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RESEARCH ARTICLE

Regulatory failure and the polluter pays principle: why regulatory impact assessment dominates the polluter pays principle

Dieter Schmidtchen[1] · Jenny Helstroffer[2] · Christian Koboldt[3]

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Abstract

This paper shows possible inconsistencies in environmental law, in which regulatory impact assessment (RIA) and the polluter pays principle (PPP) coexist. While these norms can be compatible, we show that there are a number of realistic settings in which the PPP does not reach efficiency and systematically leads to regulatory failure. These systematic errors are due to the ex-ante restriction of possible actors, in combination with possible opportunistic behavior, market power issues, the existence of multiple optima and to the neglect of second-best problems in the PPP. We show that RIA, encompasses the polluter pays option and avoids these flaws.

Keywords Polluter pays principle · External costs · Regulatory impact assessment

JEL Classification D62 · H23 · K2

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✉ Jenny Helstroffer
jenny.helstroffer@univ-lorraine.fr

[1] Center for the Study of Law and Economics, Faculty of Human and Business Science, Saarland University, Saarbrücken, Germany

[2] Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRAE, BETA, Nancy, France

[3] DotEcon, London, UK

1 Introduction

Environmental law offers two fundamental concepts for identifying which party or parties should bear the costs that arise from environmental damages (external costs). According to the polluter pays principle (PPP), those who “cause pollution” should pay for the harm they inflict on others (internalization of external costs), for example in the form of taxes, emission allowances (“cap and trade”) or command and control measures (prohibitions, restrictions of activity levels, installation of avoidance and abatement devices). A regulatory impact assessment (RIA), on the other hand, does not start from a presumption about which party should bear these external costs. Rather, it comprises a number of steps to be followed in order to determine the likely consequences of new or existing regulations. These steps essentially cover a thorough cost-benefit analysis of available policy options,[1] including taxation and command and control regulation of the polluter and of other parties, as well as the option of regulatory forbearance. Although an RIA may lead to the conclusion that polluters should bear the full cost of environmental damage and may in some instances prescribe the same measures that would arise from the application of the PPP, it considers a much wider range of policy options. By contrast, the PPP will start from the presumption that an intervention is required and that there is a party that can clearly be identified as causing the harm—the polluter—and that must bear the full cost. Alternative options for mitigating the environmental damage will not generally be considered, as well as the potential harm that may be caused by intervention in a world where many conditions for an efficient application of the PPP do not hold.

Comparing the efficiency of RIA and the PPP does not imply that the RIA approach to the design of environmental policy is to be considered as an alternative to a PPP approach, as if they were substitutes in policy design. Rather, we show that the RIA is a procedure needed before the correct instrument is chosen to address a specific environmental problem. The PPP is then one of the possible specific features of the chosen policy tool to be deployed. Whether it should be chosen depends on the specifics of the environmental problem to be taken account by RIA.

PPP and RIA coexist in various jurisdictions. The PPP has received strong support in most OECD countries (OECD 1992, 2002), 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 (1992).[3]

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[1] See Commission of the European Union (2009).

[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.” (European Union 2008).

[3] “National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution with due regard to the public interest and without distorting international trade and investment” (United Nations 1992).

It underpins most of the regulation of pollution,[4] and is also applied by courts in the United States (Masur and Posner 2015) and in the case law of the European Court of Justice.[5] At the same time, a requirement to undertake an RIA before policy measures are adopted has become standard among OECD countries. It has been a requirement for all new US regulations since 1981 and for all major policy initiatives in the EU since 2002.[6]

This paper (1) assesses whether and under what conditions a regulatory policy guided by the PPP, as typically understood, delivers socially optimal solutions to the problem of external costs; (2) shows that there are a number of realistic settings in which the PPP does not lead to efficient outcomes, leaving room for other policy options to perform better in terms of social welfare and (3) indicates that such outcomes (which amount to regulatory failure) can be identified and avoided by applying the rules of regulatory impact assessment. We also address the question whether a desire to compensate the victims of pollution could counterbalance the failure to achieve efficient outcomes and whether the possible inefficiencies of the PPP as an operational criterion may be outweighed by lower administration cost relative to RIA. We conclude that although PPP outcomes may come out of RIAs, a proper RIA can also recommend outcomes that conflict with PPP and that, where this is the case, such outcomes are superior to those that would be achieved by a narrow application of the PPP.

To prove that RIA dominates the narrow application of the PPP, we set up a simple environmental model using insights from the economic analysis of law.

Such models are a widely used and accepted tool for understanding the effects and complexities of environmental regulations,[7] ranging from “assisting in policy making, in formulating new laws and resolving legal disputes to being used as a tool for collaborative negotiations between multiple sets of parties”.[8] In particular, environmental models can show whether a particular regulatory measure is likely to achieve the desired objectives, and identify its costs and benefits.

In our framework, excessive transaction costs make it impossible for polluters to negotiate with pollutees, which is the root cause of external costs. Such external costs arise from conflicting uses of scarce resources (Coase 1960): 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 productive purposes. Since external costs are jointly caused—they would not have occurred but for the presence of both the polluters and the victims—externality problems are always of a reciprocal nature (Coase 1960): reducing costs

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[4] See, for example, the Impact Assessment Guidelines of the European Commission (Commission of the European Union 2009).

[5] See Bleeker (2009), Lindhout and Broek (2014) and De Sadeleer (2012).

[6] Cecot et al. (2008). For OECD countries and the European Union, see Deighton-Smith and Jacobs (1997), OECD (2009, 2020) and Commission of the European Union (2002a, 2002b, 2007, 2008, 2009). For its usage across countries, policy sectors, and policy instruments see Dunlop and Radaelli (2015). For special reference to environmental regulation, see Jakob et al. (2011).

[7] See Basu Roy (2018) and National Research Council et al. (2007).

[8] See Basu Roy (2018).

for one party imposes costs on the other party.[9] This view of external costs suggests that policy measures should resolve conflicts of resource use at the lowest possible cost, without any presumption as to which party is causing the damage and should therefore be responsible—a lesson which is largely neglected in the environmental economic literature. Environmental problems are typically treated as unilateral externalities where it is a foregone conclusion that only one party—the polluter—is responsible for the harm caused and must therefore take action to reduce the damage (unilateral care model). This presumption is what underpins the PPP in its narrow interpretation. By contrast, when external costs are properly understood as arising from unresolved conflicts over the use of scarce resources, it becomes obvious that actions of other agents (pollutees, government) might mitigate the harm caused, and that a socially optimal resolution to the problem of externalities may require action from all of these parties.[10]

We begin with the well-known result that imposing a Pigouvian tax on polluters can lead to a social optimum in which the marginal external costs equal polluters' marginal abatement costs.[11] However, it does so only under very specific conditions. If these conditions do not hold, there may not only be policy options that would perform better than intervention guided by a narrow application of the PPP—naively following the prescriptions of a PPP—inspired policy can even result in outcomes where social welfare is lower than it would be without any intervention. Such cases of 'regulatory failure' the public sector equivalent of market failure[12]—can arise, for example, because pollutees may behave in ways that undermine efficiency as a result of imperfect information, bounded rationality or strategic behavior; the potential role of government as an additional investor in reducing external costs is completely ignored when the starting point is a narrow focus on making polluters pay; and there may be market power or monopolies.[13]

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[9] If transaction costs are zero and property rights are well defined, bargaining between the parties involved delivers the socially optimal amount of an externality without regulatory intervention (Coase 1960). Moreover, the initial assignment of property rights will not affect the ultimate allocation of resources (this is the so-called Coase theorem).

[10] To be sure, there is also a strand of the literature which deals with bilateral externalities, where the injuring as well as the injured party may take action to reduce damage. In the context of liability law, an exhaustive discussion of bilateral care cases can be found (Shavell 2007; Miceli 2009; Cooter and Ulen 2012). However, the focus is on finding the liability rule which determines the socially optimal compensation a tortfeasor should pay the victim. See also Revesz and Stavins (2007) and Faure (2009, 2012) discussing environmental law in general.

[11] Currently about 40 jurisdictions worldwide put a price on carbon emissions, either in the form of emissions trading systems or tax or both (Kossoy et al. 2015). See also the "Economists' Statement on Carbon Dividends" (Wall Street Journal 2019) proposed by 45 prominent economists, which has been signed by more than 3000 US economists. In this paper, we focus on a Pigouvian tax as a manifestation of the PPP. However, it seems to us that its results are valid also for other polluter-based measures, including emissions trading: following the philosophy of the PPP, they all concentrate on the behavior of the polluters and do not take account of all the additional complications for an efficient treatment of external costs dealt with in this paper.

[12] As for the terms, causes and consequences of regulatory failure see also (Perman et al. 2003, section 8.4).

[13] There are a number of other economic reasons for why the PPP fails to achieve social optimality (see Faure (2012), Faure and Weishaar (2012) and Luppi et al. (2012) among others.)

The implications of these problems for the efficacy of a PPP-inspired policy would be identified through an RIA, which would also indicate how they might be avoided. In addition to allowing for a more wide-ranging conceptual approach, an RIA would also take account of implementation issues such as administrative costs. We briefly describe the RIA procedure, which requires undertaking a full-fledged cost-benefit analysis of proposed and existing regulation.[14]

We also provide an intuition for how a proper RIA, which includes lessons from the theory of second-best showing that sometimes two wrongs can make a right,[15] can avoid the regulatory failure flowing from a narrow application of the PPP.

Further, we show how a simplistic and narrow application of the PPP fails to deal with the problem of identifying the best solution in cases where there are multiple local optima, which often arises in the presence of externalities (see Baumol 1972, 316). The PPP, in contrast to RIA, provides insufficient guidance on what to do in those cases. The same holds true in case of efficient corner solutions.

We also argue that the applicability of the PPP is severely limited in the case of diffuse pollution where the combined effect of a multitude of pollutants discharged from many places interacting in a complex way makes it impossible to identify a causal link between individual emissions and environmental damage and where therefore the broader perspective offered by the RIA is essential.

Finally, we will deal with the question whether the costs of administering the PPP relative to those of handling the external costs problem on the base of RIA could make a case for following the PPP. We argue that this is not generally the case.

The paper is organized as follows: in Sect. 2 we present a standard pollution model. It acts as benchmark for determining the social welfare implications of the PPP in Sect. 3 and the RIA in Sect. 4. Section 5 concludes.

2 A basic pollution model

Consider, to begin with, two sets of agents, the polluting industry (hereafter: the polluters, or *E* for "emitters") and the set of agents who are affected by pollution (hereafter: the pollutees, or *V* for "victims"). Pollution is unidirectional. Unidirectional

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[14] See Commission of the European Union (2008, 2009), European Commission (2019) and International Association for Impact Assessment (2012).

[15] This is the basic insight of the general theory of second best (see Lipsey and Lancaster 1956). When certain conditions for a social optimum (first-best optimum) cannot be satisfied, the attempt to realize other conditions can do more harm than good. The reason is that the optimum conditions are interdependent. By changing other conditions away from the specifications that would otherwise be optimal, a second-best optimum can be realized. Second-best problems linked to Pigouvian taxes have been studied in Cremer et al. (1998, 2001), Cremer and Gahvari (2001), Gahvari (2014), Jacobs and De Mooij (2011), Parry and Oates (2000) and Kaplow (1996), but mainly by asking how the first-best Pigouvian rule must be modified in the presence of second-best constraints coming from the overall tax structure in a society. Further, a different strand of the literature deals with second best problems resulting from market power in the polluting industry (Buchanan 1969; Barnett 1980; Katsoulacos and Xepapadeas 1995), the industry providing abatement equipment (David and Sinclair-Desgagné 2005) and the endogeneity of market structures (Katsoulacos and Xepapadeas 1995).

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.[16] 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. Take for example noise pollution through traffic. The set of polluters are motorists, who create damage for a set of pollutees (residents) by making noise.

Both the polluters and the pollutees can fight pollution by investing in abatement measures. For example, the polluters could reduce their production or invest in pollution abatement technology (process-switching). The pollutees can reduce their activity levels, alter their production or consumption processes to make them less sensitive to the pollutants (the equivalent of the polluters' process-switching) or by moving away (see Burrows 1980, 33–34). Of course, simply bearing the damage is also an option. In our example, motorists can invest in measures to reduce noise pollution, such as low noise tyres or buying an electric car. The residents (pollutees) can also act to reduce their damage from the noise pollution, such as moving their bedroom to the other side of the house, or investing in windows with improved sound insulation. For both polluters and pollutees, while some measures can be taken at low cost, the higher the noise reduction, the higher the costs.

Let $\bar{e}$ represent the polluters' emissions level in the absence of control, absent any regulatory measures, and x the level of pollution abatement measures. Reducing the level of pollution below $\bar{e}$ is costly; it reduces the polluters' benefits. Let $c^E(x)$ denote the cost of abatement, i.e. of a reduction in the emission of pollutants by $x = \bar{e} - e$, where e represents the actual emission level after abatement activities. Emission level e can take values in the range from $e = 0$ to $\bar{e}$. The more polluters invest in abatement activities (the lower emissions level e) the higher are the costs, i.e., the marginal costs MC^E of an extra unit of abatement activities (reduction of emissions) are increasing.

Let $c^V(y)$ denote the costs to the pollutees associated with investing an amount of resources y in the prevention or mitigation of pollution damage. As with the polluters, we assume increasing marginal costs of an extra unit of abatement activity y.

Regarding damage abatement technologies, we make the following assumptions: First, total pollution damage D depends on the abatement activities of both the polluters and the pollutees, i.e. $D = D(x, y)$; the more the polluters and the pollutees, respectively, spend on emissions and damage reduction, the lower total pollution damage D.

Second, additional amounts spent on damage prevention reduce damage at a decreasing rate, i.e. marginal external costs decrease. Further, we assume that abatement efforts by polluters and by pollutees are substitutes. In other words, if the traffic noise is sufficiently reduced by the motorists, the residents will not invest

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[16] This is not to deny that polluters can be affected by pollution. However, we assume that the polluters internalize this effect and we concentrate on the purely external effect of pollution.

in changing their windows, and simply sleep in another room if they consider this measure less costly.

Figure 1 illustrates the logic of our model.[17] 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. One can read the horizontal axis to mean that $x = 0$ implies maximal emissions $\bar{e}$. Increasing x leads finally to zero emissions $e = 0$ (at point f).

The marginal costs of the polluters' abatement activities are represented by the upward sloping MC^E curve.[18] As shown, the marginal costs of reducing an additional unit of emissions increase with the amount of emissions already eliminated.

When the polluters reduce emissions, they reduce pollution damage and create benefits to pollutees at a decreasing rate. The downward sloping curves denoted MB^* and MB^0 indicate the marginal benefit to the pollutees from abatement by the polluters for the case where the pollutees efficiently invest in damage mitigation (MB^*) and do not invest in damage mitigation (MB^0).[19] In other words, they represent the reduction of damage $D(x; y)$ for a given level of y, with $y = y^*$ in MB^* and $y = 0$ in MB^0. Since a marginal benefit from a marginal unit of x results from the elimination of marginal external costs, the MB-curves are mirrors of the curves of marginal external costs.[20]

The fact that the marginal benefits from an increase in the polluters' abatement are lower if the pollutees invest in mitigation reflects the assumption that the abatement efforts of the sets of polluters and pollutees are substitutes.

Intersection point b, where $\mathrm{MC}^E = \mathrm{MB}^*$ and $x = x^*$, determines the socially optimal level of abatement and thus implies the optimal level of emissions. 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 ($\mathrm{MC}^E \geq \mathrm{MB}^*$), and every reduction of abatement levels would reduce marginal benefits that exceed the marginal costs ($\mathrm{MC}^E < \mathrm{MB}^*$). Realization of emissions level e^* implies abatement by the polluter up to x^* (intercept $0x^*$ in Fig. 1).

At this point social costs, defined as the sum of total external costs and total abatement costs of the polluters and pollutees, are minimized. The intuition can be explained as follows. Given $y = y^*$, with abatement level $x = 0$ total external costs (= total damage) amount to the area $0fm$ below the MB^*-curve. Polluters total abatement costs would be zero. At levels below x^* and beyond $x = 0$ each additional

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[17] We use linear functions in all figures without loss of generality. A more formal presentation of our model can be found in the Appendix. See also Ippolito (2005).

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

[19] Since emissions reduction is assumed to be a public good, the pollutees' marginal benefit curves from the reduction of pollution are added vertically. A (pure) public good simultaneously provides benefits to several people at the same time (joint consumption, nonrivalness). For public good problems see Ippolito (2005, Chapter 6).

[20] Reading along the MB-curves from left to right gives the amount pollutees are willing to pay to obtain more action from the polluters. Thus, the MB-curves can be interpreted as demand curves. The upward sloping curve MC^E is similar to a supply curve for the "good" emission reduction. See Ippolito (2005) and Butler et al. (1998).

Euro invested in abatement activities reduces pollutees damages by more than one Euro, so total social costs are reduced. Investing $x = x^*$ costs the polluters $0x^*b$ and reduces total external costs by $0x^*bm$. However, at abatement levels beyond x^*, investing an additional Euro reduces pollutees damages by less than one Euro, so total social costs rise: At point f, total additional abatement costs are x^*flb; total reduced external costs are only x^*fb.

The pollutees' abatement activities and their optimum is illustrated in Fig. 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 the pollutees' abatement on the vertical axis (given $x = x^*$ and $x = x_1$, with $x_1 > x^*$).

The downward sloping curves denoted $\overline{\mathrm{MB}^*}$ and $\overline{\mathrm{MB}^{x_1}}$, respectively, indicate the marginal benefit to the pollutees from own abatement activities for the case where the polluters either efficiently invest in abatement activities, i.e. $x = x^*$, or invest x_1. The marginal costs of the pollutees abatement activities are represented by the upward sloping curve MC^V. The optimal levels of the pollutees abatement activities, y^* and y_1, are located at the intersection points m and l, respectively. A similar reasoning as applied in the discussion of Fig. 1 reveals the intuition. In the social optimum with $x = x^*$, the pollutees' total abatement costs amount to $0y^*m$; the total benefits (reduced external costs) are $0y^*mr$; $y^*y_{\max}m$ are the socially optimal remaining total external costs.[21] At levels beyond y^* each additional Euro invested in abatement activities reduces pollutees damages less than one Euro, so total social costs are raised.

Figures 1 and 2 represent the case of a so-called interior solution: the social optimum requires both the polluters and the pollutees to invest in abatement activities, i.e. $x^* > 0$ and $y^* > 0$. However, depending on the positions and the shape of the relevant curves, so-called corner solutions can arise: $(x^* > 0,\ y^* = 0)$, $(x^* = 0,\ y^* > 0)$ or $(x^* = 0,\ y^* = 0)$ could be socially optimal.[22] In the case of ($(x^* > 0,\ y^* = 0)$ the polluters are so-called cheapest cost avoiders; with $(x^* = 0,\ y^* > 0)$ the pollutees are the cheapest cost avoiders.[23]

The simple model allows us to examine the question that policy makers need to answer: Will the PPP implement the efficient emissions reduction x^* and incentivize the pollutees to take socially efficient actions y^* where bargaining between polluters and pollutees is impossible because of high transaction costs?[24]

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[21] Area $y^*y_{\max}m$ in Fig. 2 corresponds to area x^*bf in Fig. 1.

[22] See Appendix.

[23] We can apply the idea of the cheapest cost avoider to our basic model with an internal solution. Which party is the cheapest cost avoider in our model? The answer is: both are. They "share the job". For the abatement up to $x^* = \bar{e} - e^*$, the polluters are the cheapest cost avoiders; for the remaining level of emissions $e^* = \bar{e} - x^*$, the pollutees are.

[24] The economic literature on the treatment of external costs focuses on efficiency. For the distributional issue of compensating the victims of pollution see Holtermann (1976), Burrows (1980, chap. 4), Baumol and Oates (1988, chap. 3, Luppi et al. (2012) and Ambec and Ehlers (2016). Based on a complex model, Ambec and Ehlers (2016) show that the PPP ("any agent compensates all other agents for the damages caused by his or her (pollution) emissions") leads, with constant marginal pollution damages, to a welfare distribution that induces non-negative individual welfare change. They extend this result to the case of increasing marginal damages. However, they neither examine—as done in this paper—circumstances leading to regulatory failure, nor do they ask whether RIA could be an effective procedure to deal with it.

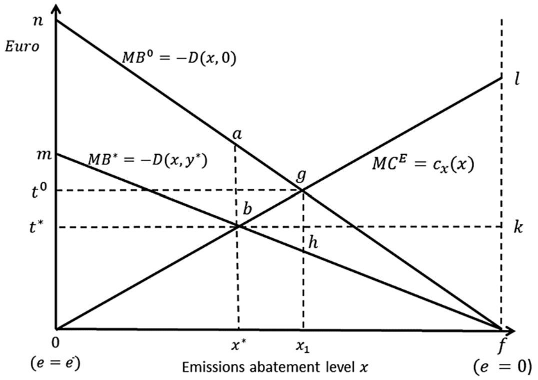

Fig. 1 Polluters' optimal emissions abatement level

3 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.

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 polluters should be confronted only with the costs of emissions control (abatement costs) or additionally with possible remaining external costs. Pezzey (1988) distinguishes two versions of the PPP depending on the definition of pollution costs: a standard and an extended version. According to the standard version, polluters are required to pay only the emissions control costs, whereas the extended version imposes both types of costs on polluters.[25] Further, do 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 present the benchmark?

We restrict our attention to the option where the government imposes a constant per unit tax rate on emissions $t^* = \mathrm{MC}^E = \mathrm{MB}^*$. Formally:

$$t^* = c_x^E(x) = -D_x(x, y^*)$$

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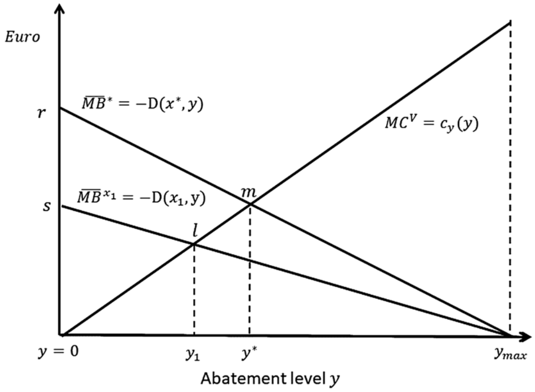
[25] There are other double interpretations of the PPP: principle of cost allocation and principle of internalization (Tobey and Smets 1996). The focus of the first interpretation is that of avoiding competitive advantages of firms by not sufficiently confronting them with external costs of production, by politically reducing abatement costs or even paying subsidies related to abatement measures. Tobey and Smets (1996) interpret cost allocation as a form of non-subsidisation. The focus of the PPP as a principle of internalization is on efficiency. Of course, internalization implies cost allocation.

Fig. 2 Pollutees' optimal abatement level



This is commonly referred to as a Pigouvian tax (Pigou (2013)[1920]). Thus, we apply the extended version of the PPP.[26]

We assume that all actors are strictly rational individual cost minimizers. This means that polluters invest in abatement measures as long as marginal tax savings exceed marginal abatement costs. With individual tax rate $t = t^{*}$, the polluters minimize $te(x) + c^{E}(x)$. Because $e_x(x) = -1$, this gives the first order condition $t - c_x^{E}(x) = 0$, which says that the marginal benefit of a unit of emissions reduction, i.e. t, equals the marginal abatement cost. This equation defines the polluters' optimal investment in damage prevention, x^{*}, given the optimal choice of damage prevention by the pollutees, y^{*}.

Pollutees invest in abatement measures as long as the marginal costs of doing so are below the induced reduction of external costs. The optimum is reached where $\mathrm{MC}^{V} = \overline{\mathrm{MB}}^{*}$ in Fig. 2, with $y = y^{*}$.[27]

Thus, we obtain the social optimum (x^{*}, y^{*}), with $x^{*} \equiv x^{*}(y^{*})$ and $y^{*} \equiv y^{*}(x^{*})$. Since no agent has an incentive to deviate from their chosen strategy—x^{*} for the polluters and y^{*} for the pollutees—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^{*}.[28]

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[26] As Kampas and Franckx (2005, p. 142) point out "the PPP provides the raison d'être for Pigouvian taxation, justifying it as a legitimate policy means of internalising externalities". But if the Pigouvian tax is both an environmental and a fiscal policy measure, there is a possibility that PPP may not be compatible with Pigouvian taxation (see Kampas and Franckx 2005 discussing rules of refunding polluters). See for the topic taxation and the environment also Smith (1992).

[27] With $x = x^{*}$, the pollutees choose y to minimize $D(x^{*};y) + c^{V}(y)$, which yields the first order condition

$$D_y(x^{*};y) + c_y^{V}(y) = 0$$

This equation defines the pollutees' optimal investment in damage prevention, y^{*}, given the polluters' optimal choice of abatement x^{*}.

[28] Regarding corner solutions, the PPP would define $t^{*} = \mathrm{MC}^{E}$ at $e = 0$ when the polluter should eliminate all externalities, and $t^{*} = 0$ when the polluter should take no action. Both tax rates would implement the respective efficient corner solution.

Conclusion 1: The PPP, applied in the form of a Pigouvian tax, implements the social optimum, whether it is an interior optimum or a corner solution, provided the pollutees choose the efficient level of pollution damage prevention.[29]

The social optimum implemented by tax rate $t = t^*$ which satisfies conditions (4) and (5) (derived in the Appendix), occurs at intersection point b in Fig. 1, with associated point x^* indicating the efficient level of abatement.

It is important to note that the social optimum implies that there still exist external costs, since emissions are not reduced to zero. Nevertheless, one might argue that the polluters have in fact internalized all external costs: first, by investing in abatement measures (see area $0x^*b$ in Fig. 1), and, second, by paying taxes amounting to x^*bkf in Fig. 1 which exceed remaining total external costs $D(x^*, y^*) = x^*fb$. Obviously, an exact match between the total of taxes paid and total external costs would require a tax $t < t^*$, which would lead to inefficiency.

Things become more complicated when one interprets abatement costs of the pollutees as external costs as well or, alternatively, measure external costs in the absence of pollutees abatement costs. Then total external costs amount to area x^*fa. Only if area bfk equals area bfa we would have an exact match of taxes paid and total external costs, i.e. $x^*fkb = x^*fa$. In Fig. 1 with its linear functions this implies $ab = kf$. Obviously, whether tax revenues from $t = t^*$ are sufficient for compensating pollutees depends on the position and shape of the MB- and MC-curves.

If one interpreted the PPP as requiring the avoidance of all external costs, the application of the PPP would not implement the social optimum. With tax $t = \mathrm{MC}^E$ (at point f in Fig. 1) additional abatement costs amounting to areas x^*flb clearly exceed the total of avoided pollution costs whether determined by MB^* ($= x^*fb$) or MB^0 ($=x^*fa$).[30]

Further, our graphical representation of the Pigouvian 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 Fig. 1. Such a reduced graphical representation, which follows from the commonly applied Pigouvian 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 Pigouvian solution to the externality problem that would suggest that it is not only the polluters who can take action, but that pollutees

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[29] Note that this conclusion is based on a static model of social optimality. An analysis of the dynamic, intertemporal or long-run aspects are beyond the scope of the Paper. See regarding possible limitations of Pigouvian taxes as a long-run remedy for externalities Carlton and Loury (1980). A general discussion of intertemporal aspects can be found in Ng and Wang (1993) and Perman et al. (2003, ch. 11). Concerning the political feasability of environmental taxes see, for example, Cremer et al. (2004) and Perman et al. (2003).

[30] However, with constant marginal abatement costs MC^E and MC^V and constant marginal benefits MB^0 (horizontal lines in Figs. 1, 2) a social optimum with internalization of all external costs will be realized if $\mathrm{MB}^0 > \mathrm{MC}^E$ and $\mathrm{MC}^E < \mathrm{MC}^V$.

might also be able to reduce pollution damage.[31] Modeling a symmetrical situation in a way that hides this aspect can induce policy makers to commit serious mistakes, as shown in Sect. 2.

4 Regulatory impact assessment and social welfare

4.1 The RIA procedure

In order to briefly describe the RIA, we refer to the European Commissions' impact assessment guidelines.[32] It consists of a set of six logical steps to be followed in preparing policy proposals.[33] We list 5 steps of RIA, which essentially cover a thorough cost-benefit analysis of available policy options, including the option of doing nothing, and briefly describe the answers to be given to the questions raised by the steps.[34] Of course, in this paper we cannot deliver a fully fledged impact assessment analysis. It must suffice to indicate what to focus on.[35]

1. Identify the problem and describe the baseline scenario, for example, by identifying the relevant MC- and MB-functions as well as the emissions level in the absence of regulatory measures ($e = \bar{e}$). In our setting, the problem to be addressed is the existence of externalities associated with external costs.
2. Define the policy objectives to address the problem. In this paper efficiency as defined in Sect. 2 is assumed to be the objective. Consequently, the first-best social optimum has priority; if a first-best solution is not available, a second-best solution should be realized. If the assumptions underpinning the basic model presented at the beginning of this section are representative for the situation to be analyzed, the two marginal conditions for a first-best outcome (2) and (3) would be derived.[36]
3. Develop effective policy options for reaching the objectives. This implies:
    - Identification of the relevant actors. Here, they can be polluters, pollutees or a third party, such as the government, acting alone or jointly.
    - Establishing the available alternative possibilites for all relevant actors to invest in measures that reduce pollution damage. For example, sound pollution can be reduced by motorists (the polluters) investing in low noise tyres,

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[31] See Wittman (2006, pp. 51–53).

[32] See Commission of the European Union (2009) and European Commission (2019).

[33] See Commission of the European Union (2009, p. 4).

[34] The sixth step is to prepare arrangements for future monitoring and evaluation. We will not discuss this step here.

[35] The main point is to perform a two stage policy evaluation where RIA has to be performed anticipating the potential issues of each candidate tool (including PPP tools but also other possible approaches) in the first stage and then, in the second stage, the selected policy approach and its implementation are designed in details and the welfare properties (together with fairness and other potential objectives) are assessed.

[36] Objectives beyond efficiency, such as distributive justice, are discussed in Schmidtchen et al. (2009).

  residents (pollutees) can invest in sound proof windows, or the government could invest in low noise road surfaces.
- Identifying possible regulatory measures suitable for incentivizing the actors to realize the established alternatives. An example for incentive compatible measures on polluters would be a Pigouvian tax.

4. Analyze, besides the effect on pollution damage reduction, the likely economic, social and environmental impacts, such as on employment, health, growth, tax revenues and income distribution.[37]
5. Compare the options in terms of efficiency and coherence in pursuing the objectives. This would require a comparison of the tax option with command-and-control measures. However, this is beyond the scope of this paper.

In step 5, options have to be found and implemented which satisfy the two marginal conditions for a first-best outcome.

4.2 RIA and PPP: the equivalence result

Suppose that efficiency is assumed to be the policy objective and that in step 1 a baseline scenario has been identified as described in Sect. 2. One of the potential policy options to be analyzed in step 3 is the PPP.

As we have seen in the previous section, a constant per unit emissions tax $t^* = \mathrm{MC}^E = \mathrm{MB}^*$ would in this case lead both the polluters and the pollutees to take efficient actions and achieve the first-best optimum. And since t^* implements the first-best outcome, a second-best solution plays no role. This also holds true for the corner solutions.

Of course, other options of command-and-control regulation may be available. If these options are cheaper to administer they would clearly beat the Pigouvian tax. But they would also be manifestations of the PPP. Since we assumed administration costs to be zero there is no better solution for the problem of external cost than this tax.

Conclusion 2: The PPP (as interpreted here) can be perfectly incorporated into an overall pollution control procedure such as the RIA. The socially optimal solution to the pollution problem according to the PPP is perfectly in line with that reached by RIA (equivalence result).

4.3 Challenging the equivalence result: why RIA dominates the PPP

We have so far presented the baseline of a cost- and flawless world of the implementation of regulatory measures, in which administration costs of the PPP and the RIA protocols are neglected. We have assumed zero information costs on the side of the regulator, as well as its willingness to realize the social optimum.

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[37] Since in this paper we focus on the minimization of social cost as defined in Eq. 1, we do not address these issues.

In this section we discuss several major qualifications to the proposition that a Pigouvian tax implements a social optimum and indicate that RIA will, in principle, take account of these qualifications by deviating from a narrow implementation of the PPP. We also address the question of whether differences in the respective administration costs can make a case for the PPP.

4.3.1 Suboptimal behavior of the pollutees

The 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 the pollutees select the socially efficient level of their activity as well. The pollutees must incur the socially optimal damage reduction costs. Thus, efficiency requires that for any given pollution level, the pollutees have incentives to invest in measures that reduce the marginal damage caused by pollution whenever they can do so at lower costs.

However, obtaining perfect information is too costly, and the pollutees may not behave in such an optimal fashion for a number of reasons. Below we discuss three of these, namely imperfect information and bounded rationality 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 the pollutees have public good characteristics—to free-ride on other pollutees' investments when there are several pollutees. Finally, we show that, if one interpreted the PPP, for example, such that victims of pollution are fully compensated for the damages suffered, they would clearly have no incentives to invest in damage prevention, even if it were efficient from a social point of view.

Imperfect information and bounded rationality Under perfect information about both their marginal abatement cost function and their marginal benefits from abatement, rational pollutees will invest in damage prevention up to the point where the marginal cost equals the marginal benefit (see Fig. 2). This means that marginal external costs are minimized for any given amount of pollution.

However, if the pollutees under- or overestimate their marginal pollution cost, this leads to over- or underinvestment in damage mitigation ($y > y^*$ and $y < y^*$, respectively). This scenario may occur if information on pollution costs or mitigation benefits is imperfect, or if pollutees are myopic[38] or boundedly rational, i.e. not fully aware of the marginal benefits of all the actions they could take, or the costs of these actions, or do not fully understand their effectiveness in reducing the damage from pollution. Here, calculating emissions tax rates with reference to the actual investment in prevention and mitigation by pollutees will lead to investment in emission reduction by polluters that is either excessive or insufficient.

To illustrate, consider the case where the pollutees do nothing, i.e. $y = 0$. The resulting MB-curve is MB^0.[39]

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[38] See Ng and Wang (1993).

[39] If $y^* > 0$, we can exclude the corner solution in which it is indeed optimal for the pollutees to do nothing.

The respective tax rate is $t^0 > t^*$, inducing emission reduction level x_1, which is inefficient because $x_1 > x^*$ (see Fig. 1). With overinvestment of the pollutees the marginal benefit function in Fig. 1 would lie below MB*, leading to a tax rate $t < t^*$ and insufficient emission reduction 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 in the case of inefficient abatement activities of the pollutees), this would not minimize social costs. The reason is that in a social optimum (x^*, y^*) two conditions must be satisfied: $x^* \equiv x^*(y^*)$ and $y^* \equiv y^*(x^*)$.[40] However, with inefficient behavior by pollutees this is not the case (in Fig. 1, point a would be realized in the case of insufficient behavior by the pollutees instead of the efficient point b).

The RIA can help with identifying problems that might exist in relation to the behavior of pollutees. In step 1 the baseline scenario has to be described, which requires among other things an identification and analysis of the MB-functions. That is to say it must, in principle, be figured out whether the pollutees have invested in damage prevention up to the point where the marginal cost equal the marginal benefit. If this should not be the case RIA will also alert regulatory authorities to the fact that, in addition to imposing a tax on polluters, they should take action to ensure efficient behavior of the pollutees (e.g. through providing information or financial incentives, or through mandatory requirements).

Where changing the behavior of pollutees is impossible or too costly, RIA also helps with establishing the second-best tax rate. In our example, the tax rate would be t^0, leading to second-best efficient emission reduction x_1 in Fig. 1.[41]

A 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 the pollutees may lower the cost of intervention and improve welfare. In any case, it would set the tax at its second-best level by chance rather than by design.

Conclusion 3: With imperfectly informed or boundedly rational pollutees, a focusing on the PPP leads to regulatory failure. RIA would, in principle, alert regulators to identify this problem and implement adequate, possibly second best, solutions. Those solutions might also require the polluters to pay, but not necessarily a Pigouvian tax.

Strategic behavior So far we have assumed that pollutees behave non-strategically in the sense that they do not use their abatement behavior to influence the choices of the regulator 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

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[40] See conditions (4) and (5) in the Appendix.

[41] The tax rate would have to satisfy the condition $t^0 + c_x^E(x) = -D_x(x, 0)$. t^* and t^0 induce abatement levels x^* and x_1, respectively. A move from x^* to x_1 implies additional abatement costs x^*x_1gb and reduces external costs (i.e., generates benefits to the pollutees) x^*x_1ga. With t^0, social costs are lower by area bga.

externalites for other pollutees, this may not be the case and there could be strategic behavior.

"*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.[42]

Consider Fig. 1 and suppose that pollutees deliberately don't invest in abatement measures, i.e. $y = 0$. Suppose further that that a regulator 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_1. 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, investing $y = y^*$ instead of $y = 0$, the pollutees adopt their own pollution abatement measures.[43] In Fig. 2, the lower curve $MB^{x_1} = D_y(x_1;y)$ now represents the pollutees' marginal benefits from emissions abatement. The pollutees' optimal response is $y^1 < y^*$. The pollutees' gain from acting strategically can be measured by the difference between total costs to be born by the pollutees with $x = x^*$ and with $x = x_1$. Total costs are the sum of abatement costs and remaining external costs: with $x = x^*$ this sum amounts to the areas $0my^*$ (abatement costs) plus areas $y^*y_{\max}m$ (remaining external costs). With $x = x_1$ we would have $0y_1l$ abatement costs and $y_1y_{\max}l$ (remaining external costs) in Fig. 2. The difference $ly_{\max}m$ measures the pollutees' total gain from acting strategically. The social optimum $(x^*;y^*)$ is not reached. If, however, the regulator identified the incentive of the pollutees to act strategically he could fix the optimal tax rate t^* in advance or in stage 2 of the four-stage process, thereby incentivizing the polluters to realize abatement level $x = x^*$ and the pollutees to invest $y = y^*$. The impact of this strategy depends crucially on whether or not the regulator can credibly commit to this strategy.[44] As an alternative a regulator might in addition to a Pigouvian tax on polluters t^* impose a tax on the pollutees (bilateral or double taxation)—a solution to an externality problem already supposed by Ronald Coase in his seminal article (Coase 1960). Consider Fig. 2: a tax on each abatement measure not implemented by the pollutees of y^*m would incentivize pollutees to choose the efficient level of abatement y^*.[45]

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[42] How to proceed in principle can be seen in Dijkstra (2007), who models a contest between polluters and pollutees to influence the regulator as a two-stage game. The regulator's decision is more favorable for each side the more it invests in its marginal benefit from pollution. Legal or lobbying expenditures are alternative means for getting a favourable decision from the regulator.

[43] This is a four-step process, the explicit analysis of which is beyond the scope of the paper.

[44] Commitment problems are discussed in Moner-Colonques and Rubio (2016), with extensive references to the literature.

[45] Regarding bilateral taxation, see Ng (2007) and Baumol and Oates (1988, chapter 4). Section 5 of Tideman and Plassmann (2017) provides a very thorough coverage of the topic.

Of course, the polluters might also act strategically by influencing the position of the MC-curve, which would lead to a much more complex interactive process.[46]

Conclusion 4: A Pigouvian tax can implement a first best solution to the pollution problem when pollutees have incentives to game the system under the condition that a regulator takes the position of a first mover credibly committing to this tax or chooses bilateral taxation. In both cases the imposition of the pollution tax must be complemented by additional actions to be identified by the RIA procedure.

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.

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 he or 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 the relatively most efficient group members to specialize in the mitigation of the external costs (Olson and Zeckhauser 1970, p. 516). Government intervention might be needed to solve the problems resulting from these collective action problems.

It is straightforward to see that 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 RIA as a result of the five-step procedure on which its application is based. In the process of finding the socially optimal intervention, collective action problems amongst pollutees would be identified (step 1) and the policy maker would learn in step 3 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

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[46] See also Moner-Colonques and Rubio (2016) who analyze the strategic use of innovation to influence environmental policy in a game.

line with steps 3 and 4). In contrast to the PPP, RIA also would consider whether a second-best solution might need to be found (step 5).

Conclusion 5: RIA, alerts policy makers to the existence of pollutees' collective action problems and the resultant free rider incentives, and realizes that the imposition of an emissions tax does not deliver a solution of the freerider problem. In addition, it provides guidance for a response to such problems.

4.3.2 Compensating pollutees

It is important to note that we define the social optimum in a very restricted way, i.e. identifying it with an efficient allocation of resources (x^*, y^*) and abstracting from the question of distributional justice (fairness). The most efficient thing to do is not only for the polluters to invest in abatement measures x^* but also to force the pollutees to bear remaining external costs and to invest in abatement measures y^*. However, one might argue that the pollutees are victims of harmful actions who should be paid compensation for the damages suffered. Uncompensated losses incurred by pollutees may be considered unjust.

Suppose the pollutees receive compensation using revenues from a pollution tax for any damage suffered by them. Their cost function would be

$$C^V = y + D(x^*, y) - D(x^*, y) = y$$

This expression is minimized at $y = 0$. Thus, with $x = x^*$ and $y = 0$ we would have a case of so-called moral hazard, which is socially inefficient.[47] In Fig. 1 the additional social costs in comparison to (x^*, y^*) amount to area *baf*. To match the actual marginal pollution costs at x^*, given $y = 0$, the tax would have to be be raised to $t = t^0$, which leads to social inefficiency.

The question thus arises whether there exist compensation schemes which do not distort pollutees' incentives to efficiently invest in abatement measures. Consider the following three rules:

1. Pollutees receive compensation $D(x^*, y^*)$ independent of their own abatement behavior, i.e. lump sum payments. This rule implies $C^V = c^V(y) + D(x^*, y) - D(x^*, y^*)$. The first order condition is $c_y(y) + D_y(x^*, y) = 0$. As long as $c_y(y) < -D_y(x^*, y)$ pollutees invest in additional abatement measures. In the optimum, $c_y(y) = -D_y(x^*, y)$, which implies $y = y^*$. Thus lump-sum payments are incentive compatible; they do not distort the pollutees' incentives, since they still must bear the marginal cost of each unit of pollution and the pollutees marginal abatement costs remain unchanged. In other words, lump-sum payments have no influence on shape and position of the curves depicted in Fig. 2.
2. Pollutees receive compensation for any damage under the condition that they have chosen abatement level $y = y^*$. With $y = y^*$, pollutees cost are

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[47] See also Burrows (1980, p. 103–107).

$$C^V = c^V(y^*) + D(x^*, y^*) - D(x^*, y^*) = c^V(y^*)$$

With $y < y^*$, costs are $C^V = c^V(y) + D(x^*, y)$. Since $c^V(y) + D(x^*, y) > c^V(y^*)$, pollutees choose $y = y^*$.[48] Note that with this rule the pollutees would still have to bear costs amounting to $c^V(y^*)$.

3. If both rules mentioned above are considered unfair, one might apply the following rule: pollutees receive compensation for any damage under the condition that they have chosen abatement level y^* and they get compensation for their incurred costs $c^V(y^*)$. Pollutees' total costs are now

$$C^V = c^V(y^*) + D(x^*, y^*) - D(x^*, y^*) - c^V(y^*) = 0$$

Investing $y < y^*$ implies total costs

$$C^V = c^V(y) + D(x^*, y) > 0$$

Thus, pollutees will choose $y = y^*$.

In conclusion, social efficiency does not require compensation to be paid.

Baumol and Oates (1988, p. 41, Proposition 1) have shown that the possibility of taxing or compensating the victims of pollution is not necessary to sustain a Pareto optimum. However, it is compatible with compensation being paid under two conditions:

1. Tax revenues from an efficient tax $t = t^*$ suffice to finance compensation.
2. Compensation schemes are incentive compatible, which means that pollutees have incentives to efficiently invest in abatement measures.

Note that the PPP as such implies neither that pollutees are fully (or less than fully) compensated, nor does it give hints as to the efficient compensation scheme. If individual pollutees are different with regard to their preferences and abatement technologies, which is the realistic case, it is not easy to obtain the information necessary for an individually just compensation. A way out is to approximate full compensation by defining reasonable care on the side of pollutees and to choose uniform payments to pollutees based on reasonable pollutee behavior.[49] Given heterogeneous pollutees, this may lead to social inefficiency and individual injustice. However, it does save administration costs and can be considered a second-best solution. RIA addresses these questions as an integral part of its procedure.

4.3.3 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. Take for example traffic noise

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[48] Of course, this rule is a variant of the rule of contributory negligence known from tort liability.

[49] See also Burrows (1980, p. 105).

pollution. The magnitude of the harm can be reduced in many different ways: by the polluters, by the pollutees, and also by the the public sector, which can re-route traffic (e.g. by building a by-pass), or invest in low noise tarmac.

Let $c^E(x)$, $c^G(z)$ and $c^V(y)$, respectively, represent the abatement cost to the transport industry, to the government (G) and the residents , and let $D = D(x;y;z)$ be the harm from emissions that now varies with the efforts of polluters, pollutees and the government. Assuming the same properties of the cost and damage functions as in the previous subsections, the social optimum to be determined by applying a calculus similar to that presented in the first part of the Appendix is now (x^*, y^*, z^*), with $x^* \equiv x(y^*;z^*), y^* \equiv y(x^*;z^*), z^* \equiv z(x^*;y^*)$. In the social optimum x^*, y^* and z^* can be zero or positive, depending on the specifics of the cost and damage functions. There are eight possible combinations of the values of (x^*, y^*, z^*): $(x^* = 0, y^* = 0, z^* = 0);(x^* = 0, y^* > 0, z^* = 0);(x^* = 0, y^* = 0, z^* > 0);(x^* = 0, y^* > 0, z^* > 0);(x^* > 0, y^* = 0, z^* = 0);(x^* > 0, y^* > 0, z^* = 0);(x^* > 0, y^* = 0, z^* > 0);(x^* > 0, y^* > 0, z^* > 0)$.

Ignoring that government investment plays a role in reaching the social optimum, i.e. $z^* > 0$, and imposing a pollution 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 may be too high (i.e. $x > x^*$ 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 $y = y^*(x^*;z^*)$

This type of regulatory failure would be identified by an RIA. In step 1 and 2 one of the eight combinations mentioned above would be identified. Suppose that the social optimum requires $z^* > 0$. In step 3 it would be realized that a pollution tax based on $z^* = 0$ would not implement the efficient solution.

Even if the constant per unit tax rate on emissions in a Pigouvian 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, for example, tax rate t^{**} with $t^{**} < t^*$, this does not guarantee that the optimal government investment in the prevention of pollution damages actually takes place. The reason why this might happen would be realized in step 3 of an RIA. 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 the 'balkanization' of public policies—a lack of coordination within and between agencies operating on all levels (central, regional, municipal) of government activities.The RIA would 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 Pigouvian tax t^{**} exactly match the funding required for achieving 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.[50] If not, the pollution tax should be adjusted or taxes that are potentially distortive have to be raised elsewhere.[51] 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 (Fullerton and Metcalf 1997; Jorgenson et al. 2013).

Conclusion 6: An RIA procedure would lead a regulator to realize that the social optimum is not (x^*;y^*) but (x^*;y^*;z^*), that it is not enough to impose only a pollution tax but also to ensure that governmental investments are necessary and must be financed in a possibly second-best way.

4.3.4 Imperfect competition

Suppose that the polluters are suppliers and pollutees consumers in what would be considered to be a relevant antitrust market, say the market for widgets.

The widget production generates a constant amount of emissions per unit of output and the marginal external costs are increasing as assumed in Fig. 1 (see the MB-curves). A perfectly competitive widget market implies that there is too much emission. The market price is lower than socially optimal since it is determined only by the private marginal production costs which do not include the marginal external costs. Thus, production and demand are higher than socially optimal. A tax set at $t^* = \mathrm{MB}^* = \mathrm{MC}^E$ may implement the efficient abatement level. Marginal production costs and the price increase lead to a reduction of demand and supply. However, this efficiency result no longer holds for other market structures such as a monopoly since it increases the marginal production costs, raises the market price and reduces supply and demand (see Buchanan 1969; Barnett 1980; Perman et al. 2003; Just et al. 2005; Requate 2006). While 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

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[50] A non-distortive lump sum tax imposed on polluters is also required in cases of $x^* = 0$.

[51] This is a second-best problem, dealt with in the economic theory of optimal taxation (Boadway 2012; Cremer et al. 1998, 2001; Gahvari 2014; Jacobs and De Mooij 2011; Parry and Oates 2000; Kaplow 1996).

no external costs because it charges a price above private marginal costs, leading to a net welfare loss[52]; 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 also include the marginal external 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, i.e. $y^* = 0$. 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 Fig. 1 (i.e. where there would be zero abatement), the monopolist only emits fx_1 (implying an efficient level of emission reduction since $x^* = x_1$).[53] 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 ($x > x_1$) 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)). This is of course also true in less extreme settings, such as oligopoly.

It is obvious that the efficient solution of the externality problem requires more than a comparison of the marginal external cost and the polluters' 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

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[52] Also labeled "deadweight loss". See Ippolito (2005).

[53] Recall that, for simplicity, we assume $y^* = 0$.

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 deadweight loss generated by the monopolist charging higher prices than at the optimum and 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 RIA. The above mentioned trade-off would be identified in steps 1 and 2 of the cost-benefit analysis. In step 4 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).[54]

It is interesting to note that market power can even require an emission tax above the level that would be optimal in a competitive market. Suppose the firms in the industry providing abatement services or equipment to the polluters possess market power. Consequently, the prices are—unlike those in competition—above marginal costs, and the marginal abatement costs for each level of emission reduction are higher than with competition. Thus, a tax t^* leading to socially optimal emission reduction x^* in competition in both the polluting and the upstream industry induces suboptimal emission reduction $x < x^*$. In order to reach efficient emission level x^* the tax should be set above the usual Pigouvian.

This may also be the second-best solution if market entry is possible, making the market structure endogenous. Now a regulator has to take account of three effects: a beneficial effect of reducing pollution, a negative effect on an already distorted output, and a positive effect of an increasing number of firms so that total output distortion is reduced (despite reduced output of each firm having entered the market). As Katsoulacos and Xepapadeas (1995, 416) conclude: "If the third effect is not taken into account, [the tax] [...] is less than the marginal external damage to compensate for the output effect. But if the third, positive, effect is taken into account and it is sufficiently strong, the optimal tax may well exceed the marginal damage."

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 RIA, but is not included in the PPP.

Conclusion 7: An RIA alerts policy makers to unresolved market imperfections. The cost-benefit analysis it is based on provides guidance for a socially optimal response to such situations.

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[54] 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 changes 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 is reduced (see Burrows 1980, 78–80).

4.3.5 Multiple optima

In this subsection we will, first, show that equating polluters' marginal abatement cost and marginal benefits from emission reduction is neither a necessary nor a sufficient condition for a first best optimal treatment of external cost. If there are several local optima this condition also holds at an inefficient local optimum.

To illustrate, suppose now that—at least over some range—the polluters' marginal costs of reducing emissions are decreasing rather than increasing. Suppose further that none of the above mentioned modifications of the basic model apply.[55]

Consider Fig. 3, which is characterized by $MB^* < MC$, between 0 and r, $MB^* > MC$ between r and x^*, and $MB^* < MC$ between x^* and 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.

Thus, equating polluters' marginal prevention costs 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^*.[56]

Note, however, that 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. The pollutees are the cheapest cost avoiders. If, unlike Fig. 3, there is a net social gain between 0 and r, a net social loss between r and x^*, and another net social gain between x^* and f and if the sum of the net social gains is superior to the net social loss, the corner solution f is the global optimum. Thus, equating polluters' marginal prevention costs to marginal benefits is not a necessary condition for ensuring a social optimum.

These examples illustrate the following implications of the efficiency analysis presented above[57]:

- First, in the case of multiple points of equality between marginal external costs (as represented by the MB^*-curve in Fig. 3) and the polluters' marginal prevention costs, policy makers need to identify which one is the socially efficient point in order to determine the correct level of an emissions tax. While local optima would be identified by the marginal cost curve crossing the marginal benefit

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[55] A similar result can be derived assuming a downward sloping marginal external costs curve (Burrows 1980, p. 65–68). See also Perman et al. (2003, p. 188–189) and ch. 8 in Baumol and Oates (1988), entitled "Detrimental Externalities and Nonconvexities in the Production Set".

[56] 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 benefits curve 'from above', decreasing marginal welfare otherwise).

[57] Similar implications hold for the cases analyzed in Burrows (1980, p. 67–68).

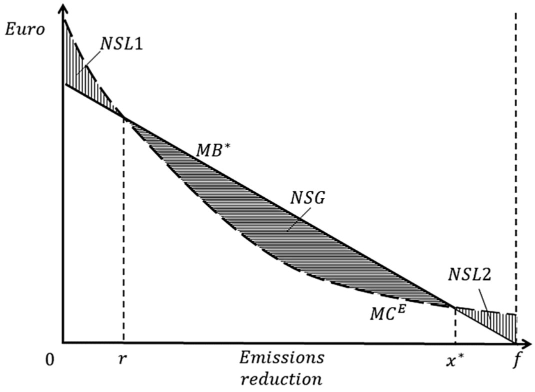

Fig. 3 Decreasing marginal costs of emission reduction

curve (points x^* and r in Fig. 3), a further assessment would be needed in order to identify which is a global optimum.[58]

- Second, in the case of multiple optima, 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).
- 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 Fig. 3, 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 three implications of an efficiency analysis mentioned above and the shortcomings of a Piguvian tax would be identified and assessed by an RIA in step 2 and 3 of this procedure after having realized in step 1 that an externality problem exists within a framework of multiple optima. Of course, if second-order conditions for a social optimum (not discussed in this paper) were taken into account when calculating the Pigouvian 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 compatible with the PPP.

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[58] 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, chap. 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).

Conclusion 8: The RIA alerts policymakers to the fact that in a framework of multiple optima equating polluters marginal abatement costs to the marginal benefits of abatement is neither a necessary nor a sufficient condition for a global social optimum. Moreover, even if the global optimum is identified, a pollution tax does not necessarily implement the efficient emission reduction level.

4.3.6 Diffuse pollution

So far, we have discussed point pollution, which features point sources of pollution which release pollutants from discernable, confined and discrete locations. In a typical point pollution case the sources, the number of polluters, the size of their emissions, and their specific contributions to the aggregate external costs can in principle be observed and measured with sufficient accuracy.

Diffuse pollution is far more complex. For example, water pollution is caused by a combination of excess nutrient losses, microbial contamination, acidification, salinity, sedimentation, toxic contaminants, thermal pollution, plastic particle pollution, and contaminants of emerging concern.[59] Here, neither the sources (agents), their spatial location, nor the size of specific emissions and their pathways can be observed and measured with sufficient accuracy.[60] Further, aggregate damage is often not only the result of one type of emissions, but of several types from multiple sources and partly multiple sectors operating in parallel in a complex way, making it nearly impossible to identify the contribution of a specific emissions type, its sources and sizes to overall damage.[61] Moreover, "although each pollution source may have relatively little impact individually, their cumulative effect can be highly damaging" (OECD 2017, p. 50).[62]

Given that in diffuse pollution problems regulators cannot observe each polluter's individual emissions,[63] the recourse to or the application of an individual source-specific emissions-based instrument such as the PPP must lead to regulatory failure. In addition to this problem, the sources of regulatory failure discussed in the previous sections of this Paper (suboptimal behavior of the pollutees, government as an additional investor, imperfect competition, multiple optima) would also have to be taken account of. In this respect, note one of the key messages in the OECD Report Diffused Pollution[64]: *The Polluter Pays Principle has typically not been successful*

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[59] See OECD (2017, p. 5), Table 1.

[60] See OECD (2017), De Vito et al. (2020), Knook et al. (2020), Sarr et al. (2019), Campbell et al. (2005), Shortle and Braden (2013), Camacho-Cuena and Requate (2012), Esteban and Albiac (2012), Xepapadeas (2011), Cochard et al. (2005), Shortle and Horan (2001) and Kirschke et al. (2019).

[61] In the theory of complex systems one would speak of the aggregate damage as an emergent phenomenon resulting from interactions of its constituent parts, here the different sources and types of emissions, with each other and the environment. The properties of an emergent phenomenon cannot simply be deduced from the properties of its constituent parts: the whole is greater than the sum of its parts.

[62] See also Ahodo and Svatonova (2014, p. 74).

[63] As Cochard et al. (2005) point out: the regulator observes the ambient concentration of the pollutant but this observation is not sufficient to allow the regulator to infer individual emissions (Cochard et al. 2005, p. 393).

[64] OECD (2017, p. 48)

in the control of diffuse pollution because of the limitations on measurement, abatement measures, poor enforcement, and political resistance.[65]

In the literature on the management of diffuse pollution, the following alternatives are discussed: collective responsibility[66]; education programs, such as moral suasion, technical assistance, and programs to create environmentally friendly and profitable innovations, emissions proxies, taxing inputs and ambient pollution taxes.[67] A detailed discussion of these policy instruments to control diffuse pollution goes beyond the scope of this paper.

In conclusion, the regulation of diffuse pollution is a very complex task that cannot adequately be dealt with by referring to the PPP. First-best optima are almost impossible to implement. Design and practicing of a workable framework for a management of diffuse pollution should be based on a procedure addressing the very nature of diffuse pollution: multiple sources and pollutants, from multiple actors and sectors, operating parallel.[68] RIA is such a procedure—describing what has to looked at but avoiding predefined results.

4.3.7 Administration costs

When analyzing the welfare impact of policies aimed at addressing 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 money spent by both the private and the public sector in acquiring information, setting up the policy framework, implementing requirements and monitoring and

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[65] The Environmental Liability Directive (ELD) is also a point in case, if we interpret liability rules as a form of PPP: Liability is not a suitable instrument for dealing with pollution of a widespread, diffuse character, where it is impossible to link the negative environmental effects with acts or failure to act of certain individual actors. (The DIRECTIVE 2004/35/CE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage, Recital 13).

[66] See Cochard et al. (2005) and the literature referred to; OECD (2017, p.12, Table 5): reward or penalize polluters collectively.

[67] See Shortle and Horan (2001). Some of these alternatives are incorporated into the European Nitrate Directive (Directive 91/676/EEC. Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (Official Journal of European Community L375: 18). Member States were asked to designate Nitrate Vulnerable Zones (NVZ). Within these zones, specific mandatory protection measures had to be adopted by farmers and a limit of nitrogen from organic manure was established. Furthermore, within the non-vulnerable zones, Member States had to propose a set of measures to be implemented on a voluntary basis, mainly regarding the periods and weather conditions for fertiliser application. European farmers are also obliged to respect the ND in order to receive the subsidies provided by the Common Agriculture Policy. Individual benefits are reduced proportionally to any detected noncompliance. The performance of the ND is considered rather mixed: After almost three decades, there is no significant reduction in groundwater nitrate contamination, and agriculture is still the main source of nitrate pollution in Europe (Musacchio et al. 2019: 504). The main reason for the ineffectiveness is seen in an inadequate governance framework. See Musacchio et al. (2019) and the literature referred to.

[68] OECD (2017, p. 50)

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. As Atkinson and Stiglitz (2015) point out, administration costs are one of the main reasons why government cannot attain the first best allocation (Atkinson and Stiglitz 2015, p. 455). In the presence of administration costs the design of a policy is a second-best problem (Atkinson and Stiglitz 2015, 358–360).

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.[69] Suppose that only polluters have to incur administration costs and that these costs are constant per unit of emission reduction. In Fig. 1 this corresponds to an upward shift of the MC^E-curve, resulting in an optimal tax level $t > t^*$.

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.

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

Nevertheless, one might argue that even though RIA dominates the PPP in terms of being able to identify the best policy option, this advantage is outweighed by the fact that by simply accepting PPP in step 3 of RIA, a regulator can forego a detailed cost-benefit analysis and the substantial costs of preparing it and delays or blockings of agency decision making associated with it (Driesen 1997; McGarity 1998; Shapiro et al. 2002). In principle, this is sound reasoning.

However, this argument is valid only if there are substantive cost savings from using the PPP and the welfare losses from using an inferior policy are small. To illustrate, consider the case of imperfect information on the side of the pollutees with MB^0 (see Sect. 4.3.1).

Suppose that realizing the efficient outcome (x^*, y^*), i.e. calculating and implementing t^* as well as incentivizing the pollutees to invest $y = y^*$, requires fixed cost $\bar{c} > 0$ to be borne by the regulator.

In contrast, PPP leading to tax rate t^0 could be implemented without any administration costs. Thus, cost $\bar{c}$ can be interpreted as the cost of implementing the first-best outcome x^*, y^*. Choosing PPP would lead to welfare losses (gains) if the difference between social costs (as defined by Eq. 4.1) with t^0 and social costs with t^* exceed or falls short of the fixed costs. To illustrate (see Fig. 1): with $t = t^0$ and $(x_1, y = 0)$,

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

social costs are $0x_1g + x_1fg = 0fg$; with $t = t^*$ and x^*, y^* they are $0x^*b + x^*fb = 0fb$. The difference amounts to bfg. If $\bar{c} > bfg$, then t^0 should be chosen instead of t^*, and vice versa.

Similar reasoning, i.e. comparing the adminstration cost disadvantage of a rigorous RIA with the welfare losses implied by simply following the PPP, can be applied in the other cases discussed in Sect. 4.3. However, for sufficiently large projects, the added value of RIA 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, p. 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 9: It is an empirical and case specific question whether administrative cost savings from applying the PPP rather than RIA outweigh the cost of foregone welfare gains and potential welfare losses as a result of misguided or inappropriate policy measures.

5 Conclusion

This paper analyzes and assesses the PPP, applied in the form of a Pigouvian tax, as a policy tool within the procedure of preparing RIA. We show that imposing the tax leads to efficient outcomes when a number of very restrictive conditions are met. However, a policy guided by the PPP cannot adequately deal with more complex settings, in particular second-best issues resulting from frictions on the side of pollutees, monopolistic markets, the multiplicity of optima, diffuse pollution and administration costs.

By relying on a comprehensive cost-benefit analysis, RIA 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 caused by pollution. This can lead policy makers to make serious mistakes. That is, however, not to deny that an emission tax is a cost-effective measure to reach a desired level of emissions reduction. The marginal costs of emissions reduction are equalized for all sources of emissions. The problem is instead whether the desired level of emissions reduction is socially optimal.

It is important to note that the dominance of RIA over the PPP does not imply that polluters should not pay. The question is rather how much they should pay. The PPP provides no answer to this question in the settings discussed in Sect. 4.3. What is required is a comprehensive cost-benefit analysis aiming to maximize social welfare. As a consequence, one may question the added value of referring to the PPP.

The paper focuses shortcomings of the PPP in terms of efficiency. However, one can ask whether efficiency is all that matters from the point of view of social welfare. Indeed, there are factors beyond efficiency which have to be taken into account in order to come to a well-founded final judgment of the PPP, such as fairness, corrective and distributive justice, employment, growth or tax revenues, as well as non-pecuniary factors such as life, pain and suffering, the intrinsic value of the environment, the interest of future generations and public opinion.[70] In contrast to the PPP, RIA can explicitly take these objectives into account.

In the paper we take up the fairness issue of compensating victims of pollution. Economic efficiency does not require paying compensation to victims of pollution for residual damages or abatement costs incurred. However, compensation is compatible with efficiency if the revenues from a pollution tax suffice to finance it and compensation rules are incentive compatible. To check whether and how both conditions can be met requires a much more complex procedure than simply imposing a Pigouvian tax.

The logic of RIA helps policy makers to avoid regulatory failure. Of course, the problems of incomplete or wrong information are as acute in applying it as they are in following the PPP. But in contrast to the shortcomings of the PPP, which are due to its deficient paradigm, this is not a systematic or paradigmatic error. 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 RIA in everything but name.

The analyses and assessments of this paper focus on the logic of the PPP and RIA. Nothing has been said about the implementation in practice, taking into account imperfect information and bounded rationality of regulators, institutional arrangements, property rights, specific interest of politicians (re-election), bureaucrats (autonomy and budget-maximization), and lobbyists. Insights from the economic theory of democracy and bureaucracy suggest these factors may be a further source of regulatory failure.[71] These issues, in particular the role of court proceedings for incentivizing decisionmakers to abide by the rules of RIA, need further research.

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[70] Possible trade-offs between these objectives and efficiency are well known in the policy arena. The European Commission mentions reasons of fairness and efficiency to be recognized in RIA in its Staff Working Paper (Commission of the European Union (2008), focussing however mainly on issues of efficiency). Article 191(2) of the Treaty of the Functioning of the European Union mentions "non-economic environmental reasons" and Article 16 of the Rio Declaration speaks of "due regard to public interest". This trade-off between efficiency and other values is discussed in Schmidtchen et al. (2009) and Kaplow and Shavell (2002)). The authors show that objectives other than efficiency do not provide a satisfactory ground for adopting the PPP rather than conducting a comprehensive cost-benefit analysis.

[71] See Ng and Wang (1993) on myopic decisions of voters and politicians and the role of economic growth, Perman et al. (2003) p. 145 on government failure, p. 222–223, Box 7.6 on emissions taxes in practice; and ch. 8, Dunlop and Radaelli (2015), Tobey and Smets (1996) and OECD (2017) on barriers of the PPP for diffuse water pollution.

Appendix

The model

Let $\bar{e}$ represent the optimal emission level of the polluters absent any regulatory measures. Let x denote the polluters' level of abatement measures and $c^E(x)$ the costs of abatement, with $c^E(0) = 0$, $c^E(x) > 0$, ${c^E}_x(x) > 0$ and ${c^E}_{xx}(x) > 0$ for every $x > 0$.

Let y denote the pollutees' level of abatement measures, and $c^V(y)$ the costs of abatement with $c^V(0) = 0$, $c^V(y) > 0$, ${c^V}_y(y) > 0$ and ${c^V}_{yy}(y) > 0$ for every $y > 0$.

Let D denote total pollution costs depending on the abatement activities of both the polluters and the pollutees, i.e. $D = D(x;y)$, with $D_x < 0$, $D_y < 0$, $D_{xx} > 0$, $D_{yy} > 0$ and $D_{xy} > 0$. Total social costs are:

$$\mathrm{SC} = D(x;y) + c^E(x) + c^V(y) \tag{1}$$

Suppose that the social goal is to efficiently resolve the conflict between polluters, who wish to avoid costs therefore causing emissions, and pollutees, who suffer harm from these emissions. Abstracting from administration costs and assuming risk-neutrality, this implies minimizing social cost, SC:

$$\min_{x,y} D(x;y) + c^E(x) + c^V(y)$$

The socially optimal levels of abatement by the polluters and the pollutees solve this problem. The first order conditions for a social optimum are:

$$D_x(x;y) + c_x^E(x) = 0 \tag{2}$$

and

$$D_y(x;y) + c_y^V(y) = 0 \tag{3}$$

with $c_x^E(x) > 0, D_x(x;y) < 0$ and $c_y^V(y) > 0$, $D_y(x;y) < 0$.

Equation (2) defines a function $x^*(y)$, which represents the polluters' optimal damage reduction level x^* for any abatement level of the pollutees.[72]

Equation (3) defines a function $y^*(x)$ denoting the pollutees' optimal damage abatement level for any abatement level of the polluters. Jointly, Eqs. (2) and (3) define the social optimum $(x^*;y^*)$, with $x^* \equiv x^*(y^*)$ and $y^* \equiv y^*(x^*)$.

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[72] An increase in the polluters' damage reduction measures x has two effects on the costs of damage reduction: it increases the costs to 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 the pollutees need to undertake to mitigate the impact of emissions. There are therefore two opposing effects on damage reduction: while an increase of x will decrease the amount of damage D directly, this effect is attenuated by the reduction in y.

Equations (2) and (3) imply the following two conditions in relation to the total effort to reduce emissions and mitigate their harmful impact:

$$c_x^E(x) = -D_x(x;y) \tag{4}$$

$$c_y^V(y) = -D_y(x;y) \tag{5}$$

Condition (4) says that the marginal cost of emission reduction by the polluters, denoted MC^E in the text and in Fig. 1, must be equal to its marginal benefit from reduced emission levels, denoted MB^* in the text and in Fig. 1. The efficient level of abatement implies an efficient level of emissions e^*, i.e. $e^* = \bar{e} - x^*$.

Condition (5) says that the marginal costs of damage prevention by the pollutees, denoted MC^V in the text and in Fig. 2, should equal the marginal benefit of the reduction of pollution damage, denoted $\overline{\mathrm{MB}}^*$ in the text and in Fig. 2.

Note that when condition (5) holds, i.e. $y = y^*$, then Eq. (4) reads

$$c_x^E(x) = -D_x(x;y^*) \tag{6}$$

When condition (4) holds, i.e. $x = x^*$, then Eq. (5) reads

$$c_y^V(y) = -D_y(x^*;y) \tag{7}$$

Equations (4) and (5) are conditions for an interior solution to the problem of finding the polluters' and pollutees' socially optimal abatement levels, i.e., $x^* > 0$ and $y^* > 0$. In the case of a corner solution, only one or neither of the conditions (4) and (5) may be satisfied. Suppose, for example, that $c_x^E(0) > -D_x(0;y^*(0))$ and $c_y^V(y) = -D_y(0;y)$. Social cost would be minimized without any abatement taking place on the side of polluters: $x^* = 0$ and $e^* = \bar{e}$. The pollutees are the so-called "cheapest cost avoiders": only they should invest in pollution damage reduction—the polluters should do nothing from an efficiency point of view.

Of course, the polluters might also be the cheapest cost avoiders. This happens if $c_y^V(0) > -D_y(x^*(0);0)$ and $c_x^E(x) = -D_x(x;y = 0)$. If $c_x^E(0) > -D_x(0;y^*(0))$ and $c_y^V(0) > -D_y(x^*(0);0)$, neither the polluters nor the pollutees should take action.[73] In the case of corner solutions, there is only one cheapest cost avoider.

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[73] More complex versions of corner solutions will be dealt with in the context of multiple optima in section 4.3.5.

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