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Replacing the Polluter Pays Principle by the Cheapest Cost Avoider Principle: On the Efficient Treatment of External Costs

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Abstract

Crucial to the analysis in this paper is the Coasian insight that external costs result from conflicting uses of scarce resources and that responsibility for these costs should not be attributed exclusively to polluters as required by the polluter pays principle (PPP). The paper argues that the PPP, unlike the cheapest cost avoider principle (CCAP), which requires resolving the conflicting use at the lowest possible costs, suffers from three partly related deficits that can cause avoidable welfare losses: First, focusing on polluters as the only addressees of regulatory measures ignores the role of pollutees and government; second, the PPP is incapable of dealing with second-best problems that may arise from government as an additional investor, inefficient behavior of the pollutees or the existence of monopolies; third, the PPP provides insufficient guidance in case of multiple equilibria, corner solutions and administration costs. In addition, the paper discusses whether the shortcomings of the PPP can be compensated by advantages in terms of lower administration costs.

JEL codes: D04, D61, D62, H21, H23, K23

Keywords: Externalities, Polluter Pays Principle, Cheapest Cost Avoider, Second Best, Coase, Pigovian Tax

1 Introduction

It is generally held to be true that negative externalities and the external costs associated with them lead to socially inefficient levels of activities if they do not

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enter the decision calculus of those who control these activities (polluters).[1] In order to avoid such an undesirable outcome, external costs should be "internalized", which means that polluters are to be held responsible for the external costs they are assumed to have caused. Making sure that they bear the cost of measures preventing and eliminating damages of pollution to human health and the environment, e.g. in the form of taxes or other financial obligations, is intended to provide incentives for polluters to adjust their activities to the efficient level. This logic goes by a name that has an intuitive appeal: the Polluter Pays Principle (PPP). The PPP has received strong support in most OECD countries (OECD 1975, 2001), is stipulated in Article 191(2) of the Treaty of the Functioning of the European Union[2] and it is also mentioned in Principle 16 of the Rio Declaration on Environment and Development. This principle not only underpins most of the regulation of pollution affecting human health and the environment, but is also applied, for example, in the case law of the European Court of Justice.[3]

However, despite its apparent appeal, the PPP is flawed. This paper identifies its flaws and proposes a paradigm shift for dealing with external costs. Crucial to the analysis is the insight, going back to Ronald Coase, that external costs are not caused by polluters alone, but that they arise from conflicting uses of scarce resources: releasing pollutants into the environment in the course of the production of goods and services, for example, conflicts with the use of the environment for recreational, residential, aesthetic or other purposes. Therefore, external costs are jointly caused by conflicting claims on the same scarce resource. Without rivalry among potential users there would be no external costs.

This view of external costs suggests that policy measures should not be exlusively targeting 'polluters'. Rather, all parties that could contribute to resolving these conflicts of resource use should potentially be taken to task, and the objectve should be to resolve these conflicts at the lowest possible cost. The presumption that the burden of the reduction of the costs generated by pollution has to be borne by one party (and one party only) – namely the polluter – entirely bypasses the question of who can avoid the cost of conflicting resource uses most cheaply.

As Ronald Coase states in his seminal paper, "[t]he traditional approach has tended to obscure the nature of the choice that has to be made. The question is

[1] In very general terms, (technological) externalities are unintended effects (byproducts, spillovers) of a consumption or production decision made by one agent on the consumption set, utility function or production function of other economic agents which do not work through the price system. Externalities may be positive or negative, i.e. they may generate a benefit for or impose a cost on other agents, which is by definition not taken into account by the decision maker.

[2] "Community policy on the environment shall aim at a high level of protection [...]. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay".

[3] See Bleker (2009), Lindhout and van den Broek (2014), and de Sadeler (2012).

commonly thought of as one in which A inflicts harm on B and what has to be decided is: how should we restrain A? But this is wrong. We are dealing with a problem of a reciprocal nature. To avoid the harm to B would inflict harm on A. The real question that has to be decided is: should A be allowed to harm B or should B be allowed to harm A? The problem is to avoid the most serious harm" (Coase 1960, p. 2). From a Coasian perspective the terms 'externality' and external costs are therefore misleading. If 'externalities' are considered to be the result of competing uses of a scarce resource and caused jointly by potential users, these 'externalities' cannot simply be internalized. The policy prescription derived from this insight is straightforward: policy makers should apply the Cheapest Cost Avoider Principle (CCAP) rather than the PPP.

According to the CCAP as interpreted in this paper, any measure that reduces the harm from a conflict over resource use should be adopted as long as its benefits exceed its costs, regardless of whether this involves requiring action from polluters, pollutees or a third party such as the government, acting individually or jointly.

The economic logic embodied in the CCAP is recognized as a powerful tool in the economics of tort law (Shavell 1987, Gilles 1992, Posner 2005, Dari-Mattiacci and Garoupa 2009, Schäfer and Müller-Langner 2009, Sinai and Shmueli 2014, Carbonara, Guerra and Parisi 2014). It is also applied in practice by the courts in tort cases – concerning either individuals or collectives of potential tortfeasors, victims or insurers.[4] However, it is largely neglected in the environmental economic literature (with few exceptions such as Cordato 2001, 2004; Endres 2011: 43-49, Piecyk et al. 2010: 70) and has not affected environmental policy or regulation. The PPP clearly dominates both theory and practice, where it has achieved the status of a 'sacred cow' (Ogus 2009: ix). To the best of our knowledge, there are only two studies on transport economics that apply the CCAP to the analysis of environmental regulatory measures in a systematic way (Schmidtchen et al. 2009 and Baum et al. 2008).

We will show that the CCAP is not confined to the economics of tort law but can be applied to externality problems involving large numbers of parties. Applying the CCAP instead of the PPP can create substantial welfare gains and avoid regulatory failure – the public sector equivalent of market failure.[5] This is because the PPP suffers from three deficiencies: First, it neglects the reciprocal nature of the problem of external costs by exclusively suggesting policy measures focusing on polluters and neglecting the potential role that pollutees and government could play in reducing the damage caused by the underlying conflict over resource uses; second, it cannot adequately deal with second-best problems that arise, for example, from government being an additional investor, the inefficient behavior of the pollutees because of imperfect information or strategic behavior, the existence of monopolies or administration costs; third, it provides insufficient guidance on what to do if there are multiple equilibria or corner

[4] See for example, Pardolesi and Tassone (2005), and Orrick (2013).

[5] We will speak of a regulatory failure if a government intervention does not solve the problems resulting from market failure, which allows for the possibility that it causes a welfare loss relative to what would occur without the intervention.

solutions. The CCAP addresses all of these points.

The PPP may produce an efficient solution to the problem of external costs if polluters are actually the sole cheapest cost avoiders and other conditions for an optimal allocation of resources hold. However, this is more by luck than by design, and in more complex settings the PPP will fail. The CCAP would produce the same recommendations as the PPP in the case where the PPP produces an efficient outcome (i.e. it would suggest that the 'polluter pays'), but would suggest a different course of action where the blinkered application of the PPP would lead to avoidable welfare losses. The CCAP thus dominates the PPP as a policy principle.

To demonstrate the superiority of the CCAP, we first present a simple model, assuming a framework in which excessive transaction costs make it impossible for polluters to enter into transactions with pollutees, and regulatory measures may thererfore be appropriate. We first derive an equivalence result, i.e. show that under certain conditions the PPP and the CCAP produce the same suggestion for achieving an efficient outcome. We then modify the model and show that the equivalence result no longer holds when government can be an additional investor in pollution abatement, when pollutees have imperfect information or act strategically, when polluters possess market power, when there exist multiple equilibria and corner solutions, or when administration costs are taken into account. We then discuss whether the PPP can have any advantage over the CCAP in terms of administration costs that might outweigh its shortcomings.

The paper is organized as follows: Section 2 analyzes the working properties of both principles and presents the equivalence result. Section 3 discusses the modifications of the basic model listed above and shows that the CCAP dominates the PPP in terms of social welfare. Section Section 4 concludes.

2 Reaching efficiency with both principles: an equivalence result

In this section, we discuss the working properties of the PPP and the CCAP with the help of a simple model of unidirectional pollution. Unidirectional pollution is a good approximation of many instances that appear in the public discussion of environmental damage and external costs, such as oil spills, air pollution, water pollution and traffic noise – and a case where the distinction between polluters and pollutees appears to be most obvious and clear-cut.

2.1 The model

Consider a set $N = \{1, ..., n\}$ of agents. An agent is either a polluter, or is affected by pollution. Let $S \subset N$ denote the subset of agents who cause emissions that harm other agents and let $R \subset N$ denote the subset of agents who suffer from this pollution. As every agent is either a polluter or a victim of pollution (but never both), we have $S \cup R = N$ and $S \cap R = \emptyset$.

We assume that the emissions are a 'public bad': no pollutee can be excluded from the harmful effects of these emissions, and pollution is non-rivalrous, as the harm suffered by one pollutee does not diminish the impact on others. This implies in turn that reducing emissions is a 'public good': each pollutee benefits from a clean-up, and no pollutee can be excluded from the benefits. This is not necessarily true for individual protection from pollution (e.g. wearing face masks), which benefit only the pollutee who invests in such protection. Pollutees' pollution damage reduction is therefore a private good: preventive measures by pollutee j reduce only j's damage.[6]

Let $\bar{e}_i$ represent the optimal emission level from the perspective of polluter $i \in S$. Reducing the level of pollution below $\bar{e}_i$ is costly; it reduces the polluter's benefits. Let $c(x_i)$ denote the cost of abatement, i.e. of a reduction in the emission of pollutants by $x_i = \bar{e}_i - e_i$ where $e_i \in [0, \bar{e}_i]$ represents the actual emission level after abatement activities. We assume $c(0) = 0$, $c(x_i) > 0, c_{x_i}(x_i) > 0$ and $c_{x_i x_i}(x_i) > 0$ for every $x_i > 0$.

Let $c(y_j(x))$ denote the costs to pollutee $j \in R$ associated with investing an amount of resources $y_j(x)$ in the prevention or mitigation of pollution damage. The amount of resources that the pollutees spend depends on the abatement efforts of polluters: $y_j(x)$, with $x = \sum_{i \in S} x_i \geq 0$. We assume $c(0) = 0$, $c(y_j(x)) > 0, c_{y_j}(y_j(x)) > 0$ and $c_{y_j y_j}(y_j(x)) > 0$ for every $y_j(x) > 0$.

Let $a_j(x; y_j(x))$ represent the harm suffered by pollutee j and $A(x; y(x))$ total pollution damage, $y(x) = \sum_{j \in R} y_j(x) \geq 0$, and $A(x; y(x)) = \sum_{j \in R} a_j(x; y_j(x))$.

Regarding damage abatement technologies[7], we make the following assumptions: First, the more polluter i spends on emissions reduction, the lower total pollution damage, i.e. $A_{x_i} < 0$ and $A_x < 0$. Second, additional amounts spent on damage prevention reduce damage at a decreasing rate, i.e. the second derivative of the damage function is $A_{xx} > 0$ and $A_{x_i x_i} > 0$. Third, we assume $a_{j_{y_j}} < 0$ and $a_{j_{y_j y_j}} > 0$, i.e. decreasing marginal returns on a pollutee's investment in damage prevention. Further, we assume that abatement efforts by polluters and by pollutees are substitutes: $A_{xy} > 0$.

Suppose that the social goal is to resolve the conflict between polluters wishing to avoid cost by causing emissions and pollutees suffering harm from these emissions efficiently. Abstracting from administration costs and assuming risk-neutrality, this means minimizing social cost, SC:

$$SC = A(x; y(x)) + c(x) + c(y(x)) \tag{1}$$

The regulator, aiming to regulate polluters' emission reduction, determines the abatemenet level x that minimizes social cost.

$$\min_x A(x; y(x)) + c(x) + c(y(x))$$

[6] The model can be altered so that pollutees' actions also have the character of public goods. This will be done in section 3.2.2.

[7] We do not distinguish between the prevention of pollution damage and mitigation measures. We use "abatement" for both types of measures.

$$\frac{dc(x)}{dx} + \frac{dc(y(x))}{dy}\frac{dy}{dx} + \frac{dA(x;y(x))}{dx} + \frac{dA(x;y(x))}{dy}\frac{dy}{dx} = 0 \tag{2a}$$

with $\frac{dc(x)}{dx} > 0$, $\frac{dc(y(x))}{dy}\frac{dy}{dx} < 0$, $\frac{dA(x;y(x))}{dx} < 0$, $\frac{dA(x;y(x))}{dy}\frac{dy}{dx} > 0$.

Equation 2a defines a function $x^*(y)$, x^* denoting the polluters' socially optimal abatement reduction level. It shows that an increase in polluter damage reduction measures x has two effects on costs of damage reduction: it increases the costs of the polluters, but it also decreases the prevention cost of the pollutees. The reason is the substitution effect between x and y: the more the polluters invest in abatement, the less investment pollutees undertake in mitigating the impact of emissions. There are therefore two opposing effects on damage reduction: while an increase of x will decrease the amount of damage A directly, this effect is attenuated by the reduction in y.

The pollutees will minimize their cost function:

$$\min_y A(x;y(x)) + c(y(x))$$

$$\frac{dc(y(x))}{dy} + \frac{dA(x;y(x))}{dy} = 0 \tag{2b}$$

Equation 2b defines a function $y^*(x)$ denoting pollutees' optimal damage abatement level. Jointly, equations 2a and 2b define the social optimum. At the social optimum $(x^*;y^*(x^*))$, $x^* = x^*(y^*(x^*))$ and $y^* = y^*(\ x^*)$.

Equations 2a and 2b imply the following two conditions in relation to the total effort to reduce emissions and mitigate their harmful impact:

$$\frac{dc(x)}{dx} = -\frac{dA(x;y(x))}{dx} - \frac{dA(x;y(x))}{dy}\frac{dy}{dx} - \frac{dc(y(x))}{dy}\frac{dy}{dx} \tag{3a}$$

$$\frac{dc(y(x))}{dy} = -\frac{dA(x;y(x))}{dy} \tag{3b}$$

Condition 3a says that the marginal cost of emission reduction by the set of polluters must be equal to its marginal benefit, which comprises the direct marginal benefits from reduced emission levels and the indirect impact through reduced investments by the pollutees in mitigating measures. The efficient level of abatement implies an efficient level of emissions e^*, i.e. $e^* = \bar{e} - x^*$, with $\bar{e} = \sum_{i \in S} \bar{e}_i$ and $e^* = \sum_{i \in S} e_i^*$.

Condition 3b says that the marginal costs of damage prevention by the group of pollutees should equal the marginal benefit of the reduction of pollution damage.

Note that when condition 3b holds, i.e. $y = y^*$, then equation 3a reads

$$\frac{dc(x)}{dx} = -\frac{dA(x;y^*(x))}{dx} \tag{4}$$

This is because the remaining two terms in equation (3a) cancel each other out.[8]

Figure 1 illustrates the logic of our model.[9] We measure the polluters' emission reduction along the horizontal axis and show the marginal costs and the net marginal benefits associated with various levels of abatement on the vertical axis.

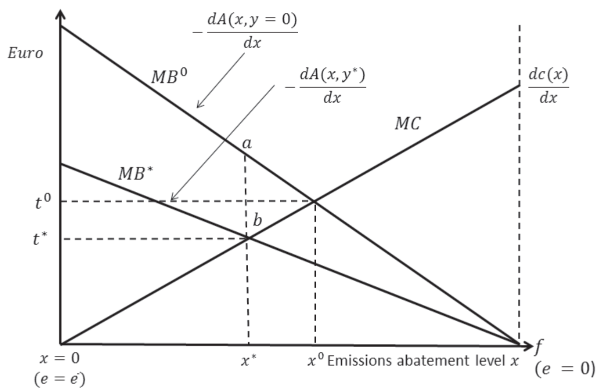

Figure 1: Polluters' optimal emissions abatement level

As $c_x(x) > 0$, the marginal costs of abatement are increasing, represented by the upward sloping MC curve.[10]

When polluters reduce emissions, they reduce pollution damage and create benefits to pollutees. The downward sloping curves denoted MB^* and MB^0 indicate the marginal benefit to the set of pollutees from abatment by the set of polluters for the case where the pollutees efficiently invest in damage mitigation (MB^*) and do not invest in damage mitigation (MB^0).[11] In other words, they represent the reduction of damage $A(x; y(x))$ for a given level of y, with $y = y^*$ in MB^* and $y = 0$ in MB^0.

[8] Proof: Rewrite equation (3a) such that: $\frac{dc(x)}{dx} = -\frac{dA(x;y(x))}{dx} + \left[-\frac{dA(x;y(x))}{dy} - \frac{dc(y(x))}{dy}\right]\frac{dy}{dx}$. The terms in the square brackets are, following equation 3b, equal to zero.

[9] We use linear functions in all figures without loss of generality. We here discuss the case of an inner optimum. Corner solutions will be treated separately.

[10] The MC curve results from the horizontal summation of the polluters' individual marginal abatement cost curves.

[11] Since emissions reduction is a public good, the pollutees' marginal benefit curves from the reduction of pollution are added vertically.

The fact that the marginal benefits from an increase in polluters' abatement are lower if pollutees invest in mitigation reflects the assumption that abatement efforts of polluters and pollutees are substitutes. The difference between both curves at each level of emission reduction reflects the minimum marginal costs of damage reduction by the set of pollutees R.

Intersection point b determines the optimal level of abatement and thus implies the optimal level of emissions. The point f represents $e = 0$, i.e. the maximum possible abatement. It is optimal to have $e^* = \bar{e} - x^*$ units of emission, because any further reduction of emission levels would have marginal costs that exceed the marginal benefit ($MC \geq MB^*$). Realization of emissions level e^* implies abatement up to x^*. Above this range, the marginal costs of further abatement are below the marginal benefits.

The pollutees' abatement activity and their optimum is illustrated in Figure 2. We measure the pollutees' damage reduction activities along the horizontal axis, and show the marginal costs and the marginal benefits associated with various levels of pollutees' abatement on the vertical axis (given $x = x^*$ and $x = 0$).

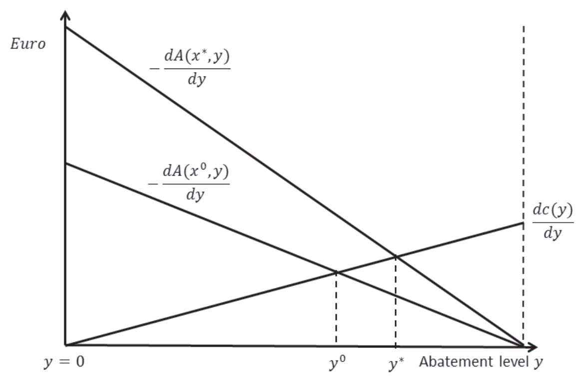

Figure 2: Pollutees' optimal emissions abatement level

As specified in the model, the marginal costs of the reduction of emissions are increasing, represented by the upward sloping $\frac{dc(y)}{dy}$ curve, whereas the marginal benefits, respectively $-\frac{dA(x^*;y)}{dy}$ and $-\frac{dA(x^0;y)}{dy}$, are decreasing. The optimal levels of pollutees' abatement activities, y^* and y^0, are located at the intersection of both curves.

This simple model allows us to examine the question that policy makers need to answer: Will the PPP and CCAP implement the efficient emissions reduction x^* and incentivize pollutees to take socially efficient actions y^* in a non-cooperative Nash-equilibrium where bargaining between polluters and pollutees is impossible because of high transaction costs (for example because a large number of people is involved on both sides)? We assume that all agents choose their actions simultaneously, and that administration costs for applying the PPP or the CCAP are zero.

2.2 PPP and social welfare

The PPP states that polluters, who are deemed responsible for creating a negative external effect, should bear the costs associated with their emissions.

Applying the PPP means that the government identifies the set of polluters, and establishes an appropriate instrument that confronts polluters with the costs that pollution imposes on pollutees, i.e. makes them internalize these costs. Internalization can be accomplished in a number of ways, e.g. by imposing an emissions tax on polluters; by adopting a command-and-control approach that restricts activity levels (e.g. a speed limit to reduce noise emission in the case of road transport), requiring the installation of avoidance and abatement devices or requiring changes in polluters' levels of production so that emissions and the associated external costs are limited. It is of course also possible to combine command-and control policies and market-based policies.

If a tax solution is chosen, the government needs to define an appropriate tax level. In this context, it is worth noting that the PPP as advocated for example in the legal documents mentioned above requires that polluters pay, but provides remarkably little guidance on how much they should pay, i.e. what costs the polluters should bear. It is not clear, for example, whether the polluter should be confronted with marginal pollution costs that actually are being incurred in the status quo, or the sum of marginal pollution costs and marginal prevention costs of the pollutees, or some measure of average pollution costs.

We restrict our attention to the option where the polluters' marginal abatement costs equal the marginal external cost (represented by MB^* in Figure 1), and the government imposes a constant per unit tax rate t :

$$t^* = \frac{dc(x)}{dx} = -\frac{dA(x, y^*(x))}{dx} \tag{5}$$

This is commonly referred to as a Pigovian tax (Pigou 1932). Equation 5 implicitly defines x^*. It corresponds to equation 4.

Note that levying a tax t^* per 'unit' of an activity that causes costs to other parties is a first-best remedy. It can achieve an efficient outcome if there are no other distortions in the economy (including distortionary taxes). Where such distortions exist, we are in a second-best environment and this prescription must be modified. This may also be the case if actors other than polluters and pollutees can take action to mitigate pollution damage. For example, formula 5 determining the Pigovian tax differs from that known from the literature where generally no reference is made to efficient mitigation efforts by the pollutees (i.e. no y^*-term is mentioned). Of course, both formulas coincide if $y^* = 0$. However, if $y^* > 0$, the commonly used formula for the Pigovian tax may miss the social optimum.

With individual tax rate $t_i = t^*$, polluter $i \in S$ minimizes $t_i e_i(x_i) + c(x_i)$. Because $\frac{de_i(x_i)}{dx_i} = -1$, this gives the first order condition $t_i - \frac{dc(x_i)}{dx} = 0$, which says that the marginal benefit of a unit of emissions reduction, i.e. t_i, equals the marginal abatement cost. This equation defines polluter i's optimal investment in damage prevention, x_i^*, given the optimal choice of damage prevention by the set of pollutees, y^*.

From $x_i = x_i^*$ for every $i \in S$ it follows that $x = x^*$. Thus, the polluters realize the efficient level of abatement. Because all polluters are paying the same tax rate, their marginal abatement costs are also identical (which means that the given level of abatement is achieved at the lowest total cost).

With $x = x^*$, a pollutee $j \in R$ chooses y_i to minimize $a_j(x^*; y_j(x^*)) + c(y_j(x^*))$, which yields the first order condition

$$\frac{da_j(x^*; y_j(x^*))}{dy_j} + \frac{dc(y_j(x^*))}{dy_j} = 0$$

This equation defines pollutee j's optimal investment in damage prevention, y_j^*, given the polluters' optimal choice of abatement x^*. Pollutee j increases expenditure on damage prevention up to the point where the marginal benefit from doing so in terms of damage reduction equals the marginal costs. From y_j^* for every $j \in R$ it follows $y = \sum_{j \in R} y_j^* = y^*$. The social optimum occurs at $x^* \equiv x^*(y^*)$ and $y^* \equiv y^*(x^*)$. Since no agent has an incentive to deviate from his/her chosen strategy – (x_i^*) of polluter $i \in S$ and (y_j^*) of pollutee $j \in R$ –, given the strategies of the other players, tax formula t^* implements both the efficient emission reduction x^* and incentivizes the pollutees to take the efficient level of pollution damage prevention y^*.

Conclusion 1: *The PPP, applied in the form of a Pigovian tax, implements the social optimum where the marginal external cost equal polluters' marginal abatement cost, provided the pollutees choose the efficient level of pollution damage prevention.*

The Nash-equilibrium implemented by tax rate $t = t^*$ which satisfies conditions 3a and 3b, occurs at intersection point b in Figure 1, with associated point x^* indicating the efficient level of abatement.

Note that our graphical representation of the Pigovian tax solution differs from that known from the literature, where only two curves are depicted – the MC-curve and a curve represented by the MB^*-curve in Figure 1. Such a reduced graphical representation, which follows from the commonly applied Pigou tax formula, concentrates on the behavior of the polluters by looking at their costs, their benefits, and the costs that they impose on the pollutees. The optimal behavior of the pollutees with respect to damage reduction is either implicitly assumed in the marginal damage cost curve to the pollutees MB^*, or is assumed to be zero. However, there is nothing in the common presentation of the Pigovian solution to the externality problem that would suggest that it is not only the polluter who can take action, but that pollutees might also be able to reduce pollution damage (see Wittman 2006: 51, 53). Modeling a symmetrical situation in a way that hides this aspect can induce policy makers to commit serious mistakes, as shown in section 3.2.

2.3 CCAP and social welfare

The "cheapest cost avoider" test was developed by Calabresi in 1970, taking up ideas from Coase (1960) and Demsetz (1967). The objective is to minimize the sum of the total costs of accidents and the costs incurred in trying to prevent them by imposing strict liability on the cheapest cost avoider. Later Calabresi (together with Hirschoff) improved the doctrine and suggested to impose strict liability on the "best decider" (Calabresi and Hirschoff 1972). The "best decider" is the party to an accident who "is in the best position to make the cost-benefit analysis between accident costs and accident avoidance costs and to act on that decision once it is made" (Calabresi and Hirschoff 1972: 1060). It is a generally held view in the Law and Economics literature that the notion of the cheapest cost avoider applies to all situations in which damages can be reduced or eliminated by either injurers or victims (see, for example, Shavell 2004: 189).

We deviate from this narrow view and apply the notion of the cheapest cost avoider to situations in which both parties, polluters and victims, need to exercise care to achieve a socially optimal outcome. In this case, there may not be a single "cheapest cost avoider", but multiple parties may have to take action to some extent.

Applying the CCAP to situations analyzed in this paper involves:

1. identifying the actors who can contribute to resolving the conflicting resource use (potential cheapest cost avoider(s)) – polluters, pollutees, both groups jointly, or potentially also a third party, such as the government;
2. determining the first-best social optimum; if a first-best solution is not available, a second-best solution should be identified;
3. establishing the available alternative ways of implementing the efficient abatement level and incentivizing all relevant actors to invest optimally in measures that reduce pollution damage;
4. calculating the minimum costs of each of these alternative implementations;
5. establishing whether the benefits of taking the actions required by the implementation with the lowest cost at least cover these costs – if so, the necessary steps for this implementation of the first-best or second-best optimum should be taken; otherwise no policy intervention should take place.

This five-step approach essentially covers a thorough cost-benefit analysis of available policy options, including the option of doing nothing.[12]

Which party is the cheapest cost avoider in our model? The answer is: both are. They "share the job". For the abatement up to x^*, the polluters are the cheapest cost avoiders; for the remaining level of emissions $\overline{x^* f}$ the pollutees are.

How to implement the efficient actions? To answer this question, we can refer to the previous section. A constant per unit emissions tax $t^* = -\frac{dA(x,y^*(x))}{dx} = \frac{dc(x)}{dx}$ would lead both the polluters and the pollutees to take efficient actions and achieve the first-best optimum; this solution would also be identified under the CCAP. [13] Since we assumed zero administration costs in this section there is no need to carry out steps four and five of the cost-benefit analysis. And since t* implements the first-best outcome a second-best solution plays no role.

Thus, a CCAP inspired policy may well result in the same recommendations as the PPP.

Conclusion 2: *When x^* is correctly calculated, the efficient non-cooperative Nash-equilibrium can be established by both the PPP (as interpreted here) and the CCAP (equivalence result).*

The following discussion shows, however, that the CCAP clearly dominates the PPP once one considers more complex setups.

3 Challenging the equivalence result

In this section we discuss several major qualifications to the proposition that a Pigovian tax implements a social optimum in which the marginal conditions 3a and 3b are satisfied. They apply for a number of reasons.

The focus on polluters as the only actors that might be the subject to regulatory measures ignores that a social optimum may require pollutees and the government to take action aimed at preventing or mitigating damage. However, optimal behavior of pollutees and the government cannot be taken as granted. Owing to imperfect information or strategic behavior, the actions of pollutees may violate marginal condition 3b. Policy makers either need to try and correct such distortions or, if that is not possible, take the non-optimal behavior by other actors into account when designing the right policy intervention. In this case, it is not necessarily the case that regulator should set a Pigovian tax. A similar question arises if the government fails to make the optimum investment in measures that reduce or mitigate pollution damage (e.g. because of distorted

[12] In Schmidtchen et al. (2009: ch. 7) one can find two case studies showing how the CCAP can be applied in practice. Chapter 8 of the book delivers a critical assessment of the European greening transport policy and shows that the rejection of the CCAP by the European Commission is based on conceptual misunderstandings.

[13] From an economic point of view such a tax is equivalent to a liability rule. Whereas in the case of a liability rule the property rights are for the victims of the pollution and the polluters are expected to pay the pollutees for the damages from their pollution, the tax creates a property right of the environment for the state.

incentives in the public sector or badly organized public sector decision making) or if making these investments requires imposing distortive taxes on other segments of the economy.

Also, the effects of market power (in the extreme case monopoly power) of polluters need to be taken into account. The incentives of a firm with market power to restrict output will also have an impact on the emissions generated in the course of production, and thus on the optimum level of abatement that is required.

For tackling these issues, one must refer to the theory of second-best, which shows that sometimes two wrongs can make a right.[14] Second-best problems linked to Pigovian taxes have been studied in Cremer et al. (1989, 2001), Cremer and Gahvari (2001), Gahvari (2014), Jacobs and de Mooij (2014), Parry and Oates (2000) and Kaplow (1996). However, this literature is only concerned with second-best constraints coming from the overall tax structure and does not address second-best issues dealt with in this paper. Whilst establishing the solutions to second-best problems is typically complex and beyond the scope of this paper, it is sufficient for our purpose to present the intuition and to indicate why the CCAP dominates the PPP in such settings. This also holds true for the case of multiple optima, corner solutions and administration costs.

3.1 Government as additional investor

The basic model can be extended to include actors who can affect the level of damage from pollution other than polluters and pollutees. For example, consider the case of vehicles using a particular stretch of road running through a village, and assume that the noise caused by driving along this road harms local residents. The magnitude of harm can be reduced in many different ways. the transport industry (the polluters) can invest in engines with reduced noise emissions; residents can invest in noise insulation (or relocate); and the public sector can re-route traffic (e.g. by building a by-pass).

Let $c(x)$, $c(z)$ and $c(y(x, z))$ respectively represent the cost to the transport industry, to the government and the residents of abatement measures[15], and let $A = \sum_{j \in R} a_j(x; y_j(x, z); z)$ be the harm from emissions that now varies with the efforts of polluters, pollutees and the government. The social optimum is now determined by three functions:

$$\begin{aligned} x^* &= x^*(y(x, z); z) \\ y^* &= y^*(x; z) \\ z^* &= z^*(x; y(x, z)) \end{aligned}$$

[14] This is the basic insight of the general theory of second best (see Lipsey and Lancaster 1956-1957).

[15] In principle, measures taken by all the different actors may interact with each other and be substitutes or complements. For the sake of simplicty we focus on the simple case where the mitigation efforts of pollutees depend on the measures taken by polluters and the government, but note that more complex relationships may exist.

At the social optimum:

$$\begin{aligned} x^* &= x^*(y^*(x^*, z^*); z^*) \\ y^* &= y^*(x^*; z^*) \\ z^* &= z^*(x^*; y^*(x^*, z^*)) \end{aligned}$$

There is no reason to assume that applying the PPP will alert policy makers to the fact that government should invest optimally in the prevention of pollution damages. Ignoring that government investment plays a role in reaching the social optimum, i.e. $z^* > 0$, and imposing a tax rate based on $z^* = 0$ clearly misses the social optimum.

- First, the optimal level of public investment is not undertaken, i.e. $z < z^*$.
- Second, the presumed level of efficient abatement by polluters x^* may be too high because polluters have to do more to reduce emissions given that the government is not investing in the reduction of pollution damage.
- Third, the investment undertaken by pollutees would be different from y^* because of substitution effects, directly via the effect of z^* on $y(x^*, z^*)$ and indirectly, because x^* is modified, thus modifying $y(x^*, z^*)$.

This is entirely different with the CCAP. The first step of the comprehensive cost-benefit analysis that underpins the CCAP would identify the role that government has to play in terms of being a potential investor into measures that reduce or mitigate pollution damage.

Even if the constant per unit tax rate on emissions in a Pigovian tax regime were set at the level that reflects marginal pollution costs at the socially efficient level of emissions reduction including the optimal action of the government (i.e. $t^{**} = -\frac{dA(x;y^*(x,z^*);z^*)}{dx} = \frac{dc(x)}{dx}$, with $t^{**} < t^*$), this does not guarantee that the optimal government investment in the prevention of pollution damages actually takes place. Typically, the regulatory agency imposing the tax does not control the activities of other parts of the public sector (e.g. local government, which may be responsible for traffic planning and local road construction). Often one can observe what Cox and McCubbins (2001) describe as 'balkanization' of public policies – a lack of coordination within and between agencies operating on all levels (central, regional, municipal) of government activities. Whilst the CCAP does so, the PPP is unlikely to inform policy-makers that there is an additional need to set up a coordinated and comprehensive policy-making apparatus. If imperfections of public policy decision-making cannot be overcome, this fact creates an additional second-best constraint, which has to be taken into account when calculating the (second-best) tax rate. If the regulator must accept $z = 0$ (though $z^* > 0$) this could well be tax rate t^* .

Another problem is related to how government investment will be funded. If the revenues raised by the pollution tax will be used to finance the government investment *and* the tax revenues from a Pigovian tax t^{**} exactly match the funding required for achiving z^*, then the tax rate t^{**} implements the social optimum. However, if tax revenues are insufficient, we will inevitably have to solve a second-best problem, unless it is possible to raise the necessary funds through non-distortive lump sum taxes. If not, the pollution tax should be adjusted or taxes that are potentially distortive have to be raised elsewhere.[16] If, on the other hand, the revenues from pollution tax t^{**} exceed the expenditures on government investment, the remaining proceeds could be used to reduce distortive taxes in other sectors in the economy, creating what has been called a double dividend (see Fullerton and Metcalf 1998, Jorgenson et al. 2014).

The upshot of this discussion is that purely relying on the imposition of a Pigou-type emissions tax – as suggested by the PPP – is not sufficient for achieving a socially optimal outcome. The CCAP, through its use of cost-benefit analysis in a welfare economics framework, enables policy makers to take into account a much broader range of relevant variables and actors. Applying the five-step procedure at the heart of the CCAP is of course not an easy task. Regulatory failure due to incomplete or wrong information cannot be ruled out. But this also holds true for the PPP. In the end, it is the different theoretical perspective that makes the CCAP superior to the PPP.

Conclusion 3: *The PPP, unlike the CCAP, does not alert policy makers to the fact that they have to ensure that other actors (such as the government) also invest optimally in the reduction or mitigation of pollution damage. It therefore fails to establish a socially optimal policy and does not help with identifying second-best optima.*

3.2 Imperfect information and strategic behavior

Polluters can be induced to take account of marginal external costs when deciding on the benefit-maximizing level of an activity, but, as we have seen, an efficient outcome requires that pollutees select the socially efficient level of their activity as well. Pollutees must incur the socially optimal damage reduction costs. Thus, efficiency requires that for any given pollution level pollutees have incentives to invest in measures that reduce the marginal damage caused by pollution whenever they can do so at lower costs.

As Burrows states: "[a] cost-minimizing pollutee will react to damage costs imposed on him either by simply bearing the cost, or by reducing his activity level (the pollutee equivalent of the polluter's output or consumption cut), or by altering his production or consumption process to make it less sensitive to the pollutant (the equivalent of the polluter's process-switching), or by moving away, whichever is the cheapest" (Burrows 1980: 33-34). Thus, in principle, pollutees should be expected to invest in damage reduction up to the point at which the marginal reduction costs equal the marginal value of damage reduction. If this holds true for every activity level that polluters might choose, the marginal

[16] This is a second-best problem, dealt with in the economic theory of optimal taxation (see Boadway 2012, Cremer et al. 1989, 2001, Cremer and Gahvari 2001, Gahvari 2014, Jacobs and de Mooij 2014, Parry and Oates 2000 and Kaplow 1996).

damage reduction costs incurred by pollutees would adapt optimally to the level of pollution they are facing, and this would be reflected in the marginal benefit curve.

However, pollutees may not behave in such an optimal fashion for a number of reasons. Below we discuss three of these, namely imperfect information and different forms of strategic behavior either to 'game the system' by making polluters invest more than is efficient, or – if the damage mitigation efforts of pollutees have public good characteristics – to 'free-ride' on other pollutees' investments.

3.2.1 Imperfect information

As above, we assume that preventive actions by each pollutee $j \in R$ have only an impact on her individual marginal pollution damage. Under perfect information about her marginal pollution cost function, a pollutee will invest in damage prevention up to the point where the marginal cost equals the marginal benefit. This means that marginal external costs are minimized for any given amount of pollution.

However, if a pollutee is not fully aware of all the actions she could take or the costs of these actions, or does not fully understand their effectiveness in reducing the damage from pollution, she may under- or overestimate her marginal pollution costs. This in turn will lead to over- or under-investment in damage mitigation. In Figure 1, this means that the actual marginal benefit curve lies below MB^* (over-investment) or above MB^* (under-investment). In these cases, calculating emissions tax rates with reference to the actual investment in prevention and mitigation by pollutees (i.e. emissions tax rate $\hat{t} = -\frac{dA(x,\hat{y})}{dx} = \frac{dc(x)}{dx}$, where $\hat{y} \neq y^*$) will lead to investment in emission reduction by polluters that is either excessive, i.e. $x(\hat{y}) > x^*(y^*)$, or insufficient, i.e $x(\hat{y}) < x^*(y^*)$.[17]

To illustrate, consider the case where the pollutees do nothing, i.e. $y = 0$. If $y^* > 0$, we can exclude the corner solution in which it is optimal for pollutees to do nothing, and we have $-\frac{dA(x^*;0)}{dy} > \frac{dc(0)}{dy}$ (see Figure 2).

It follows that the equilibrium value x^* that results from equation 3a is changed, because the right hand side is increased. Rewrite 3a:

$$\frac{dc(x)}{dx} = -\frac{dA(x;y(x))}{dx} + \left[-\frac{dA(x;y(x))}{dy} - \frac{dc(y(x))}{dy}\right]\frac{dy}{dx}$$

In the case that $y = 0$, we know that the term in the square brackets is positive: $-\frac{dA(x;y(x))}{dy} - \frac{dc(y(x))}{dy} > 0$. Referring to Figure 1, the respective tax rate would be t^0, inducing emission reduction level x^0, which is inefficient because $x^0 > x^*$.

[17] If the pollutees cannot take action at all or if the marginal damage reduction costs are excessive we would have a corner solution in the sense that the marginal external costs can only be influenced by the polluters.

Even if a policy maker were aware of the problem and set a tax rate according to a marginal benefit curve MB^* (which assumes that $y = y^*$, i.e. optimal rather than actual damage reduction by pollutees), this would not minimize social costs. The reason is that in a social optimum, condition 3a as well as condition 3b must be satisfied; but with inefficient behavior by pollutees this is not the case (in Figure 1, point a would be realized instead of the efficient point b).

However, an abatement level that is efficient in a first-best situation is not necessarily the efficient one if one of the necessary conditions for a first-best outcome is not met. If for whatever reason a first-best outcome cannot be achieved, a second-best solution may require substantial changes in variables such as tax rates relative to the levels that are usually considered to be optimal.

The PPP cannot adequately deal with this problem. It assumes that pollutees make socially optimal decisions without making this assumption explicit. In the case of imperfect information issues, it neither alerts policy makers to these problems, nor does it provide any guidance for what a second-best policy would look like.

This is entirely different with the CCAP. The five-step procedure outlined above will help with identifying problems that might exist in relation to the behavior of pollutees. It will also tell policy makers that, in addition to imposing a tax on polluters, they should take action to ensure efficient behavior of pollutees (e.g. through providing information or financial incentives or through mandatory requirements). Where changing the behavior of pollutees is impossible or too costly, the CCAP, unlike the PPP, also helps with establishing the second-best tax rate. In our example, the tax rate would have to satisfy condition 3a, which is the case with a tax rate t^0, leading to second-best efficient emission reduction x^0 in Figure 1.

The PPP-guided policy may in our example coincide with the second-best optimum, since it is common practice today to calculate tax rates on the basis of actual marginal benefits from the reduction of pollution or estimated data. However, it ignores that changing the behavior of pollutees may lower the cost of intervention and improve welfare. In any case, it would set the tax at its second-best level only by chance rather than by design.

Conclusion 4: *The PPP, unlike the CCAP, neither alerts policy makers to the fact that information may be imperfect, nor does it provide any guidance in relation to what the second-best solution might be.*

3.2.2 Strategic behavior

So far we have assumed that pollutees behave non-strategically in the sense that they do not take into account how their behavior might affect the choices of others – either polluters or other pollutees. However, if the group of pollutees is small, or if efficient mitigation of pollution damage requires some form of collective action on the part of pollutees, or if pollutees' damage mitigation activities generate positive externalites for other pollutees this may not be the case and there could be strategic behavior. Strategic behavior of pollutees creates problems for the PPP while the CCAP can address these issues.

Gaming the system Pollutees acting strategically could attempt to game the system by underinvesting in damage prevention in the hope that this will result in a higher emission tax because damage reduction measures by polluters and pollutees are substitutes.

Consider Figure 1 and assume that a policy maker imposes an emissions tax on the polluters on the basis of a marginal benefit curve MB^0 that results from strategic behavior of the pollutees, instead of curve MB^*, which would measure marginal benefits from increasing abatement if pollutees invest efficiently. The tax rate t^0 is equal to the marginal benefit of emission reduction at x^0. Without strategic behavior of the pollutees, the tax rate would be t^*. Once the tax rate and therefore the polluters' level of pollution abatement is fixed, the pollutees adopt their own pollution abatement measures. In Figure 2, the lower curve $-\frac{dA(x^0,y(x))}{dy}$ now represents the pollutees' marginal benefits from emissions abatement. The pollutees' optimal response is $y^0 < y^*$. The social optimum $(x^*; y^*)$ is not reached.

Again, the CCAP dominates the PPP because the third step in the cost-benefit analysis would indicate the pollutees' strategic behavior. In response, policy makers could consider measures addressing this or, if no suitable intervention were availabe, would be confronted with a second-best problem for which the solution, determined in the last step of the cost-benefit analysis, might be to impose tax rate t^0.

Conclusion 5: *The PPP, unlike the CCAP, neither alerts policy makers to the existence of opportunistic behavior by pollutees, nor does it provide any guidance for how policy makers should respond to such behavior.*

Pollutees as freeriders Suppose that because of economies of scale and scope, efficient mitigation of pollution damage requires collective action of all pollutees rather than measures adopted by each pollutee individually. For example, erecting a noise barrier alongside a road may be less costly than individuals installing noise insulating windows. In such a case, a public good problem arises.

We can capture this case through a minor modification of our model. Instead of $a_j(x; y_j(x))$, $a_j(x; y(x))$ now represents the pollution damage suffered by j, with y indicating the total amount of resources invested by the set of pollutees in order to create the public good "damage reduction". Total pollution damage is now $A(x; y(x)) = \sum_{j \in R} a_j(x; y(x))$. The first order conditions for a social optimum remain 3a and 3b.

In order to determine how much "damage reduction" should be provided, the pollutees must get together and decide about the individual contributions to the provision of the public good. By definition, nobody can be excluded from enjoying the benefits from the public good that is provided collectively. Therefore, particularly when the group of pollutees is large, each individual pollutee has a strong incentive for taking a free rider position by under-reporting how much she values the public good. This will then lead to suboptimal collective investment in damage prevention, or potentially failure to take collective action at all.

A similar problem arises if pollutees generate external economies with possible productive processes of different efficiency. In this case it is highly unlikely that the independent adjustments of the victims of pollution produce an efficient result: there is again a collective action problem. Nothing guarantees that mitigation efforts are chosen according to the principle of comparative advantage, which requires that the relatively most efficient group members specialize in the mitigation of the external costs (Olson and Zeckhauser 1970: 516). Government intervention might be needed to solve the problems resulting from these collective action problems.

There is no reason to assume that the PPP alerts policy makers to the existence of a collective action problem or helps them tackle it. The imposition of an emissions tax neither contributes to the solution of the collective action problem, nor does it promote an allocation of activities according to the principle of comparative advantage.

This is entirely different with the CCAP as a result of the five-step procedure on which its application is based. In the process of finding the cheapest cost avoider(s), collective action problems amongst pollutees would be identified (step 3) and the policy maker would learn that in addition to imposing a tax on the polluters it should also intervene on the side of the pollutees, either by helping them to solve their collective action problem (for example by mandating contributions of pollutees to joint investment in damage mitigation) or by ensuring that individual mitigation efforts are governed by the principle of comparative advantage (e.g. by putting in place appropriate mechanisms to allow compensation of those who would have to be induced to take action by all those who benefit from such action being taken, in line with steps 3 and 4). In contrast to the PPP, the CCAP also would consider whether a second-best solution might need to be found (step 5).

Conclusion 6: *The PPP, unlike the CCAP, neither alerts policy makers to the existence of pollutees' collective action problems and the resultant free rider incentives, nor does it provide any guidance for a response to such problems.*

3.3 Monopoly

Suppose that the set N of agents are suppliers and consumers in what would be considered to be a relevant antitrust market, say the market for widgets. S is the set of widget producers, and R is the set of consumers who buy widgets and suffer from the pollutants emitted in widget production.

For simplicity, assume that widget production generates a constant amount of emissions per unit of output. A perfectly competitive widget market implies that there is too much emission and a tax set at $t^* = -\frac{dA(x;y^*(x))}{dx} = \frac{dc(x)}{dx}$ may implement the efficient abatement level. However, this result no longer holds for other market structures such as a monopoly (see Buchanan 1969; Just et al. 2004). Whilst a non-regulated competitive market always produces too many negative externalities, a monopoly may produce more than, the same as, or less than the welfare maximizing level of output and thus generate more than, the same or less than the optimal amount of emissions.

The reason is that a monopolist generates two types of external diseconomies: on the one hand, a monopoly firm produces less than would be optimal if there were no external costs because it charges a price above private marginal costs, leading to a deadweight loss; on the other hand, it produces too much output and pollution because its decisions depend on private marginal costs rather than the social marginal costs. Which of the two offsetting effects dominates depends on the elasticity of demand for the output and on the extent of the marginal external costs.

To illustrate, suppose for simplicity that the monopoly's private marginal cost curve equals the supply curve under competition, and that the demand curves in both market structures are identical and that it does not pay pollutees to invest in damage reduction. Suppose further that the output by an unregulated monopolist (where marginal revenue is equal to marginal private cost) coincides with the socially efficient output of the competitive industry (where marginal *social* cost is equal to marginal social benefits as represented by the demand curve). Where in the absence of a pollution tax the emission level of the competitive industry would be $\overline{f0}$ in Figure 1 (i.e. where there would be zero abatement), the monopolist only emits $\overline{fx^*}$ (implying an efficient level of emission reduction $x = x^*$). Looking purely at the efficient reduction of emissions, the price impact of decreasing output due to the monopolist limiting his supply has the same effect as an optimal emission tax levied in a competitive market. There is of course a difference in terms of the distribution of benefits: whilst in the case of a competitive market with an optimal emission tax the producers earn zero profit at the margin and government raises tax revenues, the marginal profit of the monopoly is positive and government does not receive taxes. From the perspective of achieving the efficient emission level, however, there is no need for governmental intervention. On the contrary, imposing a pollution tax on the monopolist would lead to an output reduction beyond the socially optimal level. Abatement would be excessive ($x > x^*$) and consumers would pay an even higher product price. In essence, the attempt to reduce the external cost of pollution would impose external cost on the consumers of the monopolist's product in excess of the benefits from the reduced emission levels. The same would happen if the unregulated monopolist already produced less than the socially optimal output. Only if the unregulated monopolist produces more than is socially optimal an emission tax – properly designed, and below the level that would be optimal in a competitive market – improves social welfare.

Our simple example again illustrates the relevance of the theory of second-best. Two market imperfections – monopoly and externality – can offset each other such that social welfare increases, and trying to correct one market imperfection may result in welfare losses (see also Gahvari 2014).

A PPP inspired policy is unable to deal with this second-best problem adequately. The efficient solution of the externality problem requires more than a comparison of the marginal external cost and the polluter's marginal abatement cost. The increase in the deadweight loss that results from the introduction of an emission tax in a market where polluters enjoy some market power should also be taken into account when looking at the welfare effects associated with making producers reduce their output. In other words, the trade-off between the imposition of external costs on the consumers of the monopolist's product and the reduction of the external cost imposed on the pollutees must be adequately dealt with. This requires using a cost-benefit analysis in a welfare economics framework as in the application of the CCAP. The above mentioned trade-off would be identified in step 2 of the cost-benefit analysis. Here it would also become apparent that the benefits of taking action (e.g. through implementing a pollution tax) would not cover the costs of doing so. In our example the cost would include the increase in the deadweight loss and the reduced profit of the monopolist. It would become clear that the first-best solution cannot be reached and the second-best does not require any regulatory activity (step 5).

It is also worth noting that the importance of the above mentioned trade-off depends on the abatement technology used by the monopolist. If the monopolist would change the production technology – process switches – instead of cutting output in response to being faced with an emission tax, the risk of social losses created by pollution control policies will be reduced (see Burrows 1980: 78-80).

The upshot of this discussion is that solving a negative externality problem in the presence of non-competitive market structures requires much more than trying to equate marginal abatement cost with marginal external cost. Either the market imperfections can be resolved, or a complex second-best analysis is necessary. It is part of the CCAP, but is not included in the PPP.

Conclusion 7: *The PPP, unlike the CCAP, does not alert policy makers to unresolved market imperfections. It provides no guidance for a socially optimal response to such situations.*

3.4 Multiple optima and corner solutions

In the analysis presented in the previous sections, the tax rate implementing the (first-best) efficient Nash-equilibrium is uniquely determined by equating marginal abatement costs and marginal benefits from emission reduction (assuming efficient behavior of pollutees). Graphically, this is the intersection of the marginal cost curve MC, and the marginal benefit curve MB^* in Figure 1. However, this condition is neither necessary nor sufficient for efficiency:

- It is not a necessary condition where the social optimum is a corner solution (or the social optimum is second-best).
- It is not a sufficient condition if there are several local optima and the internalization of external costs occurs at the inefficient local optimum.

If $\frac{dc(x)}{dx} < -\frac{dc(y(x))}{dy}\frac{dy}{dx} - \frac{dA(x;y(x))}{dx} - \frac{dA(x;y(x))}{dy}\frac{dy}{dx}$ for all values of $x \in [0; f]$ in the model in section 2, then the marginal cost of emissions abatement is always lower than the marginal benefits from emission reduction. The social optimum in this case would be a corner solution in which polluters should eliminate all emissions (i.e. $e^* = 0$). Conversely, if $\frac{dc(0)}{dx} > -\frac{dc(y^*(0))}{dy}\frac{dy}{dx} - \frac{dA(0;y^*(0))}{dx} - \frac{dA(0;y^*(0))}{dy}\frac{dy}{dx}$, social cost would be minimized without any abatement taking place (i.e. $x^* = 0$ and $e^* = \bar{e}$). Conditions 3a and 3b cannot be met by any level of abatement.

Suppose now that – at least over some range – the marginal costs of reducing emissions are decreasing rather than increasing (which cannot be ruled out on theoretical grounds). Suppose further that none of the above mentioned modifications of the basic model apply. We consider two possible cases of decreasing marginal costs of the reduction of emissions.[18]

Case 1 (see Figure 3) is characterized by $MB^* > MC$ for $[0, r)$, $MB^* < MC$ for $[r, x^*)$ and $MB^* > MC$ for $[x^*, f]$.

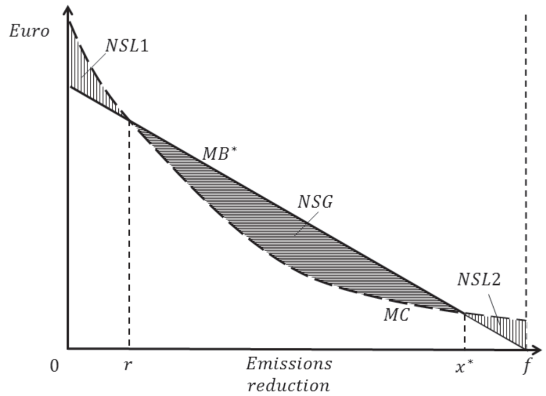

Figure 3: Decreasing marginal costs of emissions reduction with an efficient interior solution

Here, there is an initial net social gain from the expansion of abatement from zero ($NSG1$) for range $[0, r)$, a net social loss (NSL) for range $[r, x^*)$ and a net social gain ($NSG2$) for range $[x^*, f]$. Now assume that $NSG1 < NSL$ and $NSG2 > NSL$. The latter assumption implies that f is the socially efficient

[18] A similar result can be derived assuming a downward sloping marginal external costs curve (Burrows 1980: 65-68). See also ch. 8 in Baumol and Oates (1988), entitled „Detrimental Externalities and Nonconvexities in the Production Set".

level of abatement. This means that the social optimum is a corner solution in which the polluters' marginal prevention costs are not necessarily equal to marginal benefits. Thus making the polluters' marginal prevention costs equal to the marginal benefits of the pollutees is not a necessary condition for social efficiency in the case of corner solutions.[19]

Case 2 (see Figure 3) is characterized by $MB^* < MC$ for $[0, r)$, $MB^* > MC$ for $[r, x^*)$ and $MB^* < MC$ for $[x^*, f]$. This implies that polluters' marginal prevention costs equal pollutees' marginal benefits at two points r and x^*. There is an initial net social loss from the increase in abatement ($NSL1$) for range $[0, r)$, a net social gain (NSG) for range $[r, x^*)$ and a net social loss ($NSL2$) for range $[x^*, f]$. Now assume that$NSL1 < NSG$. Point r is inefficient since the initial net social loss is maximized. Because the social gain from the expansion of emission reduction from r up to x^* exceeds the net social loss up to r ($NSL1$), x^* is the socially optimal level of emissions reduction.

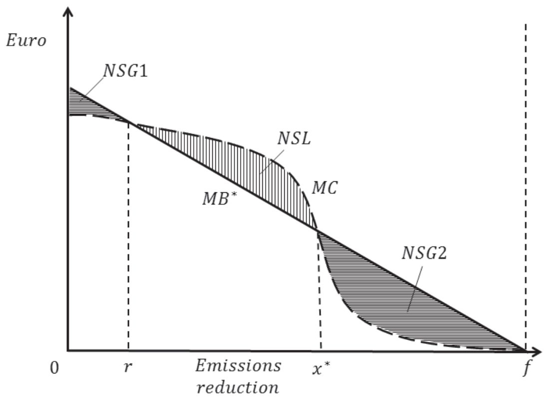

Figure 4: Decreasing marginal costs of emission reduction with no efficient interior solution

Thus, making polluters' marginal prevention costs equal to marginal benefits is not a sufficient condition for ensuring a social optimum. The sufficient conditions are that marginal prevention costs equal marginal benefits and that for a small change of the level of emissions reduction a social loss occurs, as it does at abatement level x^*. The inefficiency of point r is of course identified through the second order conditions, which would capture the marginal welfare impact (i.e. increasing marginal welfare if the marginal cost curve crosses the marginal

[19]Note that in this case, it is not a necessary condition in general, even without decreasing marginal abatement costs.

benefits curve 'from above', decreasing marginal welfare otherwise). However, the efficiency of x^* also depends on the total welfare effect of abatement. In the case that $NSL1 > NSG$, it would be optimal not to undertake any abatement activities. x^*would be a local, but not a global optimum.

Three implications of the efficiency analysis presented above are worth mentioning:[20]

- First, a simple rule requiring that emissions are taxed at the level at which marginal external costs from emissions (or the marginal benefits from abatement) equal the polluters' marginal prevention costs can lead to a social optimum only if the optimum is not a corner solution (i.e. where either all emissions should be avoided, or no abatement should take place).
- Second, in the case of multiple points of equality between marginal external costs and the polluters' marginal prevention costs, policy makers need to identify the socially efficient point in order to determine the correct level of emissions tax. Whilst local optima would be identified by the second order condition (the marginal cost curve crossing the marginal benefit curve 'from below'), a further assessment would be needed in order to identify the global optimum (as in our example, where abatement at level x^* is only optimal if $NSG > NSL1$).[21]
- Third, even if the socially efficient point is identified, there is no guarantee that an emissions tax set at the respective marginal abatement costs will generate efficient abatement. For example, under the conditions indicated in Figure 4, the efficient emissions reduction amounts to x^*. However, with a tax rate set at the marginal abatement cost at x^*, this level *will not be realized* because it is cheaper to pay the tax than to take emissions abatement measures.

The PPP as generally interpreted in the literature and the political arena neither alerts policy makers to the possibility of corner solutions (in particular those in which polluters should not pay at all) nor to multiple optima. It does not offer any guidance as to which optimum should be chosen, as in each of the optima polluters' marginal prevention costs equal marginal benefits. Of course, if second-order conditions were taken into account when calculating the Pigovian

[20]Similar implications hold for the cases analyzed by Burrows (see Burrows 1980: 67-68).

[21]Complications of multiple optima are also a result of nonconvexities in the social possibility set. Sufficiently strong detrimental externalities produce a nonconvexity in the social possibility set when there are nonzero levels of each of two activities (Baumol 1972, Baumol and Oates 1988: ch. 8). Such a nonconvexity confronts a policy maker with a choice between (at least) two local optima. The first one (call it solution A) may involve zero pollution. The second one (call it solution B) requires only the pollutees to invest in damage prevention. The only other possibility is the undesirable initial position. Now: "if B happens to be the true global optimum and society mistakenly imposes the ... Pigouvian tax appropriate for (local) optimum A, the economy may well end up with the inferior equilibrium A. This is the usual difficulty one encounters whenever there is a multiplicity of maxima" (Baumol (1972: 314)).

tax, some of the shortcomings identified above would be avoided. However, there is still the problem whether a tax implements the efficient emission reduction level. If not, the regulator should rely on some command-and-control measure (which would be compatible with the PPP).

This, again, is entirely different for the CCAP because of the five-step procedure on which its application is based, and its explicit focus on the implementation of the efficient Nash-equilibrium. Consider, for example, case 2, where x^* is the global social optimum. In the first step polluters as well as pollutees would be identified as potential cheapest cost avoiders. In step 2 x^* is determined as the global first-best social optimum. Up to x^* polluters are the cheapest cost avoiders; from x^* to f pollutees are. In step 3 it would be realized that the polluters are the sole adressees of regulatory measures, that a Pigovian tax would not work and a command-and-control approach should be chosen.

Conclusion 8: *The PPP, unlike the CCAP, does not alert policy makers to the fact that the equality between marginal costs and benefits is not a necessary condition where the social optimum is a corner solution (or is second-best), and that it is not a sufficient condition if there are several local optima.*

3.5 Administration costs

When analyzing the welfare impact of policies aimed at adddressing the problem of external costs, it is important to consider not only their impact on the behavior of polluters and pollutees and thus the allocation of resources, but also the cost incurred in administering these policies. These administration costs include the costs incurred by both the private and the public sector in acquiring information, setting up the policy framework, implementing requirements and monitoring and enforcing compliance. Administration costs should also be included in the calculation of the optimal level of the tax. The reason is that there is a trade-off between reducing the social cost of pollution by way of a tax and the costs of administering the tax. In the presence of administration costs the design of a policy is a second-best problem (Atkinson and Stiglitz 1980: 358-360). As Atkinson and Stiglitz point out, administration costs are one of the main reasons why government cannot attain the first best allocation (Atkinson and Stiglitz 1980: 455).

The optimal adjustments of a pollution tax for administration costs depend on whether these costs are fixed or variable, and whether they are borne by the government, the taxed entities or the pollutees. Polinsky and Shavell (1982) show that, depending on the circumstances and with constant marginal external costs, the optimal emission tax could be above, below or equal to the marginal external costs.

Our model illustrates the nature of the problem.[22] Suppose that only polluters have to incur administration costs and that these costs are constant per unit of emission reduction. In Figure 1 this corresponds to an upward shift of

[22] An explicit analysis of this issue requires a much more complex model than ours, which, however, is beyond the scope of this paper.

the MC-curve, resulting in an optimal tax level $t > t^*$. If, for example, the administration costs are constant per unit of emission and borne by the government, then there exists a trade-off between reducing the administration costs and increasing polluters' abatement costs, the solution of which may require a tax $t > t^*$. Administration costs may also play a role for pollutees. Suppose, that the administration costs are an increasing function of y, i.e. the amount of resources invested by pollutees in damage prevention. Then the MB^*-curve would shift downwards and the optimal tax level would be $t < t^*$. Of course, these cases may be combined, and a detailed analysis is beyond the scope of this paper.

The upshot of this argument is that the CCAP would take administration costs for all actors into account because it requires a comprehensive cost-benefit analysis. Unlike the PPP, it would identify the trade-offs indicated above and would recognize the need for tax adjustments.

Conclusion 9: *The PPP, unlike the CCAP, does not alert policy makers to the existence of administration costs. It provides no guidance for a socially optimal response to their existence.*

Administration costs should also be considered when choosing a particular policy measure. If one measure has lower administration costs than another, it may be preferable to adopt the former even if it does not perform as well as the latter in terms of welfare gains produced. Choosing a policy without taking account of administration costs could produce the wrong result. It may be better to adopt measures that do not guarantee a social optimum in each and every case if these measures are substantially cheaper to implement, e.g. because they require less effort from the addressees, or compliance is easier to monitor and enforce.

These considerations apply of course also to the decision about whether to follow the PPP or adopt the CCAP. One might indeed argue that even though the CCAP dominates the PPP in terms of being able to identify the best policy option, this advantage is outweighed by the fact that the PPP can forego a detailed cost-benefit analysis and the substantial delays or blockings of agency decision making associated with it (McGarity 1998, p. 50).

However, this argument is valid only if there are substantive cost savings from using the PPP instead of the CCAP and the welfare losses from using an inferior policy are small. For sufficiently large projects, the added value of the CCAP compared to the PPP can justify higher costs of gathering and analyzing the information required for its application, in particular, if the modifications of the basic model and second-best issues are taken into account. As Adler and Posner put it, "(a)ssuming cost-benefit analysis is more accurate in practice than competitors (taking into consideration not just intrinsic accuracy but also agency mistakes and opportunism), this direct cost will be swamped by the expected benefits" (Adler and Posner 2006: 87). Moreover, it is far from clear how large the cost savings from adopting the PPP are in practice. They may be large if the PPP is adopted in its most simplistic and naive form – but in this case the welfare cost from failing to achieve an efficient allocation of resources may be commensurately large.

Conclusion 10: *It is an empirical and case specific question whether administrative cost savings from applying the PPP rather than the CCAP outweigh the cost of foregone welfare gains and potential welfare losses as a result of misguided or inappropriate policy measures.*

4 Conclusion

Comparing the PPP and the CCAP on the basis of how well they perform in terms of social welfare clearly favors the CCAP over the PPP. A policy guided by the PPP cannot adaquately deal with a number problems, in particular second-best issues resulting from government as an additional investor, frictions on the side of pollutees, monopolistic markets, the multiplicity of optima, corner solutions and administration costs.

A cheapest cost avoider analysis incorporates 'polluter pays' as one possible outcome, but it recognizes that other agents – pollutees or the government – have their part to play as well. This can change the optimal tax rate, and second-best situations can arise. Administration costs and the possiblity of multiple equilibria and corner solutions requiring deviations from the Pigovian tax need also to be considered when determining the social optimum.

By relying on a comprehensive cost-benefit analysis, the CCAP takes into account a much broader range of relevant variables and actors. The PPP bypasses such a cost-benefit analysis and tends to promote the simplistic view of polluters being the only ones who have to take responsibility for reducing the harm from pollution. This can lead policy makers to making serious mistakes by failing to induce those who could reduce the harm from pollution at the lowest possible cost to do so and by miscalculating the optimal abatement levels of polluters.

Whether potentially higher administration costs of the CCAP shift the balance in favor of the PPP is an empirical and case specific question. However, what matters in any case is that an efficient treatment of external costs requires more than simply trying to equate marginal abatement costs of polluters with the marginal reduction of external costs.

One might argue that the PPP, properly interpreted, can take account of the modifications discussed in this paper. We are not aware of any attempt in theory or practice to do this, and if the PPP did encompass the analysis set out in this paper, it would become the CCAP in everything but name.

The logic of the CCAP helps policy makers in avoiding regulatory failure. Of course, the problems of incomplete or wrong information are as acute in applying the CCAP as they are in following the PPP, and it may be the case that the wrong party is mistakenly considered to be the cheapest cost avoider. But in contrast to the shortcomings of the PPP, which are due to its deficient paradigm, this is not a systematic or paradigmatic error.

In this paper, we focus on a Pigovian tax as a manifestation of the PPP. A PPP guided public policy, however, is not restricted to imposing Pigovian taxes. One could instead adopt a command-and-control approach. The question arises whether the conclusions derived in this paper in relation to a Pigovian tax can be generalized. We believe that this is the case, not least because a command-and-control approach following the philosophy of the PPP focuses on the behavior of the polluters and does not take account of all the additional complications for an efficient treatment of external costs identified in this paper.

This paper concentrates on how to deal efficiently with external costs. Efficiency implies not to waste valuable resources. Compared with inefficient outcomes, efficient ones have a higher value of production and higher average income. There should be no question that an efficient allocation of resources furthers the common good (i.e. social welfare). Of course, one can ask whether efficiency is all that matters. Indeed, there are factors beyond efficiency that have to be taken into account in order to judge which of the two principles is preferable overall: moral values, such as human autonomy and dignity, the intrinsic value of the environment, the interest of future generations, and corrective and distributional justice. However, when pursuing those 'non-economic' goals, one needs to be aware of the efficiency costs of doing so, and an analysis of the strengths and weaknesses of the PPP and the CCAP in this respect shows that the efficiency deficits of the PPP cannot be outweighed by those other goals (see Schmidtchen et al. 2009: ch. 6) .

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