Water and
Environment Centre

Sana'a University
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Policy and Economics

Water value / Economics

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1 Introducing environmental economics and policy

Lennart van der Burg

Environmental Economics is the study of how economic activity impacts the environment and of how economic mechanisms can be created that minimizes harm to the environment while allowing maximum economic benefit. Environmental Economics also involves the theoretical or empirical studies of the economic effects of national or local environmental policies around the world. Particular issues include the costs and benefits of alternative environmental policies to deal with air pollution, toxic substances, solid waste, global warming or water issues. The latter will be the mainly discussed in this course *water value / economics*.

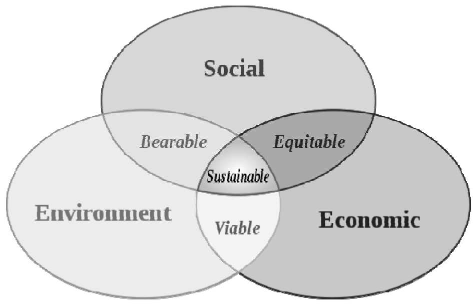

Figure 1:1 The three pillars of sustainability

The objective of the course it to get an understanding of the basic concepts of economics, such as: scarcity, efficiency, equity, sustainability, market failures and different types of costs. The concept of market failure is central to environmental economics and means that markets fail to allocate resources (e.g. water) efficiently. Three other main concepts are i) Efficiency, what is the efficient allocation of natural resources? ii) Optimality: which allocation gives the best level of 'welfare' (i.e. aggregation of individual utilities)? and iii) Sustainability: are the three pillars in figure 0:1 taken into account? The principles of (micro) economics such as producer-consumer behaviour and marginal analysis are required in order to maximise the described concepts. The coming chapters will provide general insights into the economic principles and gives an overview of the different economic and policy instruments.

Chapter 2 explains the interaction of the environmental systems with the economic system. The importance and the value of the environment should be clearly understood and taken into account in water management and water allocation.
Chapter 3 uses micro economics to introduce the basic principles of the market mechanism. By analysing the supply and demand curves the different levels of efficiency can be determined.

Chapter 4 discusses a number of environmental economic topics and environmental policy instruments which can be introduced to provide e.g. firms the incentive for a continues effort to abate their emission or reduce their uses. .

Chapter 5 gives an overview of the basic characteristics of cost benefit analyses which can be used to estimate the economic impacts of the environmental regulations (described in chapter 3). Additionally the method of assessing the economic value of the environmental goods and services, which is a major topic within economics, is described.

Chapter 6 gives an overview of the supporting literature and some case studies with assignments where the theory is used in practise.

2 An Introduction on Economics and the Environment

Ekko van Ierland and Xueqin Zhu

2.1 Interaction between the economy and the environment

Society is faced with many environmental problems, including air pollution, water pollution, excessive waste production and climate change. A proper understanding of those problems requires thorough understanding of the functioning of the economic system and the ecological system. Systems are groups of interacting, interdependent parts linked together by exchanges of energy, matter and information (Costanza et al., 1997). The economic system is an anthropogenic system, where production and consumption take place. The environmental system (or ecological system) is a natural system, where many natural biophysical processes and economic activity take place. The economic system and the environmental system influence each other in many ways. To produce and to consume goods and services, we use the natural environment by taking natural resources from the environmental system, and converting them into goods and services by means of labour and capital. We also emit emissions to the environment from production and consumption process. The inputs of natural environment to economic system (production and consumption) and emissions from economic system to the environmental system will change the stock of the resources, which give feedback to economic system. In other words, the ecosystem of the natural environment is both a source and a sink for economic system, and there are feedback effects in both directions. Figure 1 shows some important interactions between two systems, where the *processes* are indicated as *circles*, the *stocks* as *squares* and the *flows* as *arrows*. *Dashed lines* indicate the system *boundaries*. Figure 1 shows how the production process uses capital and labour from the economic system and renewable and non-renewable resources from the environmental system. The outputs produced for the economic system are products for the consumption process and investment in capital. The emissions from the production process increase the concentrations in the environmental system, which influences the bio-physical process. The consumption process influences the environmental system in a similar way. In Chapter 2 the model of the economic system is further explained. Figure 1 also reflects the spatial competition between the economic and ecological system. The more space is needed for the economic system, the smaller will be the area available for the ecological system. The time dimension for both systems is incorporated in the processes.

Considering such interactions, we have to address the economic aspects of production in addition to environmental assessment. This requires a more elaborate economic framework because neo-classical economics often takes the natural environment exogeneously or even omits it. The broadening of the scope of the economic enquiry produces a better understanding of the interaction between economy and the environment. Actually the environment itself always undergoes a series of biophysical processes.

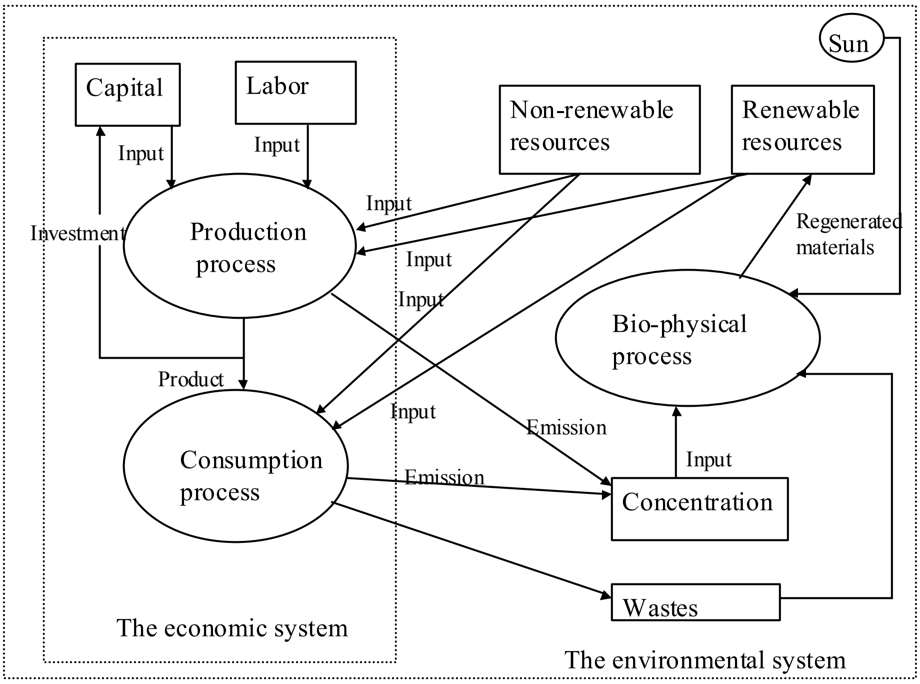

Figure 1 *Interaction between the economic system and the environmental system*

Source: Based on Van Ierland (1993).

Even without human activities, the environment is changing. An emphasis on the environmental (ecological) dimension and the *interaction* between the socio-economic system and the natural environment is an important perspective for environmental economists and ecological economists. In literature the environment is dealt with in one simplified way or another in economic models. There are different types of models that deal with different types of environmental processes. These models are actually the simplified representations of the relations between the economy and the environment as indicated in Figure 1. Although many different classifications are possible, we classify them into four important types:

1) resource use models (e.g. Clark, 1976; Krautkraemer, 1985; Keyzer, 2000),
2) environmental quality models (e.g. Smulders, 2000),
3) climate change models (e.g. Nordhaus, 1993; Manne et al., 1995; Nordhaus and Yang, 1996),
4) biophysical process models, e.g. on soil acidification (e.g. Schieman, 2001) and water pollution (e.g. Van Nes et al; 1999).

These models play a very important role in dealing with specific questions on the economic and environmental aspects of human activities. It should be emphasised that some general used assumptions on economic behavoir might no longer hold when the environmental processes are incorporated into economic framework, because environmental processes follow biophysical laws and mechanism may be highly complex, and may contain non-linearities, irreversibilities, discontinuities or hysteresis (Stern et al., 1992; Scheffer, et al, 2001; Mäler and Vincent, 2003).

2.2 Environmental problems

Environmental pollution occurs world wide at large scale. The main economic reason for environmental pollution to take place is the focus on economic growth and the opportunity costs of environmental protection. More important, however, is the *failure* of the market to protect the environment, and the *failure* of governments to protect the environment in an efficient and effective manner.

The market, highly appreciated for its capability to provide private goods and services in a very efficient way, fails if environmental protection is concerned. The main reason of its failure is (i) the existence of externalities, (ii) the public goods character of the environment and (iii) the common property resource aspects of natural resources, like water, fish or some stocks of fossil energy resources. Governments fail to protect the environment because of priorities for economic growth in its traditional meaning, or because the political support for environmental protection is still insufficient. The failure of the market for environmental protection can be easily shown, and hardly needs detailed explanation. *Externalities* occur in many situations, for example in the case of air pollution. The emissions of one individual have a negative impact on the possibilities of other producers or consumers, without any compensation through the market. This implies that inadequate incentives are provided to producers or consumers to reduce these negative impacts on others. This led in the 1960s and 1970s to tremendous air pollution problems in Europe and the USA, calling for immediate environmental policies to reduce air pollution. Similar examples of externalities are water pollution or excessive waste production.

The environment is a *public good* if it is impossible to exclude individuals from the use of the environment and if there exist no rivalry in consumption: if one individual uses the environmental amenity, it does not reduce the options of others to enjoy it. A typical example is the beauty of nature or landscapes. Everybody is enjoying it and it is impossible to exclude people from enjoying it, and, usually, the use by one individual does not reduce the possibilities of others.

Finally, *common property resources* exist for example in case of fisheries. In case of common property resources it essentially is possible to exclude people from the right of exploitation of the resources, but property rights are not individually defined. In that case open access prevails and it can easily and clearly be illustrated that this leads to overexploitation of the renewable natural resource, for example ocean fisheries. All individual fishermen have incentives to harvest as much as possible, neglecting the optimal fish stock necessary for regeneration.

This failure of the market and the often occurring failure of public authorities to introduce well functioning environmental policies have led to the following categories of environmental problems:

1. Air pollution, including acidification, ozone layer depleting substances and toxic compounds.
2. Water pollution by organic material (leading to eutrofication), and toxic compounds, including heavy metals.
3. Soil pollution by toxic chemicals.
4. Excessive waste generation.
5. Over-exploitations of natural resources (stocks of fossil fuels, fish, soil erosion).
6. Destruction of ecosystems and habitats leading to loss of biodiversity (e.g. deforestation).
7. Emission of greenhouse gasses (e.g. CO_2, N_20 and CH_4) leading to global warming as a result of the enhanced greenhouse effect.
8. Other environmental problems, like radio active pollution.

An urgent question for policymakers in almost all countries of the world is how to design and introduce environmental policies, at the same time promoting further economic development and creating sufficient employment opportunities. The failure of the market is to be corrected by environmental policy instruments and the creation of institutions that consider the environmental issues at stake, provide scientific analysis of the best options to promote sustainable development, and implement the policies.

For many industrialised countries, international environmental agreements resulted in commitments to reduce atmospheric emissions of several pollutants. Examples are the ‘Gothenburg Protocol’, aiming at the control of acidification, eutrophication, and ground-level ozone concentrations in Europe (UNECE, 1999) and the 'Kyoto Protocol', aiming at reductions in greenhouse gas emissions in industrialised countries all over the world (UNFCCC, 1997). The efficient solution for reducing environmental impacts is easy to identify, but its implementation is difficult because strong incentives to ‘free ride’ exist for individual countries. The pay-off for free riding is high, because the countries in the international environmental agreement will pay the costs of the implementation of the policies, will free riders enjoy the benefits without incurring costs. In the problems of acidification or climate change and in many other environmental problems these incentives for free riding exist.

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3 The Market Mechanism

Alex Bruijnis

3.1 Introduction

Economic activity takes place all around us. Goods like food and clothing are purchased on markets and in stores, people go to work to produce goods or services and earn a wage, farmers work the ground and produce crops which are in turn traded. Decisions are constantly made by the economic agents to produce, buy or sell. To understand the different and many aspects of an economy economists use models which represent economic activity. In the next section such a model is described in order to describe the basic principles of the market mechanism.

Circular flow model

One basic model of economic activity is the “circular flow model”. This model is the basis for many economic theories and more elaborate models. It shows the main flows of resources, goods and services and the monetary payments for these goods and services in the economy.

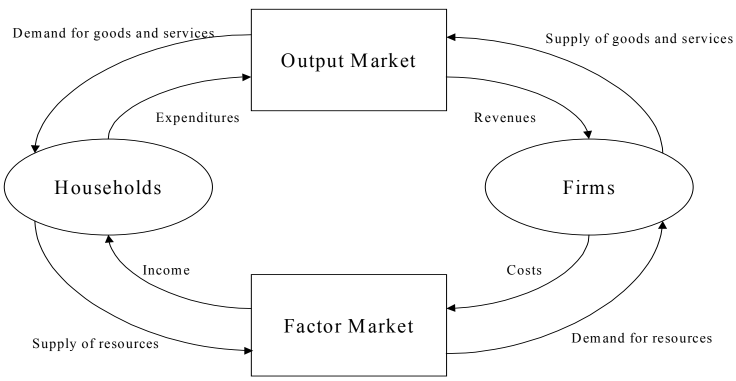


Figure 2.1 Circular flow model of economic activity (Source: Callan and Thomas, 1996)

The model distinguishes two markets, the output market and the factor market. In between the markets are the households (often called consumers) and the firms (often called producers). The outer circle represents the so-called real flow of goods and services; this flow consists of the resources needed for production and the goods and services produced with the resources. Notice that in the model the production factors (labour and capital) and resources are owned by the households. They supply these resources to the factor market and receive an income in return. This is shown in the so-called money-flow, the inner circle. The income of the households, for example from labour supplied on the factor market, is shown as the costs for firms, which demand resources like labour from the factor market. The firms produce goods and services with the purchased resources and supply these to the output market. This is shown in the top-section of the model. The households demand the goods and services supplied to the output market, and pay for the goods with the income they receive from the factor market. The expenditures are the revenues for the firms, who use the revenues to pay for resources bought from the factor market: the income for the households. This closes the money circle which flows trough the economy between firms and households. The volume of the flow in an economy can change via population growth, technical improvements and changes in labour productivity, but also natural influences like extreme weather events can influence the flows. With a larger population more goods will be demanded and produced, what will increase the volume of the two flows (Callan and Thomas, 1996). Development in technology will enable the firms to produce more goods and services. The system will adapt to this change via the markets. To explain how this works a theory is needed which can show the influence from a change in quantities in supply and demand on the coordination tool of the economy: the prices of goods and resources. This theory will be developed in the next section.

3.2 Supply and Demand

3.2.1 The consumers

The households in the circular flow model face a decision which is depended on their preferences and the price of goods. Assume that they have a certain fixed income. With this income the consumers can purchase a limited amount of goods. They will have to decide how much they will buy from a certain good. This is shown in figure 2.2. Different prices are represented by (p_x) which are shown on the vertical axis. The quantities are noted as (q_x) and are shown on the horizontal axis. If the price is low (p_1) the consumers will be able and wanting to buy more of the good then if the price is high (p_2). In that case consumers will buy less or none of the product at all and rather spent their income on other products, which is shown as the difference between (q_1) and (q_2). This is known as the law of demand which states that under normal circumstances an increase in price will cause a lower demand (Callan and Thomas, 1996). The preference and income of the consumers determines the amount of a good that will be bought at a certain price. Primary goods like basic food will be bought even at higher prices, but luxury goods, like household electronics will not be bought if the prices are too high and income is not sufficient.

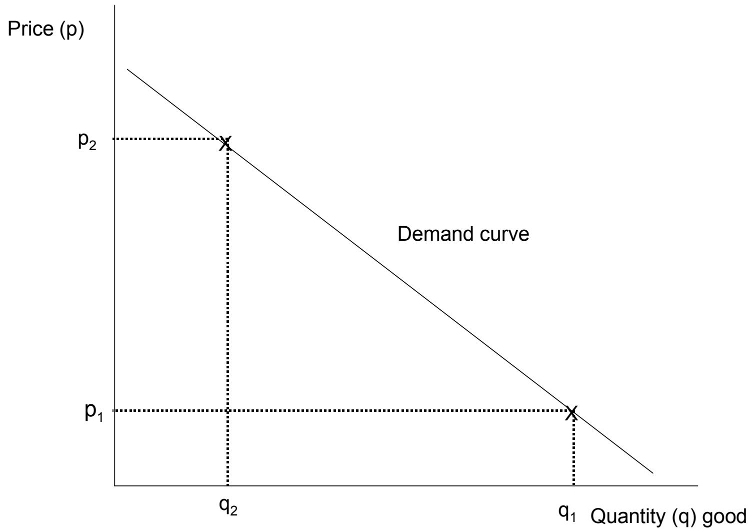


Figure 2.2 Demand curve consumers

3.2.2 The producers

The firms in the model in the previous section have to decide how many goods they will supply to the market. This depends on the costs the producers have in the production of the good, for example of wages and raw materials costs, and the price the producers receive for the product. This relation can be shown in a graph which shows the supply of the producer for a range of prices shown in figure 2.3.

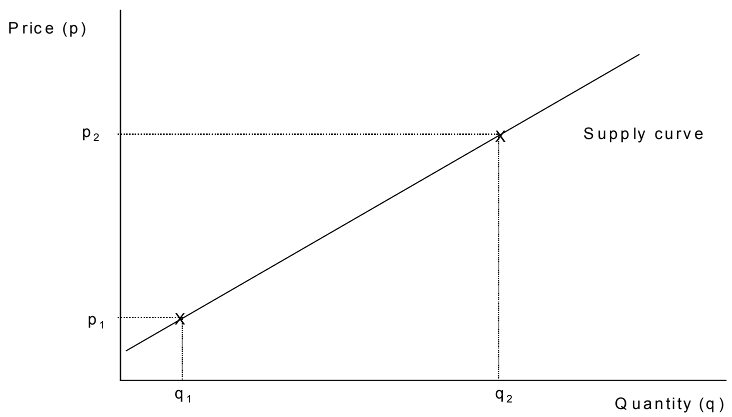


Figure 2.3 Supply curve producers

For every price on the market the quantity supplied by the producers can be found at the horizontal axis. At a low price the producers will not be able or willing to supply many goods, the supply is low. If the price rises the producers will be able to produce more and will supply more. This is known as the law of supply; when the price increases the quantity supplied will increase under normal circumstances (Callan and Thomas, 1996). Therefore the graph is upwards sloping to the right: at higher prices the producers will increase their supply.

3.2.3 Equilibrium

The price that eventually will be paid in the market can be found by combining the supply and demand curves in one graph, this is done in figure 2.4.

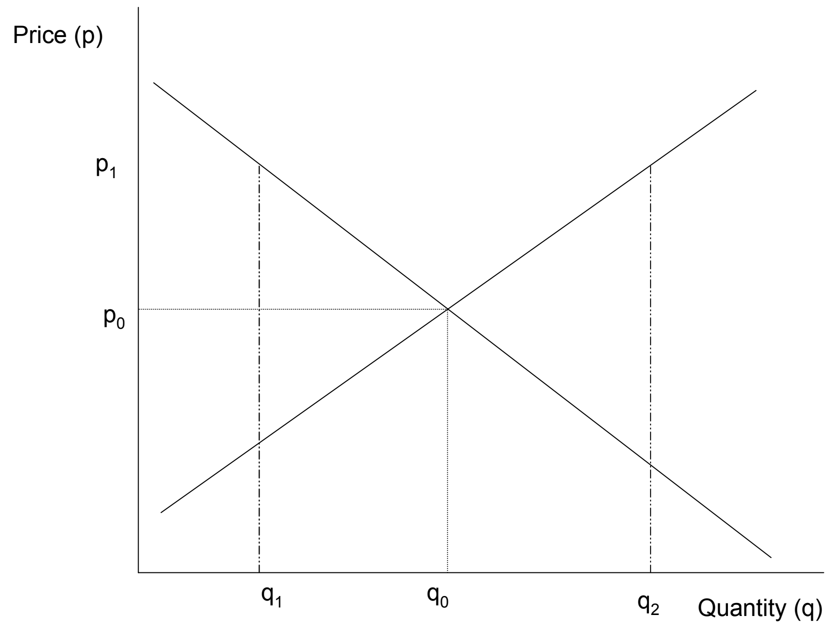


Figure 2.4 Supply curve and demand curve

From the graph it can be seen that there is a price where the demand from the consumers equals the supply of the producers, namely at (p_0). This is called the market clearing price where supply equals demand. At that point the market is said to be in equilibrium. The market mechanism is the force which will overtime drive the market to its equilibrium point. This will not happen overnight, but if for example the price in the market is (p_1) then the consumers will demand (q_1) products, while producers supply (q_2) goods. The difference between (q_1) and (q_2) is the excess supply, the amount the producers supply more then the demand from the consumers. The producers will not sell this amount at price (p_1), they can store the products, but this is no infinite solution and will include storage costs. If the situation of the excess supply will continue the producers will eventually decrease the price to sell the excess products or al least they will not let the amount of products stored increase. At a lower price the consumers will buy more of the good, while the producers will produce less. This process will be repeated until the market is in equilibrium and consumers demand precisely as much as producers supply. The process works the same if the price is too low. The consumers will then demand more products than the producers supply at that price. The consumers will compete for the available products, and pay higher prices. The producers will produce more at higher prices and the market moves towards its equilibrium point. The price of a good thus depends on the amount supplied and the amount demanded.

3.3 Efficiency in the market

3.3.1 Pareto efficiency

An important concept in the determination of efficiency was formulated by Pareto and is named after him, the so-called "Pareto-efficiency". This concept means that an allocation (of resources) is efficient when no individual in the economy can be made better off without making someone else worse off. If someone can be made better off with no harm to others, it should be done. One person gains, while no body loses, so the society in total has gained. When someone can be made better off without making someone else worse off, it is said to be a Pareto-improvement. However, in an economy where most resources are private property it becomes often almost impossible to make someone better off without making someone else worse off. Therefore, the concept of Pareto improvement is often used in a less restricting manner as a basis for allocation decisions. One way of doing this is by no longer focussing on individual persons but by focussing on society as a whole (Perman et al., 1999). In that case a Pareto improvement is considered to occur if the 'winners' are in principle capable of compensating the 'losers'.

3.3.2 Equilibrium characteristics

Important in economic theory is the efficient use of the available resources in an economy. This means that the available resources which include labour, capital and natural resources are used where they generate the highest value. It seams an extremely complicated procedure to achieve such an allocation. Under a set of very special circumstances the price mechanism does however provide the incentives for all the agents in the economy to come to an efficient allocation of the available resources. When there is full information, full competition, no externalities, and absence of public goods and all markets of an economy are in equilibrium, the allocation of resources is efficient. No resource can then be used elsewhere and generate more value. To achieve an efficient total allocation three conditions are of importance. Perman et al. (1999, p.106) describe these conditions for efficiency.

Efficiency in consumption

The consumption of goods is efficient if the marginal utility of consumption of the goods by the consumers is equal for all the consumers. If this condition is satisfied no trade between consumers is possible whereby one gains and no one else is worse off (Pareto efficiency).

Efficiency in production

The production of goods in the economy requires resources. In a simplified model this will be capital (K) and labour (L). Their allocation will be efficient if their ratio of marginal product is the same for all the products produced. In that situation it is not possible in the production of the goods to substitute some capital for labour, or vice versa, and yield a better result in terms of higher volume of goods or services.

Product-mix efficiency

The consumers value the products in the economy in different ways. If we assume that the different utilities (for an explanation of the utility concept see section 4) derived from the goods can be compared, the ratio between the marginal utilities of these goods should be equal to the opportunity costs of production of these goods compared to each other. In other words, the resources used for the production of the goods can not be changed in a way that the new mix of products will give the people a higher utility without making one person worse off.

An efficient allocation in an economy in not unique, several efficient points can exist. This will also be shown in section 2.5 with an application of the Edgeworth box. The analysis of economic efficiency in this section was done using a model of the economy which described the whole economy with consumption, production and product-mix. Another method that can be used is marginal analyses, this will be explained in the following section.

3.3.3 Marginal analyses

Instead of analysing all markets at the same time, a focus on one single market is possible. The behaviour of consumers and producers can then be studied, and reactions on for example governmental measures like tax increases can be analysed for small changes in the allocation of resources. Marginal analyses can be used to study consumer or producer behaviour separately or combined as will be done below.

3.3.3.1 The consumers

Section 2.2.2 describes that consumers have a certain budget to buy the goods or services. Given the budget, not all goods will be attainable for the consumer; hence choices will have to be made. The consumer will buy the goods from which highest utility can be derived. Given the preferences of the consumer for certain goods the consumer is willing to make choices and sacrifice part of its budget to buy goods, foregoing the possibility to buy other goods. The amount of money the consumer wants to pay to attain one unit of the good is called willingness to pay (the demand price). This is the amount the consumer is willing to give for one unit of the good. This is also the measure for the marginal benefit (MB) which the consumer derives from the good. This price will decrease if the consumer has more units of the good available. If the consumer has already ten bags of rice the MB from the eleventh bag will be lower then the MB from the first bag, when the consumer still needs to buy something to have a meal. The consumer will therefore be willing to pay considerably more for its first bag then for additional bags of rice. Therefore the MB-curve will normally be downward sloping with lower MB with increasing quantities. If the price is above the WTP from the consumers, they will not demand the product anymore. The price of the good in the market can be lower then the WTP of the consumers, because the price is determined for the total quantity demanded, not for each marginal unit.

The area below the demand curve and above the horizontal price line shows the difference between the real market price and the WTP of the consumer this is the 'consumer surplus', this is a gain for the consumer, because the willingness to pay is above the market price.

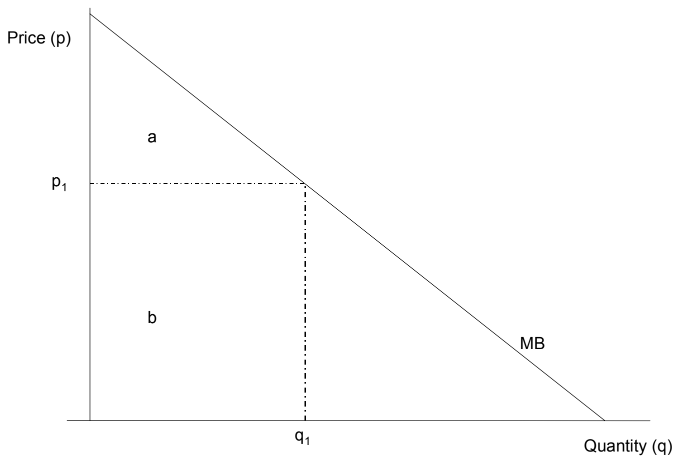


Figure 2.5 Marginal benefit curve

This is shown as area (a) in figure 2.5. The line represents the marginal benefit for the consumer at different quantities (q) of a good. Area (b) is the amount the consumer pays for the quantity of goods (q_1). The market price is (p_1).

3.3.3.2 *The producers*

The goods bought by the consumers are provided by the producers. Section 2.3 describes that the producers do not supply unlimited amounts of goods, but that the provision is costs and price depended. It is assumed in neo-classical economics that for an increase in production the producers have to make investments in man-hours, machines and other things. This will cause the total costs (TC) to rise. The extra output causes the TC to rise faster then the increase in output, therefore the ratio between TC and output increases. This ratio ($\Delta TC/\Delta Q$) represents the marginal costs (MC) of the firm, the costs to produce one more unit of output. This MC is the lowest price the firm wants to sell its goods for. If all the firms in a sector are analysed the individual marginal cost curves are aggregated to form the marginal costs curve of the whole sector. A graphical representation of the situation can be found in figure 2.6. The MB and MC curves are not fixed and can change due to several circumstances. The method of production can improve so that producers can provide the goods at a lower cost. This will cause the MC-curve to shift downwards and a new equilibrium will appear with a lower market price. The same situation can occur with the MB-curve of the consumers. If the preferences change the MB-curve will shift and change the quantity of the goods demanded causing another price to establish.

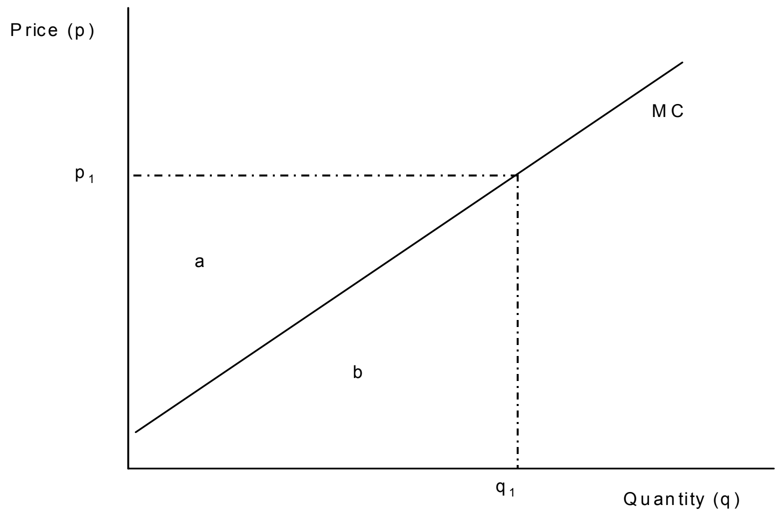


Figure 2.6 Marginal cost curve

3.4 Indifference curves

People derive pleasure from the consumption of goods and services. In economic terms this is called utility. The more pleasure someone derives from a certain good the higher the utility is. When someone is happier with two pieces of fruit then with one bag of rice, the utility derived from the two pieces of fruit is higher. In economic theory the concept of utility is used in many circumstances where choice between, or evaluation of, the situation of people is needed. It provides a tool to compare different situations. Often the choice between different baskets of goods is represented via utility functions. With these utility functions indifference curves can be made which represent the utility functions. These curves show graphically the possibilities (of choice) in a situation. Figure 2.9 shows indifference curves for the choice between apples and pears. Each indifference curve shows the combinations of apples and pears at which the consumer obtains a given (and fixed) level of utility. The more to the right the indifference curve is located the higher will be the utility. Robert has the choice between apples and pears. He will choose the combination which will give him the highest utility, given his available budget, represented by the line AB. This line shows the quantities that he can buy given his budget and the relative prices of apples and pears. He can purchase only apples, only pears or a combination of the two. If Robert buys five pears and one apple he is on indifference curve 1 (U_1). He can also choose to buy five apples and one pear which will also bring him on indifference curve (U_1). This means that he derives exactly the same amount of utility from these two combinations. It does not matter which of the two combinations of apples and pears Robert has, they both make him equally happy.

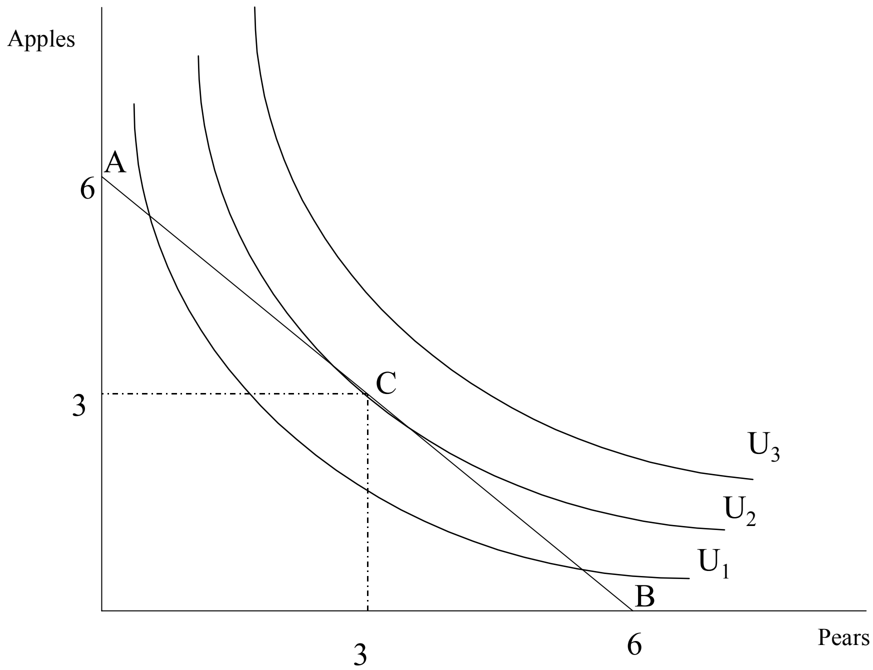
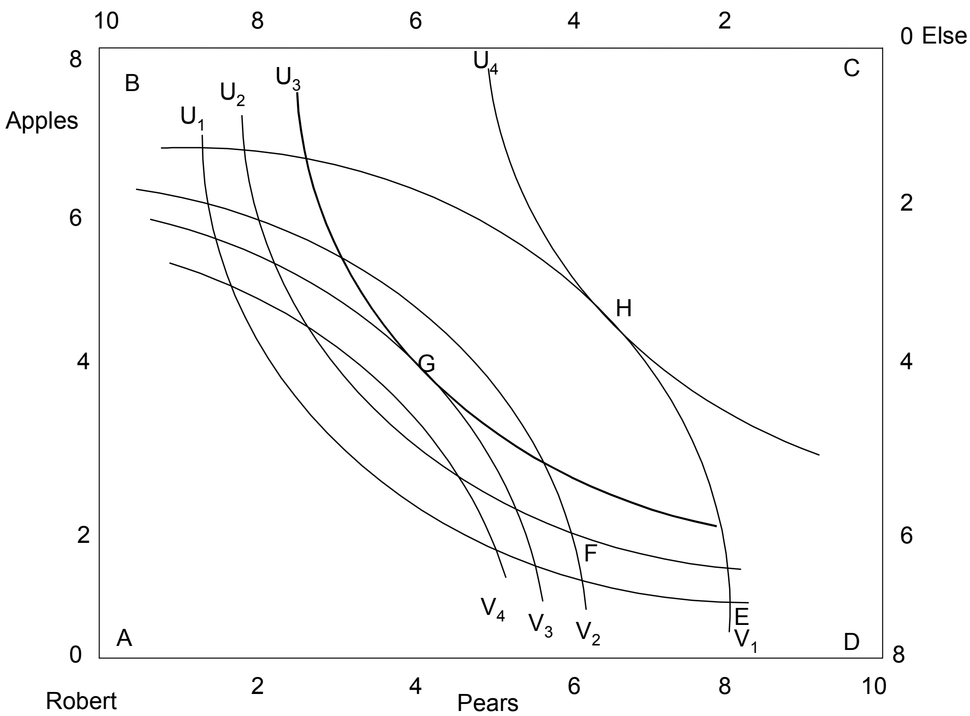


Figure 2.9 Indifference curves

This is true for all combinations of apples and pears on indifference curve (U_1). If Robert wants to derive more utility he has to find a combination of apples and pears which will bring him on utility curve 2 (U_2). The indifference curves have ordinal value, which means that the curves indicate the preferred distributions of Robert. The further the curve is situated from the origin of the graph, the higher the utility it represents. If Robert is to trade two of his pears for two apples he would have three pieces of both. It can be seen from the graph that this will bring him on (U_2), which represents higher utility then (U_1). (U_2) is actually the highest indifference curve Robert can attain, given his budget constraint. In point (C) (U_2) and the budget line are tangent which means that given the situation the most efficient point is found. There is no more room for trade which will make him better off.

3.5 Edgeworth box: optimal allocation for two consumers

The focus in this section will be on the trade between two people to improve the efficiency in allocation of goods in an economy. This improvement is measured by an increase in total utility in the economy. Imagine that two people, Else and Robert, form an economy where the only goods are apples and pears. Both have in the beginning an original allocation which is not necessarily efficient and an improvement in the allocation is possible via a voluntary trade between the two. This situation can be represented in an Edgeworth box, which contains the preferences of both Robert and Else as expressed by their indifference curves. Robert's indifference curves are the same as in figure 2.9, but Else's are turned so they mirror Robert's indifference curves. They have to be read from the upright corner, point C, while Robert's have to be read from point A. The axes contain all the goods in the economy: ten pears and eight apples. Figure 2.10 represents the situation. If in the original allocation Else has two



pears and seven apples, consequently Robert will have eight pears and one apple. If they trade with each other the allocation of goods can be changed such that both Robert and Else are better of and attain a higher indifference curve. This trade could be the following: if Else gives Robert one apple and receives two pears they both gain. Apparently their marginal rate of substitution (MRS) is different. This is the rate in which they value one good in terms of the other. This MRS is given by the slope of the indifference curves. If they are the same for both Robert and Else, no further trade is possible, because they value the two goods equally, an efficient point is then found. In the original situation Robert values one apple higher then two pears. With the trade they go to point F which is on a higher indifference curve for both (U_2 and V_2). Still their indifference curves are not tangent and room for trade is present. If Else gives two apples to Robert and receives two pears in return, they arrive at point (G). Again they are both on a higher indifference curve, so both gained. This mutual gain is however not necessary for a successful trade, if one of the two can reach a higher utility level, while the other remains at the original level, still efficiency improvement has been made. At point (G) both indifference curves are tangent (have the same slope), which means the MRS of Robert and Else are the same at that point, no trade possibilities are left.

Figure 2.10 Edgeworth box for a small economy

In this example point (G) is reached after the bargaining process. Another point could just as well have been the final point, depending on the bargaining process. As long as Robert or Else is not worse of then in the initial position, efficiency gains are made. Depending on their skills of bargaining they also could have reached (H) where Else is still on (U_1) but Robert has gained a lot, and he will end on (U_4). This point is equally efficient (as point G) because both indifference curves are tangent, so no possibilities for trade remain (Pindyck and Rubinfeld, 1989).

Depending on the initial allocation many different efficient points can be reached via trade between the two people in the economy. In fact, it is possible to determine all efficient points on forehand. In the previous section it is explained that at an efficient point the indifference curves of both Robert and Else are tangent, giving them the same MRS and no room for trade. If all points where two

indifference curves are tangent are connected, all efficient points in an economy can be shown. A pareto-efficient allocation of the two goods between the two people will always be on this line.

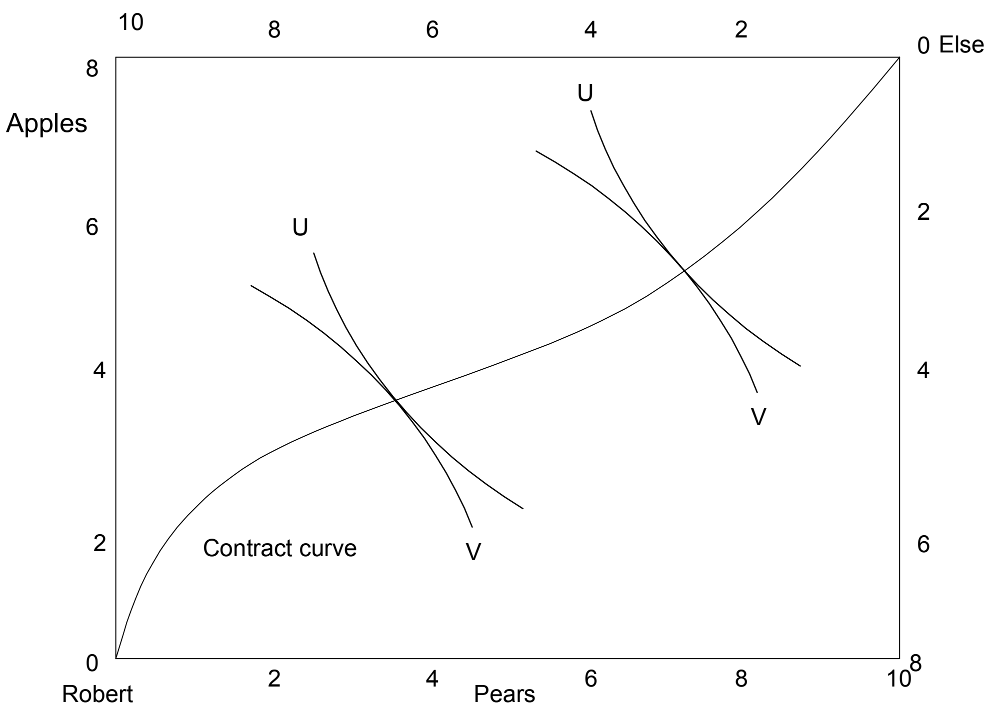


Figure 2.11 The contract curve

The line is known as the '*contract curve*'. Once a point on this curve is reached no possibility for mutual beneficial trade is present anymore. The contract curve for the economy of Robert and Else is drawn in figure 2.11 (Pindyck and Rubinfeld, 1989).

3.6 Modelling Externalities

The model of the market developed in the previous sections is an idealized (remember the assumptions in section 2.3.2) representation of reality. The market does not provide all the right incentives for sustainable use and allocation of resources. The reasons for environmental damage where mentioned in the Chapter 1 namely, externalities, public goods and common property resources. To combat environmental degradation, it is important to understand what the influence on the economy will be so that the most efficient measures can be applied. In the next section the methods of modelling externalities will be explained using marginal analyses. Imagine a coal power plant which produces energy while emitting gasses. The gasses influence the people nearby the factory, who will have less clean air and might suffer from negative influences like health problems and decreasing production from agriculture. The air which becomes polluted is however a public good. Nobody "owns" the air or is entitled to exclude people from using the air. There is no market where the local inhabitants or farmers can sell rights to pollute the air to the power plant. If there is no government that imposes an environmental tax the power plant does consequently not have to pay to emit the gasses. The emission of the gasses is not reflected in the price of the energy produced, and the price is therefore lower then socially desirable and consequently demand will be higher.

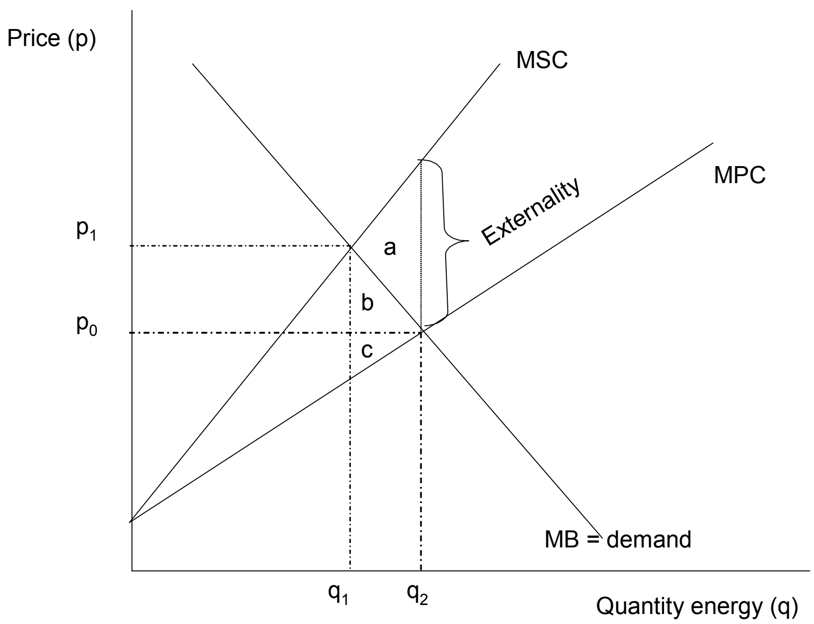


Figure 2.12 Externality from production

The gasses are emitted without any compensation in the market process (they are external of the market), and are therefore an externality from production. The marginal costs to the firm are the costs for input while the marginal social costs, the costs for the whole society, are higher because they also include the costs related to the emission of the gasses. This situation is shown in figure 2.12. The marginal private cost curve represents the costs as perceived by the power plant. This is the same as the MC-curve explained earlier. The MB-curve represents again the benefits to the consumers. The intersection between the MPC and the MB represent the equilibrium that exists if only the marginal costs for the power plant are considered. The corresponding price and quantity are (p_0) and (q_0). If the pollution from the gasses is however included in the analyses, a different picture emerges. The new marginal cost line is the marginal social cost line (MSC). This line includes the externalities from the pollution at the new intersection. The new price will be (p_1), which is higher then (p_0) and the quantity demanded is (q_1) which is lower then the original quantity. The area (a) represents the not included damage from the externalities. The total external effect in the old situation was the area between the MSC and MPC lines. The areas (b) and (c) are no longer part of the market, which is a loss for consumers and producers respectively. This can be offset by the gains to society from less pollution, the areas (a), (b) and (c) represent the decreased externality. The net gain for society is a + b + c – b – c = a. If this factory would be one of many there would be no price change if one firm would decrease until MSC = MSB.

The decrease in production would lead to less pollution for the inhabitants and farmers, this is the marginal social benefit of abatement. Implicit in this analysis is that the only way to decrease the externality is a decrease in production. The use of filters, changes in input and other measures can however decrease the externality too. This will be shown in the explanation of the use of policy instruments to decrease pollution.

3.6.1 Market for abatement

Another possible way to analyse abatement from industry or other sources is to model a market for abatement. Just like normal goods it can be assumed that people are willing to pay for a reduction of pollution. This willingness to pay is equal to their marginal benefits from abatement and can be seen as the demand for abatement. The market for abatement can be represented by the marginal social costs for abatement and the marginal social benefits of abatement. This is shown in figure 2.13, where the market reaches an equilibrium were $p = p_0$ and $q = q_0$. Further abatement would increase the costs more than society would gain from the increased pollution abatement.

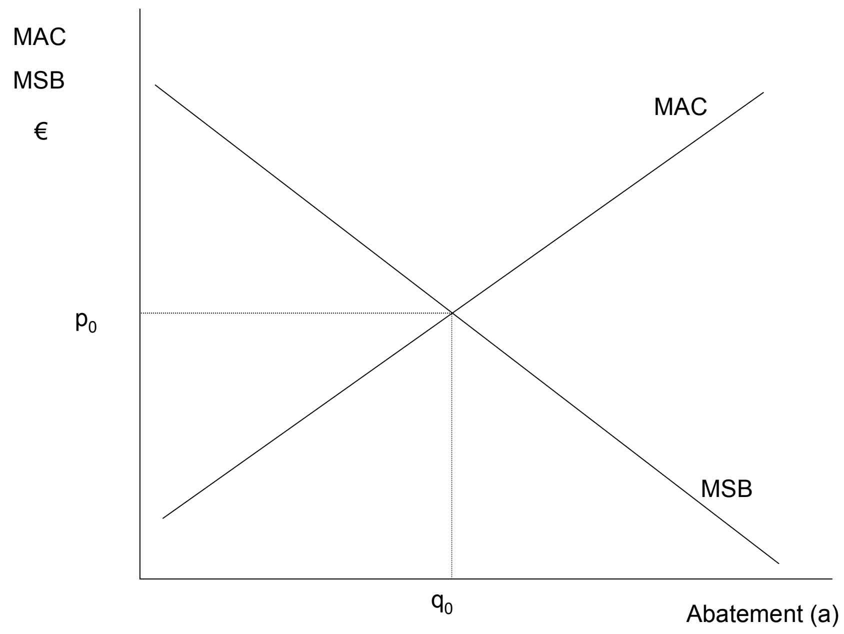


Figure 2.13 Market for abatement

The MAC-curve is for simplifying reasons drawn as a straight line. In reality this is, however, not the case. When there is a lot of pollution from a firm and no measures have been taken yet, the first abatement steps will be cheap. At relatively low costs big improvements can be made via the adaptation of parts of the process. But if these steps are taken it will become increasingly costly to achieve further abatement. Little progress will become very expensive in the end. Therefore, the MAC-curve in reality sharply bends with increasing levels of abatement, as is shown in figure 2.14.

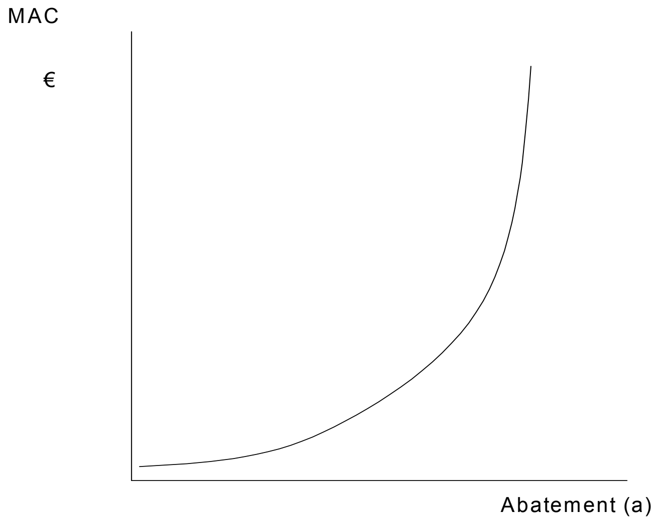


Figure 2.14 *Non-linear marginal abatement costs*

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4 Environmental Economics and Policy Instruments

Alex Bruijnis and Ekko van Ierland

4.1 Introduction

The problems with the market mechanism as discussed in Chapters 1 and 2 can to a large extent be corrected with the use of environmental policy instruments. To explain how these instruments can be used to intervene in the economy and to correct problems with external effects, public goods, or common property the theory developed in Chapter 2 is used. In practice we observe a wide variety of environmental policy instruments in Europe, in the USA and in many other countries. Also, in the area of international environmental agreements many instruments are applied. To select the most appropriate policy instrument it is essential to have a detailed understanding of the characteristics of the environmental problem in question, the technological options to reduce pollution and of the complications that may occur in the application of the instrument.

A very important distinction for the choice of policy instruments is between *uniformly* mixing pollutants and *non-uniformly* mixing pollutants. Uniformly mixing pollutants are dispersed evenly in the atmosphere, like carbon dioxide. For these it does not really matter *at which location* the emissions occur: the result for the global environment will be the same. Non-uniformly mixing pollutants however have a regionally specific impact: the concentrations are higher the closer to the point of emissions and the *location* of the source of emissions is important.

A large variety of different environmental policy instruments are available. Often a distinction is made between market based instruments and non-market based instruments. The market based instruments use the incentives the market offers to direct behaviour of polluting parties. For environmental protection the government basically has the options to apply the following policy instruments:

- Direct regulation

- Economic instruments:
    - Taxes, charges
    - Subsidies
    - Tradable permits
    - Deposit systems
- Voluntary agreements
- Government provision of environmental services
- Information, education and propaganda

The policy instruments listed above have different characteristics and influence the economy in different ways. This will be described below where first non-market based policy instruments are described followed by market based policy instruments. Information is an important aspect in the choice for an environmental policy instrument, complications with information can influence the applicability of an instrument and hence the choice for a policy instrument, as will be discussed in section 5. Transaction costs can also complicate the use of some instruments and can influence the choice for an instrument as will be shown in section 6. Finally, section 7 deals with international agreements and competitive advantage due to the application of environmental policy instruments.

4.2 Non-market based instruments

This approach consists of so-called command-and-control measures. Standards are set by a central agency which controls the compliance of the agents (firms) with the set standard. All economic agents have to meet the same standard and this will decrease the amount of pollutant for which the standard is set. There are two possibilities for the standards, they can be:

- Technology based, or
- Performance based.

Standards can be set for emissions or for concentrations in the environment.

4.2.1 Technology based standards

A technology based standard prescribes a technology that is obligatory to use for the agents. This can for example be a scrubber in an exhaust pipe of power plants or an emission filter in a drainage system. The use of the technology will decrease the environmental pollution from the regulated sites. The method of applying filters on exhausts of the production processes is called and end-of-pipe technique. The (best) available technology is used to filter the emissions and decrease the amount of pollution which is discharged in the environment, but no changes in the input or production process are made. This policy instrument does not encourage firms to search for better technology, instead firms will install the compulsory equipment but have no incentives for further investments because these do not pay off. The control by a government agency is however straightforward and can consist of a check to verify that the required technology is installed and operational. Because the firms will have different costs in applying with the standards, the MAC of the firms in the sector will be different. Therefore this method will not yield an efficient situation where the MACs for all firms are equal. Firms with high marginal abatement costs can pay a firm with lower marginal abatement costs to reduce emissions. The total abatement would then be the same only achieved at different firms and at lower cost. Prescribing technology does not make use of this option for efficiency gains, furthermore it does not supply incentives to abate in other ways like a decrease in output. In other words abatement technology is controlled not the emissions itself. Another disadvantage of technology based standards is that technological progress is continuing, where as old technologies are still required according to the standards.

4.2.2 Performance based standards

Direct regulation of performance (performance standards) is another possibility for the government to use standards as environmental policy. Limits on emission of polluting substances can be set after which the regulated firms will have to reduce their emissions of pollution to the level set by the government. Because the limit is set on the emissions and not on a certain method or technology the firms have different options to comply with the limit, this flexibility allows them to choose the abatement method they prefer. This can for example be a decrease in production or the use of cleaner technology or inputs, which ever is the most beneficial for the firm. This policy instrument provides the firms with incentives to invest in cleaner technology, because with cleaner technology the output can grow while emissions stay below the limit set by the government (Sterner 2003). The control of this policy instrument by the government is more difficult compared with technology standards, because the controlled variable is the emission from the firms, measurement of this variable can be very complicated. With the emission limits in place the firms will abate until their MAC equals their MPB of abatement. The investments in abatement will be reflected in the price of the product, which means the consumer of the polluting product pays for the costs of abatement (Sterner, 2003 p.78-81). A problem is still that standards are often uniform. This means that all firms have to abate to the same level, while it would be more efficient in the case of uniformly mixing pollution to let low-cost abaters abate more then high-cost abaters because then the total abatement costs will be smaller. This can be demonstrated with an example. Imagine an economy with two firms, which produce goods and emit polluting substances in their process. The government wants the two firms to abate 8 units in total. The firms have different costs for abatement as can be seen from the different slopes in figure 3.1. The abatement of firm 1 can be read from left to right, while the abatement of firm two can be read form right to left. On each point of the graph the total abatement is eight units. The distribution of the abatement can be changed over the two firms. If the government sets a standard and both firms have to abate four units, then it can be seen from the graph that the marginal costs for firm 2 are considerably higher then the marginal costs for firm one. Firm one can achieve the same abatement at lower costs. If the government would set the standards different for both firms the same total abatement could be achieved at lower costs. If the point would be chosen where $MAC_1 = MAC_2$ firm one would abate 5 units and firm 2 would abate 3 units. The total cost to the society would then be as low as possible. This can also be seen from the area's under the marginal cost curves (remember to read in the correct direction). These area's represent the total costs of abatement. Figure 3.1 shows that in the second situation a part of the area which was previously covered does no longer fall under the marginal costs lines. This area is the gain to the society from the second situation.

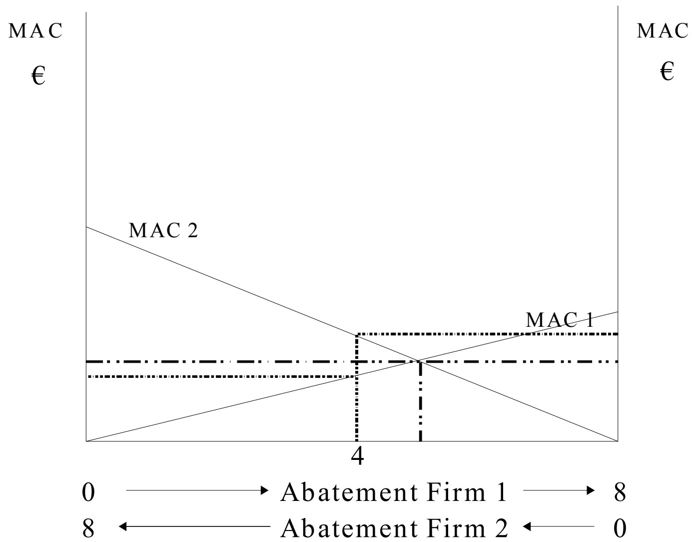

Figure 3.1 Cost-efficiency under standards

4.2.3 Determining the standards

The level at which the standard is set is important for the effectiveness of the standard. The standard needs to achieve an allocation which is efficient, this means that the marginal costs of abatement equal the marginal benefits of abatement. This is extremely difficult to achieve because when the government determines the level it acts under an information constraint. The marginal benefits, as well as the marginal costs of abatement are difficult to measure. If the standard is too lenient or too strong welfare losses to society will occur. This is shown in figure 3.2 (After an example of Callen and Thomas, 1996).

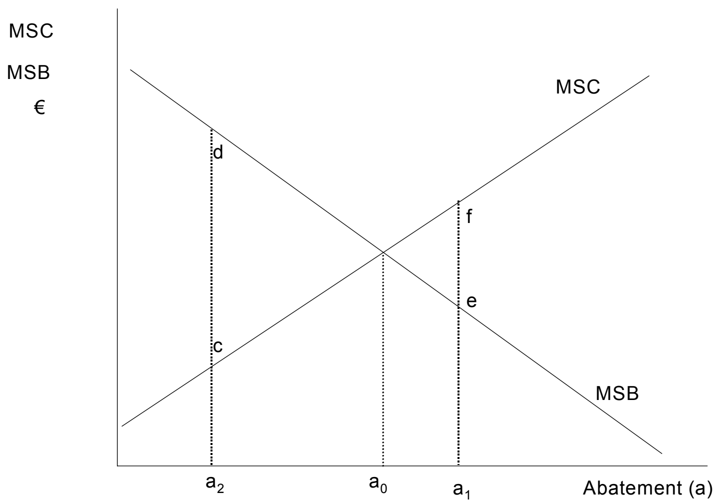

Figure 3.2 Level of abatement standard

In the example the optimal amount of abatement is (a_0), at this level the MSC and MSB of abatement are equal, and allocative efficiency is reached. In the case that the abatement level is set too high, for example at (a_1) the MSC of abatement are larger then the MSB. Too much resources are dedicated to abatement according to the preferences of the society. The opposite is possible as well. If the abatement level is set at (a_2) the MSB are larger then the MSC of abatement. Too little resources are directed towards abatement which means a loss in welfare according to the preferences of the society. If the optimal level (a_0) is determined, then this level of allocative efficient abatement needs to be realised in an cost-efficient manner. Because all firms have different abatement costs functions, they will have different costs in applying with the standards. In case of uniformly mixing pollutants it would be most cost-efficient if the firm with the lowest abatement cost would abate the largest share of the necessary abatement. This would mean that a government setting standards would have to know all the abatement cost functions of the firms to set different standards for each firm, which would allow for cost-effective abatement. This level of information is very hard (if not impossible) to attain as will be described later in this chapter. Therefore this policy instrument is often described as not efficient. It is important to note that a well-designed system of standards can be very efficient, provided that it takes into account differences in abatement costs for various producers. If all information on emission reduction costs is available a social planner could calculate the cost efficient solution and could act accordingly in setting emissions standards for individual firms. In practice this information is not or only partially available and that is the reason that direct regulation often leads to inefficient solutions.

4.3 Economic instruments

An important advantage of economic instruments is that they provide the firms with an incentive for a continues effort to abate. The firm can constantly make a gain if abatement measures can be found of which the marginal costs are lower then the marginal benefits to the firm. This provides the incentive for technology development which the policy instrument of technology based standard measures lack. With market based instruments the polluters will abate until the marginal costs of abatement are equal for al the polluters. This is an efficient allocation of abatement as will be shown in the following sections.

4.3.1 Taxes and charges

The differences between a tax and a charge is that a tax is often politically decided and tax-revenue is often claimed by the central government. Charges are more administrative in nature and revenues from charges do not necessarily go to the central government, but can often be used in region where the charge is paid to develop projects (Sterner 2003).

A common policy instrument in many countries is the use of tax to discourage certain unwanted behaviour. In the case of environmental protection it is possible that a tax on externalities achieves an efficient outcome, where the social costs and benefits of abatement are equal. To bring about such an efficient solution the tax has to be precise the size of the externality in the social equilibrium point. This kind of tax is called a

Pigouvian tax after the Englishman A.C. Pigou who formulated the concept. The way a Pigouvian tax works is shown in figure 3.3. The initial allocation in the market is at (q_1) where an externality is present (the difference between MPC and MSC). The efficient allocation from a social perspective would be (q_2) where the MSB equals the MSC. The difference between the MPC of the firms and the efficient equilibrium point, the intersection of the MSC and MSB line, is line AB.

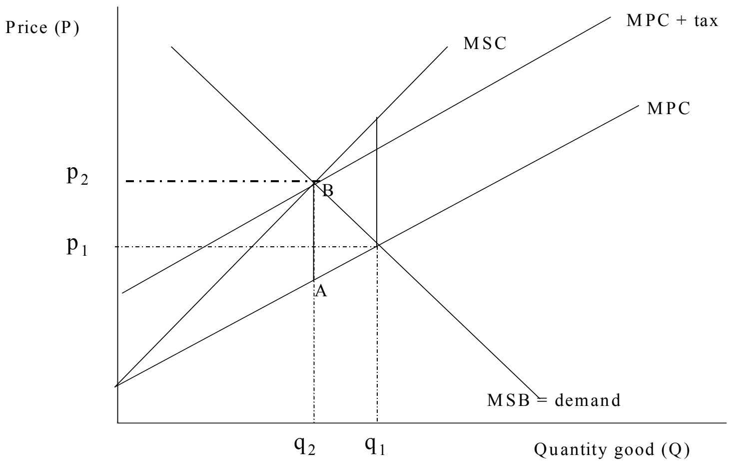

Figure 3.3 Pigouvian tax

This difference (line AB) is the size of the pigouvian tax which will yield an allocative efficient outcome, this tax has to be charged over each produced unit of the good. This raises the MPC of the firm to MPC + tax, the perceived marginal cost line of the firms increases and as can be seen from the graph, the equilibrium point is reached (q_2) where MSC = MSB. The tax effectively internalizes the externality to reach the efficient equilibrium point. The tax paid by the producers and the consumers is an income for the government. Redistribution of this money could be used to assist the industry in developing cleaner technology. The difficult factor for the government is the determination of the level of the tax. It is in practise very difficult to derive the correct MSB, MSC and MPC curves. Determination of the right tax is troubled by this information constraint. This could cause the tax to be too low and too much production and pollution will take place, or the tax could be too high and too little production will lower the benefits to society. Taxes have to be taken up in the law system, this requires time and makes the taxes inflexible. If taxes have to be adjusted (increased) protest from citizens or firms can be expected, which makes it politically undesirable to adjust a tax once it is in place. This makes the tax instrument inflexible and can cause inefficient taxes to be kept, while in practise a trial-and-error method is needed to find the right tax-level (Sterner 2003).

Taxes can be charged at different stages in the production process, tax on inputs, output or emissions are possible. Tax on inputs which are used in a polluting process will provide incentives to use less inputs, but does not encourage firms to develop technology to adapt the production process to decrease the pollution. A tax on emission of the pollutant does give incentives to decrease the emissions. It can however be very difficult to measure the emissions to put a tax on the emission per unit. If no possibilities for abatement of the production exist, a reduction in production is the only option to decrease the negative externality and a tax on the product would then be appropriate as last resort.

4.3.2 Subsidies

Subsidies can generally be modelled the same way as a tax. Economics consider subsidies to a large extent to be a negative tax. Subsidies can appear in many forms, like financing of abatement measures which can be twofold:

1. a subsidy for investment in equipment for example a grant for a filter.
2. a subsidy for reduction in pollution, where each unit of reduction receives a subsidy.

Other subsidy forms can be funding of research projects in abatement methods which knowledge can become a public good, or cleanup of public area’s after calamities like oil-spills.

Subsidies have however several draw backs:

- The polluter is paid to abate, what opposes the ‘polluter pays principle’ which is important in many countries.
- Subsidies have to be funded with taxes somewhere else in the economy and this has strong redistribution consequences.
- Subsidies can have the perverse effect that with a subsidy on abatement, new polluting firms are attracted to the market, which cannot make a profit without the subsidy, but with the extra revenue from the subsidy can exists, effectively increasing the total amount of pollution produced.

The main problem concerning subsidies is however not the subsidy on abatement, but the subsidy on pollution. An example is the use of energy, many countries offer lower taxes or even give subsidies on the use of energy by firms. This is done to make it attractive for the firms to invest in the country and provide jobs. The firms do however not perceive the right price for the energy and consequently overuse the energy, which generates negative external effects to society. These kinds of subsidies are strongly rooted in society and are difficult to remove since people have become depended on them with their investments. Removal will encounter strong protests from the beneficiaries of the subsidies.

4.3.3 Deposit and refund systems

Deposit and Refund systems provide incentives for environmental friendly behaviour via a payment from the potential polluter which is (partly) refunded when compliance with the regulation is ascertained. This effectively shifts the burden of proof from the regulator to the agent and hence lowers the costs of control for the government.

Deposit/refund systems are often applied in garbage disposal schemes to prevent illegal disposal. When purchasing a product payment above the price of the producer has to be made, this additional amount is refunded as the used product is returned to the assigned location. Control is in this system not necessary because compliance is assured when the object is returned for proper disposal. A tax on the use of the product could be implemented by not totally refunding the fee. The incentive to return the object has to be high enough, so that people will actually return it. The system has to be developed in such a way that the misuse like the import of disposed products from abroad to collect the fee, is minimised.

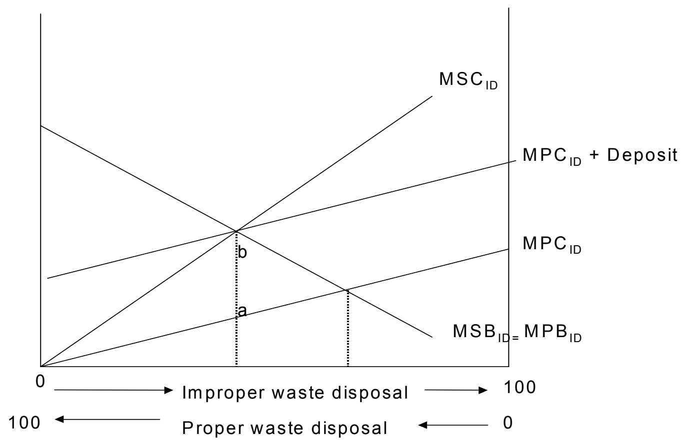

Figure 3.4 Deposit Refund system source: Callan and Thomas 1996

Another possibility of this system is to charge the consumer for the dump and disposal costs of the product. The dump costs can be refunded if the used product is returned and the disposal fee is kept to pay for the disposal. The cost for disposal are then effectively internalised. An additional advantage is that the disposed products can be recycled to reduce the demand for new (natural) resources.

If the deposit is considered as the difference between MPC and MSC in the case of illegal disposal, the deposit refund scheme can be modelled as shown in figure 3.4, ID stands for improper disposal. As can be seen from the figure the extra deposit of ab shifts the MPC curve up to the point where the new MPC curve intersects with the MSB curve. The costs of improper disposal are internalised and more waste will be offered for proper disposal. Still some people will prefer to improperly dispose of their waste, the fee they have paid and is not returned can be used for extra cleaning efforts of the improper disposed waste.

4.3.4 Tradable permits

Tradable permits are very well-suited for abatement of uniformly mixing pollutants, because *the location* of the emission is irrelevant. It is extremely complicated to introduce systems of tradable permits, although the experience so far is rather positive, because emission reduction can be obtained at relatively low costs. For uniformly mixing pollutants a system of tradable permits at the global level would be appropriate. For non-uniformly mixing pollutant's trade should be restricted to certain regions, in order to avoid accumulation of emissions at certain locations. If pollutant are nor uniformly mixing "hot spots" of pollution could emerge if the factories which pollute extra (and abate less) are concentrated in certain areas. A trade system according to location could then be developed but this is more complex and will increase the (transaction) costs of the system.

A system that uses the market mechanism to equal the MAC across polluters would allow for the abatement to be realised at the lowest possible costs.

Different systems of pollution trade can be distinguished whereby two systems are most common. These are the system for the trade of credits and the system for permit trade. In the credit system it is possible to earn credits which can be sold on the market. To earn credits companies can abate under a certain limit, often an earlier set standard, and earn credits with every unit they abate under the set standard. These units can then be sold on the credit markets to companies who emit above the standard.

A pollution permit system allows for a certain amount of pollution to be emitted, but the polluter needs to have an allowance to emit. These allowances can be distributed or auctioned by a governance agency and be traded on a allowance market. If the government gives the permits to the firms for free it is called “grandfathering”. The government can force the firms to abate by distributing less permits then is needed given the initial amount of pollution from the industry. This is called a ”cap” on the emissions.

The advantage of a trade system is that the price of abatement or the permits need not to be established. This is a problem with tax or subsidy schemes, that the ideal pigouvian tax level is hard to determine without perfect information. In the case of allowances the level of pollution is set, namely the number of pollution permits (each permit allows for a certain fixed quantity of pollution). The price is determined in the market by the supply and demand for permits. The permits create a form of property rights in pollution, people are allowed to use the right or sell the right if possible. This allows for more flexibility from the regulator because additional permits can be bought by the regulator (or environmental groups) and taken out of the market, to reduce emissions further.

The possibility for sale of the permits creates an incentive for the polluter to invest in technology for abatement. If the MAC of the firm are lower then the market price of the permits the firm can make a profit when it abates one unit more and sells the permit for that unit. New technologies can lower the marginal abatement costs of the firm so trough investment in technology profits can me made in this system. Efficient abaters will have an incentive to abate while inefficient abaters have an incentive to buy permits.

Problems with pollution permits do exist. It is important that the system is very well defined. Companies are required to make large investments for permits and to cooperation in the system. This creates a form of irreversibility. The system can not be stopped without damages to the firms. To persuade the firms to invest and make the system work the companies need to have trust in the system and the regulating agency. Therefore a well defined system is important. Problems with new firms who want to enter the market need to be addressed. If the permits are distributed new firms need to obtain permits to be able to produce, this is an extra cost for potential new firms. If they have to buy permits an extra entry barrier is created, this can be an extra difficulty if old companies do not want to trade to prevent new competition from entering the market.

The market system, which needs free entry to be efficient, is then disrupted and a new form of oligopoly created. Possible solutions are temporarily exemption from the system for new firms, or grandfathering of permits for the new firms.

The efficiency of trading in abatement can be shown by an example. Imagine an economy of two firms who produce goods but in the production create pollution which causes a decrease in benefits for society. The government wants to reduce pollution and considers two options, namely setting a fixed abatement for both firms, or setting a fixed total abatement, assigning half of the abatement to each firm, but allowing the firms to trade in abatement. The characteristics of the two firms are given below, in the function the abatement in unspecified units is represented by (A).

	firm one	firm two
Total abatement costs (€):	$TAC_1 = 6A^2$	$TAC_2 = 3A^2$
Marginal abatement costs (€):	$MAC_1 = 12A$	$MAC_2 = 6A$

The government wants a total abatement in the sector from 12 units of A, and distributes this amount equally over the two firms. Consequently they each have to abate 6 units. This means that the following costs for abatement are relevant:

Firm one:	$TAC_1 = 6*(6^2) =$	€216
Firm two:	$TAC_2 = 3*(6^2) =$	€108
In total:		€324

Due to the different abatement costs functions the firms have different costs for an abatement of six units. Firm two has an advantage in abatement and this is apparent in the lower costs for abatement. This difference in costs could be used to decrease the total abatement costs in the sector. If the government would allow the firms to trade units of abatement the total abatement would be the same but the total costs for the firms could be lower if the firms could trade until their marginal abatement costs are equal. The new quantities of abatement per firm can easily be calculated:

Total quantity of abatement:	12
Abatement firm one:	A_1
Abatement firm two:	A_2

Total abatement:	$12 = A_1 + A_2$
equal marginal costs:	$MAC_1 = MAC_2$
equal marginal costs	$12A_1 = 6A_2 \rightarrow 2A_1 = A_2$
Distributing abatement according to marginal costs	$12 = A_1 + 2A_1$
abatement firm 1	$A_1 = 4$
abatement firm 2	$A_2 = 8$

In the new situation the following costs are made by the firms:

Firm one:	$TAC_1 = 6*(4^2) =$	€96
Firm two:	$TAC_2 = 3*(8^2) =$	€192
In total:		€288

The total costs are lower with trading then in the first situation without trading. The costs of €96 for firm one are not the only costs the firm has for the abatement. Firm one will pay firm 2 to abate two units more then the amount assigned by the government (the firms both have to abate 6 units). This is revenue for firm two, payment will at least be enough to pay for the abatement (otherwise firm 2 will not abate for firm one), but probably be higher so both firms profit from the trade, the price paid will be between the marginal abatement costs of firm one and firm two (If the price is above the MAC of firm one, the firm will abate and not buy credits). This payment is however not considered a cost of abatement, because the money stays in the sector. There are several examples of trading schemes for environmental improvement in Europe and the USA. A well known example is the credit trading system developed for the Kyoto protocol which aims at reducing greenhouse gasses in the atmosphere. In this scheme countries can reduce emissions at home, or they can buy permits from other countries, but also development of projects in other countries is possible which can earn credits for the investing country.

4.4 Voluntary Agreements

Voluntary agreements can take different forms, and are usually agreements between governmental organisations and (groups of) private parties to achieve some environmental goal. Voluntary agreements can be legally binding, but in most agreements this is not the case. Motivation for private firms to initiate voluntary agreements can be to avoid other policy measures from the government, or to be more involved in the development of these policy measures. Voluntary agreements can show that the companies entering into them are conscious about the environmental impact of their activities. This can be an advantage in cooperation with the government who might in return of voluntary measures from the firms be more inclined to be lenient towards these firms in other regulation or control matters. Important is also the marketing value of voluntary agreements: with these agreements the firms can show to the public (and potential consumers) that they care for the environment, this fact is often used in marketing campaigns (Sterner 2003). This aspect has similarities with the labelling of environmental friendly products discussed in the next section. Because the agreements are voluntary, compliance is not always guaranteed. Often, voluntary agreements are used in combination with other policy instruments. Advantages for the government are that with voluntary agreements the whole organisation of a firm is involved in improving environmental performance. Improvements which are hard to reach using other instruments can be achieved because voluntary agreements do often motivate the people working in an organisation to do their best and invent small improvements on the work place. The voluntary agreements leave the firms room to determine the best option for abatement of their processes, this means that measures can be taken in an cost-effective way. The costs of voluntary agreements are relatively low compared to other instruments because the industries are closely involved in the process. Implementation of the measures should encounter less resistance and control cost could be low. Free rider effects pose a real treat to the agreements and in the design and negotiation over the agreement this should be addressed. The ambition of the goals is subject of discussion with voluntary agreements, if the goals are set too low the benefits are small and if the goals are too ambitious the private parties might not enter in to the agreement or not live up to the agreement. A combination with other instruments could then be desired (Sterner 2003).

4.5 Information

Information can be considered a “good” in the economy. This good is important for several processes, like technology for production or abatement, but also the information needed for effective policy making. Information on abatement costs and benefits is for example needed to set taxes or subsidies at the right (pigouvian) level. Information is often asymmetrical distributed; firms have information on their abatement costs, but will not make this voluntary available to others. Information can be hard to protect and therefore makes investment in information less attractive, because other parties might benefit from the information someone else invested in, if it can not be protected. Therefore information is often undersupplied and can sometimes be considered a public good, in which government investment is justified.

Information can also be considered as a policy instrument. The government can inform the population on the problems concerning environmental pollution creating awareness. This can initiate research and make the population conscious about the influence of the choices people make, for example in the case of the of labelling environmental friendly products or services. This will make the implementation of environmental policy better understood and can decrease resistance. The disclosure of information can be directed to several levels like management, government or consumers. Rating schemes of environmental pressure could be made from for example inputs and resources. Producers and consumers are then able to make well-informed choices for polluting goods or environmental friendly goods.

Labels need to be scientifically correct. But not so complicated that they become impractical. The criteria should be clear and application voluntary. Too much national labels might trouble international trade and competitiveness; an international label would enhance comparison. But competition between the labels is thought to enhance performance (Sterner 2003).

4.6 Transaction costs

The selection of the right policy instrument to combat environmental pollution is besides other considerations influenced by the available information and the transaction costs. Transaction costs can be described as the costs for the negotiation of a contract ex ante and the control and enforcement of the contract ex post. Examples of these costs are wages, information and travel costs in negotiations, costs of monitoring if the other party is keeping the agreement but also the costs of using the judicial system to enforce contracts. These costs tend to increase with information asymmetry between the parties and higher uncertainty.

Transaction costs associated with the environmental policy instruments can differ strongly between the instruments. Standards have transaction costs in determining the right standard to use, which can be in the case of emission standards very difficult. The control costs in the case of technology standards are relatively low, because a check in the firms if the compulsory equipment is installed can be sufficient. In the case of emission standards the monitoring becomes difficult because in an ideal situation the emissions are constantly monitored which is difficult and can be costly to achieve. This problem is also present in other emission based regulation. Often the measurement of the emissions is the responsibility of the polluting firm, which has an incentive to portrait low emission levels, so firm figures are not necessarily reliable (Sterner 2003). Extra difficult controls might be necessary, increasing the costs of control. This can influence the choice of the instrument or the choice of the regulated substance.

Taxes on emissions can encounter the same measurement problems, increasing the costs of control. This can lead to the choice to regulate other factors then emissions, inputs and output of process are in general easier to monitor then emissions. As shown in section 3 this is not necessarily efficient but, a tax or charge on inputs or output is easier to control, decreasing the monitoring costs. Subsidies on emission reduction encounter the same measurement problems although subsidy on the development of knowledge can decrease the information constraints and related transaction costs.

Tradable permit systems can differ in the amount of transaction costs needed to run the system. Because trading systems tend to be complex, implementation of a system ads extra uncertainty for the firms in an industry, especially in the first periods of the system. Transparency in the rigour and functioning of the system can decrease uncertainty and transaction costs. The measurement of emissions is again complicated. Additional costs are caused by the trade of permits or credits. Negotiations on the sale of permits can increase the costs even as registration of credits and their transfer, this can be countered if trade is regulated via an exchange institution witch acts as effective market for uniform pollution permits. If spatial distributed permits are used extra costs will be added to search for the right permit. Market power can be a problem especially in a small system with small numbers of buyers and sellers, manipulation of the price is possible. In larger systems this influence will be smaller or not present.

Deposit refund systems require costs for administration of the deposits and the refunding of the fees but control of compliance is not necessary, transaction costs are low for this system. Information can help decrease the transaction costs via the provision of knowledge. Well-informed agents and less information asymmetry makes the process transparent, motivate people and improve the functioning of policy instruments, decreasing the costs for monitoring and control.

Voluntary agreements require negotiation of the parties involved over the agreement, but implementation and control costs are generally low. Therefore the transaction costs of voluntary agreements tend to be low.

The choice for a policy instrument is dependent on many factors like the influence on the pollution, influence on society and many economic factors. The choice for an optimal environmental policy instrument can differ per country and is influenced by many factors, besides the national characteristics, many costs like production costs, monitoring costs, information costs, transaction costs and other costs play an important role. Lack of information can make determination of emission levels very complicated, but also the lack of insight in damages from pollution may influence the policy chosen. High costs of monitoring or development of policy instruments can force governments to chose second best options like standards instead of first-best solutions like trading schemes. The policy instruments who are in theory most efficient in allocation and efficiency can in practise function with considerable transaction costs, making other solutions more cost effective. In practise combinations of policy instruments are often used. The complex situation of many environmental problems makes a combination of instruments for several purposes attractive combining the strong points of the instruments while lessening the influence of the weak points.

4.7 International cooperation

International environmental agreements are needed to solve transboundary problems efficiently. Usually the international agreements focus on establishing the emission ceilings for the participating countries, like in the Gothenburg and the Kyoto protocol. Next the parties in the protocol will have to implement their policies to reduce emissions to the agreed level. For cost effectiveness it is essential that countries chose those policy instruments that allow for flexibility, that provide incentives for technological innovations, and that allow for cost efficient solutions if multi-pollutants and joint emission reduction options are at stake.

Because all policy instruments have impacts on the distribution of costs and benefits over countries, strong incentives exist for free riding. In the case of uniformly mixing pollutants it does not matter where the pollution takes place or where it is mitigated, the effect on the global environment is the same. This creates opportunities for free riding which poses a big problem in international cooperation. If many countries agree to work together and form a coalition to decrease a uniformly mixing pollutant, they all will have to invest in that goal, which often put restrictions on their economies compared with non-coalition countries because their firms have to invest in cleaner technology. It becomes very attractive for a country not to join the coalition, not restricting the economy, hence gaining a cost advantages in production over the coalition, while at the same time the country can benefit from the decrease of the pollutant brought about by the coalition. The optimising of benefits of countries given the expected behaviour from other countries makes international cooperation very difficult. This can be explained as follows, if all the countries co-operate in the coalition the so-called "pay-off" from cooperation is as large as possible. This is a Pareto efficient solution where no-one can be made better off without making someone else worse off. From the point of view of the total coalition an efficient point is reached and no changes are necessary. But if the focus is shifted towards individual countries the situation changes. An individual country has two options: stay in the coalition, or leave the coalition. If the country stays in the coalition it has the benefits from less pollution and the costs from the environmental policy measures in place to reduce pollution. If the country abandons the coalition it has the benefits from less pollution, but no costs because it can abandon the policy measures taken to decrease pollution. The incentives to cheat on the coalition are therefore present. This goes for all members of the coalition. Knowing that other countries may as well cheat on the coalition makes the decision for countries to stay in the coalition not rational. If other countries cheat the best thing to do is to cheat as well in order to avoid the costs of the abatement and the possible negative influence on a competitive position in trade. If the other countries do not cheat it is for a rational, selfish country still the best option to cheat so that without the costs the benefits will be gained. The result is that given the possible choices of the other countries it is best to cheat on the coalition!

This situation can be analysed using game-theory, whereby the possible pay-off for players is analysed assuming rational, self-interested behaviour from the players. This can be represented by table 3.1, where the choices of two countries are given.

Player		Player 1	Player 1
	strategy	stay in the coalition	cheat on the coalition
Player 2	stay in the coalition	6 6	7 -2
Player 2	cheat on the coalition	-2 7	-1 -1

Table 3.1 Pay-off game theory

The pay-off of the players are represented in the matrix. The first number represents the pay-off for player one and the second number the pay-off of player two, when playing the game the use of force is not possible. In the initial situation they both have an pay-off of (-1). If they start co-operating they both can achieve a pay-off of (6). If this game would be played once, it would be the strategy with the least risk to cheat and either gain (7) or loose (-1), instead of stay in the coalition and gain (6) or loose (-2). The total social welfare is lower in the first option, but still that option is chosen, this is called the "prisoners-dilemma". Together the players can be better of if they both stay in the coalition, but the risk that the other player does cheat makes it the best option to cheat, fulfilling the others expectation. If the game is repeatedly played like in real coalitions where the members can decide to quit co-operating in any period the situation is different. When a player breaks the coalition in a two player game the other can respond in the next period by cheating as well. The players will then end up in the cheat/cheat situation with lower benefits for both. Because this risk is apparent and well-known to the player they might refrain from breaking the coalition in the first place, knowing that they then will end up in a worse situation. In a big coalition with more then two players this is not necessarily the case and other safeguards need to be in place to maintain the coalition. The allocation of tradable permits over various countries, or the redistribution of tax revenues can be used to provide incentives to join the coalition and to reduce the incentives for free riding. Other reasons to join the coalition could be international solidarity or political pressure on countries that would not be willing to participate.

4.8 Porter-hypothesis

Investment in the environment and the use of policy instruments is often thought to negatively influence trade and competitive position with countries that do not make these investment. It is thought that this could lead to flight of polluting industry to countries with no or less restricting regulation, in order to have and comparative advantage in not having to invest in pollution abatement. An other disadvantage could be that trade with countries with less restricting regulation becomes more difficult because investing in abatement makes products of the regulated industry more expensive. The Porter-hypothesis states that the opposite could be true namely that investment in cleaner technology gives firms an advantage. The thought is that cleaner technologies have not been applied yet and in general seem to increase the efficiency and consequent costs savings. Another argument is that the firms who have to adapt to strong regulation have to increase their productivity, this would then give them an advantage over other firms who not (yet) had to adapt. The Porter-hypothesis is difficult to test in an empirical setting, and the debate in literature on this issue is ongoing.

4.9 The Kuznets curve

Economic development can not infinitely continue if the natural environment is degraded further and further. To sustain economic growth in the future environmental pressure need to diminish. But are harsh measures necessary to achieve this goal or will a state of decreasing environmental pressure emerge spontaneously?

It is sometimes argued that a state of decreasing pollution will emerge after a certain level of per capita income is reached. After that level the emissions of certain polluting substances will start to decrease. This is often called an “Environmental Kuznets curve” (EKC), named after S. Kuznets who hypothesized the relation between income inequality and increased economic development to be an inverted U-shape. This means that with increasing levels of income, the income inequality will first increase and with a certain level of economic development will start to decrease again. Applied to the environment this would mean that with low-levels of economic development little environmental pressure exist. When an economy starts to develop people will have relatively lower life-standards. The focus will be on the increase of the life standard, the production of enough food and other primary needs, taking environmental damage as a necessity. With increasing development polluting industries will emerge and the environmental pressure will increase. With further development the economy will transform and develop to a more service and knowledge orientated economy. With the development of the economy the primary needs will become satisfied and the focus will shift to other topics. The environment can become more important, as development increases people become aware of the problems with environmental degradation and will take measures to improve the situation. Environmental policy instruments will emerge to stimulate environment friendly behaviour. This can be seen in the early industrialized economies where the awareness of environmental problems has led to measures to combat pollution. If this hypothesis is correct the overall message of the EKC would be to stimulate economic development as an answer to environmental pollution. With higher levels of economic development the environmental pressure will decrease again.

4.9.1 Evidence

The inverted U-shape of the EKC has been investigated for substances on a national level and on a global level. The EKC does seem to apply for particular substances, especially substances which are not uniformly-mixing and have regional and short-term effects, but these results do not hold for the global environment. The conclusion drawn by Arrows et al. (1995) is that economic growth is not the overall solution to environmental damage. The world system will not be able to sustain economic development if the environmental pressure on the system is not relieved. Economic growth alone will not achieve this, other measures need to be implemented to increase environmental quality. The main comments of Arrow et al. (1995) on the EKC are:

a) the U-curve relation tends to be in place for local short term costs of pollution, not for waste and stock pollutants of which the costs are expected over longer periods and at scattered locations, like the costs for greenhouse gasses.
b) The EKC does not hold for resource stocks, only for (some forms of) pollution. If feedback effects are present the relation is even less probable to hold.
c) The EKC does not overview the whole system, the reduction in one pollutant can cause other pollution to increase due to a change in production process, also spatial changes in pollution are not represented in the EKC.
d) Where ECK relations are found the reduction in pollution are often caused by local measures and laws. These do often not take national and international consequences into consideration. When those disadvantaged by the costs of environmental pollution are other countries, poor people or future generations the incentives to seek a solution of the problem are probably less present.

4.9.2 Linking, Delinking and Relinking

The use of resources in the industry or other parts of the economy is often linked with the economic performance. If a lot of products are demanded and a lot of production takes place the use of these materials increases more or less with the same amount as the production increases. The usage of resources and consequently the production of pollution is *linked* with the economic performance. When the economy is growing the pollution increases as well, and in periods of economic downfall the pollution decreases accordingly. To sustain economic growth and relief the pressure on the environment the production processes used must become more efficient and less polluting. The use of for example fossil fuels needs to decrease for sustainable development. This does not mean that less production should take place or that economic growth should decrease. *Delinking* of the connection between the production of environmental pollution and economic production should be stimulated. This means that with stable or growing GDP (or other measures of economic performance) the emission of polluting materials should decrease. This is known as delinking, of for example fossil fuel use corresponding with a decrease in a.o. CO2 emissions. This can be achieved by more efficiency in the use of these resources and the development and use of cleaner technology. Delinking can occur in certain periods due to several reasons like improvement in technology, but after a while *relinking* of economic production and pollution is possible as well. The use of fossil fuels is then again linked with the increase in GDP. New technology or other measures should then be implemented or developed to delink again. There are two levels of delinking; weak or strong. Weak delinking refers to a situation where the intensity of pollution decreases, this means that the pollution does not grow at the same percentage as the GDP. With weak delinking the pollution does however still increase in absolute terms. Strong delinking is present when with a stable or growing GDP the absolute level of pollution is decreasing.

4.10 Conclusion

For non-uniformly mixing pollutants, it is recommended to use region or site specific instruments, like specific standards or differentiated environmental charges that are specific for various locations and regions.

Incentives for technological progress, however, are best provided by economic instruments: tradable emission permits or systems of emission charges are very effective to reduce emissions, provided that the systems of collection of charges is reliable, and that monitoring and enforcement can be effectively implemented. These systems continue to provide incentives for producers to search for low cost and cleaner technologies, because these will reduce the number of permits that the firm has to purchase, or reduce the emission charges that have to be paid. Tradable emission permits and emission charges for various pollutants provide the correct incentives to reduce several pollutants simultaneously, because both systems provide correct incentives to chose those technologies that contribute to emission reduction in the most efficient manner. For example, if charges for carbon dioxide emissions and for acidifying emissions are implemented, producers will chose those technologies that reduce both types of pollutants at the same time and they will continue to search for technologies that enable them to pay less charges to the government.

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5 Cost Benefit Analyses and the Environment

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5.1 Introduction

Decision makers are faced with the need to make explicit or implicit choices as to environmental preservation or to policies that are affecting ecosystems such as deforestation, landreclamation and land use. Such choices involve value judgements about environmental services. Although valuations are not always directly expressed in monetary terms, in practically all cases implicit value assessments are made in the decisions to protect or sacrifice ecosystems.

It is widely recognised that biodiversity is threatened and that extinction of several species occurs or may occur in the near future. Increasing population pressure and higher levels of per capita income will have tremendous impact on ecosystems and on the species that find their habitat in it.

In protecting eco-systems many policy decisions have to be made on for example how to protect the biodiversity: by means of creating reserves; by protecting natural ecosystems by means of direct regulation; by reducing pollution that is affecting ecosystems; by construction corridors between ecosystems; or by means of other policy measures. But first of all, when dealing with the environment, policymakers should make choices about what to protect or to sacrifice, where to protect and how to finance protection of biodiversity. Section 2 describes an example of several dilemma's.

5.2 Example forestry dilemmas

Decisions have to be made about preservation, use and exploitation of ecosystems. E.g. the question to preserve a forest, to use a forest for harvesting of non-timber products, to exploit the forest or to convert it into agricultural land has to be answered by many policymakers in a large number of countries. Decisions to protect a forest can be based on a large variety of motives, and for many different reasons. Some decision makers are in favour of economic cost-benefit analysis, others argue that ethical values and religious conviction should play a dominant role. Many value categories are included in the decision-making process. It is a very challenging question which value categories and which basic attitudes play a role in the decision making processes dealing with protection and exploitation of ecosystems in various countries.

Sometimes it will be possible to combine various functions of ecosystems e.g. preserving a forest in combination with some exploitation of non-timber products is generally possible. Also, some timber exploitation and preservation are possible. However, large scale timber exploitation and preservation of the ecological functions of a forest are conflicting and mutually exclusive. In those cases, difficult decisions must be made, based on explicit (economic) and/or implicit valuations (cultural) of the different issues at stake., E.g. the need to produce food and shelter, the regulation functions of ecosystems, the values attached to ecosystems on basis of ethical or religious principles and the interests of future generations.

As long as sufficient space is available and as long as population pressure and pressure from economic activity is very small no serious problem exists. However, due to increasing population and increasing economic activity, more and more potential areas of conflict are seen. This will place decision makers and local stakeholders for extremely difficult dilemma's: to choose what to protect and what to sacrifice.

5.3 Functions of environmental goods

This section discusses the various functions of environmental goods and services, the various value categories that are related to it and a number of valuation methods which are developed for assessing the economic value of (aspects of) environmental goods.

The quality of life (well-being) and human welfare depend directly or indirectly on the availability of environmental goods and services in many ways. An important aspect of environmental function evaluation is the classification of the different functions of nature. (De Groot, 1992). Early recognition of the functions and the role ecosystems play in maintaining these functions, is essential for ensuring the long-term integrity of environmental systems. In general, the following categories are distinguished (De Groot, 1992):

(1) *Regulation functions:* this group of functions relates to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems which, in turn, contributes to the maintenance of a healthy environment by providing clean air, water and soil.

(2) *Carrier functions:* natural and semi-natural ecosystems provide space and an suitable substrate or medium for many human activities such as habitation, cultivation and recreation.

(3) *Production functions:* nature provides many resources, ranging from food and raw materials for industrial use to energy resources and genetic material.

(4) *Information functions:* natural ecosystems contribute to the maintenance of mental health by providing opportunities for reflection, spiritual enrichment, cognitive development and aesthetic experience.

Clearly functions of ecosystems can be mutually exclusive or competitive, which means that one function cannot be fulfilled if another function is dominating. This competition can be qualitative (polluted water reduces the regulation function) or quantitative (habitation requires space that is not available for other purposes).

Also there are probably many unknown goods and services (functions) which are not yet recognised, but which may have considerable (potential) benefits to human society (De Groot, 1992). Therefore, although Table 1 describes 37 separate functions of nature, a complete listing and division of functions may never be produced. Supplementary to this, De Groot (1992) states: "It must be realised that research on the many functions of the natural environment has only begun and most of the few remaining natural areas on earth and notably their plant and animal life, contain a vast reservoir of still unknown functions with possible future benefits to human society. The present rapid destruction of natural habitats, notably the primary tropical rain forests, and the extermination of wild species and indigenous people, which depend directly on these natural habitats for their survival, greatly reduces the opportunity to explore and use this reservoir of potential information with possibly serious consequences for the survival and wellbeing of both present and future generations." (De Groot, 1992: 14). Very closely related to the functions of nature are the categories of value that are being distinguished in economics. The economic taxonomy of the value of environmental functions makes a distinction between direct and indirect use values and a remainder, the so-called non-use value (Perrings, 1995).

5.4 Economic values of environmental goods

The components of value are illustrated schematically in Figure 1 at the end of this chapter. The figure illustrates the use and non-use values which a multiattribute environmental asset, such as a woodland, provides (Bateman and Turner, 1993). By definition, *use value* refers to the direct value that individuals attribute to the services that an ecosystem provides to them. This can be the recreational value or the production value relating to hunting and fishery of the collection of plants or fruits. Use value is, in other words, a measure of willingness to pay for the goods and services, backed up by utility and purchasing power (Kadekodi and Ravindranath, 1997). For the production value we can usually measure the market price of the goods and services in question. For values for which no market prices are available, such as recreational values, we need to use other valuation methods (Douglas and Johnson, 1992; Clawson and Knetsch, 1966).

Option values need some further explanation, based on Turner *et al.,* 1994. They are essentially expressions of preference, a willingness to pay, for the preservation of environmental systems or components of systems against some probability that the individual will make use of them at a later date. Provided the uncertainty concerning future use is an uncertainty relating to the availability, or 'supply', of the environment, economic theory indicates that this option value is *likely* to be positive (Weisbrod, 1964). A related form of value is *bequest value*, a willingness to pay to preserve the environment for the benefit of one's children and grandchildren. It is not a use value for the current individual valuer, but a potential future use or non-use value for his or her descendants.

Finally, there are *non-use values*. They suggest non-instrumental, anthropocentric values which are in the real nature of the thing but unassociated with actual use, or even the option to use the thing. "Instead such values are taken to be entities that reflect people's preferences, but include concern for, sympathy with and respect for the rights or welfare of non-human beings." (Bateman and Turner, 1993: 122). An example of these non-values is the *existence value* or intrinsic value (Krutilla, 1967; Pearce and Turner, 1990). It refers to the value that the public attributes to the ecosystems just because of their presence, without making direct or indirect use of them. It includes a recognition of the value of the very existence of certain species or whole ecosystems. *Total economic value* is then made up of actual use value plus option value plus existence value. Clearly, the non-use values of ecosystems are in general very difficult to establish. The non-use values have typically a public good character for which no market prices are available.

5.4.1 Value categories

If biodiversity is important to the functioning of some ecological system, it will not automatically be valuable to society, or vice versa. The value of the natural environment to society depends on many factors besides its ecological significance, and these factors tend to vary from one country to another and one culture to another. Economic assessments of biodiversity are in fact also influenced by ethical judgements. They merely make explicit something that is currently implicit. However, there remains a gap between the market price of environmental services and its value to individuals and societies (Perrings, 1995). As already stated, a classification of the economic values of natural environments is shown in Figure 1.

Table 1 Functions of natural environment. Source: *De Groot, (1992), p. 15 Figure 2.0-1.*

Regulation functions	
1.	Protection against harmful cosmic influences
2.	Regulation of the local and global energy balance
3.	Regulation of the chemical composition of the atmosphere
4.	Regulation of the chemical composition of the oceans
5.	Regulation of the local and global climate (incl. The hydrological scale)
6.	Regulation of runoff and flood-prevention (watershed protection)
7.	Watercatchment and groundwater-recharge
8.	Prevention of soil erosion and sediment control
9.	Formation of topsoil and maintenance of soil-fertility
10.	Fixation of solar energy and biomass production
11.	Storage and recycling of organic matter
12.	Storage and recycling of nutrients
13.	Storage and recycling of human waste
14.	Regulation of biological control mechanisms
15.	Maintenance of migration and nursery habitats
16.	Maintenance of biological (and genetic) diversity
Carrier functions	
	providing space and a suitable substrate for
1.	Human habitation and (indigenous) settlements
2.	Cultivation (crop growing, animal husbandry, aquaculture)
3.	Energy conversion
4.	Recreation and tourism
5.	Nature protection
Production functions	
1.	Oxygen
2.	Water (for drinking, irrigation, industry, etc.)
3.	Food and nutritious drinks
4.	Genetic resources
5.	Medicinal resources
6.	Raw materials for clothing and household fabrics
7.	Raw materials for building, construction and industrial use
8.	Biochemicals (other than fuel and medicines)
9.	Fuel and energy
10.	Fodder and fertiliser
11.	Ornamental resources
Information functions	
1.	Aesthetic information
2.	Spiritual and religious information
3.	Historic information (heritage value)
4.	Cultural and artistic inspiration
5.	Scientific and educational information

5.5 Important valuation methods

To establish the benefits of environmental protection some valuation methods have been developed. These methods try to estimate a value for certain environmental area's like nature reserves.

5.5.1 Contingent valuation method

The Contingent Valuation Method (CVM) approach relies on a direct survey/questionnaire in which respondents are confronted with a hypothetical market situation. Faced with information on a specific environmental issue (for example forest conservation or the presence of certain species in nature), they are asked to make bids. Thus they elicit valuations and indicate their willingness to pay or their willingness to accept. If the questionnaires are well designed and if the respondents are responsible and co-operative, this method can reveal the preferences for some aspects of the environment and the presence of nature. However, there has been much controversy concerning the philosophy and practice of contingent valuation surveys. According to Cameron (1997), Sagoff "disputed the contention that respondents will act as potential consumers of an environmental good. He argued that in many cases, they are more likely to act as citizens, who are concerned for the common good rather than just their individual wants and needs." (Cameron, 1997: 157). Other writers suggest that the situation is rather more complex than the simple depiction of individuals acting either as citizens or as consumers. CVM studies try to measure some or all of the above-mentioned value concepts. It can reveal the preferences for some aspects of the environment and the presence of nature. Major attractions of the contingent valuation method are the (technically) applicability to all circumstances and the fact that it is often the only technique available. Its major disadvantage concerns the potential for biased answers by the respondents. However, it seems that experimental work has shown that biases can be kept at an acceptable low level when correct survey instruments are applied (Tietenberg, 1992).

The contingent valuation method is an expressed-preference valuation method and as such is inherently susceptible to various types of bias (Bateman and Turner, 1993). For example, Pearce and Markandya (1987) indicate the following:

- strategic bias, which refers to the incentive to 'free ride';
- design bias, which refers to
  a) starting point bias,
  b) vehicle bias,

c) informational bias.

- hypothetical bias, which refers to the hypothetical character of the CVM approach.
- operational bias, which refers to the question whether the indicated preferences will be the same preferences as could be indicated in an actual market.

The strategic bias emanates from the supposed problem of getting individuals to reveal their true preferences in contexts where, by not telling the truth, they will still secure a benefit in excess of the costs they pay (Pearce and Markandya, 1987). This is known as the 'free rider' problem. Since an increase in nature in general has the characteristic of a public good for which exclusion is impossible and for which no rivalry in consumption exists, the free rider problem will be evident.

The design bias refers to the design of the questionnaire and the method of obtaining the response. First, the starting point bias indicates that the results may be dependent on the level of the first bid as proposed in the questionnaire. Respondents may take this first bid as a reference which leads to a bias in the results. A procedure is developed by Cooper (1993) to determine the optimal sample design for a Dichotomous Choice CVM. Vehicle bias deals with the question of how the respondents react to the way in which they are assumed to pay, for example by tax increases, by entrance fees or surcharges on bills. The existence of vehicle bias may be tested by investigating the mean bid per vehicle type; if they differ significantly vehicle bias exists.

Information bias may be the result of the way in which the information on the environmental issue is presented to the respondents. As well as the general amount and quality of the information provided, the sequence of information may be of importance. Pearce and Markandya (1987) indicated that some studies do indicate vehicle bias, like for example, the paper by Kneese and Schulze (1985).

Hypothetical bias is present if the expressed willingness to pay in a hypothetical situation differs significantly from the willingness to pay in an actual market situation. The test of a CVM study for hypothetical bias may be combined with a situation in which actual payments are to be made [see for example Bishop *et al.* (1983) and Cummings *et al.* (1984)].

Finally, operational bias may, according to Pearce and Markandya (1987), be described "in terms of the extent to which the actual 'operating conditions' in the CVM approximate actual market conditions". To avoid operational bias a set of conditions and prerequisites for CVM could be made. For example this should include that respondents have some knowledge of the good and that they have some experience with varying quantities of the good they are asked to value.

The National Oceanic and Atmospheric Administration (NOAA) in the US asked a group of experts to evaluate the use of CVM in determining non-use values for environmental benefit estimation in particular with regard to oil spills. The panel consisted of Kenneth Arrow, Edward Leamer, Paul Portney, Roy Randner and Howard Schuman (NOAA, 1993). The panel has provided a set of guidelines for CVM studies to be valuable. As in all such cases, the more closely the guidelines are followed, the more reliable the results will be. Thus the Panel concludes: " that CVM studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including the lost passive-use values. To be acceptable for this purpose, such studies should follow the guidelines of the report. The phrase "be the starting point" is meant to emphasise that the panel does not suggest that CVM estimates can be taken as automatically defining the range of compensable damages within narrow limits". (NOAA, 1993). The report clearly indicates the strength and the weaknesses of the CVM method in valuing non-use values and public goods. If the surveys are well designed and if the results are carefully and correctly interpreted the CVM results provide at least an indication of the value of a number of non-use values of sustainable ecosystems or nature preservation. In this manner a valuation of landscape is possible as well (Willis and Garrod, 1993). Problems arise if the respondents have insufficient information or insight into the processes and mechanism that are essential for assessing the value of policy alternatives. In those cases, the CVM produces results that are not useful.

5.5.2 Hedonic pricing method

The *hedonic pricing method* (based on the assumption of hedonism as the basis for human behaviour) derives the value of some aspects of environmental quality from actual market prices of some private goods. For example, we can expect real estate prices nearby a national park, ceteris paribus, to be higher than in industrial areas. Other things being equal, the difference in housing prices shows the premium paid for the local environment: how the consumer values the availability of nature. Thus the purchaser's willingness to pay is indicated. The hedonic pricing method is founded upon a coherent theoretical base and while it does appear to be reasonably robust, it nevertheless does have some problems (Bateman, 1993; Turner *et al.,* 1994). Multiple regression techniques are used to estimate the value of the natural surroundings of houses. As it will be hard to find two houses exactly alike except for the environmental characteristics of their neighbourhood, the price of a house has to be decomposed. In this way, not only the natural ecosystem but also the contribution of for example an attached garage, the accessibility of a shopping centre, and the level and quality of local public facilities are taken into account. If a relevant variable is left out, the analysis will be biased. When irrelevant variables are included no such bias will occur. Though, it is not to be advised to include as many variables as possible, because many variables will typically be closely correlated which makes it difficult to separate out the effects of these variables.

An advantage of the hedonic pricing method is that the valuation is based on revealed preferences and not on a hypothetical market situation. However, the hedonic pricing method can only be applied in a limited number of cases (particularly air pollution and noise) and it is generally difficult to find circumstances that allow the application of the method. Moreover, it is almost impossible to generalise the individual results obtained by means of the hedonic pricing method to the total population, as the preferences of those in question may not be representative for the whole population. The hedonic pricing method requires demand functions to be estimated and the mathematical specification of the demand functions to be estimated may influence the results. When these statistical problems are dealt with satisfactorily, two other problems still remain, both with respect to the measurement of the variables. First there is the problem of measuring different degrees of 'greenness'. How do we determine the differences in the natural surroundings accurately? Second, it has to be questioned whether one is dealing with a efficiently operating housing market. In practice, the price paid for a house will not always equal the highest bidder's willingness to pay. Also the housing market will be segmented, so pooling data will render biases and it will be necessary to assess the willingness to pay separately for each area (Hanley, 1992; RMNO, 1988; Pearce and Markandya, 1987).

5.5.3 Travel cost method

The *travel cost method* (TCM) is one of the earliest methods for valuing recreational functions of the environment. Just like the hedonic pricing method, the travel cost method is based on observed behaviour. Both methods generate predictions of quantities demanded and produce welfare measures from visits to the sites in question (Clawson and Knetsch, 1966; Knetsch and Davis 1966; Brown and Mendelsohn, 1984 and Howe, 1991). The travel cost method is particularly useful in a limited number of cases and is especially valid for assessing recreational values. It allows us to estimate a demand curve and thereby recreational value. However, it is not suitable for other types of environmental valuations. If a number of recreational sites are available, the travel costs (the costs of getting there and the time spent which represents foregone earnings), the socio-economic characteristics of the population (their income, preferences for recreation and access to other recreational facilities), a possible entry fee and the number of visitors allow to develop a demand function for the site, assuming that visitation rates respond to changes in travel costs as they would to an equal (increase in) admission charge at the site. The demand function can then be transferred to the evaluation of other sites provided they have similar characteristics. The Travel Cost Method seems a relatively straightforward technique based upon the assumption that recreational value must be related to travel cost. However, several problems may arise during the practical application of this technique, a few of which we raise here (Turner *et al.,* 1994).

1. *The value of time.* The underlying theory of the TCM is that travel expenditures reflect the recreational value of visiting a site. This means that travel cost is not only related to petrol expenses, but that time is also valuable to people. After all, time spent during a long car journey cannot be spent doing something else. As a scarce commodity, time clearly has an implicit (or shadow) price. However, how should this price be estimated? The wage rate seems the correct opportunity cost if individuals are giving up working time in order to visit a site. However, because most individuals are constrained by their contracts as to working hours, most recreation time is spent at the expense of alternative recreational activity (Hanley and Spash, 1993). Furthermore, it does not seem possible to put a price on an hour spent in a car, because many people enjoy travelling. For the journey to a recreational site is not a cost and may even be a benefit. Therefore, no real consensus has yet been achieved about how to value time costs (Turner *et al.,* 1994).

2. *Multi-purpose trips.* Individuals visiting a site can be either ‘meanderers’ or ’purposeful visitor’ (Hanley and Spash, 1993). The former term describes those who visit several sites during a single day’s journey. On the other hand, purposeful visitors are those for whom a visit to the site is the sole purpose of their trip. The problem is how to apportion the travel costs of the meanderers. During the day, those visitors may have incurred high travel costs, but only a portion of these reflect the recreational site in question (Turner *et al.,* 1994).

3. *Substitute sites.* Between visitors, there may exist a difference in appreciation of the site. Some visitors visit a site which they particularly enjoy whereas others who have comparatively little enthusiasm for the same site may travel the same distance because there is no other available site near their home. Although it’s clearly incorrect to state that both groups of visitors held the same recreational value for the site, the simple TCM approach would yield this result. To solve this problem, some analysts ask visitors to name substitute sites (Turner *et al.,* 1994), but also other solutions to the problem have been put forward [see Bateman, (1993)]. However, the lack of adequate consideration of substitute sites remains a weakness in many TCM models.

4. *House purchase decision.* Individuals who most value the recreational attributes of various sites may decide to buy houses near those sites. In such cases, travel expenditures will underestimate the recreational value because those visitors will incur relatively low travel costs visiting the sites they value so highly.

5. *Non-paying visitors.* People who have walked from nearby homes are often omitted in TCM studies because they have not incurred travel costs to reach the site. However, this group of visitors may well put a (very) high value on the site in question.

In conclusion, before accepting monetary evaluations, produced by the travel cost method, there are a number of application problems which need to be solved.

5.5.4 Shadow-project method

The *shadow-project method* is closely related with the names of Klaassen and Botterweg (1976). The method is based on the view that no further deterioration of natural areas should take place. If a project has detrimental effects on the environment, these disadvantages will have to be compensated by executing shadow projects simultaneously. The shadow-project method determines the price of a natural area by calculating the costs of reproducing such an area at another location or by calculating the costs of an alternative project that avoids the damage. In other words, the shadow project method estimates the value of a natural area in a indirect way by calculating the costs of developing similar natural areas. Its constraints are the difficulties that will arise when searching for an alternative location and the time needed to develop a new area of the same quality.

5.5.5 Conclusion

It can be concluded that the methods to assess the value of the benefits of nature are suitable for a limited number of the specific functions of nature. They are particularly useful for the aspects that are easy to understand and that have well defined effects that are relevant at a local or regional level. For the public good aspect of the environment, valuation methods may reveal the preferences of the public. However, if life supporting systems and global issues are involved, these methods are, in general, not applicable because the benefits affect a group of people that is much larger than the local group of respondents. A more fundamental question is whether the valuation methods also include the valuation of nature for future generations and whether these valuation methods will lead to sustainable development. For example, these valuation methods are not suitable for assessing the issue of biodiversity and life support functions of ecosystems. In many cases, however, the optimal level of environmental policy should be established on the basis of ecological limits to be provided by groups of experts representing the relevant natural sciences. The role of economists is then restricted to finding cost effective solutions to guarantee that the environmental damage caused by the economic system can be kept within these ecological constraints.

Finally, several studies have attempted to compare the contingent valuation method with various other valuation methods. Pearce and Markandya (1987) give an overview of the work done until that time. They show that in a majority of cases the ranges of values overlap in terms of a +/- 50% interval, which are not exceptional ranges of error in estimates of demand functions in economics. Since then, more studies have been made. For example, d'Arge and Shogren (1989) compared the results of a study for water quality problems as the basis for hedonic pricing, for a market valuation by realters and real estate agents and for a contingent valuation approach. Here only the user values are taken into account. The values derived from this comparison of the hedonic pricing method and the contingent valuation method were similar in magnitude. Also, Shechter *et al.* (1989) applied the hedonic pricing method and contingent valuation to air quality in the Haifa area. They conclude that "these results could be viewed as a modest addition to the efforts of environmental economists to establish CVM as an appropriate valuation model." (Shechter *et al.*, 1989: 134).

5.6 How to make trade-offs?

Trade-offs are benefits from one decision that are bought at the expense of another. If conserving the environment conflicts with economic activity, the question is which view should prevail. Making decisions is based upon the idea that we do only those things that yield us net gains. In other words, where we have to choose between alternatives, we choose that one which offers the greatest net gain. This is the foundation of the cost-benefit analysis (Turner *et al.*, 1994). Market prices of the natural environment, however, are unreliable indicators of social cost, because they may not capture all of the effects of the use of the environment. If the cost and the benefits of environmental protection are known, economic decisions on environmental protection can be made.

It would be helpful if a common framework of analysis can be developed to understand and analyse the problems of environmental valuation. In literature, many suggestions are given that economic valuation methods (such as contingent valuation method, hedonic pricing method or travel cost method for recreational values) can play an important role in making explicit the values which play a role in protection of the environment. Value categories include such categories as ‘use value’, ‘indirect use value’, ‘option value’, ‘bequest value’ and ‘existence value’.

5.6.1 Valuation methods and their applicability

Economic valuation methods are considered to be useful tools to try to assess the above mentioned value categories, but should certainly not be considered as a panacea for all valuation questions related to the environment. In the literature it is indicated that various valuation methods can be applied to various functions or value categories (see Table 2). Table 2 shows that most methods for monetary valuation can only be used for a limited number of value categories. The CVM method is in principle applicable for all value categories, but a scientific debate is going on about it validity, its strength and its drawbacks. It is recommended to apply the relevant valuation methods in practice for the value categories to which they can be applied, in order to obtain the best information about the monetary value of various functions of ecosystems and the environment. The valuation methods make it possible to explicitly pay attention to the various functions of the environment and ecosystems. However, it should be recognised that certainly not all value categories can be captured by means of monetary valuation methods. For example, the CVM method will fail for those value categories that the public is not informed about and has little experience with.

In those cases it is not realistic to assume that useful answers about the willingness to pay can be obtained.

- The monetary valuation methods can only be usefully applied if the policymakers and other stakeholders are supporting the use of these methods. This implies that the methods should be applied if the various stakeholders have proper insight in the methods and can make a useful interpretation of the results.

Many politicians and economists agree that some of these valuation methods can play an important role in decision-making on environmental protection. However, at the same time it is felt that certainly not all valuation questions related to the environment can be solved by monetary valuation methods. Ethical and religious aspects play an important role, and the public good character of environmental amenities is not automatically compatible with value judgements based on private and individual value assessments.

Table 2 Methods for monetary valuation and their applicability.

Method	Direct use value	Indirect use value.	Option value	Bequest Value	Existence value
Market prices	++	++	?	-	-

CVM	++	++	++	++	++
Travel cost	++ recreation	-	-	-	-
Hedonic pricing method	++	-	-	-	-

If monetary valuation methods cannot provide a full solution to the question of how to deal with environmental services, which other methods for policy analysis taking into account monetary as well as non-monetary values are then available, and can be applied for actual policy making?

5.6.2 Values and attitudes

Income and wealth levels are important determinants of basic attitudes. Poverty and lack of wealth set priorities on economic development and exploitation of natural resources. The environment is in these cases a priority of second order. At high income levels preferences for environmental protection increases and the willingness to pay for protection measures also increases.

Values and attitudes play an important role in decision-making on environmental protection. In many cases, values are not expressed in monetary terms. In some countries, a start is made with explicit monetary valuation of various functions of biodiversity and ecosystems. In most countries however, a system of planning and decision-making on the basis of an assessment of various options is more important. Some international agreements have been signed that implicitly value biodiversity, like the Ramsar convention and the Convention on biodiversity. However, in many cases of economic decision-making, value categories that have no direct or indirect use value (such as option value, bequest value and existence value) receive insufficient attention. In many countries, partial cost benefit analyses are made, but in most cases only local or national benefits are taken into account. This implies that the global benefits of environmental protection are often neglected in national and local decision-making. The benefits of environmental protection can be separated into local and global benefits. These benefits often have no market, but when they can be estimated, they are often global in nature (Turner *et al*., 1994). The valuation of the benefits are all in all far from trivial.

5.6.3 The costs of protection and sharing the burden

Environmental protection implies a cost to society: the opportunities forgone by society by protecting environmental aspects. As well as the opportunity cost of protection, the protection of the environment includes also direct operating and capital costs. When the benefits of environmental protection can be classified as global benefits, it will always be in the interest of any one country to see all other countries, except itself, pay for such a protection. The global existence value (see Figure 1) of for example biodiversity often accrues to the rich nations, but does not have a cash flow. In other words, no-one pays Brazil not to set fire to its rainforests (Turner *et al*., 1994).

Environmental protection will result in many economic benefits that can be directly or indirectly attributed to the various functions of ecosystems, species or genetic information. Economic benefits include carbon sequestration, watershed protection, water supply, hydropower and development of genetic potentials for pharmaceuticals, agricultural use, and recreation and tourism. Still a large number of economic benefits are under-utilised and need further attention in order to be taken into account in the economic decision-making process.

5.7 Discounting

Governments investing in environmental projects are confronted with difficult decisions over the choice of projects to select for investment. The budget available makes decisions on which projects to carry out difficult and choices between several projects will normally be necessary. In general the project which delivers the largest benefits to society should be carried out. Determination of the benefits of several environmental projects can be very difficult as described earlier in this chapter. The benefits and costs of a project can be very hard to estimate, but it becomes even more difficult if the costs and benefits of projects befall in different time periods. Comparison of costs and benefits over time is not directly possible, because the value of money is time sensitive. Possession of money at present is valued higher then the possession of the same amount of money in ten years time. The reasons for this are mentioned in the next section. An economic tool often used to compare costs and benefits of different projects over time is the use of the Net Present Value (NPV). To calculate this value all the costs and benefits of a project in the different time periods are calculated in to present day value, which represents the total value the project is going to generate. Only projects with positive value should be carried out. Note that it is not necessary that the project actually creates cash-flows, if the benefits of a nature area are calculated using one of the valuation methods described in this chapter the value derived can be used in costs benefit analyses, but will not physically be generated.

As mentioned above the costs and benefits which are generated in different time periods can not directly be used to calculate the net present value. In the economic valuation of projects the moment in time that the costs are made or the benefits can be used is important. For the comparison of projects the costs and benefits need to be aggregated over time. This is done by 'discounting' whereby future costs and benefits are expressed in present day monetary values. This is done using a discount rate, this is a rate which describes the change of the value of money over time.
In formula 1 describes this calculation.

$$NPV = \frac{B_t - C_t}{(1+r)^t} = NV_t \frac{1}{(1+r)^t} \qquad (1)$$

NPV = Net Present Value
NV_t = Net value at time t
B = Benefits at time t
C = Costs at time t
r = discount rate
t = time period

When a project is evaluated over multiple periods the following formula can be used:

$$NPV = \frac{B_1 - C_1}{(1+r)^1} + \frac{B_2 - C_2}{(1+r)^2} + \ldots + \frac{B_T - C_T}{(1+r)^T} \qquad (2)$$

Which can be written as:

$$NPV = \sum_{t=1}^{t=T} \frac{B_t - C_t}{(1+r)^t} \qquad (3)$$

The net value at a certain time is the difference between benefits and costs in that period. The factor $(1/(1+r)^t)$ is the discounting factor. The value of the chosen discount rate (r) has a large influence on the calculation, it is important to choose this value with care. A high discount rate will put the focus on short time costs and benefits because the further in the future the costs and benefits are situated the less will be the influence on the NPV. A low rate will give more attention to future costs and benefits. The choice of discount rate in private financial decisions is often the rate of return from other investment possibilities for a firm. In public projects this is different, especially when the projects are discounted over a long time period. When values are discounted over long periods of time the value decreases to approach zero in the long run. This means that costs or benefits in the far future have little weight in present project decision making. Large negative influences in the long run are not taken into account, a consequence can be that problems of future generations of present investment decisions are ignored. This has serious ethical consequences. Therefore discounting, and especially the discount rate, is a controversial topic in welfare economics. The discounting of welfare using derived utility is described in the next section.

5.7.1 Reasons for discounting

To see which factors drive discounting one can go back to Böhm-Bawerk (1889, book IV, sect. I). He gives three reasons why future goods are worth less than present ones. First, as goods become more readily available in the future the value of the marginal unit falls over time. Second, people prefer to consume earlier rather than later, they are impatient. Third, time is productive. As productivity grows over time, through learning and technical progress, for example, future goods are easier to produce.[1] Note that the third and the first reason operate together. The third reason postulates consumption growth; the first postulates a declining marginal utility of consumption.

For a formal analysis of discounting we consider an intertemporal welfare function W, which sums up utilities at each point in time:

$$W = \int_{t=0}^{\infty} U(c_t)e^{-\rho t}dt \,. \tag{4}$$

$U(c_t)$ is a time invariant utility function and ρ is the *utility discount rate*. The weight of utility from consumption declines over time with rate ρ. In other words, the utility discount rate is the rate at which the present value of a small increment of utility falls as its date of receipt is delayed. A positive utility discount rate (or pure rate of time preference) implies some form of impatience; utility is preferred sooner rather than later. It has been argued that intergenerational equity requires a zero utility discount rate.[2] Using a positive utility discount rate gives less weight to the well-being of future generations. In this chapter we do not take sides on this issue.

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[1] Böhm-Bawerk (1889, 327) notes that accounting for uncertainty can take the form of time discounting, but he points out that uncertainty is a separate issue.

[2] E.g. Ramsey (1928). See Broome (1994) for a detailed argument and further references.

Even if we assume a zero utility discount rate the value of a unit of consumption may change over time. The rate of this change r is called *consumption discount rate*. As it is used to evaluate public projects it is also called *social discount rate*.

The utility discount rate and the consumption discount rate are related through the intertemporal welfare function (4). Utility at time t is

$$U_t = U(c_t)\,. \tag{5}$$

According to its definition the consumption discount rate r is the rate at which the value of a small increment of consumption falls as time changes. Denoting $dU(c_t)/dc_t = U_c$, we have

$$r = -\frac{\frac{d}{dt}\left(U_c e^{-\rho t}\right)}{U_c e^{-\rho t}}\,. \tag{6}$$

Define

$$\eta = -\frac{c \cdot U_{cc}}{U_c}\,, \tag{7}$$

then we obtain the Ramsey formula by rewriting equation (6):

$$r = \rho + \eta\frac{\dot{c}}{c}\,, \tag{8}$$

where $\dot{c}/c$ is the growth rate of consumption and η is the absolute value of the elasticity of marginal utility with respect to consumption; cf. e.g. Lind (1995). This brings out the relationship between the utility discount rate ρ and the consumption discount rate r most clearly.

The Ramsey formula (8) matches Böhm-Bawerk's analysis. If $\eta > 0$ (first reason), $\dot{c}/c > 0$ (third reason) and $\rho \geq 0$ (second reason) the consumption discount rate r is positive and future goods are worth less than present ones.

5.7.2 Discount rate

The discount rate is a most sensitive parameter in project evaluation. The long-lasting debate on the choice of the discount rate has largely ignored the possibility to use different discount rates to evaluate consumption and environmental quality impacts of a project. Cost-benefit analysis for project evaluation proceeds in two steps. First, costs and benefits of a project or policy at each point in time are estimated. Second, these costs and benefits are aggregated across time. Valuation, the estimation of costs and benefits, poses problems of its own which we do not discuss here.[3] The standard approach to intertemporal aggregation is exponential discounting. To calculate the value of a project future costs and benefits are discounted at a constant (positive) rate. Although this has been challenged on behavioural grounds (Loewenstein and Prelec 1992), on grounds of changing impacts of externalities (Weitzman 1994) or because of uncertainty with regard to the long-run interest rate (Weitzman 2001), time-consistency is a strong argument in favour of it (Strotz 1955). What determines the social discount rate is not a new issue and has been discussed ever since Böhm-Bawerk's (1889) seminal work on the theory of interest; see Lind (1982, 1995) for authoritative surveys. Recently, the issue has gained new importance in the context of climate change policies (see e.g. Arrow et al. 1996) as the discount rate is one of the most sensitive parameters when we deal with long-term impacts. A major result in the literature, which can be traced back to Ramsey (1928) (and indeed to Böhm-Bawerk), is that the social discount rate is made up of two components: the utility discount rate, also called the pure rate of time preference, and a term that accounts for a declining marginal utility as consumption is growing.

Exercise in Cost Benefit analyses.

Two projects provide the following net benefits per year:

Project A: 400 300 200; Project B: 400 250 250

In addition, in project B taxes have to be paid: 50 and 20 in year 2 and 3 respectively.

a. Calculate the net present value for projects A and B, if the discount rate is 3% in a private cost benefit analysis. Which project will be chosen?

b. Calculate the net present value for projects A and B, if the discount rate is 3%, but now in a social CBA.

Which project will be chosen?

Answer:

The exercise can be solved using formula 3 described in this chapter.

In both cases project A has a NPV of 854.16 monetary units

In the private costs benefit analyses the tax are considered a cost. The NPV of project B is in that case 787.35 monetary units.

In the social costs benefit-analyses the taxes are considered a transfer and are not considered a cost. The NPV of project B is in that case 852.78 monetary units.

[3] See e.g. Hanley and Spash (1993).

In case of a private CBA project A should be preferred. In the second case of the social CBA project B is the most favorable.

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6 Case studies and Literature

Lennart van der Burg

6.1 Essential literature

The following articles are essential in this course as they provide additional information on the cost and value of water and the mathematics behind the efficient allocation of water.

Rogers, P., Bhatia, R. and A. Huber, 1998, *Water as a social and economic good: how to put the principle into practice*, Global Water Partnership, TAC background paper 02, Stockholm, Sweden, pp 1- 35.

This paper addresses this lack of understanding by formulating the concept of water as an economic good and explaining, in practical terms, the economic tools that can be used to effect the environmentally, socially, and economically efficient use of water. A clear overview is given of the water value and cost calculations.

Ierland, E., 2006, A *non renewable resource extraction model and a discussion of its implications for water use in Yemen*, Sana'a, pp. 1-7.

Here the stock of fossil water in Yemen is seen as a non-renewable resource. Through the Hottelings rule the price change of water is determined according the social rate of time preference. After some derivations conclusions and discussions are given on the efficient allocation of water in Yemen.

6.2 Case studies

The following case studies are important as they provide a clear overview of how the economic principles can be applied in Yemen. Examples are given on how the standard economics can be applied on water issues in Yemen and other Arabic countries.

Al-Hebshi, M. A., 2005, *Does Small Farmer Investment In Bananas Jeopardize Macroeconomic Stability In Yemen?,* Agricultural Economics & Extension, Department, Faculty of Agricultural Sana'a University, Republic of Yemen, pp. 1-12.

A case study where the argument that private investment makes stabilization policy difficult or even ineffective is examined through small farmer decisions in different agriculture production in Surdud Yemen. If a small farmers' initiative is undertaken, it could be ineffective or negligent at the national level. Calculations are made for the different agricultural production.

Elhibshi, M. and Rabaa, S. A. B., 2006, *Economic Incentives & Water Demand Management, traditional water harvesting systems and management in Wadi Hadhramout*, Yemen, Sultan Qaboos University Water Research Center and Ministry of Regional Municipalities, Environment & Water Resources, pp. 1-17.

An overview of the water resources in wadi Hadhramout is given, which is a key area for agricultural production located in Southern East of Yemen. The different options of water harvesting and management are described and illustrated with a number of examples.

Hellegers, P.J.G.J., Perry, C.J. and Al-Aulaqi, N., 2008, *Incentives to reduce groundwater consumption in Yemen*, LEI-Wageningen UR and Water and Environment Centre (WEC) of Sana'a University in Yemen, pp. 1-17.

This case study gives a clear overview of the possible economic and policy instruments to create an incentive to reduce unsustainable (ground) water consumption in Yemen. A practical insight is gained in the application of these instruments which is more limited due to difficulties of implementing and enforcing change and creating a balance between supply and demand of water.

Walid A. A., 2000, Urban Water Management in Developing Arid Countries*, international Journal of Water Resources Development*, 16:1, pp. 7 — 20 (also used in the previous course 'Water Chain Management')

The water demand of the different water users in the Arabic countries or peninsulas is described. Additionally various aspects of the water supply and handling, such as: sources (desalinisation plants), wastewater treatment capacity and reuse practices, institutions, prices of water (subsidization by government) and Environmental impacts of urban water management.

6.3 Optional literature

The two reports underneath provide a more in depth and detailed overview of the water charging principle. On the ground examples makes the information easy readable.

Al-Eryani, M., Al-Hebshi, M. A. and Girgirah, A., 1998, *Estimation of the Operation and Maintenance Expenditures for Spate Irrigation Systems.* (Case Studies from Wadis Zabid, Rima, Abyan, and Tuban- Republic of Yemen), Background Papers for PIM Seminar (Hudiedah 22-27 Nov. 1998) Participatory Irrigation Management in Surface Irrigation Systems: Selected Studies, Sana'a, World Bank- Resident Mission (ROY) and Ghayth Aquatech, Ltd., pp. 1-53.

In this study the questions regarding the: O&M budgetary and financial requirements, actual budget allocations made to the concerned irrigation departments and the sources of finance including contributions by the government and by farmers; are answered. For this purpose, four representative spate irrigation systems are selected.

Bosworth, B., G. Cornish C. J. Perry and J Burk (2004) Water charging in irrigated agriculture. An analysis of international experience, FAO Water Report No. 28. FAO, Rome, pp. 1-98.

In this comprehensive report different aspects of the concept of irrigation water charging are described. The given examples of water problems in areas around the world are useful to illustrate and explain the theory and background of water charges in the agriculture.

6.4 Presentations

The following documents are highlighting some important social, economic and environmental water issues in Yemen.

Al-Hebshi, M. A., 2008, The Role of Terraces on Land and Water Conservation in The inKuhlanKuhlan--Affar / Wide Sharis Districts Hajja –YAR, Programm der ALUMNI – Sommerschule, Aden University & Rostock University, presentation, pp. 1-39.

Information on efficient land usage for labour, water and the environment is given. Furthermore attention is paid to the degradation of the natural resources'.

Al-Hebshi, M. A., Economic Incentive Structures for Groundwater Extraction in Yemen, Department of Agricultural Economics & Extension, Faculty of Agriculture, Sana'a University, pp. 1-29.

Overview of the cost and value of agricultural and irrigation water. Tariff calculation and comparison of different (renewable) water usage between crops and between Arabic countries.

Al-Hebshi, M. A. and Bin Rabaa, S. A., Disposal of the Water Accompanying Masila Oil in Yemen

Overview of the available water resources in Yemen and the historic and future development thereof.

6.5 Assignments

The following questions and small exercises are specifically applicable for the case study Hellegers (2008). However, it is advocated to use Van Ierland (2004), Rogers (1998) and additional background literature in order to answer the questions sufficiently.

Note: for some questions there is not a definite answer, so good argumentation will be required.

1. Efficient water allocation

Agriculture in Yemen uses between 85 and 90 percent of the national water resources while it is only contributing 15 percent to the GDP (Aslam Chaudhry). In Hellegers (2008) attention is paid to reduce the unsustainable groundwater consumption. In order to create an incentive for the farmers to change to sustainable and profitable water uses a number of economic and policy instruments are introduced.

a). Give at least 5 market based economic or policy instruments that are already or can be introduced in the Hellegers (2008) case study. Give a short description of the positive and negative aspects of each instrument.

b). Which of the instruments do **you** think can be best introduced in this case study? Give sufficient argumentation.

c). Which environmental and economic externalities (positive and negative) need to be taken in to account when introducing chosen instruments?

d). What kind of information is needed in order to make the appropriate decision of introducing a specific instrument in this case? What is the result of a shortage of information?

2. The net return to water

a). Assume that through a radical improvement in the grape production, farmers are able to produce more grapes of a better quality with a lower fertilizer and water usage. The Qat production improves slightly compared to the figures in the case study, however the crop prices are lower. Derive the value of water per unit production of Qat and Grapes with the following characteristics:

Average costs / values	Qat	Grapes
Crop yield (kg/ha)	1,000	11,200
Crop price ($/kg)	12.5	1.2
Costs of fertilizer, pesticides, clay ($/ha)	400	350
Costs of labor ($/ha)	326	327
Actual irrigation water applied (m^3/ha)	13,000	8,000
Pumping water at a depth of	180	94

b). Calculate the bio-physical crop water productivity in kg/m^3 and the economic crop water productivity in $/$m^3$ for both Qat and Grapes production. Which crop production is most effective from a water management and economic point of view?

c).Why is it difficult to compute the returns of water precisely in Hellegers (2008)? What can be the solution?

3. The Water tariff (based on Walid 2000)

Water in the Arabian Peninsula is heavily subsidized by the governments concerned. A special tariff for municipal water is designed by each country. In general, water charges are much lower than the actual costs of water production and distribution. The water tariff in the Arabian Peninsula shows clearly that with the exception of Oman and Yemen, the medium-sized family pays less than 20% of the water price in developed countries.

a). Give at least three negative or positive consequences and drawbacks of this heavily subsidized water price?

In 1996 the total desalination water represents about 47% of the total domestic and industrial water demand of the countries in the Arabian Peninsula. The rest of the water is from limited surface water and mostly from groundwater resources in shallow and deep aquifers. The desalinated water supplies vary among these countries. At the year 2000, the desalination production is estimated to be about 38%, 89%, 99% and 23% of the total domestic and industrial water demands in Saudi Arabia, Kuwait, UAE and Yemen respectively.

b). Given an estimation of the actual production cost of desalinated water and what water price do you advice to cover all the cost? (take in to account Rogers 1998:18)

c) What kind of solutions is given in Walid (2000) to deal with the rising urban water demand? Which economic principles can be / are related to some of them?

Figure 1 The total economic value of biodiversity. Source: *Adapted from Bateman and Turner (1993), p. 121 Figure 5.1.*