their portfolios directly in companies driving the Green Transition. Why? It is better economy, less risky. Some initiatives need to be mentioned. The World Bank's global partnership for Wealth Accounting and the Valuation of Ecosystem Services (WAVES) supports national environmental accounts and develops guidelines for ecosystem accounting. Frontiers pushing forward the Green Economy includes the Green Economy Coalition, GEC, the Green production and Green Business in Agriculture promoting organic farming and permaculture principles.

The universities could decrease their environmental impacts greening education and research. The intradisciplinary debate on these matters is still, however,

Figure 10.6 Ellen MacArthur is best known as a solo long-distance yachtswoman. On 7 February 2005 she broke the world record for the fastest solo circumnavigation of the globe, a feat which gained her international renown.
Following her retirement from professional sailing on 2 September 2010, MacArthur announced the launch of the Ellen MacArthur Foundation, a charity that works with business and education to accelerate the transition to a circular economy.
http://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram

extremely limited. Economics textbooks have incorporated scientific knowledge into economics only to a very small extent. Consequently, the knowledge acquired by certain economists, after long careers spent analysing environmentally related issues using economic theory, is not being passed on to the next generation of economists. Reform of education in economics is urgently needed.

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The chapter is written by Lars Rydén based on the following sources:

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Section 10.4 Chapter 11 in the book *Environmental Management volume 1 Environmental Policy - Legal and Economic Instruments* of the Baltic University Programme authored by Børge Klemmensen, Sofie Pedersen, Kasper R. Dirckinck-Holmfeld, Anneli Marklund, and Lars Rydén pp 158-159. http://www.balticuniv.uu.se/index.php/boll-online-library/826-em-1-environmental-policy-legal-and-economic-instruments-.

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Section 10.9 IUCNs *Green Economy Guidebook*: http://cmsdata.iucn.org/downloads/green_economy_guidebook_august_2010_1.pdf, *Millennium Ecosystem Assessment. 2005*: http://www.millenniumassessment.org/en/index.aspx and Green Economy coalition 2011: http://greeneconomycoalition.org/

Chapter 11
GDP, Green Budgets and Measures of Welfare

11.1 Gross domestic product (GDP)

Gross domestic product (GDP) is a measure of the size of an economy. It is defined by the OECD as "an aggregate measure of production equal to the sum of the gross values added of all resident, institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs)".

The concept of GDP was first developed by Simon Kuznets for a US Congress report in 1934. In this report, Kuznets warned against its use as a measure of welfare. After the Bretton Woods conference in 1944, GDP became the main tool for measuring a country's economy. At that time Gross National Product (GNP) was the preferred estimate, which differed from GDP in that it measured production by a country's citizens at home and abroad rather than its 'resident institutional units'. The switch to GDP was in the 1980s (Wikipedia).

GDP is most often measured as production, that is, the sum of the outputs of every class of enterprise to give a total. It can also be measured as expenditures assuming that all of the product must be bought by somebody. The GDP is then people's total expenditures in buying things. The production and expenditures approach should give the same result.

Countries report yearly, or even more often, their GDP and the dominant policy of economic growth use GDP as the standard index for growth. Even if this is increasingly criticised as we will see below it is today the standard means of discussing not only the economy of a country but also its progress and even welfare.

In terms of GDP Uzbekistan has been very successful during its period of independence. GDP Annual Growth Rate in Uzbekistan averaged 8.06%from 2006 until 2015, reaching an all-time high of 9.80% in the third quarter of 2007 and a record low of 3.60% in the first quarter of 2006. The GDP of Uzbekistan expanded 7.50% in the first quarter of 2015 over the same quarter the previous year.

Even though Uzbekistan's economy is relatively closed, it has been growing steadily due to its vast natural resources of oil, natural gas and gold. Receipts from these key industries allow the government to control the economy through investments in services (accounting for 48% of GDP) and industry (accounting for 40% of GDP). Uzbekistan is currently the world's fifth largest producer of cotton, but is attempting to diversify its agriculture towards fruits and vegetables.

GDP Annual Growth Rate in Uzbekistan is reported by the State Committee of the Republic of Uzbekistan on Statistics. The page of Uzbekistan GDP Annual Growth Rate provides actual values, historical data, forecast, chart, statistics, economic calendar and news.

11.2 GDP is not a measure of human well-being.

Economists measure the economic output of a society using indicators such as *gross national product (GNP)* or *gross domestic product (GDP)*. While it is widely recognized that such measures do not quantify human wellbeing, both economists and policy makers often assume that an increase in GDP corresponds to an increase in welfare. But an understanding of what GDP includes, and excludes, suggests that the relationship between economic production and welfare is more complex. We now turn to a discussion of the limitations of GDP.

Human well-being depends on consumption of goods and services, but on many other factors as well. We can distinguish between two broad categories of human activities: those which are "rewarded" by a payment – a monetary flow – and those which aren't. Only the first type is taken into account when computing national income. All the others – including domestic and family tasks, taking care of children and elderly relatives, volunteer community work, and leisure time activities such as

Table 11.1. List of countries by GDP growth rate. Source: Annual Statistic of Republic of Uzbekistan (2013).

CIS countries	2000	2005	2008	2009	2010	2011	2012
Uzbekistan	104.2	107.0	109.0	108.1	108.5	108.3	108.2
Azerbaijan	109.9	1264	110.8	109.3	105.0	100.1	102.2
Armenia	109.6	113.9	106.9	85.9	102.2	104.7	107.2
Belarus	104.7	109.4	110.2	100.2	107.7	105.5	101.5
Kazakhstan	113.5	109.7	103.3	101.2	107.3	107.5	105.0
Kyrgyzstan	105.3	99.8	108.4	102.9	99.5	106.0	99.1
Moldova	106.1	107.5	107.8	94.0	107.1	106.8	99.2
Russia	105.1	106.4	105.2	92.2	104.5	104.3	103.4
Tajikistan	109.6	106.7	107.9	103.9	106.5	107.4	107.5
Turkmenistan		113.3	114.7	106.1	109.2	114.7	111.1
Ukraine	109.2	102.7	102.3	85.2	104.1	105.2	100.2

reading, cooking, playing music, going to the beach – are not included in standard economic indicators. We can revise our circular flow diagram (Figure 2.1) to show that the sphere of human activities, while included within the biosphere, is broader than the purely monetary activities which are measured as GDP.

Figure 11.1 shows the division inside the sphere of human activities between the monetary portion of activities and the non-monetary part. The gross domestic product measures only the first area and neglects the second. However, when measuring human well-being or welfare, it is necessary to take into account the entire scope of the human sphere.

The first attempt to take into account some of these non-monetary activities in the measure of economic welfare was done by Nordhaus and Tobin in 1972. They calculated a value for such factors as unpaid household labour and "urban dis-amenities" (such as congestion and pollution). Using these values to modify the standard GNP measure, they constructed a "Measure of Economic Welfare" (MEW). However, their effort has not been systematically followed up. Most

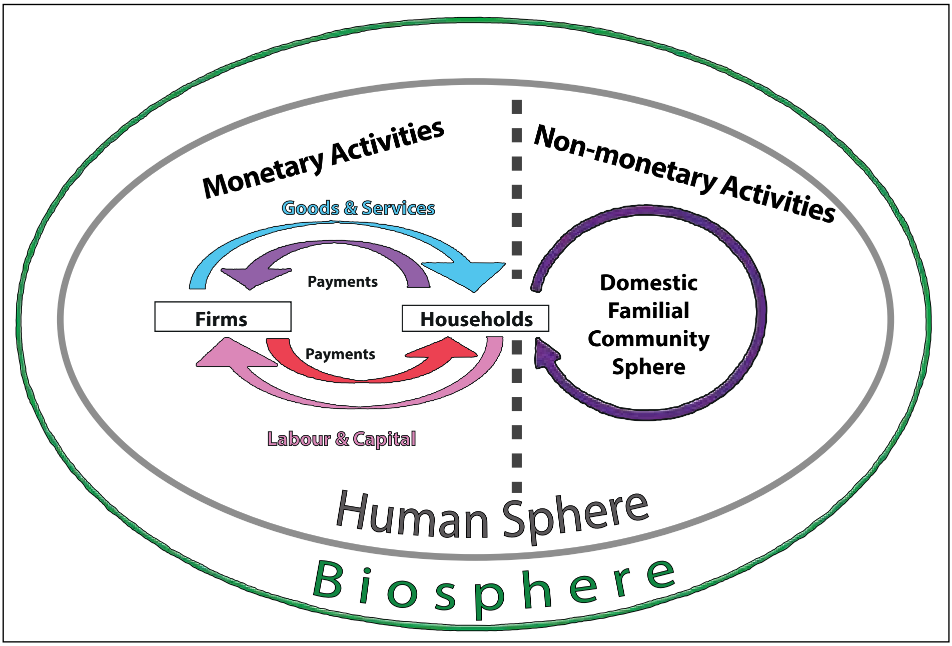

Figure 11.1 Monetary and Non-Monetary Activities. Source: Jonathan M. Harris and Anne-Marie Codur Macroeconomics and the Environment. p.6 http://www.ase.tufts.edu/gdae/education_materials/modules/macroeconomics_and_the_environment.pdf

economic analysis generally uses GDP as a measure of economic success, and – by default – as a measure of welfare.

When there is a car accident, all kinds of activities involving monetary flows result: mechanical services to repair the cars, medical services if passengers are injured, insurance services to assess the costs and possibly legal services if parties to the accident hire lawyers to sue other parties. All these flows enter positively into the calculation of GDP. Thus the car accident causes an overall increase in GDP. But we certainly cannot say it has contributed to human well-being!

The car accident is destructive for human beings – potentially leading to permanent damage or even death – as well as destructive of durable goods (the cars). It has obviously reduced the human well-being of the victims of the accident. The services involved to deal with the consequences of the accident may at most "repair" the cars and the people to try to get back to the state of things before the accident (healthy people and functioning car). Thus GDP includes monetary flows which correspond to a decrease in well-being

Overall this action of putting things back in their previous state does not create well-being but at best prevents a net loss of well-being. And these "repairing" activities all have a cost in terms of the amount of time and effort required and equipment used. In a proper measure of well-being, the costs associated with a car accident should not be considered as "pluses". Possibly they should be seen as "minuses" which reduce well-being. At the least, they should be excluded from a measure of economic activities contributing to well-being.

How can economists deal with monetary flows which not only do not increase well-being but may even decrease it? One approach is to measure *defensive expenditures* made to eliminate, mitigate or avoid damages caused by other economic activity. These defensive expenditures can then be deducted from a standard measure of GDP or GNP. A calculation of such defensive expenditures for the Federal Republic of Germany as a%of German GNP is shown in Table 11.1 and represents more than 10% of total GNP.

11.3 GDP and depreciation of manufactured and natural capital

GDP can be measured as the sum of the domestic *value added* in all sectors of the economy. But economic production also involves some loss of value: machines, equipment and infrastructure wear out over time, requiring repair and eventual replacement. This process of wearing out, repairing, and replacing capital is taken into account by measuring the *depreciation* of manufactured capital. If we

Table 11.2. Defensive Expenditures in Germany, 1985. *Source*: Leipert C. (1989) National income and economic growth: the conceptual side of defensive expenditures, *Journal of Economic Issues*, **23**, 843-56.

Defensive Expenditure Category	Percent of GNP
Environmental Protection Services of	
Industry and Government	1.33
Environmental Damages	0.80
Cost of Road Accidents	1.1
Costs of Extended Travel Routes	2.2
Higher Housing Costs Due to Urban	
Agglomeration	0.75
Costs of Personal Security	1.26
Defensive Health Care Costs	2.6
TOTAL	10.24

subtract an estimate of manufactured capital depreciation from gross domestic product, we obtain *net domestic product* (NDP):

NDP = GDP – depreciation of manufactured capital

NDP is generally considered to be a better measure of true income than GDP. If, for example, we had high short-term consumption but allowed all our capital stock to wear out without replacement, measured GDP would give an erroneously positive impression of how well we were doing economically. NDP would be a better measure since it would show the negative effects of the loss of productive capital.

But this method of measuring and accounting for capital depreciation applies only to what we have defined as manufactured capital. What about natural capital? The process of production uses up *non-renewable natural resources* such as coal, oil, and minerals. Often *renewable natural resources* such as productive soils, forests, and fisheries are also depleted or damaged through over-use. And the wastes emitted from the production process also pollute air, water, and land, and damage ecosystems. All of this can be defined as depreciation of natural capital. Despite the obvious importance of this kind of depreciation, it is not accounted for at all in standard measures of NDP or net investment. Only the depreciation of human-made capital such as buildings and machinery is counted.

To give a more accurate picture of depreciation losses in an economy, we clearly need to measure and subtract the losses from resource depletion, soil erosion, air and water pollution, and other environmental impacts. Sometimes this is difficult, both because good records of the stocks and flows of natural resources are often unavailable, and also because it can be difficult to put a dollar value on something like soil erosion. But some efforts have been made to tackle the problem, and this has given rise to several efforts to revise, improve, or replace the standard GDP measure.

GDP can thus be adjusted for natural resource depletion. In many developing countries, economic growth is strongly dependent on the exploitation of natural resources. When raw materials and forest, fishery, or agricultural products are sold domestically or on international markets, these natural resources are transformed into monetary flows which contribute a significant portion of the gross domestic product of these countries. However, this kind of growth depends upon the depletion of natural capital.

As mentioned above, the net domestic product is obtained by subtracting the depreciation of manufactured capital from GDP. Further adjusting GDP to account for the depreciation of natural capital yields *environmentally-adjusted net domestic product* (EDP):

EDP = GDP – depreciation of manufactured capital – depreciation of natural capital

Note that the calculation of EDP requires a monetary estimate for the depreciation of natural capital. While data on NDP are readily available for most nations, estimates of EDP are available for only a few countries. In studies of a number of developing countries, researchers at the World Resources Institute calculated the loss of natural capital for three types of resources such as forests, soil and petroleum. They found that in the case of Indonesia, during the period from 1971 through 1984, these three forms of resource depletion subtracted an average of 9% from the official GDP each year. A study of EDP in Korea from 1985-1992 indicated that subtracting out environmental degradation due to air and water pollution lowered GDP by an average of 3%.

11.4 National net savings and satellite accounts

Another approach to broadening national accounting considers how much a nation is saving for the future. National net savings rates are widely calculated as the total domestic saving less the depreciation of produced capital. The World Bank's *genuine saving* measure (S*) adds a social and environmental element to national saving rates. A nation's genuine saving rate is calculated as:

S* = gross domestic saving – produced capital depreciation + education expenditures – depletion of natural resources – pollution damage

Box 11.1 Green budgets or Environmental accounts in Sweden

Green budgets, more properly called Environmental accounts, use environmental statistics alongside economic statistics. The purpose is to develop a system in which it is possible to deal with the use of natural resources and the environment in the same way as all other resources in national accounts.

The data are prepared in two steps. Firstly, environmental data are given in physical terms such as tonnes of a given emission; in the second step monetary accounts are drawn up on this basis by linking figures on emissions and waste with a set price on the impact it causes.

The main objective green accounts is to produce a complete system of measures that illustrates the impact of different types of economic activity on environmental and natural resources and vice versa. In the short term it will not be possible to produce a 'green GNP' but it should be possible to achieve a 'greening of GNP'.

The Swedish system for environmental accounts has currently been adapted for data on

- energy use
- emissions of SO_2, CO_2, NO_x, VOC and organochlorine compounds
- flows of nitrogen and phosphorus
- environmental protection statistics
- solid waste
- material flows for wood, iron and steel

The material is provided for 16 different sectors of trade and industry, as well as the public sector and for private consumption.

The data have been aggregated in so-called economic environment indicators. These are key ratios representing the links between the different sectors of society and environmental impact. The indicators may for example provide information on marginal emissions quota, reflecting how emissions change in pace with changes in production volumes. The so-called environmental economic profiles calculated from the accounts show how the different sectors contribute to the economy, to employment, their energy use and emissions of pollutants.

In one study environmental accounts was carried out for the impact of sulphur emissions on forests, agricultural land, fresh water, and built-up areas. In order to make correct calculations it is necessary to have information about the cause-effect relationships between emissions and environmental impact. The real difficulty was to identify these relationships. For forests, future loss of timber was used, for agriculture and fresh water, liming costs were the basis, while for urban areas, corrosion costs were estimated.

The total costs of SO_2 deposition in 1991 in Sweden was estimated at Euro 257 million. Corrosion represented by far the largest part of this sum. This might be the result of the fact that the best data exist for this effect and also, because tangible capital is destroyed, there is a high market price. As the total sulphur deposition was 379,000 tonnes, the cost for emitting one tonne is SEK 6,525 or Euro 650.

An account of forestry output included in addition to the production of timber, production of funghi, berries, game and lichen. Quality adjustment for changes in biodiversity, acidification of the soil, and production capacity for lichen were also made. The total net output from forest was calculated to be approximately Euro 600-700 million above the net output of timber, the value of which is around Euro 2,000 million.

Source: Svante Axelsson "Environmental accounts in Sweden" in *Ecological Economics – Markets, prices and budgets in a sustainable society* Baltic University Programme, pp 28-29. http://www.balticuniv.uu.se/index.php/boll-online-library/819-a-sustainable-baltic-region.

Table 11.3. Genuine Saving Rates as a Percentage of GDP, 1997. *Source*: Hamilton, Kirk. "Genuine Saving as a Sustainability Indicator." The World Bank Environment Department Papers, No. 77, October 2000.

Region	Gross domestic saving	Depreciation of produced capital	Education Expenditure	Natural Resource Depletion& CO2 Damage	Genuine saving
Low-income					
nations	17.0	8.0	3.4	7.8	4.8
Middle-income nations	26.2	9.2	3.5	5.6	15.0
High-income					
nations	21.4	12.4	5.3	0.8	13.5
East Asia &					
Pacific	38.3	6.9	2.1	3.8	29.7
Europe &					
Central Asia	21.4	13.7	4.2	6.6	5.6
Sub-Saharan					
Africa	16.8	9.1	4.5	8.7	3.4
Middle East &					
North Africa	24.1	8.8	5.2	20.7	-0.3
World	22.2	11.7	5.0	1.8	13.6

A higher value of S*, measured as a percentage of GDP, indicates that a nation is saving more for the future. Notice that the genuine saving rate may be negative if rates of produced capital depreciation of depletion of natural resources are high. In other words, a nation's net positive investments in produced capital can be more than offset by the depletion of its natural capital.

The World Bank has estimated genuine saving rates for many countries by quantifying, in dollars, the effects of energy, mineral, and forest depletion as well as the damage from carbon dioxide. As seen in Table 11.3, genuine saving rates vary across regions. Genuine saving rates are lowest in the poor nations, primarily a result of the depletion of energy resources. Several nations in Africa and the Middle East have negative genuine saving rates. For example, the depletion of energy resources in Saudi Arabia is estimated to be 44% of GDP, leading to a genuine saving rate of -14%.

The importance of natural capital is also quantified in the World Bank's efforts to determine the true "wealth" of nations. Typical estimates of national wealth consider only the value of productive assets. But along with produced capital, natural capital is a critical input towards achieving the goals of a society.

Accounting for natural capital: The satellite accounts approach. During recent years both the United Nations and the U.S. Department of Commerce have launched significant revisions of their national income accounting systems to respond to some of the criticisms of standard accounts. The proposed revisions do not alter the fundamental structure of standard GNP/GDP accounting. Rather, they provide additional or "satellite" accounts dealing with the impacts of economic activity on natural resources and the environment.

These *satellite accounts* include developed natural assets like cultivated biological resources, developed land, exploited subsoil reserves, as well as non-produced environmental assets like uncultivated biological resources, undeveloped land, air and water, unproved subsoil assets. Satellite accounts measure list these assets in quantitative terms (tons, hectares, cubic meters, etc...) although these quantities can be converted to dollar values.

Unlike attempts to quantify a "green" GDP as a single value, the satellite account approach presents a detailed picture of each of several types of natural capital. Over time, using satellite accounts one can determine whether a nation's wealth in different types of natural capital is increasing or decreasing. An advantage of satellite accounts is that the depletion of specific critical natural capital, such as safe drinking water, can be identified and tracked.

11.5 Index of sustainable economic welfare and Genuine Progress Indicator

The most ambitious effort to reform the calculation of an indicator of economic welfare has resulted from the partnership between an economist, Herman Daly, and a theologian, John Cobb. Daly and Cobb named their proposed substitute for GDP the *Index of Sustainable Economic Welfare* (ISEW). They proceed in three steps:

They construct an indicator of aggregate welfare by taking into account the current flow of services to humanity from *all* sources (and not only the current output of marketable commodities which is relevant to economic welfare).

They deduct spending whose purpose is defensive or intermediate and not welfare-producing.

They account for the creation and losses of all forms of capital by adding the creation of man-made capital and deducting the depletion of natural capital.

A more recent measure, the *Genuine Progress Indicator* (GPI), is estimated in a similar way as the ISEW but also includes factors such as the cost of underemployment, the loss of leisure time, and the loss of old-growth forests. GPI is a metric that has been suggested to replace, or supplement, gross domestic product (GDP) as a measure of economic growth. GPI is designed to take fuller account of the health of a nation's economy by incorporating environmental and social factors which are not measured by GDP. For instance, some models of GPI decrease in value when the poverty rate increases. The GPI is used in green economics, sustainability and more inclusive types of economics by factoring in environmental and carbon footprints that businesses produce or eliminate. Among the indicators factored into GPI are resource depletion, pollution, and long-term environmental damage. GDP gains double the amount when pollution is created, since it increases once upon creation (as a side-effect of some valuable process) and again when the pollution is cleaned up, whereas GPI counts the initial pollution as a loss rather than a gain, generally equal to the amount it will cost to clean up later plus the cost of any negative impact the pollution will have in the meantime.

Table 11.4 gives the details of the GPI for the United States in 2000. We see in the table large deductions for the depletion of non-renewable resources and long-term environmental damages, such as climate change. Note that a deduction is also made for the unequal distribution of income – the U.S. has the greatest level of income inequality of any developed nation. Unlike GDP, the GPI includes the value of some non-market activities, such as household and volunteer work.

An important comparison is how the GPI relates to traditional measures of economic production over time. A divergence of the GPI and GDP would suggest that economic growth is coming at the expense of other contributors to well- being, such as environmental quality or leisure time.

Non-profit organizations have calculated ISEW or GPI for a number of countries. The divergence between GDP and the GPI for the United States is extreme. GDP has grown steadily in the U.S. since 1950. However, the GPI grew only slightly from 1950 to 1965, stayed relatively constant from 1965 to 1975, then fell steadily from 1975 to the early 1990s.

11.6 How to measure human development

How to measure human development? Basic needs have been defined in many different ways but seldom with a precision that make them operational. There is general agreement that food, water, health, education and shelter should be included. Many different indicators for these and other aspects of basic needs have been used by researchers who have tried to operationalize them. One of the first attempts was the Physical Quality of Life Index (PQLI) developed by Morris David in 1979. He took three crucial variables and made an index of them where each of them had the same weight. The variables were infant mortality, adult literacy rate and life expectancy.

Table 11.4. The Genuine Progress Indicator for the United States in 2000. Source: Cobb, Clifford, Mark Glickman, and Craig Cheslog. 2001. "The Genuine Progress Indicator 2000 Update." Redefining Progress Issue Brief, December 2001; Cobb, C., Halstead, T. and Rowe, J. (1995). The Genuine Progress Indicator: Summary of Data and Methodology. Redefining Progress, San Francisco. Available at: http://rprogress.org/publications/1999/ gpi1999.pdf [Accessed October 2014].

Cost/Benefit	Value (billions of 1996 dollars)
The GPI's starting point	
Personal consumption	6,258
Costs ignored by GDP that are subtracted	
Automobile accidents and commuting	-613
Crime and family breakdown	-93
Loss of leisure time and underemployment	-451
Air, water, and noise pollution	-108
Loss of wetlands and farmlands	-583
Depletion of non-renewable resources	-1,497
Long-term environmental damage	-1,179
Other environmental costs	-417
Adjustment for unequal income distribution	-959
Net foreign lending or borrowing	-324
Cost of consumer durables	-896
Benefits ignored by GDP that are added	
Value of housework and parenting	2,079
Value of volunteer work	97
Services of consumer durables	744
Services of highways and streets	96
Net capital investment	476
Genuine Progress Indicator	2,630

Which of these indicators are best is not easily established. The largest problem is however how to weigh them together. Any index of basic needs (or human rights) must choose the relative weight of the included factors. This choice is based on the preferences (or the welfare function as economists call it) of the person who chooses.

The Human Development Index proposed by the UNDP, the United Nations Development Programme, has aroused considerable attention. It is a composite statistic of life expectancy, education, and per capita income indicators, which is used to rank countries into four tiers of human development. They are reported annually in the human development report by the UNDP. An important aspect is that the economic inequality in societies is large (and increasing) and therefore the Human Development Report in 2010 introduced an Inequality-adjusted Human Development Index (IHDI). While the simple HDI remains useful, it stated that “the IHDI is the actual level of human development (accounting for inequality),” and “the HDI can be viewed as an index of ‘potential’ human development (or the maximum IHDI that could be achieved if there were no inequality).”

The traditional way of comparing economic levels between countries, GNP/capita can be compared with the Human Development Index. They are almost in the same order but the differences between countries are smaller if GDP/capita is adjusted for differences in purchasing power. One of the reasons is that GNP only measures production that is sold on the market and parts of total production, especially in developing countries, are therefore not included. The adjusted GDP/capita is therefore a better indicator for standard of living. Purely physical measurements, such as mortality of children under 5 years of age, are also used. Too much attention on GNP/capita does not adequately reflect the standard of living and ought to be complemented by other measures.

The Gross National Happiness (GNH) was introduced in 1972 by the small kingdom of Bhutan as a signal of commitment to build an economy that would serve Buddhist spiritual values instead of the western material development represented by GDP. The GNI has since, by a growing global happiness movement, evolved into a socioeconomic development model. The United Nations General Assembly in 2011 adopted unanimously the GNI, placing “happiness” on the global development agenda. GNI is today reported for a number of countries. The four pillars of GNH philosophy are: sustainable development, preservation and promotion of cultural values, conservation of the natural environment, and establishment of good governance.

11.7 Which index is the best measure of progress?

If we take the GPI as a reasonable measure of human welfare, then the goal of most policy makers to increase GDP appears misplaced. An important part of economic growth may be due to an increase in defensive/preventive expenditures, as well as an increase in pressure on the environment and depletion of natural capital.

Which measures should guide policy – traditional measures of economic production or the newer measures of human welfare? Many economists feel that even if GDP does not directly measure wellbeing, it measures the ability of a society to obtain the materialistic inputs necessary to a high quality of life. A higher GDP per capita gives people more options to make choices that improve the quality of their lives. Others would respond that the quantity of goods and services available in an economy may be one factor in improving the quality of life, but there are many more dimensions to human well-being. Using GDP as a measure of how well we are doing reduces the quality of life to only one of its many dimensions.

Much more than measures such as GDP, measures of human welfare require subjective judgments about what to include and how to value different variables in dollar terms. Clearly, room exists for disagreement about how to construct an index measure of human welfare. Yet the information provided by these measures provides important insights that would be missed with an exclusive focus on economic production. It is widely recognized that money is only a means to an end and that, ultimately, the goal of policies should be to increase human well-being. Attempts to construct measures such as the ISEW and GPI at least provide the starting point for evaluating whether a society is headed in the right direction.

Chapter 11 sources:

Sections 11.1 Annual Statistic of Republic of Uzbekistan (2013).

Sections 11.2-11.5 and 11.7 Jonathan M. Harris and Anne-Marie Codur *Macroeconomics and the Environment*. Chapter 2. "Redefining national income and wealth" pp. 5-14. Copyright © 2004 Global Development and Environment Institute, Tufts University. http://ase.tufts.edu/gdae. http://www.ase.tufts.edu/gdae/education_materials/modules/macroeconomics_and_the_environment.pdf

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Are these really necessary?

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Chapter 12
The Dilemma of Continuing Economic Growth

12.1 Limits of the global ecosystems

The complete circular flow picture (Fig. 12.1) shows us that the biosphere is a source of natural resources for the economic sphere, as well as a sink where the wastes and pollution produced by human activity are deposited. All economic activities ultimately depend on the biosphere continuing to perform these functions.

As long as natural limits were not apparent, as long as nature seemed endless to humans, everything obtained from it could be taken for granted. In particular, economics, the science dealing with scarcity, was not concerned about these free

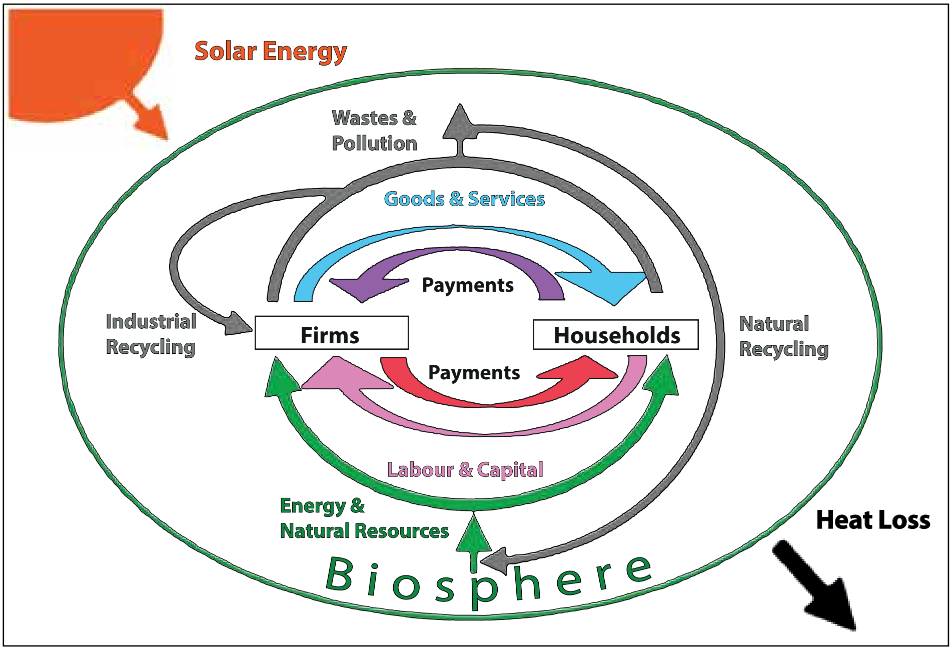

Figure 12.1. Circular Flows with Energy and Recycling. (Source Jonathan M.Harris and Anne-Marie 2004) p.4

gifts of nature to humankind. From the point of view of economic theory, if a good is free (i.e. has no price), there is no reason to limit consumption, whereas if it has a price consumption will be limited by income.

In the past, some civilizations have reached the limits of the ecosystems on which they relied. Ecological stresses and degradation have then appeared, preventing any further development of these societies and sometimes leading to their collapse, as exemplified in the case described in Box 12.1.

Never before in human history have we reached the limits of the global ecosystem itself, but today there are more and more signs that the biosphere as a whole may be affected in its regulation of biological and geophysical processes by the current scale of human activities.

Box 12.1. Exceeding the Limits: The Collapse of a Civilization

The first literate civilization in the world collapsed due to its failure to recognize ecological limits. Around 3000 B.C. the Sumerians of southern Mesopotamia, between the Tigers and Euphrates rivers, built a complex society based on irrigated agriculture, and invented wheeled vehicles, yokes, plows, and sailboats, as well as accounting and legal systems.

But their growing population placed too heavy a demand on the natural resources of the region. Deforestation and overgrazing led to heavy soil erosion. Irrigation caused the underground water table to rise, depositing salts which poisoned cropland. Eroded soils loaded the rivers with silt, leading to catastrophic flooding.

“The limited amount of land that could be irrigated, rising population, the need to feed more bureaucrats and soldiers, and the mounting competition between the city states all increased the pressure to intensify the agricultural system. The overwhelming requirement to grow more food meant that it was impossible to leave land fallow for long periods.”

“Short-term demands outweighed any considerations of the need for long-term stability and the maintenance of a sustainable agricultural system. . . Until about 2400 B.C. crop yields remained high, in some areas as high as in medieval Europe and possibly even higher. Then, as the limit of cultivable land was reached and salinization took an increasing toll, the food surplus began to fall rapidly. . . by 1800 B.C., when yields were only about a third of the level obtained during the Early Dynastic period, the agricultural base of Sumer had effectively collapsed” (Ponting 1993).

The process of irrigation, salinization of soils, and agricultural collapse was repeated twice more as later societies attempted to rebuild in the same region. Finally the land was exhausted. “Once a thriving land of lush fields, it is now largely desolate, its great cities now barren mounds of clay rising out of the desert in mute testimony to the bygone glory of a spent civilization” (Hillel, 1991).

Sources: Ponting, Clive, 1993. A Green History of the World: The Environment and the Collapse of Great Civilizations. New York: Penguin Books.
Hillel, Daniel 1991. Out of the Earth: Civilization and the Life of the Soil. New York: McMillan

The potential threat of global climate change due to accumulating atmospheric emissions of carbon dioxide and other greenhouse gases is one example of an economic activity pressing up against global limits. Similar global problems are apparent in the degradation of ocean ecosystems, loss of species diversity, and damage to the earth's protective ozone layer. As the scope of human activity grows, its impact on the natural sphere has changed in magnitude: what used to be negligible – and was neglected as such – has become significant and potentially threatening.

These new global ecological problems have led to the recognition that the natural support is finite and that there are limitations both in terms of the inputs which can be extracted from it and the wastes which it can absorb.

In traditional macroeconomics, economic growth is always considered desirable. But as we move from a relatively empty world to a relatively full world, an exclusive emphasis on economic growth could produce serious, and possibly irreversible, ecological damage. The implications of humanity now approaching natural limits is one important difference between the new field of *ecological economics* and mainstream economics.

Ecological economics has emerged in the past twenty years as a new field of research and study. This new approach builds on a long tradition of thinkers who have been concerned with the issue of the ecological limits to economic activity. Ecological economics claims that the mainstream economic approach to environmental problems is inadequate to deal with the contemporary crises of environment/human interactions and to respond adequately to the complexities of issues such as global climate change, species loss, and ecosystem degradation.

Paradoxically, mainstream economics focuses on problems of allocation of scarce resources, but has proven particularly unable to take into account the growing scarcity or degradation of many natural resources and ecological systems. Ecological economics emphasizes the issue of the scale of human activities, which potentially threatens the natural capacities of ecosystems to regenerate.

The main founders of the field of ecological economics were economists who had the ability to bring a multidisciplinary perspective on social sciences, such as Kenneth Boulding who introduced in economics many concepts coming from system analysis, or Nicholas Georgescu-Roegen who applied the physical laws of thermodynamics to economic processes. Leading contemporary contributors to the field are Herman Daly and Robert Costanza, who have developed the concepts of long-term sustainability, economic and ecological valuation, and optimum economic scale.

12.2 Population growth

There are two important dimensions in the growth of human impacts on the environment:

First *Population Growth:* Each individual has certain basic needs for food, water, and living space, so a large population will generally have a higher resource requirement and higher environmental impact. Secondly *Economic Growth:* As per capita income rises, each individual tends to consume more, increasing resource demand and waste production.

During most of human history world population grew very slowly. On average a woman during her short life got 6 children of whom 2 survived to adulthood. These in turn reproduced to get two children etc. The number of children per fertile woman is called *fertility rate*. For constant population the fertility rate should be 2.1, called *replacement rate*. This was close to the value for the human race for most of our history. But from about 1700, the beginning of industrialization, it started to grow dramatically. Family size became much larger and the population explosion became a fact. From the 18th century global population growth accelerated, with shorter and shorter doubling times, 1 billion in 1800, 2 billion in 1927, 4 billion in 1974 and 7 billion in 2011 (Table 12.1).

Population in the world is currently growing at a rate of around 1.14% per year. The average population change is estimated at around +80 million per year. But it is declining. Annual growth rate reached its peak 2.19% in 1963. It is currently going down and projected to continue to do so. It is estimated to be less than 1% by 2020 and most experts expect it to end by about 2050 at a world population of 9-11 billion. However other results have also been published. According to UN Population Division world population will reach about 10.9 billion

Table 12.1 Highlights in world population growth. (Source http://www.worldometers.info/world-population).

World Population	Year
0.2 billion in	year 0 (estimate)
1 billion in	1804
2 billion in	1927 (123 years later)
3 billion in	1960 (33 years later)
4 billion in	1974 (14 years later)
5 billion in	1987 (13 years later)
6 billion in	1999 (12 years later)
7 billion in	2011 (12 years later)
8 billion in	2024 (13 years later; according to UN estimates)

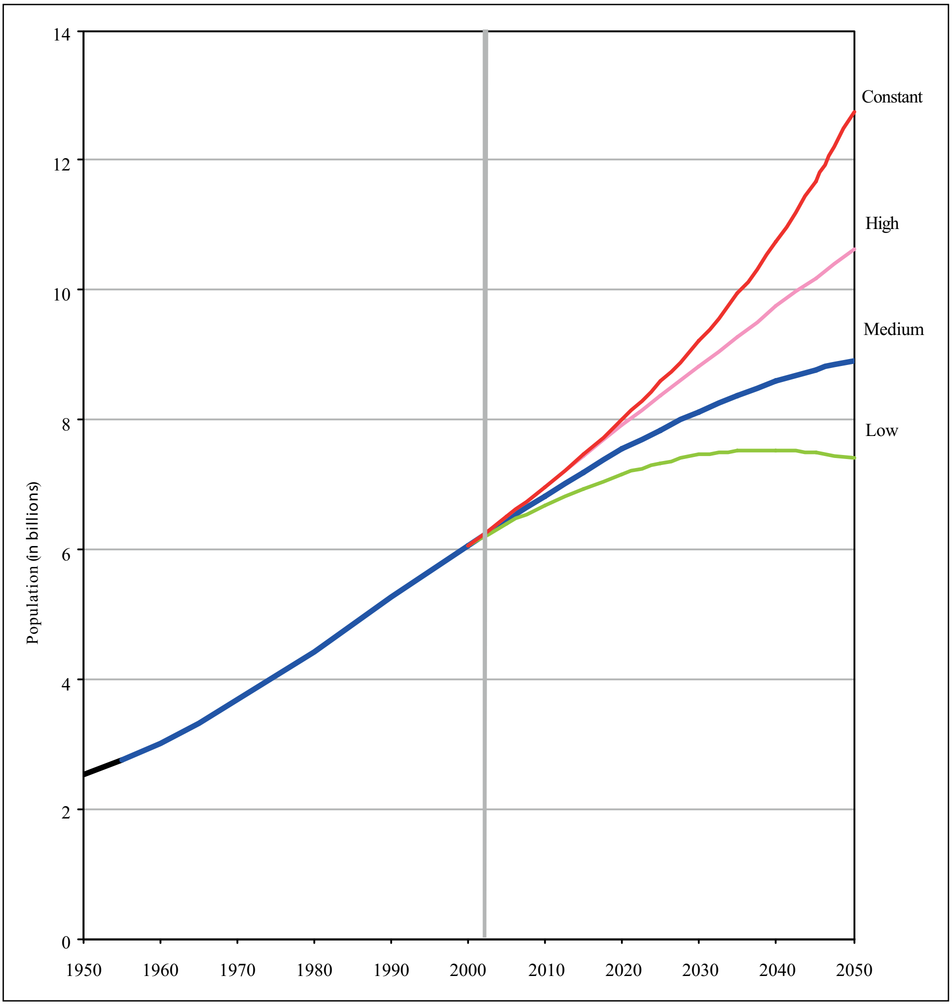

Figure 12.2. World Population Growth, 1950-2050 Source: United Nations Population Division, 2003. World Population Growth, 1950-2050 Source: United Nations Population Division, 2003.

in 2100 and continue growing thereafter. Other experts dispute that and find that birth-rates will fall below replacement rate in the 2020s. Population growth will continue to the 2040s by rising longevity but will peak below 9 billion by 2050. A most entertaining and informative film on population growth is *Don't Panic* by Hans Rosling at Gapminder.

Will the resources of the world be sufficient for 9 or so billion inhabitants? Is the *carrying capacity* enough? Most researchers believe that enough food for all will be possible. One will however have to decrease food loss, and improve agricultural productivity in many areas, not the least in Africa. Still, we see land prices increase steeply in many parts of the world as an indication that the food production issue is expected to be critical.

In individual parts of the world this development from a small population to exponential growth to finally leveling off at a higher level has already taken place. It is called the *population transition*. It begins when health improves, life expectancy increases and birth rate dramatically decreases. After some time family size will shrink. An important reason for this is decreasing child mortality. It will thus not be necessary to have many children to be taken care of at an older age; as children go to school, they are also more a cost than a help in the household; and finally that families choose to have fewer children for improving their own lives. Of course basic family planning has to be available to make these changes possible. These insights also point to what is needed to curb population growth.

A generation or two ago the so-called developing countries had many children per woman, often about 6, and a population growth approaching 3%, while in developed, industrialized countries the figure was closer to 2.1 children, that is, the replacement rate. Since then a dramatic change has taken place. Especially in Asia, birth rates of many countries have dramatically decreased. High birth rates today only remain in Africa. In all of Europe the birth rates are lower than replacement rates and in some countries much lower, e.g. in southern Europe. In Central and Eastern Europe population decline is typical both because of low birth rates and emigration. In Europe thus the development has already come to peak population and in fact population would be decreasing if not for immigration. The Population growth rate of Uzbekistan was in 2014 0.93% (Index mundi) while the fertility rate was below 2.0 and thus population increase in the country is expected to peak and decline (Table 12.2).

The reduction of fertility is a universal phenomenon, but occurs at different rates in different countries. Fertility patterns are closely linked with social and cultural norms and family structures. A change in fertility requires a dramatic shift in social structures and in mentality, notably in the status of women which plays an important role in the determination of fertility patterns.

Table 12.2 Top row Population growth and bottom row fertility rate (number of children per fertile woman) in Uzbekistan. *Source*: http://www.indexmundi.com/g/g.aspx?c=uz&v=24

Rate/ year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Growth rate	1.6	1.6	1.62	1.63	1.65	1.67	1.7	1.73	0.97	0.94	0.94	0.94	0.94	0.94	0.93
Fertility rate	3.09	3.06	3.03	3	2.97	2.94	2.91	2.88	2.01	1.95	1.92	1.89	1.86	1.83	1.8

Different patterns or styles of living imply different impacts on the environment. Take for example an African family living in a rural area and cultivating their fields with traditional agricultural techniques. This family has a limited impact on their local environment in terms of their use of local soil and water resources. Their fuel wood needs may contribute to the deforestation of local forested areas. But their production of pollution and non-degradable wastes is almost nil.

12.3 The exponential nature of growth

Approaching the millennium shift the American historian John McNeill undertook to write a global environmental history for the 20th century. He started assuming that the environmentalists were exaggerating. Yes, he said, there were environmental problems, but there has always been. “Nothing new under the sun” he told them when he started his project. But when he published he had changed his opinion and the title of the book became “Something new under the Sun”. Not surprising! During the 20th century the human population had increased 4-fold, from about 1.5 billion to 6 billion. In addition, the economy per capita had also increased 4-fold. Thus the resource use on the planet had increased about 16-fold during 100 years. Obviously it cannot go on like that.

He examined a series of resources and the result was similar (Table 12.3): Global economy increased 14 times, industrial production 40 times, that is per capita income increased about 4 times. It is also noteworthy that energy use increased about as the economy, which is explained by the fact that economy is

Table 12.3 Global Development 1900-2000. (Source: John McNeill, Nothing new under the sun, 2001)

global population	increased	4x
global economy	increased	14x
industrial production	increased	40x
energy use	increased	16x
carbon dioxide emissions	increased	17x
sulphur dioxide emissions	increased	13x
ocean fishing catches	increased	35x
number of pigs (=meat eating!)	increased	9x
forests	decreased	20 %
agricultural fields	increased	2x
Blue whale	decreased to	0.25 %

Box 12.2 Exponential growth

There is a mathematical way to find population doubling time without going through all the iterations year after year. We know that the population we are looking for will be 2 P_0 and this will happen after a certain number of years n when:

$P_n = (1.03)^n \; P_0 = 2 \, P_0$

This means that we are looking for a number of years n such that:

$(1.03)^n = 2$.

To find n, we need to apply natural logarithms to both sides of this equation:

$\mathrm{Ln}\,[(1.03)^n] = \mathrm{Ln}\,2$

Since $\mathrm{Ln}\,[(1.03)^n] = n\,\mathrm{Ln}\,(1.03)$ we can easily find the exact number of years n:

$n = \mathrm{Ln}\,2 / \mathrm{Ln}(1.03) = (0.69315)/(0.02956) = 23.45$

Therefore, with a population rate of 3% per year, the population will double in 23.45 years. A very practical rule of thumb is to divide 70 by the annual growth rate to find the approximate doubling time in years.

Source; Jonathan M.Harris and Anne-Marie Codur Macroeconomics and the Environment. Chapter 3 *Long-term growth and sustainable development p. 20.*

tightly coupled to energy for countries which are still developing. Emissions are also tightly coupled to energy use since energy use is completely dominated by fossils and thus causes much of the emissions. As people get a little richer they increase meat eating, reflected in the number of pigs, in this period about 2-fold, which is also a pressure on our environment and requires more resources. We can also see that the production from the environment is increasing and fields have expanded and forests shrink.

In Western Europe and the USA the strongest resource growth was after WWII, roughly between 1955 and 1975. During less than one generation resource consumption increased almost 3-4 fold for very many products: metals, fertilisers, fossil fuels etc. During this period our societies went from fairly sustainable to affluent societies, affluent meaning with a large resource flow.

The change was much faster in the end of the century than in the beginning. In fact increase was most often measured in% of previous year! If this%age growth is constant we have exponential growth! This means constant doubling time. This gets very soon out of hand. Exponential growth may be illustrated by anything from the number of McDonald restaurants in the world to the consumption of paper.

If a resource flow or a population grows at a rate of 3% per year how long does it take for the resource flow or the population to double?

Growth is a cumulative process: if you start with a population P_0, one year later the population will be $P_1 = P_0 + 0.03P_0 = 1.03\ P_0$. Between year 1 and year 2 the population P_1 will again be multiplied by a factor 1.03, so that the population in year 2 will be:

$$P_2 = 1.03\ P_1 = 1.03 * 1.03\ P_i = (1.03)^2 P_0.$$

After 20 years, the population will be:

$$P_{20} = (1.03)* (1.03)*.....* (1.03)\ P_0 = (1.03)^{20}\ P_0 = 1.806\ P_0.$$

It takes almost 24 years to double the resource use with a growth rate of 3% per year. If this rate of growth continues, the resource flows will double every 24 years. This is called *exponential growth.*

No population can grow exponentially forever. Ultimately the population will reach the limits of its natural environment to sustain it. This limit is called the *carrying capacity* of the environment. Currently population growth rates in most areas are slowing, so that global population growth is less than exponential. But global economic output is still growing exponentially.

On the other hand, consider the environmental impact of an American family. Through their daily consumption of food, clothing, housing, transportation, heating and air conditioning, the American family creates a considerable environmental impact, most of which they may not even be aware of. Some of this impact involves the use of renewable resources (soils, water, etc...); other involves the use of non-renewable resources (fuel, gas,..); and others again involves the release of pollutants into the environment (wastes from agricultural and industrial production, sewage and household garbage, and greenhouse gases like CO_2 which contribute to global climate change).

Would it be possible to create an indicator weighting together all these different impacts in order to measure the global environmental impact of each human being according to his/her life style? If we want to compare the impact of water pollution to that of CO_2 emissions it may be difficult, but for global resource use it is possible, using so-called the ecological footprints. In terms of carbon dioxide emissions (called carbon footprints), for example U.S. emissions are about 20 tons per person, while Indian emissions are about 1 ton per person. The differences are also large for food consumption. Each time someone eats a steak, his/her impact in terms of consumption of the product of photosynthesis is seven times higher than the impact of a person consuming the same amount of protein in the form of grains. Thus people whose staple diet is primarily based on rice, corn, wheat, beans, other cereals, and root vegetables (including most people in Latin America, Africa, and Asia) have a lower environmental impact per person than residents of the U.S., Europe, and Australia, who typically consume much more meat.

Similarly, the transportation patterns of a society may have very different impacts in terms of energy use and pollutant emissions. The environmental impact of an automobile-centered society is much higher than that of a society where transportation is primarily by bicycle.

12.4 The ecological footprint

Human activities consume resources and produce waste, and as our populations grow and global consumption increases, it is essential that we measure nature's capacity to meet these demands. The Ecological Footprint has emerged as one of the world's leading measures of human demand on nature. Simply put, Ecological Footprint Accounting addresses whether the planet is large enough to keep up the demands of humanity.

The concept of the *ecological footprint* was introduced by Mathis Wackernagel and William Rees at the University of British Columbia in the late 1980s and early 1990s. The idea was to reduce all ecological impacts of a product or service to the surface area in nature that was necessary to support its use /production. They argued that any production or other service in society is dependent on one or several *ecological services*, and that each of these required a small area in nature. The sum of these areas constituted the footprint of that production or service.

By measuring the Footprint of a population – an individual, city, business, nation, or all of humanity – we can assess our pressure on the planet, which helps us manage our ecological assets more wisely and take personal and collective action in support of a world where humanity lives within the Earth's bounds. The Ecological Footprint is now in wide use by scientists, businesses, governments, agencies, individuals, and institutions working to monitor ecological resource use and advance sustainable development.

The Ecological Footprint is an accounting tool, expressed in so-called global hectares, gha, that measures one aspect of sustainability: How much of the planet's regenerative capacity humans demand to produce the resources and ecological services for their daily lives and how much regenerative capacity they have available from existing ecological assets.

In economic terms, assets are often defined as something durable that is not directly consumed, but yields a flow of products and services that people do con-

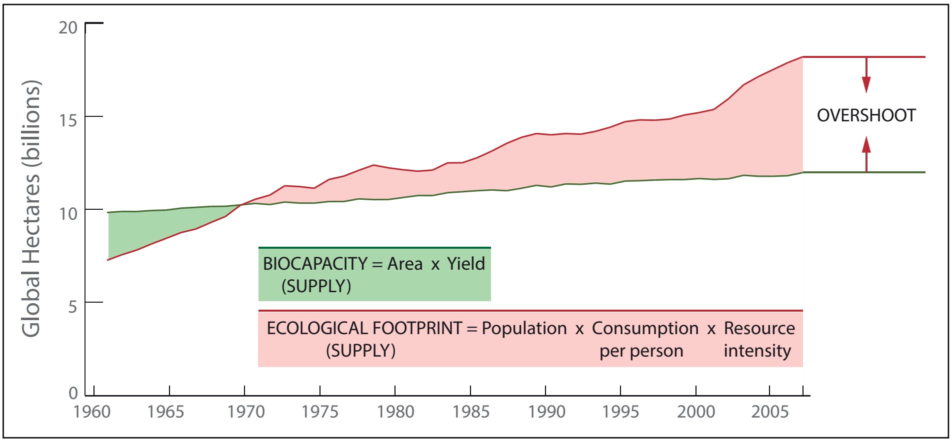

Figure 12.3 Trends in total Ecological Footprint and biocapacity between 1961 and 2008. (*Source*: Global Footprint Network, http://www.footprintnetwork.org/)

sume. Ecological assets are thus here defined as the biologically productive land and sea areas that generate the renewable resources and ecological services that humans demand.

Today humanity uses a surface area equivalent to 1.5 planets to provide the resources we use and absorb our waste. This means it now takes the Earth one year and six months to regenerate what we use in a year. Moderate UN scenarios suggest that if current population and consumption trends continue, by the 2030s, we will need the equivalent of two Earths to support us. And of course, we only have one.

This situation is known as *ecological overshoot*. Its consequences can be seen in the form of climate change, water scarcity, land use change and land degradation, declining fisheries, loss of biodiversity, food crises and soaring energy costs. If human demand on nature continues to exceed what Earth can regenerate, then substantial changes in the resource base may occur, undermining economic performance and human welfare.

Overshoot also contributes to resource conflicts and wars, mass migrations, famine, disease and other human tragedies and tends to have a disproportionate impact on the poor, who cannot buy their way out of the problem by getting resources from somewhere else.

Global trends, however, hide the huge variability that exists at the regional level. From 1961 to 2008 Europe and Middle East/Central Asia experienced the largest increase in their per capita Ecological Footprint (+1.2 and +1.1 gha per person, respectively), but while Europe's population growth was relatively slow

(+29%), population grew 330% in Middle East/Central Asia. North America had a smaller increase in per capita consumption (+ 0.6 gha per person) and a 63% growth in population. At the other end of the spectrum, Africa saw its per capita Ecological Footprint decline (-0.1 gha per person), while its population increased by 255%. In the Asia-Pacific region, per capita Ecological Footprint increased slightly (+0.6 gha per person), while population grew by 136%.

In less than 50 years, humanity doubled its demand for renewable resources and ecological services. At a global level, the causes are easily identified. Population growth recorded a 118% increase from 1961 to 2008, while the world's per capita Ecological Footprint increased by 15% (from 2.4 to 2.7 gha per person).

While ecological assets have long been ignored as irrelevant to a country's economy, the goods and services that sustain a healthy human society (access to food, safe water, sanitation, manufactured goods and economic opportunity) all depend on the functioning of healthy ecosystems.

The increase in biocapacity is due to an increase in land bioproductivity as well as in the areas used for human purposes. However, the increase in the Earth's productivity is not enough to compensate for the demands of a growing global population.

12.5 From growth to sustainable development

Economists have always realized that there was more to the pursuit of "progress" than the mere growth of the quantities of goods and services produced. The process of economic development should improve people's standard of living not only in materialistic terms but also in terms of improving well-being in the broader sense of the quality of life.

One way to decompose the environmental impact **I** of human economic activity is to take into account three dimensions of this impact:

P: the population involved in the activity;
A: the affluence factor, which represents the standard of living of this population – usually measured by an indicator of income or consumption per capita;
T: the technological factor, indicating the environmental impact per unit of income.

Then it must be true that: **I = P * A * T**

For instance, considering CO_2 emissions in the atmosphere, the global impact **I** is the total amount of emissions which is the product of: the number of people **P,** the affluence factor **A** which can be measured by the amount of energy use per person, and the technological factor **T** which measures the amount of CO_2 released in the atmosphere for each unit of energy produced and consumed.

True development must provide benefits to all, and must not destroy the natural life-support systems on which it rests. One definition of *sustainable development,* proposed by the World Commission on Environment and Development, is:

"Sustainable development is development which meets the needs of the present without endangering the needs of the future." (WCED, 1987).

The concept of sustainability has now become more widespread in economics. However, there are differing interpretations of the economic meaning of sustainability.

One interpretation, sometimes called *weak sustainability*, is related to the concept of natural capital depreciation. According to this view, any loss of natural capital should be balanced by creation of new capital of at least equal value. Thus future generations will have access to a stock of capital which is of at least the same value as that which the present generation has available. But in this view, it is acceptable to use up or destroy natural resources, provided that manufactured capital of equal value is substituted for what is lost.

For example, a developing nation could cut down its forests, replacing them with plantations and sawmills, or destroy its natural fisheries and replace them with aquaculture facilities where fish are raised in pens for human consumption. This would meet the definition of weak sustainability, provided that the productive value of the new facilities was at least equal to that of the former natural systems.

This view is criticized by the ecological economics school of thought, on the grounds that economic valuation does not reflect the full value of ecological services, and therefore encourages us to ignore ecological limits. This could lead the process of economic development on very dangerous roads. In the past, destructive ecological feed-backs have caused civilizations to collapse.

Where there is a danger of irreversibility – damage that cannot be repaired – ecological economists often suggest that we should observe the *precautionary principle*. This principle implies that we should not risk environmental damage which could permanently harm our own society or future generations. This argument could be applied to atmospheric emissions which result in ozone depletion or unpredictable climate change, the release of long-lived chemicals or bioengineered organisms into the environment, or the creation of long-lived nuclear wastes.

In general, advocates of *strong sustainability* argue that natural systems should be maintained intact wherever possible. They identify critical natural capital, such as water supplies, as resources which must be preserved under all circumstances. In this view, for example, maintaining the natural fertility of the soil is essential even if it is possible to compensate for degraded soils with extra fertilizer. Notice that the strong sustainability perspective is compatible with the system of satellite accounts discussed previously. Maintaining satellite accounts, policy makers can determine if critical natural capital is being depleted.

12.6 Policies to promote sustainable development

Much of macroeconomic theory and policy is oriented towards promoting continuous economic growth. What kind of policies would be required to promote sustainability? Are the goals of economic growth and sustainability compatible?

Some ecological economists view "sustainable growth" as a contradiction in terms. They point out that no system can grow without limit. However, some kinds of economic growth seem essential. For the large number of people in the world who lack basic needs, an increase in consumption of food, housing, and other goods is clearly required.

For those who have achieved a high level of material consumption, there are possibilities for improved well-being through expanded educational and cultural services which, as we have noted, do not have a large negative environmental impact. But, there is nothing in standard macroeconomics which guarantees that economic growth will be either equitable or environmentally benign. Specific policies for sustainable development are therefore needed.

These proposals have implications for macroeconomic policy. If policies aimed at promoting sustainability also encourage labour-intensive development, this could help to achieve full employment. Public investment in rail transit and renewable energy would have budgetary implications, as would the reduction of subsidies for roads and fossil fuels. Tax changes could be *revenue-neutral*, meaning that every dollar collected in new energy and resource taxes would be matched by a dollar of income, payroll, corporate or capital gains tax reduction. But even if new tax systems were revenue-neutral, there could be macroeconomic effects due to the different incentives created for employment of labour and capital, and the implications for investment.

Thus analysis of macroeconomic issues needs to take account of long-term sustainability. Policies oriented towards economic growth alone risk damage to the broader "circular flow" of the biosphere, unless they are modified to include consideration of environmental impacts and sustainable scale. This adds a new dimension to the debate over macroeconomic policy, a dimension which will be increasingly important for both developed and developing economies in the twenty-first century.

12.7 The dilemma of economic growth

How societies respond to challenges will depend largely on the behavior of human beings acting individually or collectively. Economic analysis provides an incredibly useful set of tools for anyone interested in understanding and/or modifying human behavior, particularly in the face of scarcity. In many cases, this analysis points out the sources of the market system's resilience as embodied in negative feedback loops.

Environmental economics is the subset of economics that is concerned with the efficient allocation of environmental resources. The environment provides both a direct value as well as raw material intended for economic activity, thus making the environment and the economy interdependent. For that reason, the way in which the economy is managed has an impact on the environment which, in turn, affects both welfare and the performance of the economy.

Environmental economics takes into consideration issues such as the conservation and valuation of natural resources, pollution control, waste management and recycling, and the efficient creation of emission standards. Economics is an important tool for making decisions about the use, conservation, and protection of natural resources because it provides information about choices people make, the costs and benefits of various proposed measures, and the likely outcome of environmental and other policies. Since resources – whether human, natural, or monetary – are not infinite, these public policies are most effective when they achieve the maximum possible benefit in the most efficient way.

One of the best known critics of traditional economic thinking about the environment is Herman Daly. In his first book, *Steady-State Economics*, Daly suggested that "enough is best," arguing that economic growth leads to environmental degradation and inequalities in wealth. He asserted that the economy is a subset of our environment, which is finite. Therefore his notion of a steady-state economy is one in which there is an optimal level of population and economic activity which leads to sustainability. Daly calls for a qualitative improvement in people's lives – development – without perpetual growth. Today, many of his ideas are associated with the concept of sustainable development.

By the late 1970s, the late economist Julian Simon began countering arguments against economic growth. His keystone work was *The Ultimate Resource*, published in 1981 and updated in 1996 as *The Ultimate Resource 2*, in which he concludes that there is no reason why welfare should not continue to improve and that increasing population contributes to that improvement in the long run. His theory was that population growth and increased income puts pressure on resource supplies; this increases prices, which provides both opportunity and incentive for innovation; eventually the innovations are so successful that prices end up below what they were before the resource shortages occurred. In Simon's view, a key factor in economic growth is the human capacity for creating new ideas and contributing to the knowledge base. Therefore, the more people who can be trained to help solve arising problems, the faster obstacles are removed, and the greater the economic condition for current and future generations.

Another of the now famous books about the dilemma of economic growth is Tim Jacksons *Prosperity without growth*. It was published as a report from the British Commission for Sustainable Development after a two years long series of seminars. It discussed in depth the most important drivers of economic growth. First of all is increased consumption, which is very much a result of the wish for social equity: "What my neighbor has I want to have as well."

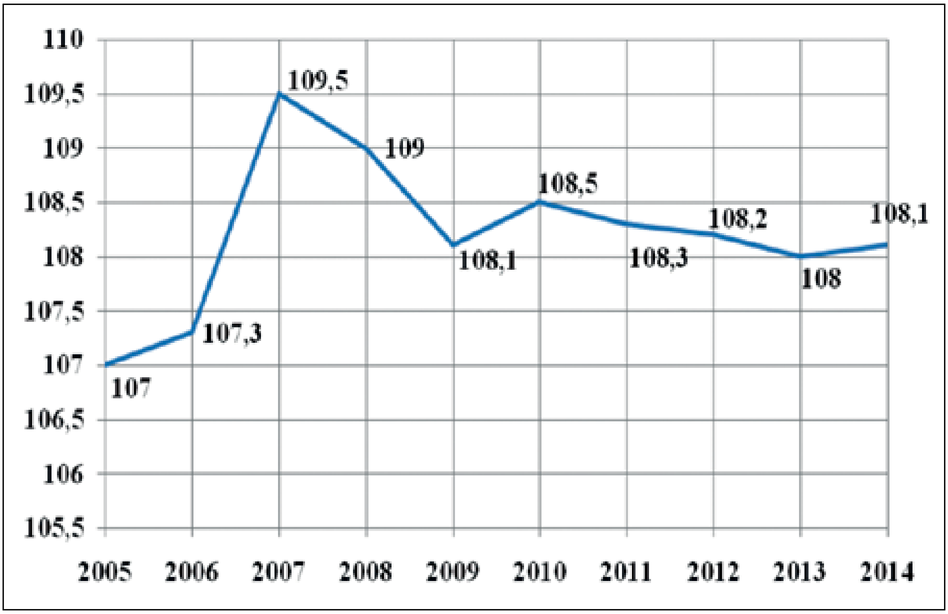

Figure 12.4. Rates of growth GDP of Uzbekistan (total internal product) in the comparable prices in % to the previous year. During 2005-2014 the stable average gain GDP was 8,2 %.

An often discussed solution to the dilemma of economic growth is *decoupling*. Decoupling means that economic growth occurs without increased consumption of natural resources. A certain level of decoupling is observed in all economies, as efficiency improves. But the increased efficiency is typically counteracted for by an even larger increased consumption: The money saved by increased efficiency is used for new consumption. This is called the *rebound effect*. We then have *relative decoupling*, but not *absolute decoupling* and thus no decrease of resource flows. Decoupling does not solve the problem. Instead we have to change our consumer behavior.

Politicians are typically afraid that a stop of the economic growth will result in economic and social collapse. It is of course a possibility: Less consumption, gives less production, fewer jobs etc. But there are ways to avoid collapse and develop a steady state economy which still is prosperous. Tim Jackson and others describes macroeconomic models which would allow a welfare society without growth.

12.8 A steady-state or non-growth economy

A *steady state* or *non-growth economy* is an economy of relatively stable size. A zero growth economy features stable population and stable consumption that remain at or below *carrying capacity*. The term typically refers to a national economy, but it can also be applied to the economic system of a city, a region, or the entire planet.

Development of non-growth economics (sometimes also called *full-world economics*) is a response to the observation that economic growth has limits. Macroeconomic policies in most countries, particularly those with large economies as measured on a GDP scale, typically have been officially structured for economic growth for decades. Given the costs associated with such policies (e.g., global climate disruption, widespread habitat loss and species extinctions, consumption of natural resources, pollution, urban congestion, intensifying competition for remaining resources, and increasing disparity between the wealthy and the poor), some economists, scientists, and philosophers have questioned the biophysical limits to growth, and the desirability of continuous growth.

Either concept of sustainability, but especially the "strong" version, implies some limits to economic growth. The part of economic activity which relies heavily on natural resources, raw materials or energy, cannot keep growing indefinitely. Because the planetary ecosystem has certain limits, there must also be limits on *macroeconomic scale*: the overall level of resource use and goods output.

Figure 12.5. Japan scientists delegation at Ohalik Oltin Bog'i farm, Samarkand region, Samarkand, Uzbekistan

There is a need in the long term to reach a plateau, a *steady-state* in terms of the consumption of material and energy resources.

On the other hand, activities which do not involve resource consumption, which are environmentally neutral or environmentally friendly, can grow indefinitely. Such activities could include services, arts, communication, and education. Once basic needs are met and reasonable levels of consumption achieved, the concept of sustainable development implies that economic development should be increasingly oriented towards this kind of inherently "sustainable" activities (Jonathan M.Harris and Anne-Marie, page 25).

12.9 The development of Uzbekistan

Economic growth in terms of a modern state economy means an increase in the production and consumption of goods and services. It is facilitated by increasing population, increasing per capita consumption, and productivity gains, and it is indicated by rising real GDP. For millennia most economies, in the current sense of the term, remained relatively stable in size, or they exhibited such modest growth that it was difficult to detect. Proponents of steady state economics note that the general transition from hunter-gatherer societies to agricultural societies resulted in population expansion and technological progress. From this they stress that the industrial revolution and the ability to extract and use dense energy resources – fossil energy – resulted in unprecedented exponential growth in human populations and consumption.

Uzbekistan after gaining its independence in 1991, having denied the obsolete totalitarian, administrative-command and planning-distributive system, chose its own "Uzbek model" of development. The essence and substance of the model, which was elaborated and is being put into practice today, are as follows:

- radical change and renewal of the state and constitutional order;
- implementing political, economic and social reforms based on such principles as de-ideologization of the economy and its priority over politics;
- giving the state the role of a major reformer, i.e. the functions of an initiator and coordinator of reforms;
- ensuring rule of law;
- providing strong social policy;
- implementing the reforms on the step-by-step and gradual basis.

Today the world community, as well as such high-profile international financial institutions as the International Monetary Fund, the World Bank, the Asian Development Bank and others, does recognize sustainable high growth rates of Uzbekistan. They also recognize the stability and reliability of the functioning financial and banking system, successful structural reforms in the economy and in general Uzbekistan's confident steps on the way of modernizing the country.

After less than 20 years of our independent development Uzbekistan's GDP increased 3.5 times, and per GDP/capita 2.5 times; the real income of the population increased 3.8 times. The achieved successes in social and humanitarian dimension are also substantial. The expenses for social security of the population increased 5 times, a considerable improvement of living standards, which have resulted in a decrease of maternal mortality rate to less than half, and children's mortality rate to a third. The average life expectancy in the country increased from 67 to 73 years for men and to 75 years for women.

Nevertheless Uzbekistan, together with the rest of the world community, needs to question its present model of growth economy. It is not sustainable. In the longer term it is necessary to develop an economy which is resource efficient and based on renewable energies. Growth needs to stay within the ecological limits set by the planet. The development of the country needs to focus on improved quality rather than quantity, and its measures of progress and development focus on wellbeing and happiness rather than consumption.

Chapter 12 sources:

Sections 12.1, 12.3 (later part) **12.5 and 12.6** Jonathan M. Harris and Anne-Marie Codur Macroeconomics and the Environment. Chapter 3 *Long-term growth and sustainable development* pp 14-17 (Section 12.1), pp 20-21 (Section 12.3 later part), pp 21-25 (Section 12.5) and pp 26-27 (Section 12.6) Copyright © 2004 Global Development and Environment Institute, Tufts University.

Section 12.2 Lars Rydén Chapter 1. *Building sustainable societies – the human dimension* UZwater book 5. Lars Rydén, Rustam Eshnijazov, and Rifkat Gimush, eds, Building Sustainable Societies, Uzwater project.

Section 12.3 (first part) Chapter 1 *A history of human development, resource use and sustainable development* in Uzwater Book 1. "Sustainable Use and Management of Natural Resources" Lars Rydén, and Natalia Akinshina eds

Section 12.4 Chapter 5 *Measurements of resource flows* in Uzwater Book 1. "Sustainable Use and Management of Natural Resources" Lars Rydén, and Natalia Akinshina eds

Section 12.7 From *Environmental & Resource Economics* The Environmental Literacy Council. http://enviroliteracy.org/environment-society/environmental-resource-economics/. Comment on *Prosperity without Growth* added by Lars Rydén.

Section 12.8 Partly from Jonathan M. Harris and Anne-Marie Codur *Macroeconomics and the Environment. Policies for sustainable development*, p 25. Copyright © 2004 Global Development and Environment Institute, Tufts University. https://www.academia.edu/5177610/STUDENT_READING_FOR_INTRODUCTORY_MACROECONOMICS

Section 12.9 Statistics: GDP of Uzbekistan grows 3.5 times in the past 20 years http://news.uzreport.uz/news_4_e_82002.html

IV

The Economics of Land, Water, Agriculture and Forest

Chapter 13
Water Challenges in Central Asia

13.1 The Potential for water scarcity

The earth's renewable supply of water is governed by the hydrologic cycle, a system of continuous water circulation (Figure 13.1). Enormous quantities of water are cycled each year through this system, though only a fraction of circulated water is available each year for human use.

Of the estimated total volume of water on earth, only 2.5% (1.4 billion km^3) of the total volume is freshwater. Of this amount, only 200,000 km^3, or less than 1% of all freshwater resources (and only 0.01% of all the water on earth), is available for human consumption and for ecosystems.

If we were simply to add up the available supply of freshwater (total runoff) on a global scale and compare it with current consumption, we would discover that the supply is currently about ten times larger than consumption. Though comforting, that statistic is also misleading because it masks the impact of growing demand and the rather severe scarcity situation that already exists in certain parts of the world. Taken together, these insights suggest that in many areas of the world, including parts of Africa, China, and the United States, water scarcity is already upon us. Does economics offer potential solutions? As this chapter demonstrates, it can, but implementation is sometimes difficult.

Available supplies are derived from two rather different sources – surface water and groundwater. As the name implies, *surface water* consists of the freshwater in rivers, lakes, and reservoirs that collects and flows on the earth's surface. *Groundwater,* by contrast, collects in porous layers of underground rock known as aquifers.

Though some groundwater is renewed by percolation of rain or melted snow, most was accumulated over geologic time and, because of its location, cannot be recharged once it is depleted. Shallow groundwater resources are filled with water as a consequence of precipitation. When water sinks into the ground it is where it ends up. The aquifers are then emptied into rives or other surface waters, as part of the hydrological cycle. Deep layers of groundwater are often much older and has so-called "fossil" water and are thus not renewable.

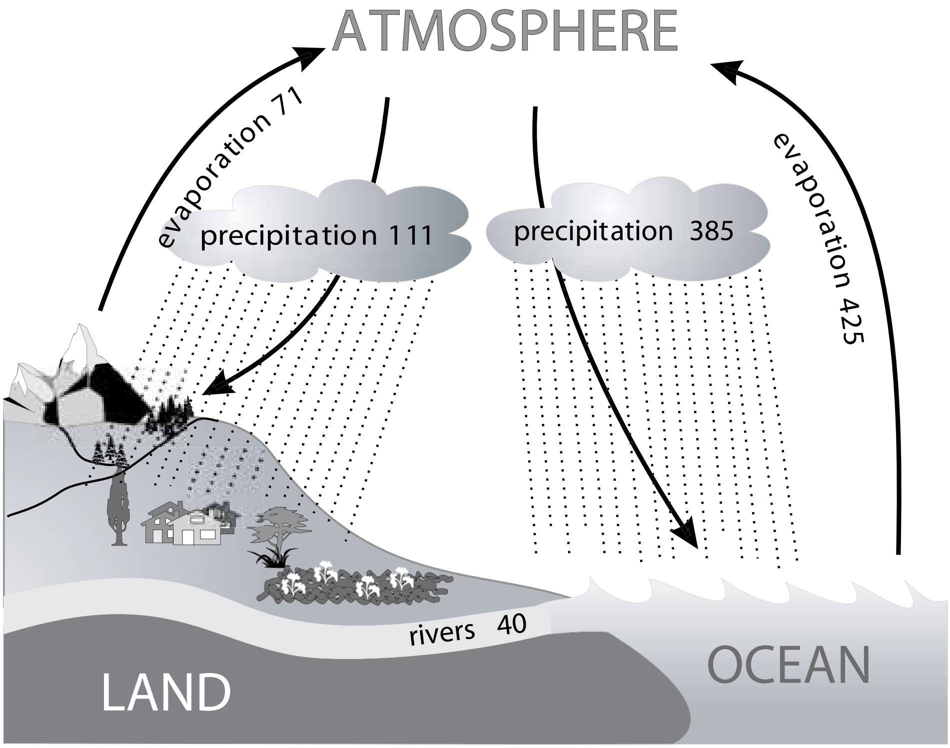

Figure 13.1 The hydrological cycle. Water evaporates from the oceans and land, is transported in the atmosphere, condenses as clouds and finally precipitates and runs through rivers back to the oceans. The numbers in the Figure are millions of M tonnes of water per year globally (Source: Environmental Science, Rydén et al 2003)

According to the UN Environment Program (2002), 90% of the world's readily available freshwater resources is groundwater. And only 2.5% of this is available on a renewable basis. The rest is a finite, depletable that is non-renewable, resource.

The Republic of Uzbekistan and the majority of the neighbouring countries are situated in the Aral Sea drainage basin. Its trans-boundary waters are in shared use for economic and environmental needs. The fresh waters of the rivers, lakes and reservoirs are used for irrigated farming, industrial and public utility sector needs. Water resources of the Republic of Uzbekistan are formed from renewed surface and underground water. Volumes of natural mean annual flow of the rivers are 123 m^3/year including 81.5 km^3 in Amu-Darya basin, and 41.6 km^3 in Syr-Darya basin. Volumes of actually available water resource of Republic of Uzbekistan by sources of formation are given in Table 13.1. The table shows that about 60% of available water is trans-boundary flow which became subject to

Table 13.1: Available water resources of Uzbekistan. Average for 2002-2013. (Source: Data from MAWR, (2014) Ministry of Agriculture and Water Resources. Distribution of agricultural area of Republic of Uzbekistan by grounds. http://www.agro.uz).

River basin	Intake from river			Underground water use	Collector drainage flow	Available water resources
	Trans boundary	Small rivers	Total			
Syr-Darya	10,49	9,20	19,69	1.59	4,21	25,49
Amu-Darya	26,92	6,98	33,90	1,00	2,63	37,53
Total	37,41	16,18	53,59	2,59	6,84	63,02

political issues. 10.8% of the water has collector drainage source with high level of mineralization and pollution.

In drought years these parameters are reduced with up to 54.2 km^3. National renewed water resources of Uzbekistan make 11.5 km^3/year or 18.4% from total quantity of water consumption and 457 m^3 per capita/year. From 55.1 km^3 of average total water consumption 49.7 km^3 or 90.2% is used for irrigation purposes (MAWR, 2014).

Environmental conditions and sustainability of the national economy, in particular of the agricultural sector, greatly depends on water availability in a given region. Climatic peculiarities, a strong continental climate, high evaporating capacity (up to 1700 mm a year), insignificant and irregular seasonal patterns of precipitation (on average 150-200 mm), as well as high summer temperatures (up to 50°C) have led to the development of irrigated farming. The arid climate and high level of natural soil salinity has resulted in salt accumulation in the soil. The use of low productivity saline lands for agricultural production, in-stream disposal of collector drainage waters and inefficient wastewater purification systems results in a deterioration of water resource quality and an increase in water salinity (UNDP, 2008).

The last years of the Soviet period witnessed an increasing natural resource degradation due to massive irrigation and drainage system development as well as the conversion of vast tracts of deserts into irrigated agricultural land (Gleick 2000). Downstream regions of Uzbekistan along the Syrdarya and the Amudarya basins have exhibited increased trends in land and water degradation with declining crop yields as a result. This has threatened the food security not only within the areas where degradation is happens, but also in Central Asia as a whole (Klotzli 1994). Since 1961, the water level of the Aral Sea has been declining progressively at the rate of 20 to 90 cm/yr. Accelerated salinization and desertification of land along with the severe water pollution occurs in the Amu-Darya and Syr-Darya deltas. The former bed of the Aral Sea is now an area of dust, pesticides, and

Figure 13.2. Katta-Kurgan reservoir, K.Kurgan, Samarkand, Uzbekistan.

salt. The decline of the Aral Sea also causes climate changes in its basin. The water deficit increases over time, caused by population growth in Central Asia, an increase in water use in Afghanistan and an intensified desertification process and climate change. Growth of water intake from the rivers into irrigation canals and losses in canals cause flow reduction, and the discharge of collector drainage water worsen its quality. Since the early 1960s irreversible consumption of the river flow was doubled, and at present level it is increased 4 times in comparison with the 1930s and 1940s.

13.2 Water as a tradable property – the efficient allocation of scarce water

Intergenerational effects are less important because future supplies depend on natural phenomena (such as precipitation) rather than on current withdrawal practices. For deep groundwater, on the other hand, withdrawing water now does affect the resources available to future generations. In this case, the allocation over time is a crucial aspect of the analysis. Because it represents a somewhat simpler analytical case, we shall start by considering the efficient allocation of surface water.
An efficient allocation of *surface water* must

1) strike a balance among a host of competing users and
2) supply an acceptable means of handling the year-to-year variability in water flow.

The former issue is acute because so many different potential users have legitimate competing claims. Some (such as municipal drinking water suppliers or farmers) withdraw the water for consumptive use, while others (such as swimmers or boaters) use the water, but do not consume it. The variability challenge arises because surface-water supplies are not constant from year to year or month to month. Since precipitation, runoff, and evaporation all change from year to year, in some years less water will be available for allocation than in others. Not only must a system be in place for allocating the average amount of water, but also above-average and below-average flows must be anticipated and allocated.

With respect to allocating among competing users, the dictates of efficiency are quite clear: the water should be allocated so that the marginal net benefit is equalized for all uses. (Remember that the marginal net benefit is the vertical distance between the demand curve for water and the marginal cost of extracting and distributing that water for the last unit of water consumed.).

Extending this analysis to encompass *deep groundwater* requires that the depletable nature of groundwater supplies be explicitly taken into account. When withdrawals exceed recharge from a particular aquifer, the resource will be mined over time until either supplies are exhausted or the marginal cost of pumping additional water becomes prohibitive. The similarity of this case to the increasing-cost, depletable resource model allows us to exploit that similarity to learn something about the efficient allocation of groundwater over time. The first transferable implication is that a marginal user cost is associated with mining groundwater, reflecting the opportunity cost associated with the unavailability in the future of any unit of water used in the present. An efficient allocation considers this user cost.

The first reform would reduce the number of restrictions on water transfers. The "use it or lose it" component that often accompanies the prior appropriation doctrine can promote the extravagant use of water and discourage conservation. Typically, water saved by conservation is forfeited. Allowing users to capture the value of water saved by permitting them to sell it would stimulate water conservation and allow the water to flow to higher-valued uses. An example is given in Box 13.1.

13.3 Water markets

Water markets and water banks are being increasingly utilized to transfer water seasonally via short-term leases or on a long-term basis, either by multiple-year

Box 13.1 Using Economic Principles to Conserve Water in California

In 1977, when then-California Governor Jerry Brown negotiated a deal to settle one of the state's perennial water fights by building a new water diversion project, environmental groups were opposed. The opposition was expected. What was not expected was the form it took. Rather than simply block every imaginable aspect of the plan, the Environmental Defense Fund (EDF) set out to show project supporters how the water needs could be better supplied by ways that put no additional pressure on the environment.

According to this strategy, if the owners of the agricultural lands to the west of the water district seeking the water could be convinced to reduce their water use by adopting new, water-saving irrigation techniques, the conserved water could be transferred to the district in lieu of the project. But the growers had no incentive to conserve because conserving the water required the installation of costly new equipment and as soon as the water was saved, it would be forfeited under the "use it or lose it" regulations. What could be done?

On January 17, 1989, largely through the efforts of EDF, an historic agreement was negotiated between the growers association, a major user of irrigation water, and the Metropolitan Water District (MWD) of California, a public agency that supplies water to the Los Angeles area. Under that agreement, the MWD bears the capital and operating costs, as well as the indirect costs (such as reduced hydropower), of a huge program to reduce seepage losses as the water is transported to the growers and to install new water-conserving irrigation techniques in the fields. In return, the MWD will get all of the conserved water.

Everyone stands to gain: The district gets the water it needs at a reasonable price; the growers retain virtually the same amount of irrigation benefits without being forced to bear large additional expenditures.

Because the existing regulatory system created a very large inefficiency, moving to a more efficient allocation of water necessarily increased the net benefits. By using those additional net benefits in creative ways, it was possible to eliminate a serious environmental threat.

The success of this agreement has spawned others. For example, two water-transfer agreements, finalized in October 2003, provide an additional 250 million m3 of water annually to the San Diego region as a result of conservation measures taken in the Imperial Valley and financed by the municipal payments for the water.

Source: Tietenberg, T., Lewis, L. (2012) Environmental & Natural Resource Economics 9th Edition Chapter 9 "Replenishable but Depletable Resources: Water" Potential Remedies – Water Transers and Water Markets. [pp. 220].

leases or permanent transfers. While most markets and banks are restricted to certain geographic areas, water is allowed to move to its higher-valued uses to some extent. Buyers and sellers are brought together through bulletin boards, water brokers, and electronic computer networks. For example, the Westland Water Irrigation District in California uses an electronic network to match buyers and sellers (Howitt, 1998). Drought-year banks have been successful in California.

One unique water market in the State of Colorado is the Colorado-Big Thompson Project. Here water was pumped from the Colorado River on the west side of the Rocky Mountains uphill and through a tunnel under the Continental Divide where it finds its way into the South Platte River through an extensive system of canals and reservoirs. Shares in the project are transferable and the Northern Colorado Water Conservancy District (NCWCD) facilitates the transfer of these C-BT shares among agricultural, industrial, and municipal users. The original price of the share in 1937 was USD 1.5 had increased to USD 10 000 in 2006. This market is unique because shares are homogeneous and easily traded; the infrastructure needed to move the water around exists and the property rights are well defined (return flows do not need to be accounted for in transfers since the water comes from a different basin). Thus, unlike most markets for water, transactions costs are low. This market has been extremely active and is the most organized water market in the West. When the project started, almost all shares were used in agriculture. By 2000, over half of C-BT shares were used by municipalities.

The transfer of water, however, can incur high transaction costs, both in the time necessary for approval (up to two years in some cases) and in potential downstream impacts. One reason for the success of the Colorado-Big Thompson Project market is low transactions costs due to the structure of the water rights and the availability of infrastructure. An electronic bank also aids in the transparency of sales. The Web site www.watercolorado.com operates like a "Craigslist" for water, bringing buyers and sellers together. Water markets are gaining importance as a water allocation mechanism. Do they succeed in moving water to higher-valued uses, thus helping to equate marginal benefits across uses?

The water resources of Uzbekistan are part of general water resources, of which the basin of Aral Sea disposes. To this basin relate the largest rivers of Central Asia: Amudarya and Sirdarya, being main sources of surface flow and directly coming to Aral Sea, as well as river hydrographicaly relate to basin and located in borders of Aral depression.

The share of water resources, forming directly on territory of Uzbekistan, is equal – on Amudarya basin – 6%, on Sirdarya basin – 16%, and as a whole on Republic – 10% from their summary flow. From requirements of ecology and obvious necessity of preservation Aral sea, the volume of water resources, on which can calculate Uzbekistan at the present stage and on period till 2010 makes 59.2 km^3, from them on Sirdarya river – 24.1, on Amudarya river -35.1 km^3.

Table 13.2. Water resource availability and consumption in Uzbekistan. (Source: ECOGeoscience, 2009)

	Syrdarya basin	Amudarya basin	Aral Sea basin total
Water resources formed/км^3	6,39	5,14	11,53
Water resources consumed/км^3	17,28	38,91	56,19

13.4 Water management under Soviet system – large scale irrigation

Regardless of source, economically efficient allocations have not resulted for most water-sharing situations due to the legal and institutional frameworks governing water resources.

Irrigation has always played a central role in the development of Central Asia. But it was only after the Soviet Union began the systematic cultivation of cotton, rice and wheat in the region beginning in the 1930's that irrigated agriculture became such a tremendous presence, as well as one of the principle reasons that the independent states of Central Asia are currently in such a difficult predicament with relation to water, irrigation and agriculture. Prior to widespread Soviet re-engineering of irrigation systems, traditional forms of irrigation in Central Asia, while quite extensive, were rudimentary. This is not to say that they were ineffective. In fact, today's irrigation schemes of first, second and third tier canal systems mirror that of irrigation schemes used by farmers prior to the intervention of the Soviets. Canals were for the most part unlined, but were constructed with proper gradients to minimize erosion as a result of water moving too fast through the canals, or conversely blockage as a result of water moving too slowly. Irrigation construction included the use of drainage dikes and dams to capture and keep water, and was designed in such a way as to maximize water efficiency (Conti, Patrick, 2004).

This system changed with the appearance of the Soviets in Central Asia. Between the years 1930 and 1990, the Soviet Union constructed one of the largest irrigation schemes in the world. At the time of the breakup of the USSR more than 300,000 km of main and secondary canals, drainage ditches and on-farm irrigation channels had been constructed in the region to irrigate some 8 million hectares of cotton and wheat fields. In just 50 years, land specified solely for cotton cultivation in Uzbekistan alone grew from 1,022,600 hectares (ha) in 1940, to almost 2,103,000 ha by 1987 (Spoor, Max.). From 1970 to 1989 new areas that fell under irrigation increased by 130% in the Syr Darya River Basin and more than 140% in the Amu Basin (World Bank, 2004). Current total flow capacity of the Syr Darya River has diminished as a result of increased irrigation and hydropower stations in upper riparian states.

Water distribution in Central Asia was always highly uneven. At the highest peak of Soviet irrigation in Central Asia, the two republics with the largest cultivated areas for cotton, Uzbekistan and Turkmenistan, experienced dramatic increases in their annual uptake of water for agricultural purposes.

This highly weighted system of water allocation and distribution was mandated by two separate Soviet protocols. In February of 1984 the USSR's Scientific-Technical Council of Ministry of Land Reclamation and Water Management ratified Protocol 413, which set distribution limits for water emanating from the Syr Darya basin for the entire region. In the initial agreement, more than 50% of the entire Syr Darya basin surface flow was allocated to Uzbekistan and Kazakhstan. Uzbekistan received 30.3% and Kazakhstan was allocated 22.3% of total surface flow. Three years later representatives of Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan again met in Moscow and ratified protocol 566, which guaranteed Uzbekistan 48.2% and Turkmenistan 35.8% consumption rights of the total river flow of the Amu Darya basin (Trans-boundary Water and Related Energy Cooperation for the Aral Sea Basin Region of Central Asia, 2002). The collapse of the Soviet Union, however, brought rapid changes.

13.5 The current allocation system

After 1991, the five countries of Central Asia gained new powers to unilaterally craft internal economic and social policy. Of primary concern regarding independence, especially in the water dependent lower riparian states, was the uncertainty of existing water allocation schemes between the new sovereign states without central planning to enforce water distribution limits. To fill in the vacuum of water management after the collapse of the USSR, the countries met in February 1992 and concluded a joint agreement, establishing an Interstate Commission for Water Coordination (ICWC) which became responsible for the water allocation for the five former Soviet states in the Aral Sea basin. It was decided that the states would maintain allocation limits established in Soviet Protocols 566 and 413, and that furthermore, it would be the ICWC that would ensure adherence to these allocation quotas (Water Management: Assessment of the Political/Economic Environment for Improving Agreements on Trans-boundary Waters, 2001).

The next matter of importance is to examine how this water is utilized. Table 13.3 shows the rough breakdown of end uses for Uzbek water resources. It can be seen that 5.5% is consumed or used in service capacities, all less than half that in total for industry, fishing and energy. In contrast, more than ninety% is used for irrigation purposes and is consumed in the rural economy, a much higher%age than found on average for agricultural countries.

Realistic water resources of Uzbekistan make 11.5 km^3/year or 18.4% of the total quantity of water consumption and 457 m^3 per capita/year. From a total available water resources 90.2% is used for irrigation purposes which means the main water consumer is rural economy. We have seen in the tables above which natural water resources Uzbekistan relies on. There are two primary sources, the Amu and Syr Darya rivers, which are responsible for most of the freshwater available across the country. Table 13.3 shows how that water has been utilized when it is channelled off. The remarkable fact is that 92% of the water is used for agriculture. Though agriculture is our country's primary economic sector, this%age is higher than average for agricultural countries.

Services and industry lag far behind agriculture as economic sectors, and energy production barely impacts the water portfolio. However, as we have seen in other chapters, we also know that the agricultural percentage represents not a thriving agricultural sector, but a wasteful one. All of the water taken from the rivers for agriculture is accounted for, but a significant portion of it is wasted through inefficient irrigation.

In April 30, 1998 the Cabinet of Ministers and the President, Islam Karimov, responding to the need for change in the agricultural sector, introduced and/or modified four laws related to internal agricultural restructuring. These laws included the existing Land Code, the Law on Shirkat Farms, a Law on Private Farms, and the Law for Small Dekhkan Farms.

The process of eliminating collective farms set the stage for agricultural restructuring through Irrigation Management Transfer (IMT). The basis of IMT is Participatory Irrigation Management (PIM), which is a concept that envisions the participation of farmers in all aspects of Operations and Management (O&M) of an entire Irrigation and Drainage (I&D) apparatus, including, planning, design, construction, operation and maintenance, financing, decision rules and the monitoring and evaluation of the irrigation system. PIM seeks to include farmers into the decision making process related to agricultural production. Research of I&D systems managed by farmers shows that active participation by farmers helps ensure the sustainability of irrigation systems through better and timely water

Table 13.3 Water use by branches of economy in Uzbekistan. Source: (Samylov, et al., 2006)

Agriculture	Service	Industry	Fishery	Energy
92%	5.5%	1.5%	0.8%	0.2%

delivery and allocation, better design and construction of I&D schemes, a reduction of conflict between farmers concerning water, increased crop production and improved contact with government personnel. IMT has been implemented in many parts of the world, from Mexico to Sri Lanka, with generally positive results. IMT involves the full or partial transfer of responsibility and authority for the governance, management and financing of irrigation systems from the Government to Water User associations. These Water User Associations or (WUA) are the underpinning of Uzbekistan's current agricultural reform.

In its most basic form the WUA is a body made up of a group of water users who pledge to work together to manage and maintain the local irrigation systems that serve their farms. Members of a WUA coordinate the sharing of irrigation water among users, as well as assuming responsibility for the maintenance and repair of the related infrastructure (such as pumps, storage reservoirs, drainage wells, drainage collector system, etc.). WUA implementation in Uzbekistan is intended to begin the devolution of government responsibility for maintaining irrigation and drainage systems throughout state farms that are no longer financially viable under new market forces. In Uzbekistan, WUA were officially recognized as the institution to take responsibility for all on-farm irrigation and drainage requirements, according to a government degree announced on January 5, 2002 (Water Users Associations in Uzbekistan, 2006). Since then, the government of Uzbekistan has been in the process of organizing, in some instances pressuring, farmers on disbanded collective farms to unite and form WUA with the explicit desire of transferring responsibility for all on-farm related costs to them.

13.6 Water economics and water price

In The Wealth of Nations, published in 1776, Adam Smith pointed out a well-known paradox regarding the usefulness of water and its price: "Nothing is more useful than water, but it will purchase scarce anything; scarce anything can be had in exchange for it." During the 1999 summer drought on the U.S. East Coast, one could "refill an 8-ounce glass with tap water 2,500 times for less than the cost of a can of soda" (Stavins 1999). Water prices typically lie far below what economists consider efficient levels. This is true in urban settings, as well as in the case of agriculture. Since water is not traded in markets, we would not expect prices to adjust automatically to reflect periods of scarcity, as they do for other goods and services. Instead, most water pricing is regulated by public institutions. Given the public benefits provided by many aspects of water supply and management, this could be a good thing from an economic perspective, if these price-setting public institutions had some way to measure the true economic value of water supply and to use this information to establish economically rational water tariffs.

From an economic perspective, water resources can be viewed as a form of natural asset that provides service flows used by people in the production of goods and services, such as agricultural output, human health, recreation, and more amorphous goods such as quality of life. This is analogous to the manner in which real physical capital assets (for example, factories and equipment) provide service flows used in manufacturing. As with real physical capital, a deterioration in the natural environment (as a productive asset) reduces the flow of services the environment is capable of providing. Ecological benefits are very much part of this picture.

Providing or protecting water resources involves active employment of capital, labour, and other scarce resources. Using these resources to provide water supplies means that they are not available to be used for other purposes. The economic concept of the "value" of water is thus couched in terms of society's willingness to make trade-offs between competing uses of limited resources, and in terms of aggregating over individuals' willingness to make these trade-offs. Economists' tools of valuation were originally developed in a more limited context, one in which policy changes mostly cause changes in individuals' incomes and/or prices faced in the market. Over the last thirty years, however, these ideas have been extended to accommodate changes in the qualities of goods, to public goods that are shared by individuals, and to other non-market services such as environmental quality and human health. The economist's task of estimating the benefits or loss of benefits resulting from a policy intervention is easiest when the benefits and costs are revealed explicitly through prices in established markets. When it comes to measuring environmental and some other impacts, however, valuing benefits is more difficult, and requires indirect methods. With markets, consumers' decisions about how much of a good to purchase at different prices reveal useful information regarding the surplus consumers gain. With non-market environmental goods, it is necessary to infer this willingness to trade off other goods or monetary amounts for additional quantities of environmental services using other techniques.

Economists have developed a repertoire of techniques that fall broadly into two categories: indirect measurement and direct questioning. Both sets of valuation methods are relevant for assessing the anticipated benefits of policies regarding water resources. Thus, every environmental amenity, ecosystem service, and natural resource has multiple benefits or values to people. The sum of these

Figure 13.3. Cotton fields in rural Uzbekistan, Tashkent region. Photo: Shuhrataxmedov

economic benefits are essentially captured by people's total willingness to pay, including use value, the value of water in its many uses, including drinking, energy production, recreation, irrigation, and species habitat, and non-use value, the value of a water resource beyond that associated with particular uses. Non-use value can be associated with the mere existence of a water resource in some unspoiled form, or with a desire to leave such a resource to future generations. As water, or any other good or service, becomes more scarce, people are willing to pay more for incremental units. This inverse relationship between marginal willingness to pay, on the one hand, and quantity, on the other hand, is captured by a downward sloping demand curve. The economist's notion of cost, or more precisely, opportunity cost, is linked with – but distinct from – everyday usage of the word. Opportunity cost is an indication of what must be sacrificed in order to obtain something. In the water resources context, it is a measure of the value of whatever must be sacrificed to make those resources available. These costs typically do not coincide with monetary outlays, the accountant's measure of costs. This may be because out-of-pocket costs fail to capture all of the explicit and implicit costs that are incurred, or it may be because some prices may themselves provide inaccurate indications of opportunity costs. Hence, the costs of providing water are the forgone social benefits due to employing scarce resources for water provision purposes, instead of putting those resources to their next best use.

It has been observed over and over again in diverse markets for goods and services of various kinds that the incremental costs of providing an additional unit increase as the total quantity supplied increases. In the language of economics, there are increasing (or upward sloping) marginal costs. The costs of a litre of water flowing out of a kitchen faucet include the costs of transmission, treatment and distribution; some portion of the capital cost of reservoirs and treatment systems, both those in existence today and those future facilities necessitated by current patterns of use; and the opportunity cost in both use and non-use value of that litre of water in other potential functions. This is the long-run marginal cost of supplying water.

In a competitive market – which, as we have explained above, is not the context for most water resources – the quantity of a good or service provided and its price are jointly determined by the forces of supply and demand, which are closely linked with costs and benefits, as described here. In fact, the downward-sloping marginal benefit curve is the demand curve, and the upward-sloping marginal cost curve is the supply curve. Where these intersect, where demand and supply balance one another, markets achieve an equilibrium, determining quantity provided and price in the process. And that particular combination of price and quantity maximizes the difference between benefits and costs, that is, it maximizes what economists call net benefits (the sum of consumer surplus and producer surplus). This is the definition of economic efficiency, and the efficient quantity and the efficient price of any good or service. Although this free-market interaction of supply and demand does not take place in the context of water resources, it is nevertheless the equivalency of downward-sloping marginal benefits and upward-sloping long-run marginal costs that defines the efficient quantity and price of specific water resources. This is because at this level of consumption, consumers would use water until the marginal benefits from consumption were just equal to the long-run marginal costs. Net benefits would be maximized.

If water were efficiently priced, then price would – in effect – be equal to long-run marginal cost (LRMC), and consumers would face an appropriate choice from the perspective of society: consume this unit of water only if the private benefits you obtain from doing so exceed its full social cost. Thus, efficient pricing maximizes the net benefits to society of a particular water resource or set of water resources. With water prices below LRMC, water consumption is excessive relative to the economic optimum, in that some consumption that takes place is worth less in its current use than the economic cost of its supply. This has severe consequences. In the short run, without price increases acting as a signal, water consumption proceeds during periods of scarcity at a faster-than efficient pace. Water conservation takes place only under “moral suasion or direct regulation” (Howe 1997). In contrast, if water prices rose as reservoir levels fell during periods of limited rainfall, consumers would respond by using less water, reducing or eliminating uses according to households’ particular preferences. During an extended drought in California, USA from 1987 to 1992, for example, a handful of municipal water utilities implemented price increases to reduce water demand, achieving aggregate demand reductions of 20 to 33% (Pint 1999).

13.7 The Aral Sea disaster

The two great rivers that fed the Aral Sea run a gauntlet of irrigation canals, channels and ditches, diverting and diminishing its flow all along their course. Historical water flow to the Aral Sea was 56 km^3 per year from both the Amu Darya and Syr Darya. It decreased to 47 km^3 between 1966 and 1970. Then, water flow plummeted to 2 km^3 between 1981 and 1983 around the time when the Aral Sea disaster really gained international attention. Today it measures less than 1.8 km^3 per year. So to compare the measurements and understand the implications: in Table 13.1 we saw that water resource formation for the main rivers in Central Asia is 63.02 km^3/year. However the inflow from the same rivers at their final destination at the Aral Sea is less than 2 km^3 per year.

The rapid growth in water consumption is connected not only to waste through poor quality irrigation channels, but also to putting new land under cultivation – only possible with heavy irrigation – where mainly cotton and rice are grown. This expanded cropping, combined with population growth and additional employment in agriculture, has led to the current situation where the flow of water to the Aral sea from the two major river systems – the Amu Darya and Syr Darya – have slowed to a trickle. In some recent years water flow to the Aral Sea has completely stopped.

A recent World Bank publication estimates that anywhere from 20% to 40% of these countries’ GDP is derived from agriculture, most of which requires steady irrigation in the late spring and summer months. Accordingly, agriculture is estimated to account for more than 90% of all water withdrawals in the Aral Sea basin (MAWR, 2014). Despite the creation of a bi-lateral agency to approve

Figure 13.4. The Aral Sea 1989 (left) and 2014 (right). Photo: NASA.

and monitor water distribution in the newly independent republics, water management in each of the five republics remained highly problematic. As early as the mid-1990s, problems began emerging as state budgets were stretched thin in order to maintain authority over state owned enterprises, especially in the water management sector. Rapid changes as a result of independence, mainly a severing of the many economic strings to Moscow, put tremendous pressure on the republics to reorganize their economies.

Partly in response to international outcry over the rapid desiccation of the Aral Sea resulting from tremendous water diversions for cotton production and partly as a response to internal financial deficiencies after the collapse of the Soviet Union, the governments of Central Asia began, in varying degrees, decentralization of their agricultural and water sectors.

Table. 13.4. Reservoir and lakes of the Republic of Uzbekistan 1998-2007. (Source: Kamildjanov, A.H., Shoumarov, S.B., Mirzakarimov, M.A., 2013).

No	Territory	LAKE			RESERVOIRS			RESERVOIR AND LAKES		
		Amount	Area km^2	Capacity mln m^3	Amount	Area km^2	Capacity mln m^3	Amount	Area km^2	Capacity mln m^3
1	Karakalpakistan Republic	28	4118,3	303,239	-	-	-	28	4118,3	303,239
2	Andijan	-	-	-	3	56,4	625,65	3	56,4	625,65
3	Buxara	6	587,31	304,67	1	42,2	64,5	7	629,51	369,17
4	Djizzakh	1	3508,0	403,60	6	171,57	76,2	7	3679,5	497,22
5	Kashkadarya	3	12,67	8491	14	160,68	267,377	17	173,35	1116,47
6	Navoi	2	37,0	6,0	3	2,56	2500,0	5	39,56	2506,0
7	Namangan	-	-	-	18	20,664	168,345	18	20,664	168,345
8	Samarkand	-	-	-	6	102,8	127,24	6	102,8	127,24
9	Surkhandarya	6	10,83	33,85	5	41,55	289,52	11	52,38	312,37
10	Sirdarya	5	5,81	8,26	-	-	-	5	5,81	8,26
11	Tashkent	2	5,0	75,0	5	135,67	543,4	7	140,67	618,48
12	Fergana	-	-	-	4	51,583	47,537	4	51,583	47,537
13	Khorezm	41	73,89	116,009	4	20	30	45	93,89	146,009
14	Total in Uzbekistan	94	8388,8	2099,72	69	805,68	4746,27	163	9194,4	6845,99

Natural population growth has not helped the situation. Seven to eight million people lived in the region at the beginning of the 20th century. Irrigated lands made up about 3.5 million hectares which effectively serves as the foundation of society's economic base. At present the population of the region has enlarged seven times, to more than 50 million people. In response to the increase in population, irrigated lands have been doubled (7.5-7.9 million hectares). In the sunny climate of the Aral Sea region, 60 cubic km of water inflow per year would be needed to maintain the water surface of the sea at its original area of approximately 60,000 km^2. However, the expansion of irrigation agriculture between 1930 and 1960 meant a fourfold increase in water usage from the Aral Sea basin and from its feeder rivers.

There are many perverse outcomes of the Aral Sea disaster that reflect on the systemic interconnections of the entire region. As the sea shrank ever more, the fishing industry was decimated, increasing economic dependence on agriculture in the overall Western region. Meanwhile, the desiccation of the sea has undermined the cotton harvest that was its cause. The evaporation of the Aral Sea caused salt-laden dust, which is then transported by wind, and has been measured as far away as Europe and Asia. Slowly but surely, the cotton crop yields have measurably declined in the region due to these dusts, as well as several factors directly linked to the methods of irrigation in use: erosion, water pollution and soil salinity. At the same time, the cotton industry's increased use of pesticides and fertilizer (and their runoff) have resulted in the pollution of surface and groundwater. Significant health impacts result from the consumption of impure water and from the blowing dust. The areas closest to the Aral Sea thus have health issues which are in turn connected to social issues. There is a high incidence of infant mortality, as well as many diseases, including anaemia, bronchitis and other respiratory infections, tuberculosis, kidney and liver disease, cancer and even arthritis. The local population has thus been affected in every way, from loss of productivity in agriculture and fishing to widespread health issues.

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Chapter 14
Multiple Resource: Land

14.1 Sustainable use of land resources

Land use is a critical concern in sustainable development. Land is what we live and travel on, it is a key resource for food production, but it is also where the rest of the inhabitants of our planet thrive. The dominant reason for the dramatic reduction of biodiversity is changed land use, and the consequential decrease of habitats. The value of land may be described in terms of the ecosystem services which a particular piece of land can provide. The result of the 2005 Millennium Ecosystem Assessment tells us that some 60% of the assessed ecosystem are degraded. Land has thus been degraded in many ways and for a sustainable future we need to carefully judge each proposed development of land use.

Administratively land use is carefully regulated. In most countries the local authority has a planning monopoly and thus has to manage all requests on land use, such as for habitation, industrial development, road construction, agriculture production etc. For larger scale issues there are normally decisions taken on regional or national levels. In addition governments have to take into account internationally agreements such as the biodiversity convention, conventions on the use of wetlands, agreements regarding forest degradation (REDD, part of the climate conventions) and the convention to combat desertification.

The biodiversity convention request each signatory country to protect a certain percentage of each of its nature types. Countries and local authorities in addition have their own goals for nature protection which then address specified areas. In the European Union these are collected in the so-called Natura 2000 system, which presently has many tens of thousands of objects. Protected areas may have very different degrees of protection and for most cases the public is welcome to visit.

Areas for tourism – tenting, fishing (angling), canoeing etc – have a value which often is high and in most cases exclude other uses, such as agricultural production. In some countries ownership of land excludes visitors e.g. for picking berries, while in others, like Sweden, there is a general access for the public on all land for trespassing, picking berries or just enjoy hiking.

Sometimes these different goals coincide. Thus traditional agriculture, such as sheep farming, or having grazing animals, is connected with a much higher biodiversity than protected and unused land, such as forest. The European convention of the protection of meadows is there to support such land use, then in conflict with modernisation of agriculture, which may be more efficient but on the expense of other values. The EU agricultural policy, a policy area which takes a very large part of the European budget, supports such land use and in fact sees the farmers not only as producers but also as managers of land to produce other values than just crops and economic benefits.

Presently the value of land is increasing in the whole world. Land is a crucial asset for being able to produce food and renewable energy, goods which are in increasing demand as the global population rockets. So-called "land grabbing" refers to buying land in poor countries, especially referring to Chinese land acquisitions in Africa, to secure future food production.

14.2 Uzbekistan's land resources

Agriculture accounts for most of the land use in Uzbekistan. Consequently it is one of the main determinants of environmental quality. From an economic point of view, Uzbekistan is an agricultural country. Agriculture accounts for about 60% of the foreign currency revenue, 17% of the GDP and 18% of the employment. About 63% of the population lives in rural areas, and 44% of rural population work in agriculture.

After the independence in 1991, the large state farms inherited the problems which are typical for the high-input, energy-intensive, traditional agricultural production methods adopted during the Soviet system. Intensive irrigation and poor drainage networks resulted in waterlogging and secondary salinization of soils. Due to the lack of resources, this former state-operated, large-scale irrigation system collapsed. With the breakdown of the supply and subsidy system, there have been a dramatic decline in the input for crop production such as fertilizers, chemicals, and farm machinery.

In 1992, 65.2% of the land in Uzbekistan was used for agriculture and 10.5% of the agricultural land was irrigated. The figure hardly changed from 1992 till 2007 (Table 14.1). At the largest oases farmers have used irrigation for centuries. The history of irrigation in Uzbekistan spans more than 2500 years. It originated in seven oases at the present territory of the country: Ferghana valley (East), Tashkent and Zarafshan valley in the central part, Kashkadarya and Surkhan-Darya valleys in a southeast, and Khorezm oasis and Karakalpakstan in the delta of the Amu Darya

Table 14.1. Agricultural land and population of Uzbekistan. (Source: FAO, 2008, http://faostat.fao.org)

		1992	2007	change
Total population	thous. persons	20,515	26,593	6,078
Agricultural population	thous. persons	12,042	16,926	4,883
Agricultural land	thous. Ha	27,724	27,890	166
Irrigated land	thous. Ha	4,474	4,700	226
Agricultural land per agricultural population	ha/person	2.30	1.65	-0.7
Irrigated land per agricultural population	ha/person	0.37	0.28	-0.1
Agricultural land (% of total land)	%	65.2	65.6	0.4
Irrigated land (% of agricultural land)	%	10.5	11.0	0.5

Table 14.2 Temporal use of arable lands and changes in major agricultural crops in Uzbekistan. (Source: http://faostat.fao.org)

Major crops	**Arable land (%)**			**Yield (Mg ha-1)**		
	1992	2007	Change	1992	2007	Change
Barley	6.8	1.7	-5.1	0.94	1.51	0.57
Maize	2.2	0.78	-1.42	3.72	5	1.28
Rice	4.1	1.5	-2.6	2.96	3.25	0.29
Wheat	14	32.8	18.8	1.54	4.21	2.67
Cotton	37.3	32.5	-4.8	2.48	2.28	0.20

river (West). At the beginning of the 20th century the total irrigated area in the territory of present Uzbekistan reached 1.2 mln ha, and by the end of the century it had increased to 4.2 mln ha or 3.6 times and covers 81% of the cultivated area.

Uzbekistan is the world's fifth largest cotton producer and is self-sufficient in grain production in the post-Soviet period. During this time the wheat fields increased by a factor 2.34 while the production of other cereals and cotton decreased (Table 14.2). The wheat yield per hectare increased by a factor 2.73. The yield of other cereals also increased. Meanwhile the yield of main cash crop-cotton decreased by 7.9%. The area under barley, maize, rice and cotton decreased. The area under wheat significantly increased from 14% to 32.8% of total arable land in the post-Soviet period.

14.3 Land use economics

Virtually all resource allocation takes place on land. Land represents an aggregate of many different attributes. Different uses of land call for a different mix of land

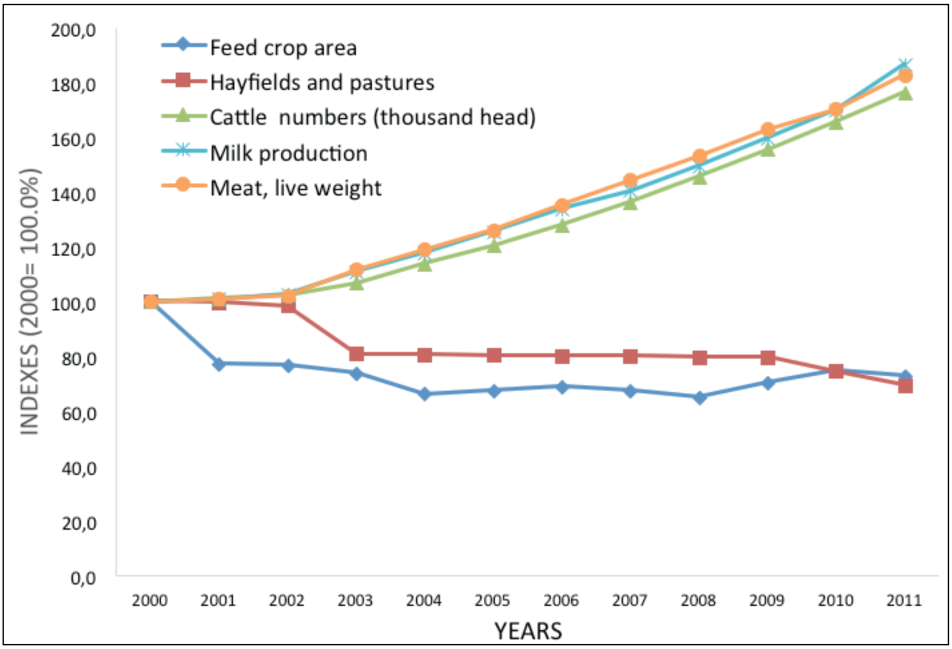

Figure 14.1. Main indices of cattle sub-sector's development in all production systems. (Source: Abruev, A., Murtazaev, O. (2013). Productivity change analysis of cow's milk in Uzbekistan. Spanish Journal of Rural Development, Vol. IV (3): 63-72.)

attributes and affect the land in different ways, some of which might be very long lasting.

Land use decisions are influenced by three groups of factors. First, physical, biological, and technical factors. These include the quantity, nature, availability and characteristics of land resources, which set definite limits on what operators, can do in using land resources. Secondly, institutions, which are the 'rules of the game' in a society. These establish the human devised constraints and unconscious habits that shape human interactions. Thirdly, within these constraints, economic forces, supply and demand, are shaping present land use.

To explain land-use change economic analysis uses a number of basic assumptions. The most important is that economic agents, consumers and operators, are rational entities that try to maximize their income (profit) or welfare (utility). The stimuli to which these market agents respond are prices. Prices therefore allocate scarce recourses, such as land or minerals. This cause-and-effect reasoning happens in a quasi-experimental condition of all-other-things-equal (or ceteris paribus). This allows us to make statements such as "other things equal, if the relative price of a good decreases (increases) people will buy more (less)." This brings about another assumption of more is always better than less. The condition of all-other-things-equal includes the assumption of given and constant preferences, constant technologies (e.g. no substitute of the good appears on the market), and no conspicuous consumption or prestige values (buying because the price is high) during the time period of analysis. In this model economy the so-called economic human has perfect information to be able to assess all the different opportunities and their associated advantages and disadvantages as well as prices.

The amount of land producers need to sustain the production of goods is directly influenced by the signals they receive from their customers by the way of prices. For instance, land resources tend to gravitate to those uses that command the highest market prices and offer the highest net returns to investment. Rising price levels usually encourage bringing more land into use and to use the land already in use more intensively. Nevertheless, producers are also faced with factors that can affect their desire of land, which can be understood as independent of the actions of customers. Most of these factors have to do with the way in which producers use land, in combination with other factor inputs such as labour and capital, to produce their economic output. In order to understand how producers make decisions about the combinations of its inputs, we need to introduce a few important concepts that are at the core of production theory in economics.

The first of these concepts is that of diminishing returns. Land, as well as other factors of productions is governed by the *Law of Diminishing Returns*. Whenever additional inputs are added to a production process, a point is eventually reached after which the additional product per unit of the input decreases and eventually becomes negative. Faced with this constraint, producers then have to know the point at which a further increase of factor inputs such as land becomes uneconomical. Their objective of course is to maximize net returns; net profits minus net costs. In order to accomplish this, they need information about the contribution of each input to total output, specifically the marginal contribution of each input to output. Economists call this the *value of the marginal product* (VMP), which is the value of additional unit of output produced by each additional unit of input. At the same time, producers also need to have information in which way inputs contribute to the overall cost of production. Again, the important information is the way production costs increase with every unit-marginal-increase in inputs. Economists call this the *Marginal Factor Costs* (MFC) of each input. Since producer's objective is to maximize their returns they will want to produce at a point where their total net profits minus their total net costs are at the highest. This point is reached when the VMP equals the MFC.

Producers treat land as another input to production. Land operators then, will try to find the proportion of inputs that derive the maximum returns for them. Therefore, they will evaluate not only the marginal value of their land by itself, but in comparison with the marginal value of other factor inputs. Competition among the owner of each factor ensures that land rents, wages, and returns to capital do not exceed the value of marginal product. For this comparison to have any use for them, substitution between factors of production needs to be possible. In the short-run producers are unable to make this substitution between land and other factor inputs because land is a quasi-fixed factor of production. Most of the time producers can make proportionate decisions between land and other factor inputs only when they are deciding over long-term investments. This fact is also referred to as the *concept of proportionality*. Here the main question to be asked is how land compares with other factor of production. This is when another main economic concept in land use comes into play: intensity. When applied to land use, the term refers to the relative amounts of capital and labour combined with units of land in the production process. At the margin, levels of intensity in land use are usually classified into two types: intensive and extensive. Intensive margin of land use occurs at points were any use of a given tract of land with marginal or last variable inputs of capital or labour barely pay their costs. On the other hand, extensive margin of land use occurs when operators who are applying their variable inputs to the intensive margin for a given use of land find that they are using the lowest grade of land of decreasing use-capacity they can afford to operate.

Rent is the price of, or income from, land and any real property computed per unit of time. This concept is called the *contract rent*. For tenants, contract-rent payments are operating costs. From an investor's point of view, rent is the return of investment amongst different investment possibilities. The rent paid by the user of the real estate compensates for the investor's opportunity costs, which represents the returns they could receive from alternative investments. In contrast to other concepts of land, contract rent involves an actual payment to the property owner, which may differ from the imputed rent as conceptualized in the following concepts.

Land rent in the classical sense is income derived from selling the services of a unit of land, independent of the services of capital or labour. It represents the economic return that accrues to land for its use in production. Differences in rent-paying capacity or different classes of land are often explained in terms of different locations or different qualities of land. The former may include closeness to water, infrastructure, amenities, and cultural centres while the latter might refer to soil types or factors related to climate, and human-made improvements, such as buildings.

Land resources are at their highest and best use when they are used in a manner that provides an optimum return to their operators or to society. The highest and best use is subject to change in the quality of the land resource, changes in technology, changes in the demand structure, or changes in zoning ordinances or other legal frame conditions. In modern societies, land resources usually earn a higher return when used for commercial or industrial purposes than for any other uses. This simple ordering of land uses manifests itself in a profile with successively lower rates used for residential, cropland, grazing or forestry purposes (Barlowe, 1986, p.13). The more highly valued and more economically productive uses usually take the better lands for their purposes leaving the lower-priority areas to other uses. Continuing expansion of high-priority lands leads to a discrimination of the economic supply of land available for other users and eventually reduces idle land for undisturbed succession of the environment.

14.4 Efficient allocation of land resources

So far we have discussed the market forces governing the consumption and use of land. Nevertheless, the basic question still remains: do these laws of supply and demand assure the most efficient allocation of land for society as a whole, that is, where the total net present benefits from its alternative uses are maximized? Decisions about land use usually affect individuals in a society in different ways and what is favourable for one person might be a disadvantage for others.

Since it is difficult or unfair to say that the welfare of one person is more important than the welfare of the other, how can we decide which land use option is better for the society? Economists have a specific way of identifying at which point the most "efficient" allocation of resources can be reached. We can think of occasions when it is in fact possible to move to a better state of affairs. We can say that a situation B is preferred over situation A when

(1) Everyone is better off in B than in A; or
(2) At least one person is better off in B and no one is made worse off by moving from A to B. Those who gain by moving from A to B can, out of their gains, compensate those who lose and still be left with a positive gain.

If any of these conditions are met, either by governmental action or by contractual agreements, we can say that it is possible for society to improve its total net benefits. The potential for the market system by itself to derive the most efficient allocation of resources given a private property approach is based on these three

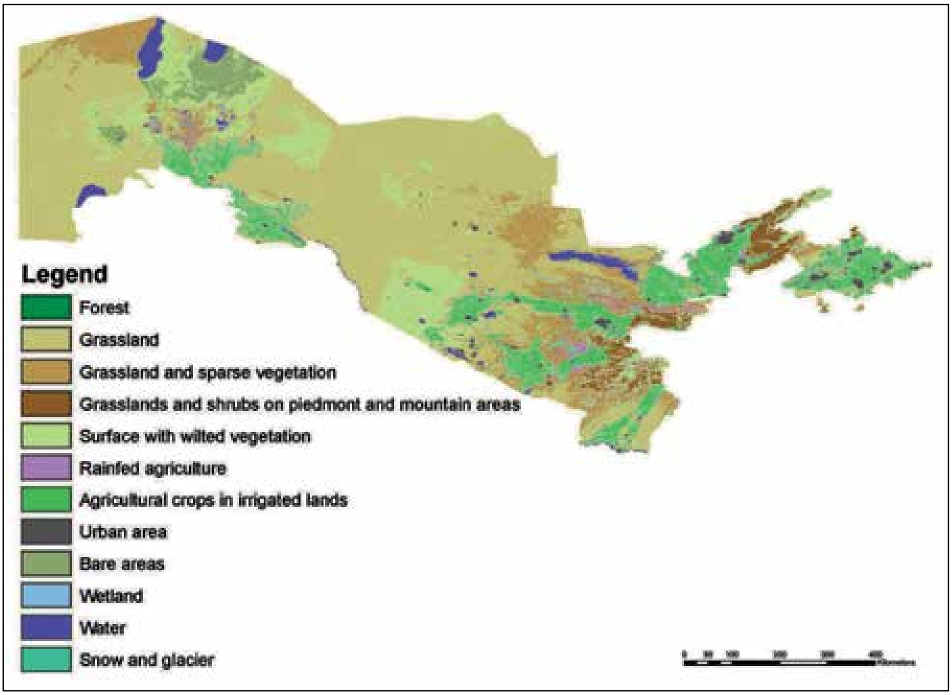

Figure 14.2. Land cover map of Uzbekistan. Source: Based on compilation of national ecosystem and biophysical resource base with global system (GLCN,2000), 9 main classes of land cover were defined.

requirements. In the real world these requirements are not necessarily met in all instances. Particularly the first requirement, exclusivity, is frequently violated in practice. While economic analysis typically assumes that land operators bear all the costs and benefits from their activities, individual action usually affects third parties. For instance, if a developer does not take into consideration the loss of welfare to other people caused by his project, an external effect exists.

An externality (or a negative externality in this case) exists every time the action of one individual negatively affects the welfare of another, and the latter is given no compensation to account for these losses. Externalities are very frequent in land use situations given the multiple products and costs often associated with uses of land resources. For instance, forests can be used for timber production, recreation, watershed protection, and wilderness, and often it is not possible or too costly to avoid interference amongst these different uses. This has to do with the public good character of many environmental goods. The main feature of these goods is its open access, that is, nobody can be excluded as soon as it is provided. Also, public goods are said to be non-rival goods, since one person's consumption of a good does not diminish the use by others. Examples of public goods are sunshine, clean air, open space, and scenic amenities. Most of the goods represent a mixture of public good and private good elements.

By far the most popular approach to deal with externalities is by government intervention. There are many different ways by which the government can exercise its power to influence land use decisions. For example, the government has the power to tax. These taxes can be used for many different purposes such as encouraging land utilization, attain conservation and environmental goals, promote ownership, favour particular types of investment, and others. The government also has the power to purchase land for various reasons; highways, conservation, resource development. In the US approximately 39% of the surface land area is held in public ownership. Also, the government has the power to subsidize certain purposes, such as the promotion of particular land-use practices. But the central instrument of land use control is *zoning*. The idea of zoning means the division of land into districts having different regulations. Since zoning implies the separation of different uses of land, many of the negative effects resulting from physical interdependencies in production and consumption can be eliminated. Other important land use controls are subdivision controls, which impose restrictions to developers of land; and building and housing codes, which regulate construction, maintenance and use of structures.

A different possibility of dealing with conflicting land use options is negotiation amongst stakeholders. In this process all of the potentially affected groups and individuals of a land development project are invited to discuss the implications, alternatives, and modes of compensation.

Nevertheless, all government intervention modes have something in common. If the transaction costs (that is the costs of intervention, negotiation, collecting information) are high enough to exceed the benefits of intervention, a non-intervention policy might be the best option.

In general, as with other resources, markets tend to allocate land to its highest valued use. Consider Figure 14.3, which graphs three hypothetical land uses – residential development, agriculture, and wilderness. The left-hand side of the horizontal axis represents the location of the marketplace where agricultural produce is sold. Moving to the right on that axis reflects an increasing distance away from the market.

The vertical axis represents net benefits per acre. Each of the three functions, known in the literature as *bid rent functions,* records the relationship between

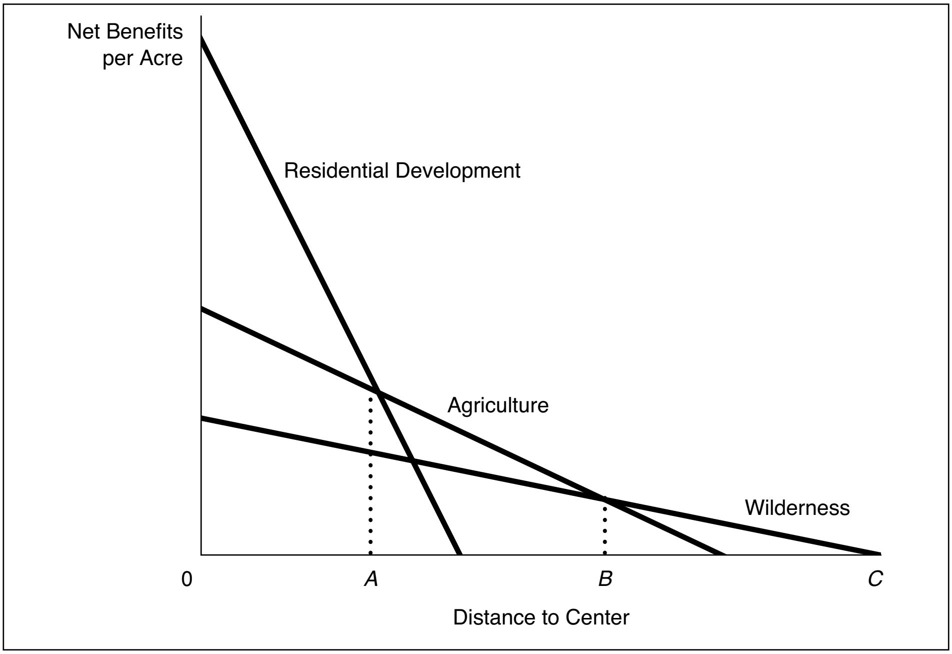

Figure 14.3. The Allocation of Land. (Source: Tietenberg, T., Lewis, L. (2012) Chapter 10. A Locationally Fixed, Multipurpose Resource: Land in Environmental & Natural Resource Economics 9th Ed., p.238)

distance to the centre of the town or urban area and the net benefits per acre received from each type of land use. A bid rent function expresses the maximum net benefit per acre that could be achieved by that land use as a function of the distance from the centre. All three functions are downward sloping because the cost of transporting both goods and people lowers net benefits per acre more for distant locations.

According to Figure 14.3, a market process that allocates land to its highest valued use would allocate the land closest to the centre to residential development (distance of *A*), agriculture would claim the land with the next best access (*A* to *B*), and the land farthest away from the market would remain wilderness (from *B* to *C*). This allocation maximizes the net benefits society receives from the land.

Although very simple, this model also helps to clarify both the processes by which land uses change over time and the extent to which market processes are efficient, subjects we explore in the next two sections.

14.5 Sources of inefficient use and conversion

In the absence of any government regulation, are market allocations of land efficient? In some circumstances they are, but certainly not in all, or even most, circumstances. What forces drive land use in conditions of market lead economy?

We shall consider several sets of problems associated with land-use inefficiencies that commonly arise in the industrialized countries: sprawl and leapfrogging, the effects of taxes on land-use conversion, incompatible land uses, undervaluation of environmental amenities, and market power. While some of these may also plague developing countries, we follow with a section that looks specifically at some special problems developing countries face.

Zoning, preferential tax treatment, and purchase of transferable development rights are some of the conservation and planning policies that affect Land Use and Land Cover.

a) *Zoning*: Some communities use zoning to direct land use. Zoning is a set of regulations that specify where different types of land use can occur. The primary purpose of zoning is to prevent situations where incompatible land uses occur near each other. A zoning map divides the community into zones. For each zone, an allowable use is defined. For example, in an R1 zone, single family detached housing is allowed, but industrial facilities are not. In this way, residential properties are protected from new development that will decrease their utility and value. Zoning regulations can specify what type of development can occur in a zone, how densely development can occur, and can place limits on building height, setbacks, how much open space must be provided in residential developments, and how many parking spaces must be provided for commercial buildings, for example.

Zoning has sometimes been blamed for encouraging Urban Sprawl. One common zoning tool is a limit on how densely houses can be built. Such a limit will lead to more land in residential use and more houses located further from downtown, resulting in loss of open space and increased commuting travel. However, zoning is also used to try to curb urban sprawl. A system of zoning rules called "Effective Agricultural Zoning" allows some residential development in agricultural areas, but does so in a way that preserves much of the farmland. With a traditional set of agricultural zoning rules for a rural area might require 10 acres of land for each new house, in order to avoid problems associated with wells and septic systems located too close to each other. However, if a 100 acre farm is converted into 10 estates, no farmland is preserved. In contrast, in an Effective Agricultural Zoning system, the owner of a 100 acre farm might be allowed to subdivide off 10 1-acre lots, resulting in 10 new homes but preserving a 90 acre farm.

b) *Preferential Tax Treatment*: this policy consists of the provision of property tax relief to preserve land in its current use. An example of Preferential Tax Treatment policy is the so called "use value assessment". A farm or woodlot may be very valuable because of its potential for development. The farmer or woodlot owner may wish to keep their land undeveloped, but might not be able to afford to pay the property taxes on the valuable land. Use value assessment allows the owner to pay taxes on the value of the land in its undeveloped use, rather than its value as a developable parcel. This reduces the property tax bill, and allows the owner to keep the land in its current state.

The major land uses benefited from preferential taxation include farmland, forest land and in recent years, a number of states have adopted preferential tax programs for open space and recreational lands.

c) *Purchase of Development Rights* (PDR): Development rights are designed to protect parcels of land that have environmentally valuable areas such as wetlands, wildlife habitat, or to protect lands that have productive agricultural value. Sometimes, when the value of a farm is higher as developable land than as a farm, the local government or a non-profit agency may buy the development rights from the farmer. The farmer keeps the land, but the government or agency purchases an easement that prohibits development of the land. The farmer can sell the farm, but the new owner is also prohibited from developing the land. Purchase of such a conservation easement is a good way to protect specific farms of particular importance from development.

d) *Transferable Development Rights* (TDR): In a TDR system, all owners of rural land are given limited development rights. If one owner wants to build more houses than he has rights to, he can buy development rights from other owners. Some areas (receiving areas) are designated as areas where owners can buy rights; other areas (sending areas) are designated as areas where owners can sell rights. Usually, local governments determine the number of rights that a bought on a case-by-case basis.

14.6 The influence of taxes on land-use conversion

Many governments use taxes on land (and facilities on that land) as a significant source of revenue. For example, state and federal governments tax estates (including the value of land) at the time of death and local governments depend heavily on property taxes to fund such municipal services as education. In addition to raising revenue, however, taxes also can affect incentives to convert land from one use to another, even when such conversions would not be efficient.

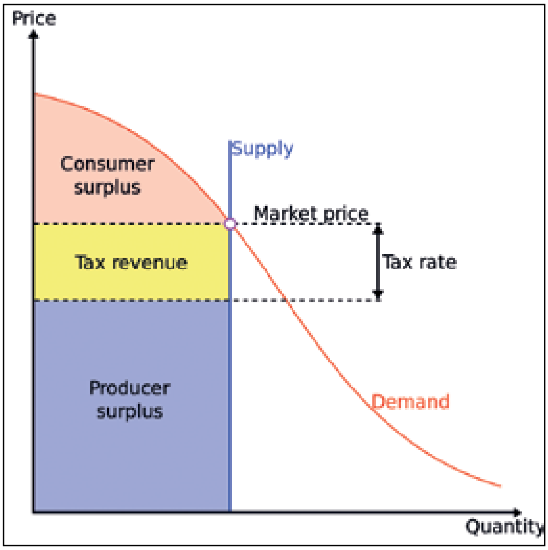

Figure 14.3. A supply and demand diagram showing the effects of land value taxation. (Source: McCluskey, William J.; Franzsen, Riël C. D. 2005).

Market Power. For all practical purposes, the total supply of land is fixed. Furthermore, since the location of each parcel is unique, an absence of good substitutes can sometimes give rise to market power problems. Because market power allows the seller to charge inefficiently high prices, market power can frustrate the ability of the market to achieve efficiency by preventing transfers that would increase social value. One example of this problem is when market power inhibits government acquisitions to advance some public purpose.

The value of the land (and many other macro-economic quantities too) can be expressed using two independent concepts:

The value, or, strictly speaking, the price, of a particular site of land is what a fair exchange brings in terms of money during an agreed trade or transaction between two parties, one of whom is the landowner. (This definition is conditional on no LVT being applied, because when it does apply, the exchange value is affected.)

The land value of the site is also directly related to its *demandable ground-rent*, which is its potential for use in either production or residential capacities. The capitalization of this rent gives the land value too. Land which is not useful has no value and is called *marginal land*, as explained by British economist David Ricardo already in 1816.

If the supply of land is fixed, the burden of the tax will fall entirely on the land owner, with zero or even negative deadweight loss.

Most taxes distort economic decisions and suppress beneficial economic activity. LVT is payable regardless of whether or how well the land is actually used. Because the supply of land is inelastic, land rents depend on what tenants are prepared to pay, rather than on the expenses of landlords, and so LVT cannot be directly passed on to tenants. The direct beneficiaries of incremental improvements to the surrounding neighbourhood by others would be the land's occupants, and absentee landlords would benefit only by virtue of price competition amongst present and prospective tenants for those incremental benefits; the only direct effect of LVT on prices in this case is to lower the unearned increment (reduce the amount of the socially generated benefit that is privately captured as an increase in the market price of the land). Put another way, LVT is often said to be justified for economic reasons because if it is implemented properly, it will not deter production, distort market mechanisms or otherwise create deadweight loss.

Box 14.1 Case study - Willingness to pay for land

Using the stated preference methods, research in the United States has found that the annual willingness to pay varies from a low of $.0002 (Bergstrom, Dillman and Stoll 1985) to a high of $44 (Swallow, 2002) per household per year per acre with mean willingness to pay values being $0.142 for contingent valuation studies and $0.17 for choice experiments (see Bergstrom and Ready 2006 and McConnell and Walls 2005 for a synopsis.

Values are higher in areas which are losing agriculture more rapidly - Suffolk County, New York, and Alaska as compared to a rural South Carolina county. Farmland conservation can benefit local communities in many ways resulting in food security, economic viability, better quality of life (amenities), and orderly development. Gardner (1977, pp. 1028-9) summarized these goals, arguing that market intervention is best warranted for providing amenities because they have public goods characteristics.

The strongest evidence comes from the amenity goal. Numerous studies show that the public has coherent preferences for the amenities of preserved farmland and stated preference evidence estimates statistically and substantively significant values for these services. In sum, the valuation studies suggest that much of past conservation activities probably passes the benefit- cost test. Research also shows that conservation is likely enhancing the economic viability of agriculture. Participating landowners tend to be more actively engaged in farming and use conservation funds to bolster their operations, hence revealing a future commitment to agriculture.

While in wetland mitigation banking the goal is to replace the exact function and values of the specific wetland habitats that would be adversely affected by a proposed project, in conservation banking the goal is to offset adverse impacts of habitat loss to a specific species.

Source: Beasley, Workman and Williams 1998, Bowker and Didychuk 1994, Ready, Berger and Blomquist 1997, Rosenberger and Walsh 1997, Johnston et al. 2001, Ozdemir 2003, Swallow 2002).

Land value tax can even have negative deadweight loss (social benefits) for societies, particularly when land use improves. Nobel Prize-winning Canadian economist William Vickrey believed that "removing almost all business taxes, including property taxes on improvements, excepting only taxes reflecting the marginal social cost of public services rendered to specific activities, and replacing them with taxes on site values, would substantially improve the economic efficiency of the jurisdiction. A correlation between the use of LVT at the expense of traditional property taxes and greater market efficiency is predicted by economic theory, and has been observed in practice.

Proponents, such as American free-market economist Fred Foldvary, state that the necessity to pay the tax encourages landowners to develop vacant and underused land properly or to make way for others who will. They state that because LVT deters speculative land holding, dilapidated inner city areas are returned to productive use, reducing the pressure to build on undeveloped sites and so reducing urban sprawl. For example, Harrisburg, Pennsylvania in the United States has taxed land at a rate six times that on improvements since 1975, and this policy has been credited by its long-time mayor Stephen R. Reed with reducing the number of vacant structures in downtown Harrisburg from around 4,200 in 1982 to fewer than 500. LVT is an eco-tax because it ostensibly discourages the waste of locations, which are a finite natural resource. LVT is an efficient tax to collect due to its immobility. Unlike labour and capital, land cannot move to escape tax.

14.7 Conservation banking

A *conservation bank* is a parcel of land containing natural-resource values that are conserved and managed, in perpetuity, through a conservation easement (described below) held by an entity responsible for enforcing the terms of the easement. Banks are established for specified listed species (under the Endangered Species Act) and used to offset impacts to the species occurring on nonbank lands.

The values of the natural resources are translated into quantified "credits." Project proponents are, therefore, able to complete their conservation needs through a one-time purchase of credits from the conservation bank.

Many people privately, or intellectually, support farmland conservation because of perceived benefits, including food security, less sprawl development, and environmental benefits. Such support might manifest financially, expressed directly through donations to land trusts or indirectly though voting for bond referenda or for representatives who fund state and local conservation programs. This revealed public support derives from a balancing of economic benefits expected to accrue from conservation and the expected costs. Incentive problems, such as missing markets and free riding, prevent the perfect alignment of private and public support.

There are four types of economic benefits from agricultural land conservation: (1) food security; (2) a viable local agricultural industry; (3) environmental amenities; and (4) orderly and fiscally sound development. Additional benefits include the slowing of suburban sprawl, providing a productive land base for the agricultural economy, the amenity values of open space and rural character, protecting wildlife habitat, and providing an opportunity for groundwater recharge in areas where suburban development is occurring. Despite farmland in Uzbekistan is disappearing from certain regions, sufficient national land resources remain to ensure the nation's food security. However, many people are revealing preference for and supporting the provision of local sources of farm products, presumably to obtain fresher products, avoid lengthy transportation, and support the local agricultural economy.

Providing the "option" for future food security may be a strong justification for conservation programs even if food security is not currently a concern. For many economists, rural and environmental amenities are the main reason why local communities might consider farmland conservation programs.

Food supply/security and the agricultural economy constitute goals that have related markets where goods and services are bought and sold. If people want to have locally grown food and a strong local agricultural economy, then they can patronize local farms and buy local goods to achieve these ends. However, rural amenities are not what we consider market goods – they are not bought and sold – and instead have the characteristics of public goods. Some type of public intervention is needed to ensure they are supplied. It is not surprising, therefore, that a large number of economic studies have valued the amenities from land conservation and these values suggest that many communities are receiving larger benefits from conservation than it costs.

Rural and environmental amenities could include views of cows in the meadow or fields of flowing wheat, open fields where rainfall recharges the groundwater, and areas where wildlife enjoy quality habitat. Bergstrom and Ready (2006, p. 2) define three types of amenity benefits of farmland protection: public access use values (e.g., farm and ranch tours, local "pick-your-own" fruits and vegetables), use values that do not involve public access (e.g., countryside scenery viewing, prevention of undesirable development) and non-use values (existence values of wildlife living on farm and ranch land, cultural heritage values, national food security). Researchers used surveys to determine which of these benefits were important to individuals and local communities considering a farmland conservation program.

In general, the public favours a mix between agricultural objectives such as local food production and a rural way of life and environmental objectives such as water quality and wildlife habitat. Also, rural amenities are frequently mentioned, which may incorporate both agricultural and environmental objectives as well as attributes like scenic quality.

Economists use two approaches to assess how much people are willing to pay for these amenities, which then helps evaluate whether the benefits of provision exceed the cost and also signals how much land should be preserved. The first approach asks people directly to state their preference about how much they would be willing to pay to preserve farmland giving people various scenarios to consider (i.e., contingent valuation, choice experiments, conjoint analysis). The second is to evaluate actual housing sales in the market to determine if the presence of preserved farmland, forest, and cropland increases or decreases the value of a house (i.e., hedonics).

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Chapter 15
Uzbekistan Agricultural Policies from Independence

15.1 The role of agricultural policies

Past gains in agricultural productivity have come at a large environmental cost. Why?

Part of the answer, of course, can be found in an examination of the externalities associated with agriculture. Many of the costs of farming are not borne by the farmers, but by others subjected to contaminated groundwater and polluted streams. But that is not the whole story. Government policies must bear some of the responsibility as well.

Agricultural policy is the set of government decisions and actions relating to domestic agriculture and imports of foreign agricultural products. Governments usually implement agricultural policies with the goal of achieving a specific outcome in the domestic agricultural product markets. Some overarching themes include risk management and adjustment (including policies related to climate change, food safety and natural disasters), economic stability (including policies related to taxes), natural resources and environmental sustainability (especially water policy), research and development, and market access for domestic commodities (including relations with global organizations and agreements with other countries). Agricultural policy can also touch on food quality, ensuring that the food supply is of a consistent and known quality, food security, ensuring that the food supply meets the population's needs, and conservation. Policy programs can range from financial programs, such as subsidies, to encouraging producers to enrol in voluntary quality assurance programs.

Agrarian reforms are an intrinsic component of the package of market-oriented policy measures implemented in the transition economies of the former Soviet Union (FSU). In the less industrialized countries of Central Asia, which are heavily reliant on agriculture and primary extraction, restructuring the rural economy presents special challenges. In Uzbekistan, continuing central controls and a state monopoly over agricultural land has led to a different configuration of transition to the market from that of the European republics of the FSU. Nonetheless, the initial stages of transition in Uzbekistan, as elsewhere, have been accompanied by economic recession and rising unemployment, as well as greater reliance on

Table 15.1.Main indicators of agricultural development in Uzbekistan (Source: www.fao.org)

	1992	1997	2002	2007	2012	2014
Population economically active	7 686 000	8 637 000	10 040 000	11 711 000	13 404 000	13 966 000
Population economically active in agriculture	2 568 000	2 569 000	2 643 000	2 714 000	2 723 000	2 689 000
Male population economically active in agriculture	1 376 000	1 391 000	1 450 000	1 518 000	1 553 000	1 547 000
Female population economically active in agriculture	1 192 000	1 178 000	1 193 000	1 196 000	1 170 000	1 142 000
Agriculture, value added to GDP (%)	34.83	32.18	34.25	23.95	19.02	18.8
Human Development Index (HDI) [highest = 1]				0.6263 (2005)	0.6571	0.661 (2013)

the domestic economy for basic goods and on informal self-help networks to palliate increasing pressures on existing safety nets.

The agricultural sector has acted as a "shock absorber", providing livelihoods for an ever greater number of people on a shrinking resource base, especially in the high population density areas of the Ferghana valley. It must be noted here that only 10% of the territory of Uzbekistan is habitable land and that the rural population over 60% of the total is concentrated on 4.5 million hectares of irrigated arable land in oases and along rivers. The amount of arable land per rural resident (0.37 hectares) is low compared to other FSU republics (two hectares per person in Ukraine and 0.75 in densely populated Moldova).

The main function of Agrarian Policy of Uzbekistan are:

- Provide population of the country with food products an economic reasonable price;
- Provide an agriculture share on country's budget
- Solving the problem such as preservation of the environment

The pace and content of agrarian reform in Uzbekistan is being shaped by a complex set of factors. These range from the inheritance of the Soviet period to current domestic political considerations and the agenda of the international donor community. This section offers a general introduction to the discussion of the gender-differentiated outcomes of agrarian reform based on fieldwork in the provinces of Andijan and Khorezm. It focuses on three key issues: 1) the place of agriculture in the overall economy and its significance to the state; 2) the nature and scope of agrarian reforms; and 3) the place of land in the household economy.

15.2 Agriculture in industrialized nations

The rather dramatic historic increases in crop productivity were stimulated by improvements in machinery; increasing utilization of commercial fertilizers, pesticides, and herbicides; developments in plant and animal breeding; expanding use of irrigation water; and adjustments in location of crop production. For example, in the United States, corn is produced on more acreage than any other crop. Yields per ha more than quadrupled between 1930 and 2000. Milk and dairy production have also shown marked productivity improvements. In 1944, average production per cow was 2,074 kg of milk per year. By 1971, the average had risen to 4 500 kg. By the end of the twentieth century, the average had risen to 7,700 kg per cow! Other areas of the livestock industry show similar trends.

Among other aspects it points out that a huge shift to mechanization has occurred as farm equipment (dependent upon non-renewable fossil fuels) is substituted for animal power. This trend has not only provided the foundation for an increase in scale of the average farm and a reduction in the number of farms, but it also raises questions about the sustainability of that path.

In the past century agriculture has been characterized by increased productivity, the substitution of synthetic fertilizers and pesticides for labour, water pollution, and farm subsidies. In recent years there has been a backlash against the external environmental effects of conventional agriculture, resulting in the organic and sustainable agriculture movements. One of the major forces behind this movement has been the European Union, which first certified organic food in 1991 and began reform of its Common Agricultural Policy (CAP) in 2005 to phase out commodity-linked farm subsidies, also known as decoupling. The growth of organic farming has renewed research in alternative technologies such as integrated pest management and selective breeding. Recent mainstream technological developments include genetically modified food.

In 2007, higher incentives for farmers to grow non-food biofuel crops combined with other factors, such as overdevelopment of former farm lands, rising transportation costs, climate change, growing consumer demand in China and India, and population growth, caused food shortages in Asia, the Middle East, Africa, and Mexico, as well as rising food prices around the globe. As of December 2007, 37 countries faced food crises, and 20 had imposed some sort of food-price controls. Some of these shortages resulted in food riots and even deadly stampedes. The International Fund for Agricultural Development posits that an increase in smallholder agriculture may be part of the solution to concerns about food prices and overall food security. They in part base this on the experience of

Vietnam, which went from a food importer to large food exporter and saw a significant drop in poverty, due mainly to the development of smallholder agriculture in the country.

Agriculture imposes external costs upon society through pesticides, nutrient runoff, excessive water usage, loss of natural environment and assorted other problems. A 2000 assessment of agriculture in the UK determined total external costs for 1996 of £2,343 million, or £208 per hectare. A 2005 analysis of these costs in the USA concluded that cropland imposes approximately $5 to 16 billion ($30 to $96 per hectare), while livestock production imposes $714 million. Both studies, which focused solely on the fiscal impacts, concluded that more should be done to internalize external costs. Neither included subsidies in their analysis, but they noted that subsidies also influence the cost of agriculture to society.

In 2010, the International Resource Panel of the United Nations Environment Programme (UNEP) published a report assessing the environmental impacts of consumption and production. The study found that agriculture and food consumption are two of the most important drivers of environmental pressures, particularly habitat change, climate change, water use and toxic emissions. The 2011 UNEP Green Economy report states that agricultural operations, excluding land use changes, produce approximately 13% of anthropogenic global GHG emissions. This includes GHGs emitted by the use of inorganic fertilisers agro-chemical pesticides and herbicides; (GHG emissions resulting from production of these inputs are included in industrial emissions); and fossil fuel-energy inputs. "On average we find that the total amount of fresh residues from agricultural and forestry production for second generation biofuel production amounts to 3.8 billion tonnes per year between 2011 and 2050 (with an average annual growth rate of 11% throughout the period analysed, accounting for higher growth during early years, 48% for 2011-2020 and an average 2% annual expansion after 2020)."

Considerable and persuasive evidence suggests that the problem is one of distribution and affordability. Poverty, population growth, and the sufficiency of food production are all related. High poverty levels have historically been associated with high population growth, and high population growth rates may increase the degree of income inequality. Furthermore, excessive population levels and poverty both increase the difficulty of achieving food sufficiency. We shall focus here on strategies to increase the amount of food available to the citizens in the poorest counties. What can be done?

15.3 Agriculture in developing countries

What are the relative merits of increasing domestic production in the developing countries as opposed to importing more from abroad? There are several reasons for believing that many developing countries can profitably increase the percentage of their consumption domestically produced – one of the most important is that food imports use up precious foreign exchange.

Most developing countries cannot pay for imports with their own currencies. They must pay in an internationally accepted currency, such as the American dollar or the Euro, earned through the sale of exports. As more foreign exchange is used for agricultural imports, less is available for imports such as capital goods, which could raise the productivity (and hence incomes) of local workers.

The lack of foreign exchange has been exacerbated during periods of high oil prices. Many developing nations must spend large portions of export earnings merely to import energy. In 2005, for example, fuel imports made up 30 percent of all imports for countries including Cameroon, the Cote d'Ivoire (Ivory Coast), Jamaica, Kyrgyzstan, Mongolia, India, and Indonesia. Little remains for capital goods or agricultural imports. While this pressure on foreign exchange suggests a need for greater reliance on domestic agricultural production, it would be incorrect to carry that argument to its logical extreme by suggesting that all nations should become self-sufficient in food. The reason why self-sufficiency is not always efficient is suggested by *the law of comparative advantage.*

Nations are better off specializing in those products for which they have a comparative advantage. Total self-sufficiency in food for all nations is not an appropriate goal. Those nations with a comparative advantage in agriculture due to climate, soil type, available land, and so on, such as the United States, should be net exporters, while those nations, such as Japan, with comparative advantage in other commodities, should remain net food importers. This balance should not be allowed to get out of line, however, by creating an excessive reliance on either domestic production or imports.

Due to price distortions and externalities in the agricultural sector, most developing countries have developed an excessive dependency on imports. What kind of progress has been made in reducing this dependency? Generally, import dependency has increased, not fallen and the lowest-income countries as a group are having trouble even keeping up with population growth, much less making headway in reducing imports. Progress on this front is elusive, it seems.

The structure of agricultural production in developing countries has radically changed in the last two decades. Since the late 60s and 70s, the World Bank and its various agricultural research institutes have actively promoted the adoption of industrial (high chemical input) agricultural methods such as the Green Revolution 'miracle' seeds, promising landfall yields. These high technology methods were expected to benefit all farmers, including the poor. Since yields would increase, incomes were also expected to increase.

However, the heavy dependence on imported inputs could not be sustained economically by developing countries. This was compounded, in the 1970s and 1980s, by the oil crisis and the debt crisis. The economic and financial crisis in developing countries led to the proliferation of loan packages from the international financial institutions. Structural adjustment policies were then introduced as a condition for loans borrowed by countries. Since the 1980s, close to 100 countries have been forced to take on structural adjustment packages. The policies included on the one hand forced liberalization, and on the other, the conversion of domestic agricultural production for exports.

Over the last two decades, the experience of small farmers from Central to South America, Africa and Asia have been strikingly similar. Many have been pressured to switch from diverse traditional polycultures to monocultures for overseas markets. For example, the provision of extension services and credit were often conditioned upon farmers accepting the new technologies in export crops that were promoted. Farmers have been likewise forced to switch to export crops when local prices in staples and traditional crops have plummeted as a result of cheap subsidized imports often from the industrialized countries flooding the local markets. For the majority of small farmers, the process has been one of systematic impoverishment. Many have even been squeezed out of farming altogether. Instead of abating food scarcity, which has always been the reasoning for public investment in agricultural technology and hybrid seeds, food surpluses are increasing on the world market, yet ironically, for those most in need, hunger and food insecurity remains more of a problem.

15.4 Why do large farms have an advantage?

How does agricultural industrialization and production for the export market lead to the uprooting and destruction of small farmers while benefiting the large farms? According to Shiva, agricultural industrialization and exports increases single commodity harvests. With all farmers growing the same commodity over large areas, the prices farmers receive from their crops come down, while the costs of inputs which are imported have been on an upward spiral. As a result, farmers' profit margins get drastically narrowed. As costs of production increase, farmers experience a cost-price squeeze. In this process, only the larger farms can survive.

The market is such that the costs for small farmers to use the high input system are larger than for big farmers. Poor farmers cannot afford to buy fertilizer and inputs in volume. Big growers get discounts for large purchases. Poor farmers cannot hold out for the best price for their crops, while larger farmers whose circumstances are less desperate can. Big farmers can afford to pay for irrigation services, which may not be within reach of small farmers.

Yield increases from high yielding Green Revolution technologies have been decelerating, and in some cases stagnating and even contracting. The highest yields have been obtained by using ever larger inputs of fertilizer and irrigation water, which in many places have passed the point of diminishing returns. Greater use of these inputs is becoming less productive.

In comparison to traditional varieties, outputs are small. Traditional rice farming in Asia produced 10 times more energy in food than was expended to grow it. Today's Green Revolution rice production cuts the net output in half.

In India, adoption of the new Green Revolution seeds led to a six-fold increase in fertilizer use per ha. Farmers used an average of 12.7 kg/ha of fertilizer in 1970. By 1995, usage had gone up to 76.6 kg/ha. While food grain production increased 84% from 82 million tonnes in 1961 to 185 million tonnes in 1997, consumption of chemical fertilizers rose from 292 thousand tonnes in 1961 to 16,422 thousand tonnes in 1996-97, a 15,000% increase.

Similarly, in the Philippines, rice production increased in the late 1970s, and early 1980s as a result of the Green Revolution, but has since been on the decline. Analysts attribute it to these 'high yielding varieties'.

The big question that many sceptics would ask is: why then is there so much food scarcity in developing countries? If industrial agriculture and cheap subsidized imports from the North eliminated, can developing countries produce enough food for themselves?

Africa is home to 213 million chronically malnourished people (25% of the total in developing countries). By 1995, over one-third of the continent's grain consumption apparently depended on imports. However, according to researchers, Africa has enormous, still unexploited potential to grow food. In countries notorious for famines, the area of unused good-quality farmland is many times greater than the area actually farmed. A central reason for Africa's lack of food production is due to the colonial land grab that has continued into the modern era. It has displaced peoples and production of foodstuffs from good lands toward marginal ones. The good land is mostly dedicated to the production of cash crops for export or is even unused by its owners. Also, public resources, including research and agricultural credit, have been channelled to export crops to the virtual exclusion of peasant-produced food crops. Since the 1980s, the pressure to export to pay interest on foreign debt has reinforced this imbalance.

The other factor which has greatly impoverished African peasants is the subsidized food surpluses from the developed countries which are dumped on Africa. This often takes away the entire local market for the local producers, who end up in debt, landless or even bankrupt. It is critical for small farmers in developing countries to have adequate protection from drastic liberalization measures since the market does not work in their favour, but in favour of the big players.

Trade policies must therefore provide small farmers and the rural poor in developing countries the protection needed to ensure the continued viability of their livelihoods. They also need protection against dumping and unreasonable competition from subsidized producers abroad. Providing greater security for the rural masses will bring about more even and equitable development for countries as a whole.

Furthermore, for reasons of food security, national, political and economic security, as well as due to the special place of agriculture in developing countries' economies, developing countries also need policy flexibility to ensure that existing production of staples and food crops for domestic consumption are not threatened, and, if insufficient, can be increased.

To these ends, we recommend the following:

A. Demolish WTO's Single Undertaking Structure:
B. Create a Development Box for Developing Countries
C. Market Access
D. Domestic Supports
E. Export Subsidies
F. Market Structures
G. State Trading Enterprises (STEs)

15.5 Agricultural policies in Uzbekistan since independence

After the collapse of the Soviet Union, the newly emerging states began to change their agricultural policies. In Uzbekistan, changes included: (1) re-distribution of land to families, in order to prevent social unrest; (2) increasing wheat production for food security; (3) implementing a quota system for cotton and wheat; (4) changes in agricultural subsidies; and, (5) disintegration of large collective farms. In the following we will describe in detail these developments in Uzbek agriculture and some of their impacts on water resource use.

Figure 15.1. New Porloq cotton variety at Mirzaev Shavkat Dalalari farm, Paxtachi, Samarkand, Uzbekistan.

Land re-distribution to family plots in order to prevent social unrest as in most other former Soviet republics, the collapse of the Soviet Union brought massive disruption to the economy and hardship to the people of Uzbekistan. In rural areas, the centralized command system broke down and millions lost their livelihood as the social infrastructure, previously supported by collective farms, collapsed.

The first series of post- Soviet policy changes in the agricultural sector occurred in response to this crisis in the form of the expansion of individual family plots. The objective of the policy was to ease social tension, already in evidence before the end of the Soviet Union, by ensuring that the population would be able to produce basic foodstuffs. Starting in 1986, over 1.5 million families were given the opportunity to extend their personal plots, and some 0.5 million additional families acquired plots for the first time. In 1991, additional plots were allocated to families living in rural areas to provide forage for cattle. During this short period of time, over 0.5 million hectares of irrigated lands, more than 10% of the total irrigated area, was allocated for small-scale production, and mainly used for growing vegetables. These plots previously produced cotton and were, in fact, some of

Uzbekistan's most productive cotton lands, with soils of high organic matter and low salinity. The increase of both size and area of the family owned plots had a two-fold impact on water resources: an increase in irrigation water consumption and competition for water between family plots and farmlands. The competition for water between the family plots and farmlands is one of the challenging water problems of irrigated agriculture in Uzbekistan and elsewhere in Central Asia.

The second major change made to Uzbek agricultural policy after the end of the Soviet Union was driven by the desire to reconsider national food security and achieve grain (wheat) independence. During the Soviet period, approximately 3-4 million tons of wheat was imported into the Uzbek Soviet Socialist Republic annually, primarily from other Soviet States, in exchange for cotton. After the collapse of the Soviet Union, the demand for cotton from traditional barter-based exchange markets (Russia and other FSU states), while still high, declined in favour of cash-based markets elsewhere. Similarly, wheat could no longer be bartered for cotton, but rather had to be paid for in cash.

The intention of the Uzbek government to reduce state ownership of business enterprises was formulated in the Law of Destatization and Privatization adopted in November 1991, just two months after the declaration of independence. In application to agriculture, the general strategy for reducing the direct involvement of the state in business enterprises primarily involved transformation of state farms into collective farms and other shareholder forms, as well as reorganization of large-scale state-owned livestock and poultry complexes into joint-stock companies. The destatization of state farms in Uzbekistan had been completed by 1992, as most were transformed into collective farms, agricultural production cooperatives, and joint-stock companies. The small number of state farms remaining are appropriately engaged in the production of public goods, such as agricultural education, research and development, livestock and crop selection.

It was originally thought that the transformation of collective and state farms into production cooperatives and private agricultural companies would dramatically improve their efficiency and help them go from chronic losses to new profits. In the 1990s all farm-reorganization programs in Uzbekistan stressed the goal of restructuring loss-making enterprises and various pilot projects were implemented with the objective of transforming loss-makers into profitable farms. This strategy espoused the traditional socialist ideology of economies of size ("large is better") and accordingly strove to achieve "horizontal transformation" of inefficient large-scale enterprises into hopefully efficient large-scale corporate farms.

This strategy was doomed to fail, as experience in all CIS countries shows, and the *shirkat* (agricultural cooperatives) phase of Uzbek agriculture was short-lived. The 1998 Land Code introduced the shirkat as the new organizational form that would make agriculture efficient and profitable. It was decreed at that time that all collective farms and other agricultural enterprises should reorganize as shirkats by 2001. Yet the 7 hopes placed in this old-new organizational form did not materialize and just five years later, in 2003, a new strategy abandoned the shirkat as unprofitable and shifted the emphasis to peasant farms as the optimal organizational form for long-term development of agriculture. The main points of the 2003 strategy are:

- Recognize peasant farms as the preferred farm type for the future development of agriculture, based on long-term leasing of state land
- Create a legal framework for complete economic and financial independence of peasant farms
- Ensure market-based financing arrangements for peasant farms: o complete accountability for farm production expenses o access to commercial bank credit with an option to mortgage the land use rights
- Create education and training programs in business and farm management for peasant farmers
- Ensure accelerated development of a market-oriented rural infrastructure capable of providing the full range of services to peasant farms
- Facilitate the development of "alternative" providers of machinery and mechanical field services for peasant farms
- Confirm the farmers' obligation to produce for the state in accordance with the sowing pattern prescribed in the lease contract (Kontseptsiya razvitiya fermerskikh khozyaistv na 2004-2006 gody, Presidential Decree 3342, October 2003).

The new strategy opened the road for "vertical transformation", i.e., transition from large-scale corporate farms to much smaller family farms with clear commercial orientation. In response to the new strategy, the number of shirkats declined rapidly from over 2,000 in 2003 to just 314 in 2006 as their land was broken up into relatively small allotments, and the remaining shirkats are slated to be dismantled into peasant farms in 2007-2008.

The land reform legislation that emerged in Uzbekistan after 1989, and especially in 1998, proved resilient enough to take the country through three major waves of farm restructuring. The first wave involved strengthening of household plots and first attempts at internal reorganization of agricultural enterprises through introduction of independent subdivisions and intra-farm family-based leases (1989- 1997); the second wave mainly focused on formal reorganization of traditional collective farms into shirkats simultaneously with further strengthen-

Figure 15.2. Siyab Dehkan Market, Samarkand.

ing of household plots (now called *dekhkan* farms) and establishment of peasant farms as an entirely new organizational category (1998-2002); finally, the third wave starting in 2003 boldly shifted the agricultural sector to predominantly individual farming – dekhkan farms in livestock production, peasant farms in crops – while restricting the role of corporate farms (agricultural enterprises) to highly specialized operations].

15.6 Livestock farming in Uzbekistan

The livestock sector in Uzbekistan is traditionally dominated by rural families, not large commercial farms. Back in the Soviet period, more than 50% of livestock were in the care of rural households. The share of households increased over time as large state-owned livestock complexes were privatized and dismantled during the first phase of reform in the 1990s. In parallel efforts began to encourage livestock specialization among the emergent peasant farms, but these essentially preferred to concentrate in crop production. Today peasant farms manage about 5% of cattle in Uzbekistan, while 95% is in households (dekhkan farms). Agricultural enterprises have no role in the livestock sector beyond livestock selection farms, experimental stations, and some specialized karakul sheep operations in the desert. Livestock production in Uzbekistan suffers from low efficiency, which is manifested in very low milk yields.

Figure 15.2. Ghannam fat tail sheep at the market.

The Presidential Decree 308 of March 2006 is intended to provide strategic and tactical instruments for the improvement of milk yields and overall efficiency of livestock production. Recognizing the dominant role of household farms in the livestock sector, the decree appropriately focused on support measures designed to increase the number of cattle or cows in each family and on development of services designed to improve livestock productivity. The size of the household herd is one of the main factors for increasing family incomes and wellbeing, while quality feed and veterinary services, including artificial insemination, are crucial for increasing milk yields. Moreover, larger household herds and greater production volumes are likely to stimulate commercialization among households, which on the one hand will further raise family incomes, but on the other hand requires government support for the development of sales channels.

The livestock development program in Uzbekistan has the following objectives:

- Increasing the number of both dekhan farms and peasant farms engaged in livestock production
- Improve livestock productivity

By these means resolve existing difficulties with rural employment and raise rural family incomes

Box 15.1 Presidential Decree 308 of March 2006 on livestock farming

The decree introduces the following measures:
Rural people engaged in livestock production in household plots and dekhkan farms (i.e., rural households that do not qualify as peasant farms) will be regarded by the state as gainfully employed and will be accordingly entitled to state pension. This decision applies irrespective of whether the rural households sell any of their livestock products or consume everything within the family. This is a totally new approach to the standing of rural households in the labour economy.

Encourage household plots and dekhkan farms to increase their herd. Implement a charity program financed by businesses, wealthy peasant farmers, and public organizations, whereby poor families with many children will be entitled to receive one cow. These efforts should increase the cattle herd in dekhkan farms from 6 million head in 2005 to 8.5 million head by the end of 2010.

Encourage peasant farmers to double their herd from 330,000 head of cattle in 2005 to 660,000 head of cattle in 2010, while increasing the number of specialized livestock farmers from 8,000 in 2005 to 11,000 in 2010. The share of peasant farms in the cattle herd will accordingly increase from 5% in 2005 to about 7.5% in 2010.

Improve the access to veterinary and artificial insemination services by expanding the network of service points.

Organize auctions for sale of pedigree cattle to household plots, dekhan farms, and peasant farms. The program envisages sale of 100,000 head of pedigree cattle through auctions to farmers between 2006-2010.

Expand microcredit facilities for household plots and dekhkan farms (excluding peasant farms) to facilitate purchase of cattle. A total of 158 billion sum will be allocated to microcredit between 2006 and 2010, of which 80% will come through commercial banks (at subsidized interest rates and using streamlined lending procedures) and 20% through the rural support fund. Given that cattle sells for about 2 million sum in auctions, the microcredit facility will be sufficient to buy less than 80,000 head of cattle between 2005 and 2010 – a drop in the sea compared with the projected increase of 2.5 million head in household plots and dekhkan farms (see 1 above).

Improve the access of rural households (household plots and dekhkan farms) to concentrated feed by instructing the state-controlled suppliers to establish feed storage facilities and sale outlets in rural areas. The program envisages a seven-fold increase in the number of sale outlets for concentrated feed across the country, from 113 in 2005 to 773 in 2010. State-controlled feed mills will be allowed to purchase grain directly from peasant farmers (and not through state procurement channels) as a raw material for concentrated feed production.

Pedigree livestock breeders will be exempt until 2010 from custom duties on all imports of genetic materials and related equipment.

Source: Zvi Lerman. (2008). *Agricultural Development in Uzbekistan: The Effect of Ongoing Reforms.* Discussion Paper No. 7.08. The Hebrew University of Jerusalem. pp 8. http://ageconsearch.umn.edu/bitstream/37945/2/lerman-uzbek.pdf

15.7 National food security

Paying for food imports was a major challenge for the newly independent Uzbekistan and had implications for national food security. In response, the Uzbek government mandated a reduction of cotton production and an increase in that of wheat. Due to an overlap of the growing seasons for wheat and cotton, an increase in the wheat area meant a decrease in the cotton area. The result was an expansion of winter wheat area from 620,000 ha in 1991 to 750,000 ha in 1996 and a similar decline in cotton area. Wheat production increased substantially, from 1.0 million tons in 1991 to 5.2 million tons in 2004, and Uzbekistan has become a wheat exporter of some 500,000 tons annually over the last three years.

The shift towards wheat production appears to have had two impacts on water use in Uzbekistan, one related to the total quantity of irrigation water consumed and the other related to irrigation management. In terms of water use, cotton receives 10,000-12,000 m^3/ha, with virtually all water coming from irrigation. On the current area of 1.5 million ha, this amounts to 15-18 bln m^3 of water or 27-35% of agricultural water use. Winter wheat is irrigated four to six times during the growing season (October-June) and consumes approximately 8,000-9,000 m^3 of water per hectare. However, only about 60% of total water consumption is delivered through irrigation, with the rest supplied by rainfall. With a total area now similar to that of cotton, winter wheat consumes approximately 10 BCM of irrigation water, equal to the 20% of agricultural water use.

Thus, the shift from cotton to wheat area has decreased overall irrigation water requirements. In terms of irrigation management, the large increase in the area under winter wheat has had a negative impact on the state of the irrigation-drainage (I&D) network, and has resulted in higher irrigation water consumption rates than would otherwise have been the case. Earlier, under cotton monoculture, during the non-vegetation period of October-March, there were no crops in the field, and the I&D network was cleaned and prepared for the next season during the fallow fall-winter months. At present winter wheat is grown from the fall (October) to the next vegetation season (June). While the evapotranspiration of wheat during this period is low, it still requires five to six irrigations. Therefore, the I&D network is operating almost 12 months a year, leaving little time for cleaning or minor repairs.

According to FAO experts, food security status is determined by indicators of food security, stability, access and healthy food. These are

Stability: to be food secure, a population, household, or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity).

Food availability: the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid). The most frequently utilised measure for food availability is per capita daily energy supply (DES) in calories. According to FAO methodology, the DES indicator is calculated by types of food consumption on the basis of the food balances. The FAO calculates food balances using data on specific goods in the source equivalent (before processing) for various sources of food supply (production, reserve stocks, trade) and various kinds of use (or consumption) of products (forage, seeds, industrial application, waste).

Food access: physical, economic and social access to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Physical accessibility of food entails the availability of food articles in the market in a volume and assortment required by consumers, as well as the existence of infrastructure to supply the population with the foodstuffs. Economic accessibility of food means that all social groups of population are able to purchase sufficient foodstuffs. In other words, economic access is present when households generate sufficient income to buy food and the country generates enough hard currency to pay for food imports. Social accessibility denotes fair access to the food for the entire population, regardless of culture or religion.

Utilisation: utilisation of food through adequate diet, clean water, sanitation, and healthcare to reach a state of nutritional well-being in which all physiological needs are met.

15.8 The production quota system

During the Soviet period, central planners could influence the cropped area and production by controlling state farms as well as inputs to those farms. After independence, the new government still tried to maintain control of some aspects of farm output, for example, influencing the shift away from cotton and towards wheat production described above. Initially, the Uzbek government had quotas for almost all agricultural products. The major objectives of the state quota policy at the beginning of 1990s were to supply essential agricultural products to protect people from food deficits, increase agricultural productivity, increase rural employment, increase agricultural exports and decrease imports.

Water management organizations are forced to deliver water to the cotton and wheat growing farms first, and withhold supplies from potentially higher value agricultural and non-agricultural users. A second problem with the quota system with respect to water management is its impact on operational costs and their recovery. While irrigation water delivery at the system level is still free, newly established Water Users Associations (WUAs) who distribute water at the farm level must charge for their services in order to generating operating funds. The fixed prices at which cotton and wheat are procured simply do not leave enough money with farmers to pay for WUA services and, as a result, many of WUAs are unable to pay for operations and maintenance and are in effect non-operational.

The system of interaction between water management organizations (WMOs) and primary water users was based on seasonal water contracts. The contracts had the status of water rights for users and described the amount and timing of water delivery. The contracts also described the roles and responsibilities of WMOs in water supply and the obligations of primary water users in conservation and efficient water use and maintenance of irrigation infrastructure. As the transformation to smaller farm units progressed, the number of water users and the number of requests for water services increased, while the quantity of water needed per request fell. WMOs were unable to sign water contracts with the large number of water users, discipline in water use declined and both WMOs and water users failed to follow the established rules, resulting in widespread disruption in water provision with direct impacts on farm productivity.

Other important aspects of farm reform include land rights and the tenancy system. Together with farm restructuring, legal changes in land use and allocation were introduced, which strengthened land use rights and gave greater security of tenure to individual farmers. At present, individual farmers have 49-year tenancy agreements. However, legally, the land rights can be cancelled if farmers do not fulfil production agreements three years in a row. This uncertainty makes strategic investment in land conservation as well as water management risky, reducing resource productivity.

15.9 Irrigation water management reforms

After the disintegration of collective farms into numerous individual farming, units' workload of water management organizations (WMOs) has increased tremendously. Former on-farm water management level, previously handled by collective farms has been left unattended. However, financial and human resources of WMOs have not been increased since agricultural reforms. Therefore, WMOs could not sign water contracts with numerous water users at the former on-farm level, resulting in a loss of discipline and neglect of roles by both parties. Ownership and funding of on-farm water infrastructure of collective farms was discon-

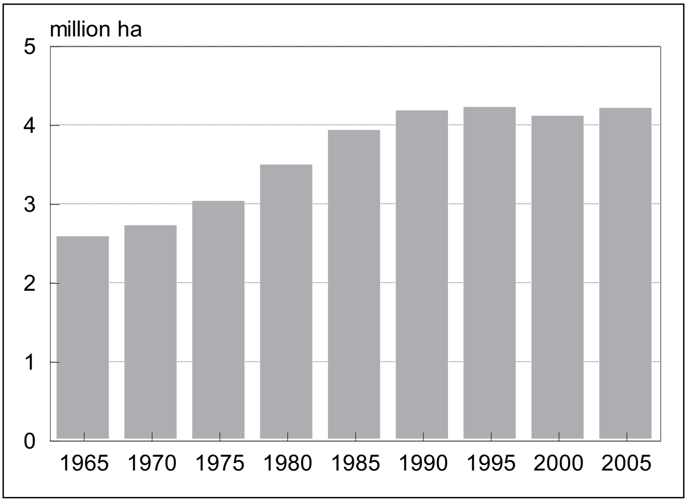

Figure 15.3. Growth of Irrigated land in Uzbekistan. (Source: Zvi Lerman. 2008.)

tinued after de-collectivization of agricultural production, the funding of on-farm water infrastructure started to diminish and, as result, it has degraded dramatically.

Until 2003, the management of major irrigation canals and water reservoirs was solely under state control. All irrigation infrastructure at the main system level was managed territorially, through provincial and district level water management organizations. Each of the territorial units (district, province) had state production quotas for cotton and wheat. As water was such a crucial factor, each governor tried to appropriate more water for his or her district. The resulting territorial fragmentation of water resources management led to inequitable water distribution and head-tail water disputes.

On 21 July 2003, the Cabinet of Ministers of the Republic of Uzbekistan issued a decree (No. 320) to reform the water management system by transferring water management from an administrative-territorial system to a basin approach. The main goal of this reform was to consolidate water management through the establishment of Water Users Associations (WUAs) and Canal Management Organizations (CMOs), operating within single hydraulic units, in order to ensure equal access to water for different users and improve water use efficiency.

Agriculture in Uzbekistan is critically dependent on water. Crop production and most of livestock production (with the exception of the karakul sheep grazing in the desert) is confined mainly to irrigated areas. All cotton is grown under irrigation, and grain production largely shifted to irrigated lands in the 1970s. The share of dry farming declined over the years, and it accounts for less than 20%

of arable land today. The rapid population growth necessitated continuous expansion of irrigated areas over the years. The total area under irrigation increased from 2.2 million hectares in 1953 to 4 million hectares in 1985 (Figure 15.3). The expansion of irrigation accelerated after 1970, and peak growth was achieved in the decade 1976-1985, when the irrigated area was growing at an average rate of 90,000 hectares per year. The introduction of new irrigated lands slowed down considerably after 1985 (to about 30,000 hectares per year) and stopped almost completely after independence. This slowdown in the last twenty years was due not only to increasingly acute budget constraints, but also to the realization that the potential for irrigation expansion had been largely exhausted and new reclaimed areas were of marginal quality for agriculture. The irrigated area has remained static at 4.2 million hectares since 1990.

Huge glaciers covering more than 8,000 sq. km in the high mountains in the East are the main store of water for Uzbekistan: glacier-fed rivers and mountain streams rising mainly in Tajikistan and Kyrgyzstan provide more than 95% of the water used for irrigation. The groundwater resources do not contribute significantly to the total supply of irrigation water, and groundwater is mostly used to water desert pastures from wells. Water is pumped from reservoirs, and also directly from the two major rivers of Amu Darya and Syr Darya, in quantities fixed by multilateral agreements with Uzbekistan's neighbours. Water has always been regarded as a nationally owned resource, and the irrigation system is built, run, and operated by the state. The volume of water needed to irrigate crops is set by scientists working in research institutes, and not by farmers who produce the crops. The government absorbs the cost of delivery through the regional canal network, and farms pay today 10,000-20,000 sum ($7.5-$15) per hectare per year for irrigation water.

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Chapter 16
Storable, Renewable Resources: Forest

16.1 Forests and sustainable development

Forests provide a variety of products and services. The raw materials for housing and wood products are extracted from the forest. In many parts of the world, wood is an important fuel. Paper products are derived from wood fibre. Trees cleanse the air by absorbing carbon dioxide and adding oxygen. Forests provide shelter and sanctuary for wildlife and they play an important role in maintaining the watersheds that supply much of our drinking water. Although the contributions that trees make to our everyday life are easy to overlook, even the most rudimentary calculations indicate their significance.

Forests have a key role in sustainable development. The most typical single character of collapsed societies is the loss of their forest. The most telling example may be Easter Island in the middle of the Pacific Ocean, where a once vivid society after destruction of the forests only could house a small and desperate population in a barren landscape. The story has been told repeatedly, but a most convincing version is in the book *Collapse* by Jarred Diamond. In his book Diamond analyses a dozen societies which collapsed, all of them characterised by the loss of forest resources. Most of these examples refer to the history but some are contemporary, e.g. the development in present Montana, USA.

Forests in Europe today are increasing; the forested area reached a minimum around the beginning of the 20th century, when agriculture expanded to include also less profitable, previously forested land; much of this has later been reforested. There was, however, a previous deforestation crisis in Europe, which occurred in the beginning and mid of the 1700s. Large area of forests was then almost clear-cut, due to the large demand for timber, mostly in the mining industry. A number of proposals for resolving the forest crisis included:

- Applying energy-saving stoves in housing and metallurgy and by improving the heat-isolation of buildings.
- Searching for substitutes for timber, such as peat.
- Cultivating new forests by “sowing and planting of wild trees”.

In 1713 von Carlowitz published the book *Sylvicultura oeconomica*, the first comprehensive handbook of forestry. The 400 page book deals with the question, how to achieve "Conservation and cultivation of timber, a continuous, steady and sustained use". The concept of Sustainability (Nackhaltigkeit) appears for the first time in his book on forestry.

Also in mid Sweden forest was a critical resource. Wood was burned to heat the rock and crack the mountain to mine the iron ore; it was used to reduce iron from its oxides, and to melt it in the blacksmiths' ovens. Sweden was then the largest iron exporter in the world, feeding the wars in Europe. In 1767 the "kakelugn" a channelized stove, which very efficiently took up and stored the heat, was introduced. It made Swedish energy technology the best in Europe, and meant much to reduce wood use for heating. Swedish homes got a reputation for being warm and nice.

It is interesting to see that the ways to deal with the resource crisis were then the same as today. Management skills – as in the handbook on forestry – and technological solutions – such as the channelized stove and insulation of buildings – and substitution for example by the use of peat are all on today's agenda.

Today again forests are in focus in the Sustainability discussion. Half of the original forests of our planet are gone. In the climate negotiations deforestation in the world have been recognised as a main reason for climate gas emissions, accounting for up to 25% of global greenhouse gases, and in the discussion on a global treatment the out phasing of the fossils fuels are accompanied by the so-called RED, REDD and REDD+ Programmes which address "reduced deforestation and forest degradation" in developing countries.

Almost the entire deforestation dilemma refers to tropical forests on the southern hemisphere. The boreal forests in northern hemisphere, including northern Europe, may however significantly contribute to reducing the emission by serving as a sink of atmospheric carbon dioxide, and they are included in the REDD negotiations.

In its Global Forest Resources Assessment 2000, the Food and Agricultural Organization of the United Nations reports that during the 1990s, the world lost 4.2% of its natural forests through deforestation. During the same time period, the world gained 1.8% of natural forests through reforestation (including plantations), afforestation (the conversion of un-forested land to forest), and the natural expansion of forests. The result was a net reduction in natural forests of 2.4% over the 10-year period. These data suggest that current forestry practices may be violating both the sustainability and efficiency criteria.

Managing forests is no easy task. In contrast to crops such as cereal grains, which are planted and harvested on an annual cycle, trees mature very slowly.

The manager must decide not only how to maximize yields on a given amount of land but also when to harvest and whether to replant. In addition, a delicate balance must be established among the various possible uses of forests. Since harvesting the resource diminishes other values (such as protecting the aesthetic value of forested vistas or providing habitat for shade-loving species), establishing the proper balance requires some means of comparing the value of potentially conflicting uses. The efficiency criterion is one obvious method.

One serious problem, deforestation, has intensified climate change, decreased biodiversity, caused agricultural productivity to decline, increased soil erosion and desertification, and precipitated the decline of traditional cultures of people indigenous to the forests. Instead of forests being used on a sustainable basis to provide for the needs of both current and subsequent generations, some forests are being "cashed in."

16.2 Uzbekistan's forest resources

The forest fund, i.e. Goskomles of the Republic of Uzbekistan as of January first 2010, makes 9,120 thousand ha. Of them the area covered by wood was 2 776 thousand ha. The specific weight of this wood makes 30,6%, and the total wood volume of the Republic of Uzbekistan -6,2%.

The forest fund of Goskomles for 5 years, i.e. from 1993 to 1998 increased 1 159 thousand ha at the expense of transmission to bodies of forest economy of sandy massif of Navoi district, and special protection natural territory for this period, which was increased by 12,1 thousand ha (NAPCDRU, 1999).

On soil-climatic conditions the forest fund is distributed on sandy, mountainous, flood lands and valleys' zone. Table 16.1 summarises the species growing in these different zones. The main species of cultivated forests are shown in table 16.2.

The preliminary analyses of condition of woods in Republic of Uzbekistan has shown the occurrence of complex of problems in field of social and economic life of people, uses of natural resources and preservations of ecological balances. The open bottom of sea on large spaces is sharp deteriorated the condition of environment of territory of Republic of Uzbekistan and has resulted in unwanted ecological problems: the processes of desertification, cover with salt sands the settlements and agricultural areas, particles of the salts are transferred with wind on huge territories.

The effects of ground water and particles of the salt and other adverse factors have resulted in to decrease of biological stability of planting and as a whole of forest ecosystems, decrease of their useful function, wide distribution of centres

Table 16.1 Forest species in different nature types in Uzbekistan?

Nature zone	Area of the nature zones (thous. ha)	Species	Area covered by wood or shrubs (thous. ha)
Sandy zone	7,833	saksaul, kandim, cherkes, grebenchik and other sandy shrubs	2,655.3
Mountainous zone	1,173	zarafshan archa, pistachio-tree and maple	280.3
Floodlands wood along Amudarya, Sirdarya, Chirchik, Zarafshan and Akhangaran rivers	84	turanga, willow planting and shrub-grebenchik.	30.9
Valley zone	57	artificial woods – wood cultures	
In salinity and marsh-ridden soils		the shrubs – grebenchik and malts	9,120.0
Total	9,120		2,776

Table 16.2 Distribution of forests on main species. The percentage ratio in forests of Republic of Uzbekistan.

Species	Abundancy (%)
trout	1,80
tamarisk	9,10
other bushes	5,40
nut trees	2,30
other trees	1,50
saltwort	6,80
Asiatic poplar	2,60
saxaul	60,60
spruce	9,90

of vermines and illnesses of wood and sharpening of problems of forest-protection. At present, the dry bottom of Aral Sea makes more 1 200 thousand ha, ground deposits of sand are fixed with forces of wood-economies of the Goskomles of Republic of Uzbekistan. The annual volume of planting and sowing of sandy and wood kinds, with simultaneous execution of mechanical fastening of salinity sand does not exceed 10 thousand ha and for total wooding and fastening of sand is required more one hundred years. Moreover in coastal zones of Aral Sea – in Republic Karakalpakstan, Bukhara, Navoi and Khorezm districts – require the fastening and wooding of mobile sand on areas 300 thousand ha.

Wood-economy enterprises is conducted sand-fixed works. The work on creations of protective wood plantings are executed in heavy soil-climatic and social

– household conditions, in large removal from settlements (150-200 km), and experience the difficulties because of shortage of means and insufficient equipment with powerful tractors, gears and automobiles with high practicability, capable to work in heavy soil-climatic conditions. Thus, the serious problems in fields of ecological safety, creation of protective wood planting, sand-fixing, wood-recreation, protection of woods, protection of wood from pests and illnesses were generated.

16.3 The economics of forest harvesting

How can economics be combined with forest ecology to assist in efficiently managing the important forest resource? Starting simply, we first model the efficient decision to cut a single stand or cluster of trees with a common age by superimposing economic considerations on a biological model of tree growth. This model is then refined to demonstrate how the multiple values of the forest resource should influence the harvesting decision and how the problem is altered if planning takes place over an infinite horizon, with forests being harvested and replanted in a continual sequence. Turning to matters of institutional adequacy, we shall then examine the inefficiencies that have resulted or can be expected to result from both public and private management decisions and strategies for restoring efficiency.

We begin by characterizing what is meant by an efficient allocation of the forest resource when the value of the harvested timber is the only concern.

In the early days of Natural Resource Economics, first model the efficient decision in the problem of maximizing profits for a private forest owner by means of optimal decisions about the "rotation period" for a commercial forest. In recent years, the non-commercial value of forests has become an important consideration and attention within the subject of forest economics has expanded to include questions about optimal management for forests which have multiple uses. These uses include not only timber and paper pulp production, but wildlife habitat, recreational opportunities, ecosystem support, carbon sequestration, watershed enhancement, fire cycles, etc.

As a stand of trees grows, the amount of wood usable for commercial harvests changes over time. Assume a stand of trees (monoculture=same species) is planted at time 0. The total volume of wood produced grows until time t_e. Beyond that, the trees become "over mature" and begin to decay from old age, disease, insect predation, fire, or wind, and eventually collapse. Wood volume develops slowly in the beginning and increases until time t_x, then slows toward date t_e, when the maximum volume is achieved (Figure 16.1). The volume-age relationship can be

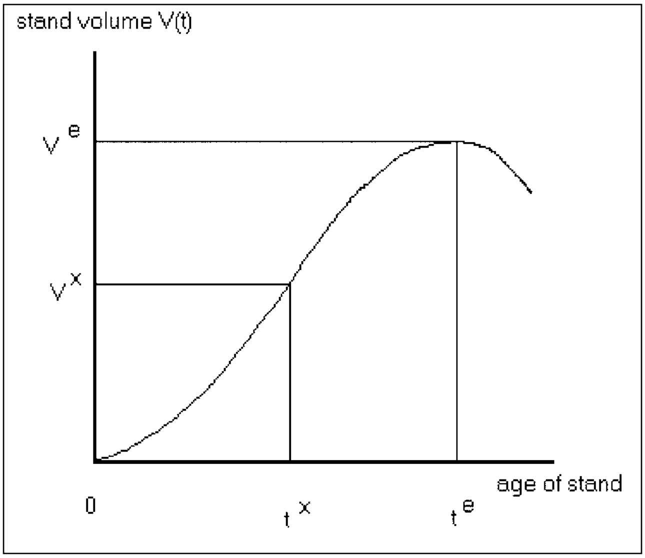

Figure 16.1. The growth and decay of a forest stand. v = volume of the forest stand, t = time (age of stand).

influenced by thinning, fertilizing, and repressing pests. Forestry cultivation and management is known as *silviculture*.

When should a stand of trees be harvested? We will get a different answers from a biologist and from an economist. Biologists used to focus on a concept called "mean annual increment" (MAI). The biological harvest rule is to harvest the stand of trees when MAI is maximized. The maximum of the MAI is called the "culmination of the mean annual increment" (CMAI). The marginal growth in a stand of trees has been called the "current annual increment" (CAI). An economist would think of the CAI as the marginal product of time and the MAI as the average product of time. Strictly biological considerations would lead to a decision to harvest when the age of the stand maximizes the MAI.

The biological criterion for deciding upon a harvest time ignores several of the considerations an economist would take into account. To begin with, we must worry about the costs of harvesting and planting. The simplest case is one single harvest cycle. Planting costs are incurred at time 0, and harvest costs are borne when the stand is harvested. Harvesting costs, as well as the value of the wood when sold, must be discounted back to the present. Suppose p is the price at which a unit volume of wood can be sold, and c is harvest cost per unit of wood, so that revenues from harvesting V volumes of wood at time t are

$$R(t)=(p-c)*V(t).$$

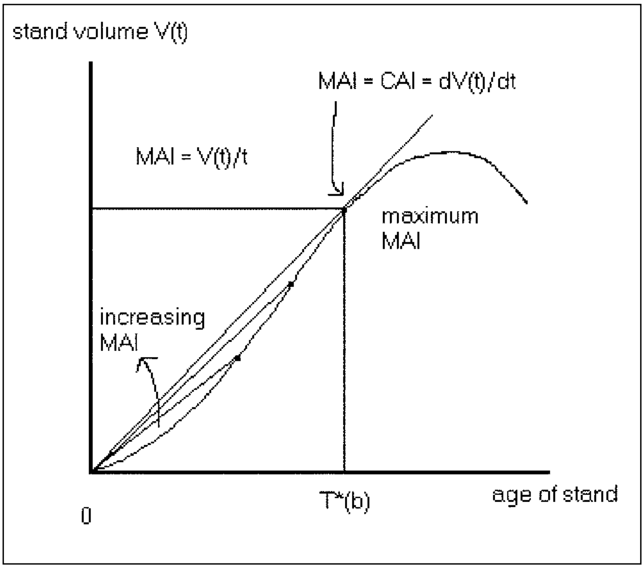

Figure 16.2. Optimal harvest time dependence on revenue. Harvest V m^3 of wood as a function of time t. MAI = mean annual increment and CAI = current annual increment.

If we let net harvest revenues be

P = p-c, then R(t)=P*V(t).

Let q(T) signify the set of current values at each point in time which have a common present value, q(0), when discounted back to the present. Conversely, the profile q(T) represents the value of a sum of money, q(0), when it is capitalized forward for each number of years. Finding the harvest time, T, which maximizes the present value of the harvest means finding the highest iso-present-value line that just touches the harvest revenue function R(t). We can see in Figure 16.2 that harvest time T maximizes the present value of the harvest. [There is only one discount rate in this diagram. The higher iso-present-value curves rise more quickly because they start at a higher base level.]

Intuitively, the time interval T will depend upon the discount rate, dq/dt. It is interesting that, at T*, the slope of the iso-present-value curve equals the slope of the function that describes the current net value of the harvest. The slope of the latter is approximately dR(t)/dt, where R is the revenue and t is time. The slope of the former is dq/dt = rq. [In discrete time, when one unit of time passes, q increases by rq.] Thus we have

dR(T*)/dt = rq(T*). Where R(T*)=q(T*)

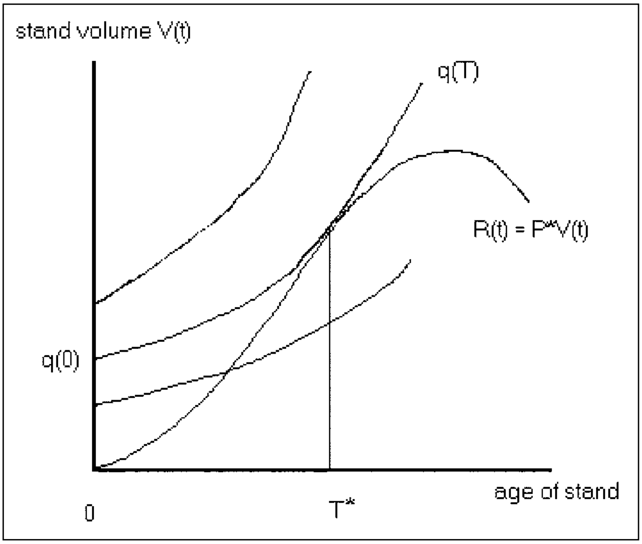

Figure 16.3. Optimal harvest time dependency on discount rate. q = the current value at each point in time, v = the stand volume of the forest, r = revenue and t = time.

as well, because the two curves are the same height at T*. Substituting, we can write:

dR(T*)/dt = rR(T*) or [dR(T*)/dt]/R(T*) = r,

which we can write more simply as ? dR/dtR = r.

Back in 1930, American economist Irving Fisher noticed that this meant that trees should be cut when the proportional rate of growth of their net sales value equals the interest rate. They should be cut when their value grows as fast "on the stump" as "in the bank." Living trees are natural assets that compete with financial assets in terms of rate of return. At time less than T*, the rate of return on the natural asset exceeds the interest rate on financial assets. Beyond time T*, the rate of return on the natural asset falls short of the return on financial assets. Therefore, time T* is the optimal point at which to convert your holdings from the natural asset to the financial asset. When tree growth slows so that the rate of return is higher on financial assets, it is time to liquidate your natural assets (time for portfolio adjustment).

What happens to the optimal harvest time, T*, when we change any of the features of the problem:

a. *Higher interest rates*: This will make the family of iso-present-value curves steeper, meaning that the tangency with the current net value function for the harvest will occur at an earlier point in time. Lower interest rates will have the opposite effect.
b. *Higher planting costs:* Planting costs occur at time 0 and will have no effect on the optimal harvest time unless they exceed the present value of the net harvest revenues, in which case it would not make any economic sense to plant such a crop of trees. As long as planting costs are less than the present value of net harvest revenues, they will have no effect on the optimal harvest time.
c. *Higher lumber prices or higher harvest costs*: Recall that R(t) = (p – c) V(t). If p or c changes (each is assumed to remain constant over time), then R(t) will be scaled up or down, proportionally. However, the condition for T* is determined by dR/dtR = r. Any change in scale for R will factor out of the left hand side, leaving no effect on the optimal harvest time, T*.

Within the context of this mathematical model, it is possible to consider the consequences of different types of interventions. We will not derive them formally, but you should be aware that a model such as this can be used to demonstrate these policies. Some potential policies will make the value of forestry on the plot of land go negative and end commercial forestry, but let's consider some policies that would not completely eliminate the industry:

a) Tax per ton harvested (royalty or severance tax): equivalent to an increase in harvesting costs. This will cause longer rotation periods. More wood will be harvested because efficient rotation interval is typically less than the time for maximum mean annual increment, so longer rotations will increase average annual harvests.
b) *Site-use tax:* tax per acre (equivalent to an increase in D). This will increase rotation intervals, more wood harvested overall.
c) *Tax on profits*: tax on residual income accruing to land in forest production; this cannot be shifted by changing rotation interval
d) *License fee per year* (rather than per rotation). The optimal rotation period is unaffected.
e) *Property tax based on value in current use*. This encourages keeping land in forestry rather than converting to higher-valued uses, especially if "rollback" clause is included, where change in land use incurs cumulative back taxes for differential in value.

16.4 Forests ecosystems values and proper forest management

The discussion above applies to the case where the only value derived from a forest is its value in commercial timber production. Here we shall discover sources of inefficiency in that decision, which have the effect of biasing profit-maximizing decisions toward excessive rates of deforestation. Non-timber values (NTV) values of forests have surged to the forefront of modern forest management problems. These values include

a) *Forests as reserves of biodiversity*. Gene splicing now allows researchers to transplant desirable genes from one species into another, creating new species with more valuable characteristics. Declining forest habitat contributes to the escalating rate of extinctions among species which may prove to be valuable.
b) *Global climate change*. Trees absorb carbon dioxide, one of the major greenhouse gases suspected of contributing to an apparent global warming trend, and thus may function as a *carbon sink*. Trees *sequester* (store) carbon. Reforestation would store carbon, burning of forests (or natural decay) releases carbon. The role of forests in *carbon sequestration* (or "pickling" of carbon) has been receiving considerable attention.
c) *Habitat and biodiversity.*; The protection of biodiversity is of immense value in tropical forests where diversity often is enormously large with a large number of indigenous species, that is, species which do not exist in any other part of the world.
d) *Ecosystem values*. Forests contribute to watershed maintenance and prevention of soil erosion. Deforestation has been a dominating factor in some of the large flooding events in recent years, for example in India.
e) *Population pressures*. Squatters with insecure tenancy on forest lands have no incentive for proper management of the resource. In poorer countries, fuel wood is a significant source of energy for cooking. Therefore population pressures can contribute to deforestation.

The recognition of the global scale of some of the uncompensated positive externalities associated with good forest management has led to a more efficient forest management, which explains the reversing trend towards deforestation, especially in developing countries. There are several ways in which this can occur.

Governments issue formal permits, *forest concessions,* to individuals or private corporations to manage certain areas of public forest for timber production. A concession is thus a kind of forest utilization contract. Governments can capture economic rents via forest charges, including taxes, charges per volume harvested, area charges, and exploration fees. Evidence is that forest concessions have been widely and seriously under-priced. If government does not use appropriate rents, they are earned by the firm as profits. Many countries are now reforming their forest concession policies. One consideration is that the concession time period should be long enough to foster efficient dynamic optimization by the firms, which enjoy the concession.

Debt-for-nature swaps are financial transactions in which a portion of a developing nation's foreign debt is forgiven in exchange for local investments in environmental conservation measures, in particular the protection of forests. Deacon and Murphy has examined the structure and occurrence of debt-for-nature swaps empirically. The emerging contract form is a product of weak enforcement of legal claims to environmental resources in developing countries, high costs for delineating and monitoring environmental outcomes, and nominal government ownership of the resources involved. The occurrence of swaps in individual countries is significantly related to host country attributes, including the presence of tropical land and threatened species, democratic political institutions, and large debt burdens.

Authorities may also establish *Extractive Reserves* to prevent that forest are clear cut to allow agricultural or urban development in forest regions where timber harvest has lower economic value to local communities, than what otherwise the land can be used for. The plantation of oil palms in Indonesia is a typical example, another is cattle farming in the Amazonas.

Land use controls that permit only certain restricted activities on the land are called *Conservation Easements*. For example, traditional uses by indigenous people may be allowed, and this further leads to that clear-cutting is prohibited.

The Bottom line on modern "forestry economics" are thus that the classic optimal rotation period models apply strictly to profit-maximizing commercial forest management. Newer versions of these model include amenity values as well as timber values (more complex models). Amenity values will change the optimal rotation periods. It may even make it optimal never to harvest. Modern research has less to do with commercial exploitation and more to do with understanding the positive externalities (and market failures) associated with forest management. Current fashionable topics are deforestation and debt-for-nature swaps and measurement of amenity values.

16.5 Poverty and debt may lead to deforestation

Poverty and debt are also major sources of pressure on the forests. Peasants see unclaimed forest land as an opportunity to become landowners. Nations confronted with masses of peasants see un-owned or publicly owned forests as a politically more viable source of land for the landless than taking it forcibly from the rich. Without land, peasants descend upon the urban areas in search of jobs in larger numbers than can be accommodated by urban labour markets. Politically explosive tensions, created and nourished by the resulting atmosphere of frustration and hopelessness, force governments to open up forested lands to the peasants or at least to look the other way as peasants stake their claims.

In eastern and southern Africa, positive feedback loops have created a downward cycle in which poverty and deforestation reinforce each other. Most natural forests have long since been cut down for timber and fuel wood, and for producing crops from the cleared land. As forests disappear, the rural poor divert more time toward locating new sources of fuel. Once fuel wood is no longer available, dried animal waste is burned, thereby eliminating it as a source of fertilizer to nourish depleted soils. Fewer trees lead to more soil erosion and soil depletion leads to diminished nutrition. Diminished nutrition reinforces the threats to human health posed by an inability to find or afford enough fuel, wood, or animal waste for cooking and boiling unclean water. Degraded health saps energy, increases susceptibility to disease, and reduces productivity. Survival strategies may necessarily sacrifice long-term goals simply to ward off starvation or death; the forests are typically an early casualty.

At the national level, poverty takes the form of staggering levels of debt. Repaying this debt and the interest payments flowing from it reduces the capacity of a nation to accumulate foreign exchange earnings. In periods of high real interest rates, servicing these debts commands most if not all foreign exchange earnings. Using these foreign exchange earnings to service the debt eliminates the possibility of using them to finance imports for sustainable activities to alleviate poverty. According to the "debt-resource hypothesis," large debts owed by many developing countries encourage these countries to overexploit their resource endowments to raise the necessary foreign exchange. Timber exports represent a case in point. Although a number of studies find empirical support for this hypothesis, not all do. And the support for extending the hypothesis to natural resources other than forests seems particularly weak.

16.6 Sustainable forestry

We have examined three types of decisions by landowners – the harvesting decision, the replanting decision, and the conversion decision – that affect the rate of deforestation. In all three cases, profit-maximizing decisions may not be efficient and these inefficiencies tend to create a bias toward higher rates of deforestation.

These cases present both a challenge and an opportunity. The current level of deforestation is the challenge. The opportunity arises from the realization that correcting these inefficiencies can promote both efficiency and sustainability.

Does the restoration of efficiency guarantee sustainable outcomes? Let's suppose that we apply the environmental sustainability definition to forestry. By this definition, sustainable forestry can be realized only when the forests are sufficiently protected that harvests can be maintained perpetually. Also, sustainable forestry would require harvests to be limited to the growth of the forest, leaving the volume of wood unaffected (or non-decreasing) over time. Efficiency is not necessarily compatible with this definition of sustainable forestry. Maximizing the present value involves an implicit comparison between the increase in value from delaying harvest (largely because of the growth in volume) and the increase in value from harvesting the timber and investing the earnings (largely a function of r, the interest rate earned on invested savings). With slow-growing species, the growth rate in volume is small. Choosing the harvest age that maximizes the present value of net benefits in slow-growing forests may well involve harvest volumes higher than the net growth of the forest.

The search for sustainable forestry practices that are also economically sustainable has led to a consideration of new models of forestry. One involves a focus on planting rapidly growing tree species in plantations. Rapidly growing species raise the economic attractiveness of replanting because the invested funds are tied up for a shorter time. Species raised in plantations can be harvested and replanted at a low cost. Forest plantations have been established for such varied purposes as supplying fuel wood in developing countries and supplying pulp for paper mills in both the industrialized and developing countries.

Plantation forestry is controversial, however. Not only do plantation forests typically involve a single species of tree, which results in a poor wildlife habitat, they also tend to require large inputs of fertilizer and pesticides. In some parts of the world, the natural resilience of the forest ecosystem is sufficiently high that sustainability is ultimately achieved, despite decades of earlier unsustainable levels of harvest. In the United States, for example, sometime during the 1940s, the net growth of the nation's timberlands exceeded timber removals. Subsequent surveys have confirmed that net growth has continued to exceed harvests, in spite of a rather large and growing demand for timber. The total volume of forest biomass in the United States has been growing since at least World War II; for the country as a whole, harvests during that period have been sustainable, although the harvests of some specific species in some specific areas have not.

16.7 Priority needs

What should be done to improve the management of forests in Uzbekistan? The Ministry of Agriculture and Water Management of Uzbekistan should include environmental issues in its agenda for agricultural policy development and consider establishing a separate environmental unit. Capacity building through environmental training for agricultural policy makers and other stakeholders is needed. Communication and coordination between the State Committee on Nature Protection and the Ministry of Agriculture and Water Management should be strengthened. Extension services should be developed, inter alia, to communicate information on environmentally friendly practices, such as soil conservation, fertilizer management, and improved water soil and salinity management technologies. Environmental standards should be established, with incentives for compliance, for example in the areas of water and salinity management, chemical use, and soil management.

Irrigation and drainage systems require further massive investments in rehabilitation and improved management, including expanding the role of water users associations. Water charges should be phased in as the state order system is phased out to give farmers an incentive to save water. In cooperation with other riparian states, a systematic basin-wide approach to water and soil salinity management should be developed and implemented.

Forests in Uzbekistan are state-owned and fill a protective role, with minor production of fuel wood and other timber from thinning (about 27,000 m^3/year and declining). Forests also produce about 500 t/year of food and medicinal plants. Most timber is imported from Russia and Kazakhstan (The World Bank, 2007).

Forest cover has shown a modest increase in recent years, despite a drop in designated forest areas. Illegal cutting occurs but does not appear to be of major proportions. Excessive grazing in forests is also a problem in some areas. While total forest land in Uzbekistan has declined by 31,000 ha, the area within that land that is actually covered by forest has increased by 49 000 ha (Uzbekistan 2005). The forest area is growing about 0.25% per year due to reforestation programs.

There are two strands to the government's forest policy. The first is reforestation – for example, in 2006 the target was to reforest 13,300 ha by seeding, planting of seedlings on 17,900 ha, and allowing natural regeneration on 11,000 ha. The second strand is sustainable management, including enforcement of sanitation and illegal cutting regulations, forest rehabilitation, and use of biological pest control methods. Nevertheless, some problems remain with illegal cutting and excessive grazing. As there is no commercial logging: certification is not used.

Table. 16.1. Brief characteristic of protected territories of the Republic of Uzbekistan
(Source: Evgeniy Botman, 2009.)

Name of protected territory	Prevailing landscape	Year of creation	Area (km²)
Zamin State Reserve	Mountain forest	1926/ 1959	268.4
Chatkal State Biosphere Reserve	Mountain forest	1947	356.8
Kyzylkum State Reserve	Tugai-sandy	1971	101.4
Nurata State Reserve	Mountain nut-bearing	1973	177.5
Kitab Geological Reserve	Mountain forest	1979	53.7
Zerafshan State Reserve	Valley-tugai	1975	23,5
Badai-Tugai Reserve	Plain-tugai	1971	64.6
Gissar State Reserve	Mountain-juniper	1973	814.3
Surkhan State Reserve	Mountain forest	1986	276.7
Zamin National Park	Mountain- juniper	1976	241.1
Ugam-Chatkal National Natural Park	Mountain forest	1990	5,745.9

There is some international support for these policies. Donor support has been received from GEF, UNDP, and Finland, especially for the Aral Sea region.

The mount of protected forests area also need to be enlarged. At present, there are nine reserves in Uzbekistan, three of which refer to valley-tugai reserves (Badai-Tugai, Kyzylkum, Zerafshan), four reserves refer to mountain juniper reserves (Chatkal, Gyssar, Zamin and Surkhan), one reserve refers to a geological reserve (Kitab), and the last one refers to a mountain-nut-bearing reserve (Nurata). The total area of Uzbekistan's reserves amounts to 2,274 km^2 or a little more than 0.5% of the country's territory. In most countries of the world the area of reserves varies between 3% and 7% or more. In addition, two national parks have been opened for ecotourism, with an area of 5,987 km^2 or about 1.4% of the country's total area (i.e. Zamin National Park and Ugam Chatkal State national Natural Park).

Reserves and national nature parks are administratively under the jurisdiction of various authorities such as the regional Khokimiyat, the State Committee for Nature Protection, the State Committee for Geology, and the Main Department for Forestry. Unfortunately, such distribution of responsibilities between establishments does not promote the implementation of a uniform nature protection policy in these protected territories.

The existing reserves and natural parks do not cover essential components of biodiversity of Uzbekistan. These under-represented vegetation types include populations of pistachio growing in the territory of Babatag forestry enterprise and in Sangardak forestry area of Uzun forestry enterprise, subtropical natural populations of fig, persimmon, pomegranate, sumach, grapes in the Tupolang river basin, and nut-bearing cenosises in most favourable places for their growth in Burchmulla forestry enterprise. For this reason, the network of protected territories of Uzbekistan requires significant expansion. This is also required by the Biodiversity Convention, to which Uzbekistan is a partner, and requested by the decision of the 2010 COP10 of that convention in Nagoya, Japan, and the *Strategic Plan for Biodiversity 2011-2020* and the Aichi Biodiversity Targets to be implemented by 2020.

Chapter 16 sources:

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UZWATER

This compendium is produced for a master level course in the UZWATER project. It consists of some newly written material as well as previously published texts extracted from freely available books, reports and textbooks on the Internet, dominated by publications from the Baltic University Programme. The sources used for each chapter is listed at the end of the chapter. The compendia of the Uzwater project are produced exclusively for Master students free of charge at the participating Universities and is not to be sold or be freely available on the Internet.

The UZWATER project is an EU TEMPUS project. It includes 8 universities in Uzbekistan and deals with university education for sustainable water managment in Uzbekistan. Uppsala University and Baltic University Programme is one of the six EU partners in the project. Lead partner is Kaunas University of Technology.

The main objective of the project is to introduce a Master level study program in environmental science and sustainable development with focus on water management at the eight partner universities in Uzbekistan. The curriculum of the Master Programme includes Environmental Science, Sustainable Development and Water Management.

The Sustainable Development unit will include the basic methods used in Sustainability Science, in particular introduce systems thinking and systems analysis, resource flows and resource management and a series of practical tools for good resource management, such as recycling, and energy efficiency.

The specific objectives of the project are:

- to establish study centers at the partner universities in Uzbekistan
- to improve the capacity to train master students with expertise to address the severe environmental and water management problems of the country;
- to support the introduction and use in Uzbekistan of modern education methods, study materials, and e-learning tools;
- to encourage international cooperation at the partner universities;
- to strengthen capacities to provide guidance to authorities and the Uzbekistan society at large;
- to ensure the visibility and promotion of the Master Programme through web pages, printed material and cooperation with society;
- to ensure continuity of the Master Programme and long-term support of the project outcomes at partner universities beyond Tempus funding.

http://uzwater.ktu.lt