A Sketch of Environmental Microeconomics 7

7.1 Internalizing Externalities

It has been explained in Sect. 6.3 that firms striving for profit maximization are anxious to minimize cost (by definition). Cost minimization is also a socially welcome project because it implies the minimization of resource use and thereby an important contribution to the social goal of softening the problem of scarcity. The problem for firms minimizing cost within a market system is that they are interested in minimizing the use of only those resources that they have to buy in the marketplace. Profit maximizing firms do not care about minimizing the use of resources they do not have to pay for, but can instead take out of the environment for free.[1] As a result of this, the aim of harmonizing the objective of society not to waste scarce resources and the objective of the firm not to do so, is only achievable when the market system forces the economic agents to behave economically by making them pay.

A competent diagnosis is the first step towards a successful cure, in medicine as well as in other areas of human life. Given that the problem of market failure due to externalities is generated by the fact that firms do not have to pay for using up environmental resources, then we just make them pay! This is the general idea underlying any environmental policy obeying the *polluter pays principle*.

Today, this principle comes in many different variants. The original idea is due to the work of the British economist *Arthur Cecil Pigou*. In his ground-breaking work (1920) Pigou suggested that the government should make the polluters pay for the

[1] We are talking about the firm as it is stylized in mainstream microeconomic models. It is not so easy in reality. Here, the manager of a firm might care for the environment because his/her conscience does not allow doing otherwise, or because doing otherwise would draw punishment from the consumers, or employees (or even his/her children at home at the breakfast table!). In this introductory textbook we ignore these real deviations from the standard model of the firm. We may do so without worrying too much about this omission because the standard model of the firm catches an important part of reality. If it were otherwise we would not suffer as much from environmental problems as we do.

A. Endres and V. Radke, *Economics for Environmental Studies*,
Springer Texts in Business and Economics, DOI 10.1007/978-3-642-31193-2_7,

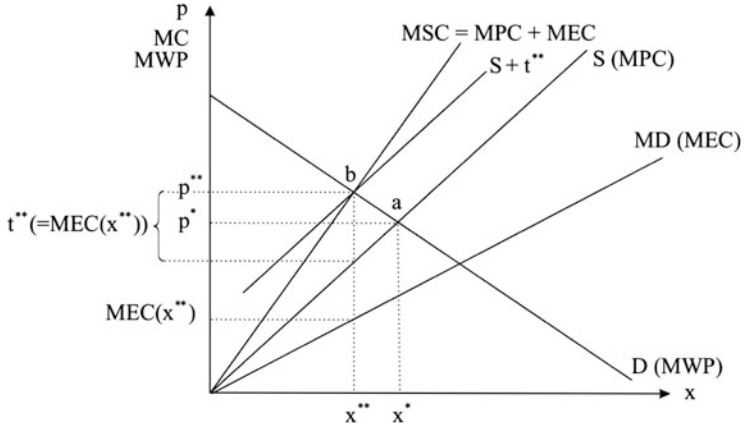

Fig. 7.1 Internalizing externalities with a Pigouvian Tax

environmental resources they use by taxing their emissions. To honour the originator of this idea the subsequent literature calls the special kind of tax the *Pigouvian tax*.[2] Here is how it is to be designed and what effect it is supposed to have.

The Pigouvian tax tries to do for *marginal external cost* what prices of the inputs bought in the factor markets do for *marginal private cost*: make the firms pay! Thereby, the firms are "persuaded" to acknowledge the scarcity of *all the resources* they use, when deciding upon the quantity to be produced. So the idea of the Pigouvian tax is to induce the firms to act upon environmental resources just as economically as they do with respect to resources bought in the market. If this succeeds, the market failure generated by externalities is corrected by the use of the Pigouvian tax. Then, externalities are said to be *internalized*. Given internalization, equilibrium output is driven down from the initially distorted level, x^*, to the socially optimal level, x^{**}.

In order to arrive at this attractive result the Pigouvian tax has to be designed correctly (Fig. 7.1).

Pigou's idea is to use a tax on emissions with a constant *tax rate*. The tax rate is the tax per unit of the pollution. To say it is constant means that the level of the tax rate does not depend on the level of emissions. In the simple model used above (and also used in the work of A.C. Pigou), the level of emissions is in proportion with the level of output. Pursuantly, the Pigouvian tax is constant per unit of output. In order to make the firms acknowledge the damage done to the environment by their production, the tax rate has to be equal to marginal external cost. However, we assumed that marginal external cost is increasing in unison with the level of

[2] The Pigouvian tax is the *Godfather* of all kinds of *ecological taxes* that are presently used in most industrial countries. See Dias Soares et al. (2010) for a recent overview. The authors emphasize that the numerous examples of environmental taxes from the many different countries discussed in their analysis are all part of the "Pigouvian approach" (p. 23).

production. On the other hand, the tax rate is supposed to be constant. To solve this apparent contradiction, it has to be indicated at which level of output marginal external cost is to be evaluated to determine the level of the tax rate. The answer is that the tax rate equals the marginal external cost evaluated at the level of socially optimal production, $t^{**} = MEC(x^{**})$.

Given that, the producers have to pay an amount of t^{**} for each additional unit they produce, on top of marginal private cost. Since the inverse supply curve equals the marginal private cost curve (in its relevant section), as explained above, imposition of the Pigouvian tax makes the inverse supply curve shift upward by an amount of t^{**}. So the inverse supply curve after the imposition of the Pigouvian tax is parallel to the pre-tax inverse supply curve, and the vertical distance between the two curves is t^{**}. The allocation for which the new inverse supply curve intersects the inverse demand curve, thereby constituting the new market equilibrium, features the property that marginal willingness to pay equals the sum of marginal private cost and marginal external cost, $MWP = MPC + MEC$. In other words, the feature of the market equilibrium transformed by the imposition of the Pigouvian tax is that inverse marginal willingness to pay equals marginal social cost, $MWP = MSC$. This feature has been explained as constituting the condition for socially optimal output, above. Thereby, a constant tax rate set at the level of marginal cost evaluated in the socially optimal situation is exactly what Dr. Pigou ordered in terms of his internalization cure for market failure. In the figure, imposition of the Pigouvian tax makes the supply curve shift from S to $S + t^{**}$ and thereby market equilibrium move from a to b. Thereby, the equilibrium provision of the commodity under consideration goes down from the uncorrected market equilibrium level x^{*} to the post-tax equilibrium level x^{**}, which just happens to be socially optimal. That does the trick! The market price increases from the pre-tax level p^{*} to the post-tax level p^{**}.[3]

It is sometimes said that “green taxes” inspired by the Pigouvian idea generate a *double dividend*: the first dividend is the welfare gain reaped by the internalization of negative externalities as explained above. The second dividend is generated if the government uses the tax revenue to reduce the cost of labour as a productive factor. This might be done by reducing the contributions of employers to the social insurance system. This is expected to have an employment stimulating effect. The double dividend hypothesis stylizes ecological taxes as silver bullets simultaneously fighting environmental destruction and unemployment. This stylization might increase the social acceptability of these kinds of taxes. However, closer economic analysis cautions against the double dividend story, suggesting that it cannot be taken at face value under all kinds of circumstances.[4]

[3] It may be noted that the tax rate drives a wedge between the price consumers pay (p^{**}) and the price producers receive ($p^{**} - t^{**}$). Market price increases due to the imposition of the tax, although the price increase ($p^{**} - p^{*}$) is smaller than the tax rate (t^{**}). So the burden of the tax is shared among producers and consumers in that consumers pay a higher price and producers receive a lower price compared to the situation without tax.

[4] See, e.g., Endres (2011, pp. 174–187), for a critical appraisal.

We have explained the Pigouvian tax as a means to internalize externalities. Even though this is still the most well-known internalization strategy, it is not the only one. In environmental economics textbooks (like Endres 2011, and Faure and Skogh 2003), focus is given to negotiations between polluters and pollutees, environmental liability law, and also to the Pigouvian tax. However, we do not deal with these further options in our introductory economic textbook.

7.2 Standard-Oriented Environmental Policy

7.2.1 Introduction

In the previous section we discussed the concept of internalizing externalities. The essence of the matter is to make the polluter pay for the value of the environmental resources used up for production. By definition this concept requires that the relationship between the level of emissions and the level of environmental damage is known, or can be at least assessed in a reasonable way. In mathematical terminology, this relationship is called the *damage function*. It must be emphasized that it is not enough to know a damage function that maps different levels of pollution to different units of different physical dimensions of damage, such as decreased visibility, corrosion of certain materials, or an increased incidence of certain illnesses, e.g., in the respiratory system. Instead, in order to act on the programme of internalization, different levels of pollution must be mapped to different levels of damage in terms of a single dimension – money.

However, there are many people who believe that environmental damage cannot be monetized, and if it could, it shouldn't be.[5] Of course, practical difficulties and ethical concerns vary among different forms of environmental damage. In particular, there is little opposition against monetizing damage such as the corrosion of machinery and buildings, but there is a lot against monetizing damage in terms of increased morbidity and mortality.

We do not deal with this controversy here. Instead, we ponder on the question as to the consequences for the economic approach, if we cannot assess the damage function, be it because of methodological or because of fundamental ethical reasons. Is this the end of *environmental economics*? To the relief of economists interested in environmental issues the answer is "no!" There are many ways to use economic methods to analyze environmental problems and to make recommendations on how environmental policy might be designed to use economic incentives for the benefit of the environment, even if we do not know the damage function.

To get the idea, it is useful to keep in mind what the role of monetizing externalities is, within the internalization framework. Firstly, the marginal external

[5] Issues of monetary valuation of environmental resources are discussed, e.g., in Hackett (2011), Tisdell (2010), and particularly sceptically so in Hahnel (2011). A practical application of these methods (to the cost of oil spills) is in Carson et al. (2004).

cost function has been used, jointly with the private cost function and the demand curve (indicating marginal willingness to pay), to determine the socially optimal level of pollution. In the simple model in which emissions are proportional to output, socially optimal output levels are simultaneously determined with socially optimal emission levels. Secondly, it was used to design the rate of the Pigouvian tax through reconciling the market equilibrium level of output with the socially optimal level of output.

Consequently, without the environmental damage function, the concept of social optimality (and socially optimal output and emission levels, in particular) cannot be applied in a framework where production uses up environmental resources.

Still, society (and policy makers) may take the level of pollution produced in the uncorrected competitive market equilibrium to be too high. Society may wish to reduce pollution even though it cannot specify the target level of this pollution reduction (as from the criterion of social optimality), as defined in microeconomics. So the target level has to be specified otherwise. Suppose that in the process of societal discussions, lobbying, and political decision-making, some target level of the emissions, e, of a certain pollutant, E, is defined. This target level, $\bar{e}$, is supposed to be below the level of emissions of the pollutant under consideration as it is generated in the uncorrected competitive market equilibrium, e^*, i.e. $\bar{e} < e^*$. According to that, society has determined a certain cut back of a certain pollutant by means other than microeconomic social optimization. However, defining the social target of emission reduction is not sufficient to qualify for a comprehensive policy programme regarding the pollutant under consideration. At least two additional problems have to be simultaneously answered by policy makers. The first problem is due to the fact that, in most cases, the pollutant is not generated by one firm only. Most often, emissions of the same kind are produced by many firms. These firms may or may not produce the same commodity. So in addition to determining the amount of pollution reduction, $e^* - \bar{e}$, necessary to arrive at the emissions target level, society must decide how the aggregate pollution reduction burden will be distributed among the firms emitting pollutant E. For the goals of aggregate emission reduction to be achieved, each individual firm has to take action such that the sum of all the firm-specific emission reductions add up to the aggregate emission reduction envisioned by society. Secondly, society must decide on how to induce the firms to follow the societal plan.

7.2.2 Cost-Effective Inter-firm Allocation of Aggregate Pollution Abatement

Beginning with the first issue, we see that in order to argue how a given aggregate emission reduction is to be distributed among the firms emitting the pollutant under consideration in a rational way, we first need a criterion according to which this issue should be decided. Taking the microeconomic view, the task to "produce" emissions reduction has a very important feature in common with all other kinds of production: it uses up scarce resources. Using scarce resources generates costs and, following the microeconomic programme of social welfare maximization, costs must be minimized as a prerequisite. Even if the socially optimal level of pollution cannot be determined in the present framework, the idea of economically dealing with scarce resources requires that no such resources will be wasted, i.e. arriving at the target level of emissions must be achieved in a cost-minimal manner, for every point along that reduction journey.

In applying traditional microeconomic reasoning, the criterion for the determination of the emission reductions of the individual firms is cost minimization.

In general, different firms may incur different costs in curtailing their "production" of the same pollutant. This is so even in the simple model that we have used above with the level of emissions being proportional to output. There, the reason for differences in the cost of abating a certain pollutant is that the firms might produce different kinds of outputs. Then, the cost of output reduction (as a means of emission abatement) generally differs between X producing and Yproducing firms. These costs are the reductions in consumer and producer surplus due to reductions in the level of X and Y, respectively.

Differences in the costs of firms in the abatement of pollution are even bigger in reality, and in a model that is somewhat "richer" than the simple one with emissions proportional to output used above. In this richer model, we allow for all kinds of possibilities in the abatement of emissions, in addition to output reduction. These possibilities consist of "end-of-pipe"-technologies like filters, substitution from high emission intensity inputs to low emission intensity inputs (e.g., coal of different sulphur content), or environmentally-friendly changes in the production methods (e.g., processes with higher effectiveness in combustion).

When we think about how a typical firm might decide between these different options of pollution reduction, we can apply what we have said in Sect. 6.3 on the theory of a firm. Since we assumed there (and continue to do so throughout this book) that firms strive to maximize profits, we conclude that they also strive to minimize costs. It has been argued above that cost minimization is a prerequisite ("a necessary condition") for profit maximization. Accordingly, each firm planning to abate a certain amount of pollution chooses to apply the cost minimizing mix of the available pollution reducing methods. This is true independent of the level of pollution the firm decides to abate. Putting this into mathematical terms we can derive a pollution *abatement cost function*. This function indicates the minimum amount of cost (as the dependent variable) incurred for any amount of pollution reduction (the independent variable). Specifying this function for (small) additional units of emission reductions we arrive at the *marginal abatement cost function*.[6] From the point of view of the economic theory of the firm, there is no difference between a production cost function (marginal production cost function) as used in Sect. 6.3, above, and the abatement cost function (marginal abatement cost function) used in this section. In terms of the cost, producing a commodity follows the same principles like producing pollution abatement.

[6] *Calculus club, mini session*: the marginal abatement cost function is the first order derivative of the total abatement cost function.

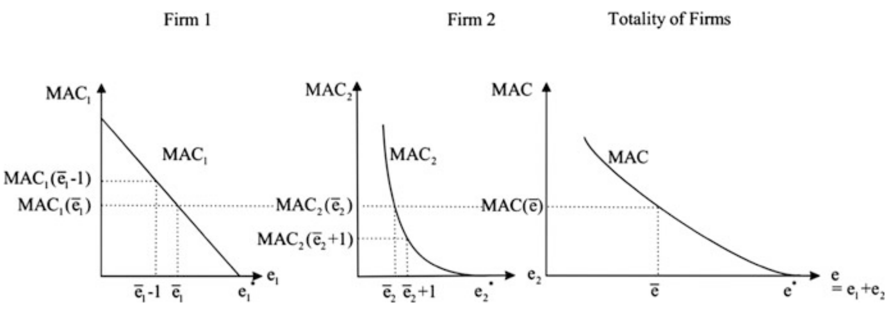

Fig. 7.2 Cost minimizing inter-firm allocation of aggregate pollution abatement

Figure 7.2 shows the marginal abatement cost curves of two typical ("representative") firms, MAC_1, MAC_2 and the aggregate marginal abatement cost function, MAC. This illustration is a complete analogy of Fig. 6.12, illustrating the cost-effective inter-firm allocation of aggregate production. The only inconvenience for the reader (as long as you did not get used to it) is that in the standard production graph the marginal cost curves are to be read "from left to right!" for increasing levels of production, whereas in the pollution abatement graph the marginal abatement cost curves are to be read "from right to left" for increasing abatement levels. This reversal of the direction in the present illustration is due to the fact that the independent variable of the marginal abatement cost function is emission abatement. However, the variable measured on the abscissa of the graph is not the level of emission abatement but the level of emissions. The more the firm abates the lower is the release of emissions. Abatement starts from the uncorrected emission level $e_1^*(e_2^*)$. Emissions move in the direction of zero emissions with increasing abatement levels. As a result, emission abatement is $e_i^* - e_i$ for any emission level e_i between 0 and e_i^*. There, "i" is a general "name" for the firm under consideration, which denotes firm 1 equally as well as it denotes firm 2.[7]

Because of the analogy to what has been said in discussing the theory of the firm we can be brief here regarding the description of the cost minimal allocation. The overall emission reduction $e^* - \bar{e}$ is brought about in the cost minimizing way if firm 1 abates $e_1^* - \bar{e}_1$ units and firm 2 abates $e_2^* - \bar{e}_2$ units. The general rule for these cost minimizing firm-specific abatement levels is that the marginal abatement costs of the two firms must be equal to each other, $MAC_1 = MAC_2$. This is illustrated in the figure for the example of society's emissions target, $\bar{e}$. Of course, the statement is perfectly general: it can be also applied to any other emissions target.

Analogously to what we have said in discussing Fig. 6.12, you can demonstrate that the social cost of reducing overall pollution to a level of $\bar{e}$ would increase in cases where the allocation of total abatement among the firms is changed, for example, to a situation where firm 1 abates one unit more (going to $\bar{e}_1 - 1$) and firm 2 abates one unit of the pollutant less (going to $\bar{e}_2 + 1$). The additional cost to

[7] In formal terms, $i \in \{1, 2\}$ holds.

firm 1, which would be a consequence of this reallocation, would be higher than the cost saving for firm 2 due to this reallocation. Therefore, the reallocation would make the cost for society increase. Accordingly, the situation in this (and any other) reallocation cannot be a cost minimum.

Calculus Club: Session 4

The objective is to minimize total abatement cost, $AC(e_1^* + e_2^* - e_1 - e_2)$, which is defined to be the sum of the firms specific abatement costs, $AC_1(e_1^* - e_1)$, $AC_2(e_2^* - e_2)$. We do this for two firms here without any loss of generality: the exercise does not change, in principle, if extended to the case of many (“n”) firms. The formal expression for this cost minimization problem is

$$AC = AC_1(e_1^* - e_1) + AC_2(e_2^* - e_2) = \min!$$

Cost minimization is subject to the requirement that the aggregate emissions target, $\bar{e}$, is not to be exceeded by the sum of the two firms specific emissions, $e_1 + e_2$.[8] So the minimization is to be done under the constraint of

$e_1 + e_2 = \bar{e}$

Consequently, the Lagrange function is

$L = AC - \lambda(\bar{e} - e_1 - e_2) = \min!$

Writing $\mathrm{MAC_i}$ for $\partial AC_i/\partial(e_1^* - e_i)$, the first order conditions are first order conditions are

$\partial L/\partial e_1 = -MAC_1 + \lambda = 0$

$\partial L/\partial e_2 = -MAC_2 + \lambda = 0$

$\partial L/\partial \lambda = \bar{e} - e_1 - e_2 = 0$

$\rightarrow MAC_1 = MAC_2$

So the necessary condition for the cost minimum allocation for which we are looking is that marginal abatement costs are equal across firms.

Since the second cross derivates equal zero, the second order conditions are

$\partial^2 L/\partial e_1^2 = \partial MAC_1/\partial(e^* - e_1) > 0$

$\partial^2 L/\partial e_2^2 = \partial MAC_2/\partial(e^* - e_2) > 0.$

Accordingly, the extreme value characterized by the first order condition is indeed a minimum if it is located on the increasing parts of the two marginal abatement cost curves. Since, for simplicity, we assumed the marginal abatement cost curves to be monotonously increasing, above, this second order condition is, *ab initio*,[9] met.

We are confident that most (all!) of our cherished readers have noted the complete analogy between the task of deriving the cost minimizing inter-firm

[8] For simplicity, we interpret “not to be exceeded” such that the two individual emission quantities add up to exactly $\bar{e}$.

[9] “ab initio” is a mildly snobbish expression for “right from the start”.

allocation of aggregate pollution abatement, as presented in this calculus club session, with the deriving of the cost effective inter-firm allocation of production, presented in Calculus Club Session 3. Indeed, the structure of these two kinds of problems is identical, and *structure* is exactly what is in the focus of microeconomic theory. In the context of cost-effective inter-firm allocation, pollution abatement is just a production activity like any other. To highlight these kinds of analogies is in the focus of our concept for “Economics for Environmental Studies”.

So the first question asked above has been answered: in order to arrive at a cost-effective inter-firm allocation of a given aggregate emission reduction, the individual reduction proportions of each firm have to be determined such that the marginal abatement costs of all the firms involved are equal.

The second question is how environmental policy can be designed so as to achieve this cost minimizing situation. In the terminology of microeconomics, the question is how environmental policy can create incentives for the polluters such that their equilibrium pollution abatement quantities are identical to the cost effective abatement quantities.

7.2.3 Cost-Effective Design of Environmental Policy Instruments

Among the many environmental policy instruments considered by environmental economics analysis, we focus our attention on a tax on emissions. This is done for the sake of comparability with what we have said about the Pigouvian tax as one of several internalization strategies, as discussed above.

Consider how a firm might react to the imposition of a tax on pollutant E defined by a constant amount per unit of the pollutant (a constant *tax rate*), $\bar{t}$.

Since the firm is striving to minimize costs it would compare the cost of emitting a given unit of the pollutant under consideration, i.e. paying the per unit tax, with the cost of abating the unit under consideration, i.e. the marginal abatement cost. Following this principle, any unit for which the marginal abatement cost is lower than the tax rate will be abated in equilibrium, and vice versa, such that abatement will not be chosen when the marginal cost is higher than the tax rate.

The cost minimizing decision of a typical firm, i, can be understood using the illustration given in Fig. 7.3. If no emissions would be abated at all, the firm would produce the uncorrected equilibrium pollution quantity of e_i^*. The firm would have to pay a tax of $\bar{t}$ for each of the emitted units of a pollutant, resulting in a total tax bill of $\bar{t}e_i^*$. It would be obvious for the firm that it can do better than that in terms of cost. Consider the first unit of the pollutant that might be abated, making pollution go down from a level of e_i^* to a level of $e_1^* - 1$. As you can see from the illustration the costs to abate the first unit are quite low. Specifically, they are much lower than

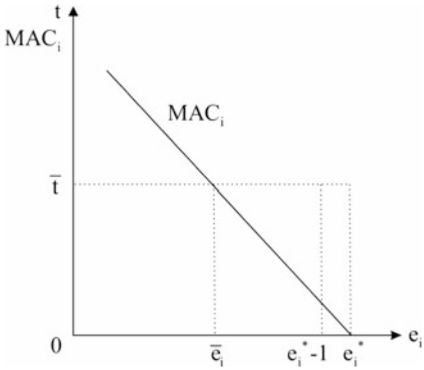

Fig. 7.3 Equilibrium emission abatement with pollution tax

the tax that has to be paid if this unit is emitted. By abating, the firm on the one hand saves the tax on this unit, while on the other it has to pay the cost for abating. Since the former cost is much higher than the latter, it is a good deal for the firm to abate this "marginal" unit. The same reasoning with the same result applies to any additional ("marginal") unit between the initial emission quantity e_i^* and emission quantity $\bar{e}_i$. $\bar{e}_i$ is defined by the fact that the marginal abatement costs of the firm under consideration are equal to the tax rate at $\bar{e}_i$. $\bar{e}_i$ is the equilibrium residual emission quantity given tax rate $\bar{t}$, and $e_i^* - \bar{e}_i$ is the corresponding equilibrium abatement quantity. The equilibrium condition "marginal abatement cost = tax rate", which is fulfilled for abatement quantity $e_i^* - \bar{e}_i$ is written as $\bar{t} = MAC_i$, in mathematical "shorthand". To abate any unit beyond this equilibrium abatement quantity would be unadvisable according to the criterion of cost minimization. For all the units between $\bar{e}_i$ and 0, marginal abatement cost is higher than the tax rate, making the firm lose money by abating.

Calculus Club: Session 5

The cost minimal adjustment of a firm in light of a pollution tax can be stylized in mathematical terms. The total cost, C_i, involved with the emission and with being subject to a pollution tax, consists of the abatement cost, AC_i, for the units not discharged, $e_i^* - e_i$, plus the tax rate, $\bar{t}$, multiplied by the emission quantity, e_i. Resultantly, the problem of the firm is $C_i = AC_i(e_i^* - e_i) + \bar{t}e_i = \min!$

Differentiating for e_i and setting to 0 leads to

$$\partial C_i/\partial e_i = -\frac{\partial AC_i}{\partial(e_i^* - e_i)} + \bar{t} = 0.$$

Writing MAC_i for $\partial AC_i/\partial(e_i^* - e_i)$,

$$\bar{t} = MAC_i$$

turns out to be the first order condition for the cost minimum. Accordingly, the firm minimizes costs by reducing emissions to an extent for which the marginal abatement cost of this firm has risen to a level that is identical to the tax rate.

The second order condition is

$$\partial^2 C_i / \partial e_i{}^2 > 0,$$

i.e., the cost minimum is located on the increasing part of the marginal abatement cost curve. Again, our assumption that the marginal abatement cost curve is monotonically increasing guarantees that the second order condition is met.

The rules of cost minimizing abatement explained above for a representative firm i apply to all other firms. So for one of these firms, j, the equilibrium abatement decision in the presence of a pollution tax with rate $\bar{t}$ is defined by the condition $\bar{t} = MAC_j$: firm j decides to reduce pollution starting from the initial level e_j^* down to a level $\bar{e}_j$ at which the marginal abatement cost is equal to the tax rate.

Above, we have explained the cost minimizing reaction of any individual firm to a pollution tax with a constant rate. That each individual firm behaves in a cost minimizing way, however, does not guarantee that the situation is cost minimal for the economy as a whole. Cost minimization of each individual firm is a necessary, but not a sufficient condition for this to occur. Additionally, the allocation of aggregate pollution abatement is to be allocated between the involved firms in a cost minimizing way. We therefore need one further step in the analysis to show that the pollution tax that we consider here is able to achieve cost minimization for the polluting industry as a whole.

We have established that each firm reduces pollution in a way that equalizes its individual marginal abatement cost with the tax rate. If this tax rate is the same for all the firms, then it follows that in the equilibrium situation the marginal abatement costs are at an identical level for all involved firms. From $\bar{t} = MAC_i$ and $\bar{t} = MAC_j$ for any firms j and i, it follows that $MAC_i = MAC_j$.

In answering the first of the two questions asked in the introduction of this section, we have established that the equality of individual marginal abatement costs is the requirement for the cost-effective inter-firm allocation of the aggregate pollution reduction at which society is aiming. In answering the second question, we have established that after the firms have adjusted to a constant and *general* pollution tax rate, the condition for a cost minimizing inter-firm allocation is met in the equilibrium.[10] So a pollution tax with the properties presumed here is a cost-effective instrument of environmental policy. We illustrate using Fig. 7.4.

[10] With the term "general", we mean that a tax rate is not differentiated across firms.

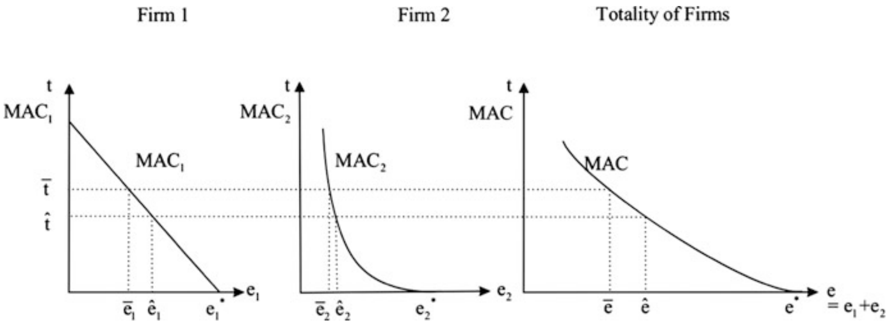

Fig. 7.4 Pollution tax as an instrument of standard oriented environmental policy

In the figure, $\bar{e}$ is the predetermined pollution target of the society. Given that the tax rate is set equal to the aggregate marginal abatement cost at the level of $\bar{e}$, i.e. at $\bar{t} = MAC(\bar{e})$, firms 1 and 2 reduce their respective emissions to $\bar{e}_1$and $\bar{e}_2$. These two individual quantities add up to the societal target level $\bar{e}$ and, according to what has been said above, the aggregate emission reduction $e^* - \bar{e}$ is brought about in a cost minimizing way by the individual contributions of the two firms. It should be noted that any other constant and general tax rate would induce cost-effective adjustments of the two firms, but in achieving that the aggregate societal pollution target would be missed. Consider, for example, a tax rate $\hat{t}$ that is lower than $\bar{t}$. This tax rate would induce the firms to make decisions to abate pollution in a way that minimizes the social costs of pollution. This is so because the marginal abatement cost of the two firms would be equal to one another (and equal to $\hat{t}$) in equilibrium. However, the two equilibrium pollution levels of the firms, $\hat{e}_1$and $\hat{e}_2$ would add up to an aggregate pollution level of $\hat{e}$, which is incompatible with the social target.

We have discussed the properties of taxing pollution in two different forms, above. In Sect. 7.1 we dealt with the Pigouvian tax. This is an instrument to internalize externalities. In the present section we dealt with a different kind of a pollution tax. This latter consideration is not a means by which externalities can be internalized, since it applies to a framework where there is no information on the damage function, which is a prerequisite for any internalization. Instead of aiming at achieving the socially optimal level of pollution, the tax discussed in the present context aims to achieve a more modest goal: to reduce pollution to some predetermined target level. This target level is sometimes called an aggregate *pollution standard*. This standard is not (necessarily) socially optimal. From this, an important difference between the two kinds of pollution taxes that we have discussed is that they serve different goals. On the other hand, they are quite similar. Both forms change the framework under which the individual firms make their decisions in a way that renders pollution reduction economically worthwhile for the firms to a certain extent. In both cases, the tax introduces incentives to treat environmental resources economically just as the price mechanism does for resources bought in private markets.

In order to terminologically distinguish the Pigouvian tax and the tax we have dealt with in the present section, the latter is called a tax in the *pricing and standard approach*. In this term, the word "pricing" alludes to the aspect in that the two taxes are similar: they both use a tax incentive to economize on environmental resources, and one which is a substitute for the incentive generated by the price mechanism. The terminological part with "standard" highlights the respect within which the latter tax is distinguished from the Pigouvian tax. The goal of the policy is not to achieve a socially optimal situation, but to achieve a predetermined outcome with reduced pollution. The main result of the economic analysis of the tax in the sense of the pricing and standard approach is that this is an instrument which achieves the societal goal at minimum abatement cost.

The tax we consider above is just one of several instruments that might serve to achieve a pollution target (although not necessarily a socially optimal one). Another instrument is a system of *transferable discharge permits*. Here, the environmental authority issues a certain number of "rights to pollute". The quantity of these allowances is designed to be compatible with the goal of pollution reduction followed by the environmental policy maker. In order to be able to pollute legally the firms must own the appropriate number of rights.

Emission allowances are auctioned off or given away for free. In the case of the auction, pollution permits obviously carry a market price. The permit price makes emissions costly for the polluter and thereby fulfils the same allocative task as the tax rate in the case of the pricing and standard approach explained above. Even though, at first glance, things might look completely different if permits are given away for free, the market mechanism works similarly. In the case of free initial permit distribution, a market price for each pollution allowance is generated by the firms trading permits among each other.[11]

A practical example for this kind of an environmental policy is the greenhouse gas trading programme of the European Union.[12]

Another standard-oriented approach to environmental policy is *direct governmental intervention* limiting the pollution quantities that are allowed for firms. These interventions may take various forms and are usually summarized under the expression *command and control approach* in the analysis of environmental policies. There are very many examples for this approach in practical environmental policies, such as America's *Clean Air Act*.

These and other "standard-oriented" instruments are discussed in intermediate environmental economics textbooks (like Endres 2011; Sterner and Coria 2011 and Wiesmeth 2012). Moreover, environmental economics highlights cost effectiveness as one of a number of criteria in the comparative assessment of these instruments.

[11] A prerequisite for the evolution of a market is that emission rights are scarce. If the firms are "flooded" with costless pollution allowances, no one wants to buy and the equilibrium permit price is zero.

[12] See, e.g., Ellerman et al. (2007), Endres (2011), Faure and Peeters (2008) for details and assessment.

Among these, the incentives generated by alternative policy instruments to introduce environmentally friendly technologies are important. Further, the accuracy with which the societal pollution target is attained through the use of alternative policy instruments is discussed. However, within the limits of our introductory economics textbook we cannot deal with these extensions and must refer to the literature mentioned above.

That said, there is one line of argument dealing with the economics of standard-oriented environmental policy instruments that carries a particularly favourable benefit-cost-ratio in terms of explaining policy instruments to a novice audience.

The cost of explaining it is low because it directly relates to an argument that we have discussed above at some length. The benefit is high because it is an example for how microeconomic reasoning can support environmental policy analysis and help to derive environmental policy recommendations.

Above, we have characterized the cost-effective inter-firm allocation of a predetermined level of aggregate pollution reduction. As we saw, cost-effective allocation was such that marginal abatement costs are identical across firms. Moreover, it was shown that applying a tax on pollution in the sense of the pricing and standard approach induces the firms to abate pollution to an extent that equalizes their marginal abatement costs in equilibrium. Accordingly, this particular approach of pollution taxation is a cost-effective environmental policy instrument.

Now, compare the cost effectiveness of an alternative approach to environmental policy, a "one size fits all" command and control approach. This command and control policy is defined by requiring proportional emission reductions by the firms emitting the pollutant to be regulated as follows: if aggregate pollution is supposed to be brought down by a certain percentage as a result of the command and control regulation, then each of the involved firms is required to reduce the level of pollution by exactly this percentage.

We illustrate this in Fig. 7.5[13]

On top of this, we assume that in the example we use to illustrate the command and control policy, the approach is designed to bring the aggregate level of pollution down from an aggregate level of e^* to a target level of $e^*/2$. Then, the proportional variant of command and control that we consider here forces each of the two firms involved to cut its pollution by half. The level of firm 1 goes down from e_1^* to $e_1^*/2$ and the level of firm 2's pollution goes down from e_2^* to $e_2^*/2$. This is fine in terms of the target the policy strives to keep, since the two individual post-regulation emission levels just add up to the aggregate target, $e_1^*/2 + e_2^*/2 = e^*/2$. However, what about cost effectiveness? In general, if the two firms are forced to reduce emissions proportionally, they will end up in a situation where their marginal abatement costs differ. This is due to the fact that the marginal abatement cost functions of two firms emitting the same pollutant will have way different shapes in

[13] The curves in this figure are the same as in Fig. 7.4 illustrating the pollution tax in the standard and pricing approach. This is to facilitate the comparison between these two standard-oriented environmental policy instruments.

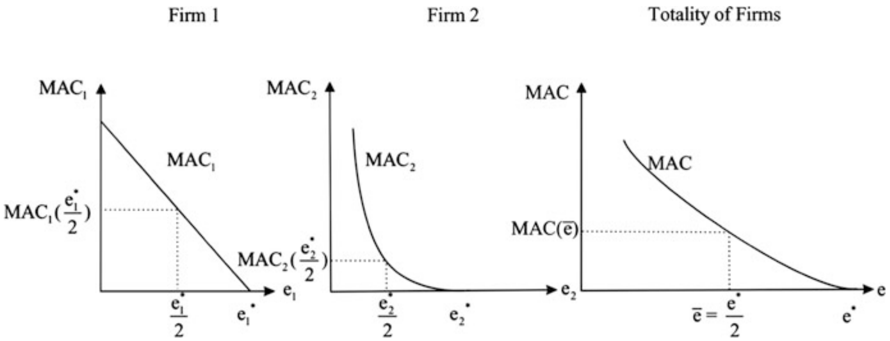

Fig. 7.5 "Command and Control" as an instrument of standard-oriented environmental policy

most cases. This general case is illustrated in the graphic. There, the marginal abatement cost of the first firm is higher than the marginal abatement cost of the second firm in the situation where both firms comply with the regulation, $MAC_1(e_1^*/2) > MAC_2(e_2^*/2)$. Applying your knowledge on the feature of the cost-effective allocation, $MAC_1 = MAC_2$, you can see at one glance that the allocation induced by the command and control regulation stylized here is cost-ineffective. So the goal of arriving at the environmental policy target, $e^*/2$, is achieved by burdening the society with unnecessary cost. Society would reduce total abatement cost and thereby save scarce resources by having the first firm abate a little less and the second firm a little more. This is exactly what a correctly specified emission tax would induce the firms to do.

7.3 International Environmental Problems

Analogously to the societal discussion in many industrialized countries, the analysis of international (specifically global) environmental problems has attracted increasing attention in the environmental economics discussion. This is a reflection of the severe societal worries that have been triggered by problems like the *greenhouse effect* and the damage to the ozone layer.

Much of what has been said above on environmental economics analysis can be applied to international environmental issues. However, there is one crucial respect within which the economic model must be changed so that it can be applied to the international arena.

In the traditional analysis used above, the state (the government) plays a superior role: the government is assumed to recognize the allocative distortion generated by externalities and to make amends it applies strategies of internalization (or in a more pragmatic context, instruments of standard-oriented environmental policy). The objective of the government is assumed to be social welfare maximization and in case the policy maker does not have sufficient information to operationalize the concept of social welfare maximization, the modest substitute of cost effectiveness is applied. Of course, these assumptions are somewhat heroic, even in the national context.[14] The assumptions are highly inappropriate for the analysis of global environmental problems. Here, a *world government* that might be able to play the role of the policy maker akin to what is assumed in the traditional environmental economics models just does not exist. Instead, global environmental policy has to be *voluntarily* agreed upon among sovereign countries.

The question is how to design an international system of policy governance that is able to coordinate the decisions of the independent individual states and to mediate conflicts among them. Basically, this system of policy governance should be able to fulfil the same tasks as the market system coordinating sovereign firms and mediating conflicts among them, as has been discussed in the setting of Sect. 6.3, above.

Of course, in the international policy arena there is a high degree of interdependence between the states of the world. For instance, what the United States' Federal Government decides to do (or not to do) in terms of greenhouse gas abatement certainly affects the situation in China as well as in the countries of the European Union, and vice versa. This is so with respect to the effect greenhouse gas reducing activities in one country have on the level of global warming, as well as in relation to the consequences these activities have on the international competitiveness of national industries.

The problem with this interdependence is that it puts the individual decision making government into the situation of a *dilemma,* which generates extremely adverse incentives to cooperate.[15] This is so because a global environment is sort of a *public good*, the properties of which have been discussed in subsection 2.3.3. Consider global warming as an example. Given that an individual country reduces its greenhouse gas emissions, the beneficial effect of this activity is enjoyed not only by this country itself but by all other countries of the world as well. This is so because the global warming attenuating effect of a certain reduction of greenhouse gas emissions does not depend at all upon the location in which this reduction has been brought about. On the contrary, there is perfect worldwide diffusion of this effect. On the other hand, the costs incurred by the greenhouse gas producing activities do not diffuse at all. They have to be exclusively born by the country that runs these activities. Given these extremely unpleasant asymmetries in the distribution of the benefits and the costs of greenhouse gas reducing activities for a single country, it is plausible that in equilibrium national activities to reduce greenhouse gases will be underprovided. That means that the equilibrium level of these activities falls considerably short of what would be required for the benefit of the worldwide common good (the "global optimum of greenhouse gas-reduction").

---

[14] See, e.g., Kollmann and Schneider (2010).

[15] The problem referred to above is called a "prisoners' dilemma" in microeconomics. See, e.g., Estrin et al. (2008, pp. 343–346), Varian (2010, pp. 527–529). A critical assessment of the prisoners' dilemma's application to global environmental problems is in Endres (2011, pp. 228–235, 247–249).

In order to overcome this frustrating situation, environmental economic theory has struggled to come up with all kinds of designs for international environmental agreements. A prerequisite for these agreements to be successful is that they are *incentive compatible*. The concept of incentive compatibility has two dimensions. First, it requires that it is attractive for a government that has the welfare of its own citizens exclusively in mind to join a coalition of countries taking measures to fight global environmental problems. This property is called the *individual rationality* in environmental economics terminology. Moreover, international environmental agreements must be designed such that each country in effect keeps to what it has promised in the treaty. This property is called the *stability* of a treaty. An important problem in this respect is that cooperative behaviour would be supported by effective sanctions in the case of a breach of contract. However, it is much more difficult to punish offenders in a context where the signatories of an agreement are independent states compared to a situation where the signatories are citizens of one country.

The work on the theory of international environmental problems and policy to which we have alluded, above, is used to assess actual environmental agreements on global issues. Examples are the *Kyoto Protocol* to attenuate global warming (which is in force since 2005) or the *Montreal Protocol* to protect the old ozone layer of the earth (which went into force in 1989).

It is well-known that the international community has been struggling for decades to form a global coalition of countries to fight global warming, and has not been able to deliver. The microeconomic explanation of this highly frustrating experience is the persistence of the well-known problems to provide a pure public good by voluntary contributions of its beneficiaries.

In the environmental economics literature there is an extensive discussion of theoretical issues in international environmental cooperation as well as regarding the assessment of actual international environmental treaties and suggestions for their reform.[16] In the context of our introductory economics textbook, we must confine ourselves to the few remarks we made above.

Review Questions

1. Why is cost minimization on the part of individual firms not sufficient to avoid a waste of natural resources on a societal level?
2. Please explain the “polluter pays principle”!
3. What is the basic idea underlying a Pigouvian tax?
4. How is a Pigouvian tax to be designed in order to ensure the implementation of the idea behind it?
5. Please explain in which way a Pigouvian tax alters the polluters’ behaviour!
6. Please describe the properties of the new market equilibrium realized after a Pigouvian tax has been imposed!
7. Why is an internalization of externalities (e.g., by imposing a Pigouvian tax) not suitable for environmental policy in its pure form?

[16] See, e.g., Aldy and Stavins (2007), Endres (2011), Finus (2008), Woerdman (2004).

8. Please describe the standard oriented approach to environmental policy and distinguish it properly from the internalization approach!
9. Please deduce and explain the condition for a cost effective inter-firm allocation of aggregate pollution abatement!
10. Please describe the pricing and standard approach and distinguish it from the concept of a Pigouvian tax!

Exercises

1. Please find an example of an everyday external effect and describe the governmental response you observe!
2. Please find an example for a negative external effect where it is difficult to specify the damage function!
3. Please discuss the cost effectiveness properties of
   (a) The standard and pricing approach, and
   (b) A variant of the command and control approach, which obliges all individual polluters to reduce their emissions by the same percentage!
4. Consider the following example: a car driver and the owner of a filling station conduct a market transaction specified by the amount of petrol handed over by the owner to the car driver and by the price paid by the car driver for any single unit of petrol. The car driver undertakes a weekend trip to his/her favourite destination and, thereby, firstly uses up the petrol and secondly, through the emission of noise and pullutants, affects the people living near the road he/she uses. Please identify:
   (a) Some components of the private cost of the owner of the filling station;
   (b) Some components of the external cost imposed on the people living near the road;
   (c) Some components of the abatement cost that would be generated by an environmental policy measure that would bring about a reduction in the amount of petrol sold and used up!
5. Please explore the relevance of "free riding" in the context of international efforts to limit climate destabilization!

References

Aldy JE, Stavins RN (2007) Architectures for agreement. Cambridge University Press, Cambridge/New York

Carson RT et al (2004) Valuing oil spill prevention. Kluwer, Dordrecht/Boston/New York

Dias Soares C, Milne JE, Ashiabor H, Kreiser L, Deketelaere K (eds) (2010) Critical issues in environmental taxation, vol VIII. Oxford University Press, Oxford

Ellerman A, Buchner B, Carraro C (2007) Allocation in the European emissions trading scheme. Cambridge University Press, Cambridge/New York

Endres A (2011) Environmental economics. Theory and policy. Cambridge University Press, Cambridge/New York

Estrin S, Laidler D, Dietrich M (2008) Microeconomics, 5th edn. Pearson, Harlow
Faure M, Peeters M (2008) Climate change and European emissions trading, lessons for theory and practice. Edward Elgar, Cheltenham
Faure M, Skogh G (2003) The economic analysis of environmental policy and law: an introduction. Edward Elgar, Cheltenham/Northampton
Finus M (2008) Game theoretic research on the design of international environmental agreements: insights, critical remarks and future challenges. Int Rev Environ Resour Econ 2:29–67
Hackett SC (2011) Environmental and natural resources economics, 4th edn. M.E. Sharpe, Armonk/London
Hahnel R (2011) Green economics. M.E. Sharpe, Armonk/London
Kollmann A, Schneider F (2010) Why does environmental policy in representative democracies tend to be inadequate? A preliminary public choice analysis. Sustainability 2:3710–3734
Sterner T, Coria J (2011) Policy instruments for environmental and natural resource management. Resources for the Future, Washington, DC
Tisdell CA (2010) Resource and environmental economics. Modern issues and applications. World Scientific Printers, Singapore
Varian HR (2010) Intermediate microeconomics. A modern approach, 8th edn. Norton, New York
Wiesmeth H (2012) Environmental economics. Theory and policy in equilibrium. Springer, Berlin/Heidelberg/New York
Woerdman E (2004) The institutional economics of market-based climate policy. Elsevier, Amsterdam