Using emission standards under incomplete compliance[1]

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Abstract

Using the case study of water pollution in the Flemish textile industry, we discuss three empirical questions concerning the use of emission standards. We find that the Becker result ("maximal fine / minimal inspection") does not hold if we include rule making, implementation and enforcement costs into the model. There is a balance between the fine and the inspection variables. Making enforcement more stringent does not mean to put the fine levels as high as possible and only then increase the inspections. We have also shown that is extremely important to have correct estimates of people's willingness to pay for environmental improvement. These WTP estimates determine in great part the optimal environmental strategy and its associated optimal monitoring and enforcement policy. Moreover, it really pays off to optimise the monitoring and enforcement strategy associated with an emission standard. This optimisation does not necessarily mean that monitoring and enforcement should be as stringent as possible. It is often possible to obtain the desired result by some intermediate value of the monitoring and enforcement parameters. This is due to the balancing of costs and benefits associated with monitoring and enforcement.

JEL codes: K32 Environmental Law; K42 Illegal behaviour and the Enforcement of Law

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I. INTRODUCTION

Traditionally many economists have been promoting market-based instruments (such as emission taxes) over emission standards for reasons of cost effectiveness (Field, 1994; Bohm and Russell, 1985). However, in practice environmental policy consists mainly of command-and-control regulation. Generally it is believed that this observation can be explained by, among others, the existence of transaction costs, monitoring and enforcement costs, the influence of lobbying or the importance of other policy objectives (such as distributional considerations or political feasibility). In this paper we concentrate on emission standards and consider the importance of transaction costs and incomplete compliance. In Billiet et al. (2002) and Rousseau and Proost (2002) we show empirically that emission taxes can, under certain circumstances, be more expensive than emission standards when we take all associated costs into account.

In Billiet et al. (2002) we discuss the importance of the design of emission standards. Emission standards are generally thought of as being inflexible with respect to firm heterogeneity. However, some margin of flexibility is proper to all emission standards. Emissions standards determine which amount of emission reduction should be achieved but they do not specify how firms have to reduce their emissions (Russell and Powell, 1996). Additional flexibility can be achieved by the formulation of the standard. Moreover we include information, monitoring and enforcement costs in our analysis. Using a case study we show the immense importance of the monitoring and enforcement strategy. Choosing the optimal level of the parameters is crucial for the choice of policy instruments.

We limit our analysis to one specific type of emission standards; i.e. the emission standard combined with a documentation duty, a notification duty and an administrative fine. The emission standard is expressed as a concentration measure (mg/l) for waste water. The documentation duty forces firms to keep a paper record of their emissions. The notification duty implies that firms report these emission records to the government.

Using the case study of water pollution in the textile industry of Flanders (Belgium), we discuss three empirical questions concerning the use of emission standards. Firstly, given a particular emission standard and the willingness to pay (WTP) for an environmental improvement, which monitoring and enforcement policy provides us with the highest welfare? Secondly, given the WTP, which combination of an emission standard and a monitoring and enforcement strategy gives the highest welfare level? Thirdly, if one wants to attain a certain level of emissions, which combination of an emission standard and a monitoring and enforcement strategy maximises welfare?

In section 2 we describe the theoretical framework. In section 3 we focus on the case study and in section 4 we discuss its results. In section 5 we conclude.

II. THEORETICAL FRAMEWORK

Using a static partial equilibrium framework we define the behaviour of and the costs for two types of agents in the economy: firms and government. Each agent has a specific objective function. The environmental regulation and the associated enforcement policy determine the feasible options. The problem is one of asymmetric information since the abatement costs are known to the firms but not to the regulator.

For the government there are three stages in selecting an environmental policy: the rule-making stage, the implementation stage and the enforcement stage. This succession of stages is called the regulatory chain. In the rule-making stage the government chooses how to reduce or even solve the environmental pollution problem. Administrations and interest groups are consulted in order to help deciding on the environmental goals and on the instruments used to attain those goals. Costs linked to this stage are called rule-making costs. In the implementation stage the environmental regulation is in force and in order to ensure its correct implementation some extra regulation is needed. This supplementary regulation often concerns the gathering of information about the implementation and its transfer to the government. Costs linked to this stage are abatement costs and implementation costs. In the enforcement stage compliance with the regulation is ensured. A monitoring and enforcement policy is developed. Costs linked to this stage are the enforcement costs. For a more detailed study of the legal and administrative process we refer to Billiet (2001).

The government determines its environmental regulation by setting an emission standard and an appropriate monitoring and enforcement policy while taking as given the behaviour of firms. Government will want to maximise social welfare. It has to make choices with regard to the design of each instrument: the emission standard, the documentation duty, the notification duty and the administrative fine. We assume that the government can commit to its policy choices.

Firms minimise their expected costs after the government has fixed the environmental policy and has decided on the monitoring and enforcement policy. All firms incur costs of gathering information about the exact legal requirements and about the description, effects and costs of all possible abatement technologies. Only after gathering and analysing these data, firms will decide whether to comply with the new regulation or not. Firms will minimise the expected costs associated with the environmental regulation in force. These costs include abatement costs, rule-making costs, implementation costs, expected enforcement costs and the expected sanction for violating the standard.

In the following sections we discuss the behaviour of the different agents in greater detail.

Firms

Firms have to make at most two decisions with respect to their discharge strategy. First they have to decide whether to comply or not with a given emission standard. Next they have to decide what abatement technology to use and the amount of emissions to discharge.

Firm *i* minimises the expected costs associated with the environmental regulation in force. These costs include abatement costs (AC_i), rule-making costs (RC_f), implementation costs (IC_f), expected enforcement costs $(p_i \overline{EC}_f$ and $p_i y_{F_i} EC_f)$ and the expected sanction $(p_i.F_i)$. Some of these costs are identical for all firms and are marked with the index *f*. There are n_f firms in our model.

Formally firm *i* faces the following optimisation problem[2]:

$$\begin{aligned} \min_{y_{ij_i}} \exp TC_i &= A_i + p_i F_i + RC_f + IC_f + p_i \left(\overline{EC}_f + y_{F_i} EC_f \right) \\ s.t. \quad E_i &= E_i^o - EA_i \le \overline{E} \end{aligned} \tag{1}$$

$$\begin{aligned} with \quad A_i &= \sum_{j_i} AC_{ij_i} y_{j_i} && = \text{total abatement costs for firm i} \\ EA_i &= \sum_{j_i} Eab_{ij_i} y_{j_i} && = \text{total emission reduction by firm i} \\ y_{j_i} &= 1 && \text{if technology } j \text{ is chosen by firm } i \\ &= 0 && \text{otherwise} \\ y_{F_i} &= 1 && \text{if } F_i > 0 \\ &= 0 && \text{if } F_i = 0 \end{aligned}$$

Firms discharge an amount of emissions E_i equal to the difference between initial emissions E_i^0 and the firm's total emission reduction EA_i. These emissions are subject to an emission standard $\overline{E}$.

The rule-making, implementation and expected enforcement costs are identical for all firms. These costs include, among others, the contributions to federations or the costs of the firms' extra administration. Managers need to be informed about their legal obligations and the implications for their company. Moreover they need to collect information about the technological possibilities to comply with the standard. Measurement of emissions is also necessary to evaluate the compliance status. Enforcement costs of firms consist of two parts: inspection costs ($\overline{EC}_f$) and sanctioning costs (EC_f). The inspection costs are incurred every time an inspection is performed on the firms' premises. Examples of these costs are the costs of having to follow up the inspection and to perform a second test if necessary. Sanctioning costs are only relevant if firms are actually fined. Examples

[2] We assume that firms are risk neutral. This is no trivial assumption when it comes to enforcement.

are costs of legal representation and court costs. A detailed identification and estimation of these costs can be found in Billiet et al (2002).

When the firm is violating the environmental policy, it faces an expected sanction p_iF_i ; where p_i is the inspection frequency and F_i is the fine. The fine depends on the size of the violation and the penalty parameter π_{es} (expressed in €/ton BOD in violation).

$$\begin{aligned} p_i &= \min\left(\overline{p} + \alpha \frac{E_i - \overline{E}}{\overline{E}} \ ; 1 \right) \\ F_i &= \pi_{es} \max\left(E_i - \overline{E} \ ; 0 \right) \end{aligned} \tag{2}$$

Every firm, whether it is violating the environmental regulation or not, will be inspected with a certain fixed probability $\overline{p}$. A violator, however, faces an extra possibility of being inspected on top of this fixed probability. This violation-dependent or variable probability is proportional to the level of violation. This does not imply that the agency knows the level of violation or even which firms are in violation. It simply represents the practice that every complaint is followed up by the environmental inspection agency. The neighbouring community, environmental pressure groups or civil servants can issue complaints when they notice something suspicious. We assume that complaints are highly correlated with the degree of violation. Moreover, we assume that every violation that is detected leads to a conviction. In other words, there are no measurement errors or uncertainties present. The administrative fine we use is a function of the level of violation. Finally we assume that firms know the relation between the level of violation, the probability of inspection and the sanction.

Firms decide which abatement technology to install based on a very simple decision rule: they install technology $\tilde{j}$ if total costs are smaller with that technology than without. If more than one technology or technology combination gives a costs reduction, the technology with the highest cost reduction is chosen. Abatement will lead to a cost reduction for the firm if the difference in expected fines and expected enforcement costs with and without abatement exceeds the investment costs. We cannot derive general first-order conditions since our abatement cost functions are step-functions and firm specific. Nevertheless we can derive a firm-dependent decision rule. Firm i will choose technology $\tilde{j}$ or

$$y_{i\tilde{j}_i} = 1 \qquad if \qquad D_{i\tilde{j}_i} = \max\left(D_{ij_i} \right) \text{ and } D_{i\tilde{j}_i} > 0 \tag{3}$$

$$
\begin{aligned}
with \quad D_{i\tilde{j}_i} = \; & \min\left(\overline{p}+\alpha\frac{E_i^o-\overline{E}}{\overline{E}}\;;1\right)\left(\overline{EC}_f + y_{F_{io}} EC_f\right) \\
& +\min\left(\overline{p}+\alpha\frac{E_i^o-\overline{E}}{\overline{E}}\;;1\right)\pi_{es}\max\left(E_i^o-\overline{E}\;;0\right)-AC_{ij_i} \\
& -\min\left(\overline{p}+\alpha\frac{E_i^o-Eab_{i\tilde{j}_i}-\overline{E}}{\overline{E}}\;;1\right)(\overline{EC}_f + y_{F_{i\tilde{j}}} EC_f) \\
& -\min\left(\overline{p}+\alpha\frac{E_i^o-Eab_{i\tilde{j}_i}-\overline{E}}{\overline{E}}\;;1\right)\pi_{es}\max\left(E_i^o-Eab_{i\tilde{j}_i}-\overline{E}\;;0\right)
\end{aligned}
$$

Without abatement firms have initial emissions equal to E_i^o. Installing abatement technology $\tilde{j}$ allows them to reduce their emissions by $Eab_{i\tilde{j}_i}$. Once the abatement decision is taken, actual emissions E_i are determined as the difference between initial and abated emissions. The abatement decision also determines the degree of firm violation. Notice that due to the indivisibilities in the abatement cost function, firms can overcomply with the regulation. The extra emission reductions benefit society but not the firms.

Government

Given the behaviour of firms, the government determines its environmental regulation by setting an emission standard and an appropriate monitoring and enforcement policy. It has to make choices with regard to the design of each instrument: the emission standard (e.g. the choice of unit and value), the documentation duty (e.g. the profile in time of a measurement and registration obligation), the notification duty (e.g. the frequency level of notification) and the administrative fine (e.g. the degree of flexibility of the fining amount). We assume that the emission standard is expressed in milligram per litre (mg/l). The documentation duty forces firms to keep a paper record of their emissions by monthly sampling. Once a year firms will report these emission records to the government. The expression for the administrative fine is found in equation (2).

Government maximises social welfare *(*SW):

$$
\max SW = \max\begin{pmatrix} PS+CS+EQ-n_f.RC_f-n_f.IC_f-\sum_i p_i(\overline{EC}_f+y_{F_i}EC_f) \\ +MCPF\sum_i\left(\tau E_i^R+p_iF_i-RC_g-IC_g-\sum_i p_i(\overline{EC}_g+y_{F_i}EC_g)\right)\end{pmatrix} \tag{4}
$$

Social welfare consists of producer *(PS)* and consumer *(CS)* surplus, environmental quality *(EQ)*, regulatory costs for firms and the governmental budgetary surplus corrected with the marginal cost of public funds *(MCPF)*. We assume that the marginal cost of public funds equals one.

In the global welfare function we include all rule-making, implementation and enforcement costs associated with a particular set of instruments but also subtract environmental benefits. Environmental benefits are subtracted to allow us to deal with the indivisibilities of the abatement costs that make comparisons across instruments more difficult (Oates et al., 1989).

Rule-making costs for the government result from meetings within the administration and with interest groups and experts. Governmental implementation costs have to do with, for instance, distributing regulatory information through official publication of laws and statutes. Enforcement costs include inspection and prosecution costs.

III. EMPIRICAL ILLUSTRATION

Benchmark and description

In order to illustrate our theoretical model we focus on the textile industry in Flanders (Belgium). More specifically we concentrate on the water pollution caused by textile improvement and carpet production. These two subsectors are, after all, responsible for most of the water pollution in the sector. Several sector studies (PRESTI, 1994-1997; Jacobs et al., 1998; Centexbel, 1996 and OVAM, 1996) provide us with useful information. For reasons of tractability we limit our study to water pollution caused by BOD emissions and we only consider point sources.

In our benchmark scenario there is no environmental regulation in place. We do, however, assume that all necessary legal and economic institutions are already in place; such as the environmental inspection agency, courts, senate…

Abatement cost function

We explicitly model the firms' heterogeneity to capture the advantages – with respect to cost effectiveness – of market-based versus command-and-control instruments. Therefore we made use of a firm level survey on abatement costs. We first contacted by mail 106 Flemish companies active in textile improvement and carpet production. Then we conducted a follow-up interview on site. We obtained useful cost estimates from about 20 firms. We asked firms to state the costs of presently installed abatement technologies and of planned investments in the next two years. These data were used to estimate abatement cost functions for each company in order to represent firms' heterogeneity (see Billiet et al., 2002).

The cost estimates take both fixed and variable costs into account. We include initial investment costs, subsidies, personnel, energy and other costs. The life span of an investment is assumed to be 20 years. We assign all costs to only one pollutant, i.e. BOD, and therefore assume that the sole purpose of the investment is to reduce BOD emissions[3]. After calculating the net present value (NPV) of each technology we derive the associated annuities and use these in the model.

An extensive range of technologies was reported including filters, use of different inputs and wastewater treatment. Cost differences of abatement technologies between firms turn out to be large indeed; cost estimates (NPV) for one particular technology ranged from 1 million € in one firm to 4.7 million € in another firm.

Rule-making, implementation and enforcement costs

We identified cost factors that resulted from the legal context and from the instrument itself (see Billiet et al., 2002). For each of these cost factors we performed a relative valuation per instrument and per agent; and we took into account the different stages of the regulatory chain. We included a wide variety of costs: the costs of lobbying, filling in forms, communicating with the administration, performing inspections, internal meetings, legal counselling… (see table 1)

Emission standard	Firm			Government		
	RC	IC	EC	RC	IC	EC
Technicallity	1d lobbying expertise	8d info production and technology	1/2d + lab contra-analysis	15d state of the art, meetings		
Knowability			1/2d proof (expert)		2d + printing info brochure	2d samples
Procedure						
Legal formalisation				XL		
Time profile		5d Self controle	2 1/2d accompanying contra analysis			1/2d planning
Administration as implementation partner						
Flexibility		2d info translation to own situation				

Table 1: Rule making, implementation and enforcement costs

[3] In reality investments in abatement technologies often serve multiple purpose and reduce the output of several pollutants. This means that firms can 'overachieve' and do better than legally required. One way to deal with this overachievement problem can be found in Oates et al. (1989). In this paper firms gain noting by overachieving although society does through the improvement of water quality.

The rule making, implementation and enforcement costs were estimated using the firm survey, by checking court rulings and by interviewing experts in the administration and in the law profession.

These costs (see Billiet et al., 2002) are not used as such in the model. We have estimated and taken into account how often a particular instrument is used or changed by government, how often firms are punished for being violators, etc. Costs associated with an emission standard are assumed to occur every four years and we, therefore, use the initial estimate divided by five (we look at a time period of 20 years). Costs associated with inspections depend on the number of inspections performed.

In order to show how much these rule making, implementation and enforcement costs weigh on the results, we represent the costs for firms and government in figure 1. We give the firm costs excluding abatement costs and including abatement costs and government costs as a percentage of the change in social welfare for different specifications of the emission standard. We take the monitoring and enforcement strategy as given: $\overline{p} = 0.1, \alpha = 0.5 \text{ and } \pi = 2$ and change the stringency of the standard.

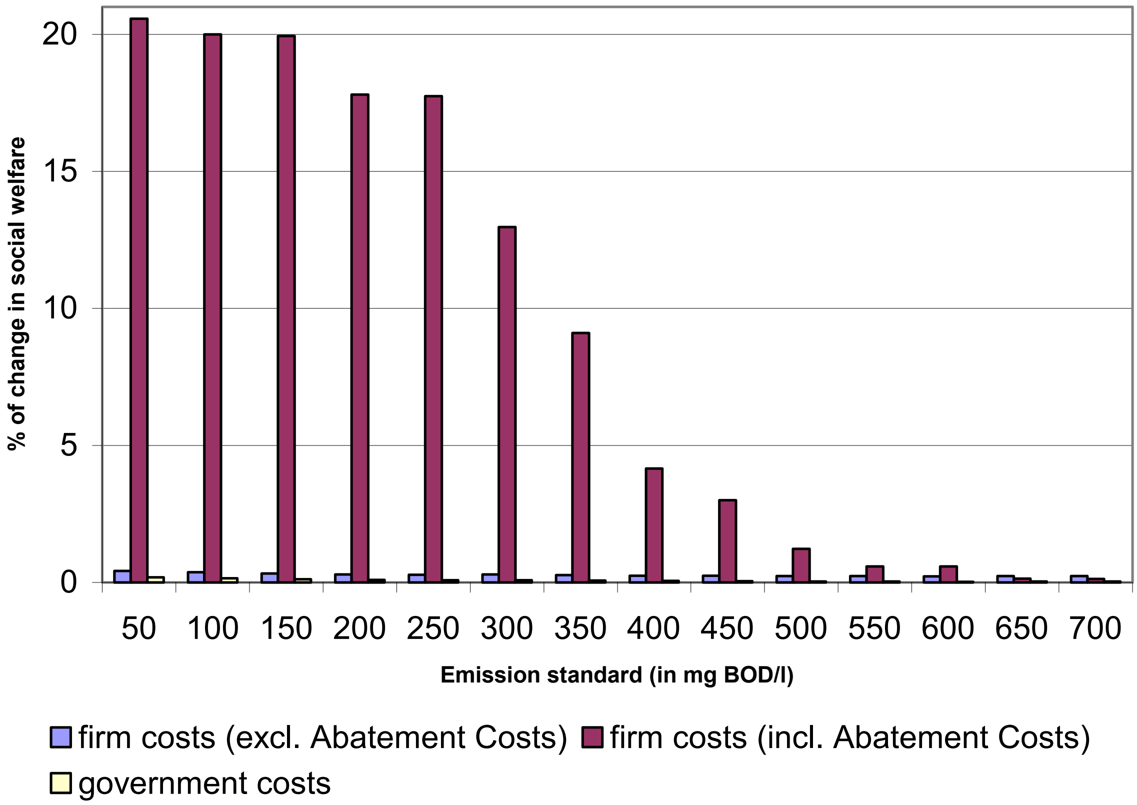

Figure 1

It is immediately clear that the costs for firms, including abatement costs, are much higher than for the government. Even if we do not include abatement costs, costs for firms are still at least twice as high as for the government (see figure in appendix). Moreover we also notice that the amount of rule making, implementation and enforcement costs decrease substantially if the standard becomes less stringent. It is obvious from looking at the costs for firms with and without abatement costs, that the abatement costs constitutes the largest part of the costs. If the standard becomes more stringent, the abatement costs increase significantly, while the increase in other firm costs and government costs is much lower (see appendix).

We now turn to our three research questions concerning the use of emission standards.

IV. RESULTS

Assumptions

We have calculated the results with the GAMS software package and Microsoft Excel. In order to limit the number of possibilities somewhat we made the following assumptions. The emission standard ($\overline{E}$ or ebar) can attain all values between 0 and 660 that are products of 20. The fixed emission frequency ($\overline{p}$ or pbar) and the variable inspection parameter (α) can equal all values between 0 and 1 that are products of 0.1. The sanction parameter (π) can take all values between 0 and 5 that are products of 0.5. These limitations still provide us with over 45000 different regulatory combinations.

We want to investigate the way to maximise social welfare under different circumstances. We start with three different scenario's: firstly both the emission standard and the willingness to pay (WTP) for an environmental improvement are given, secondly only the WTP is given and thirdly, an emission target is given. We then maximise social welfare by optimising the remaining parameters. These parameters always include the monitoring and enforcement parameters ($\overline{p}, \alpha$ *and* π). Depending on the scenario the emission standard $\overline{E}$ is also a policy variable.

Before we discuss the results, we want to stress that the results depend greatly on the model's assumptions. Therefore they should not be taken too literally. What is important, is the intuition they reveal not the numbers themselves.

WTP and $\overline{E}$ *given*

Firstly, we take an existing emission standard, 260 mg BOD/l, as given and we want to optimise the monitoring and enforcement policy designed by the regulator. Our results (see figure 2 and the appendix for the exact numbers) show that this optimal policy depends crucially on the willingness to pay (WTP) for the removal of one ton BOD. Depending on the monitoring and enforcement strategy and thus on the WTP, different levels of BOD emissions are reached. In our example, they can vary between 12 and 37 million ton BOD.

We find that for very low values of the WTP, it is not worthwhile to enforce the emission standard. This is what we intuitively would expect. When people do not care about water quality, it does not pay for the government to invest in enforcing environmental regulation. The environmental benefit would not outweigh the costs associated with the necessary monitoring and enforcement policy.

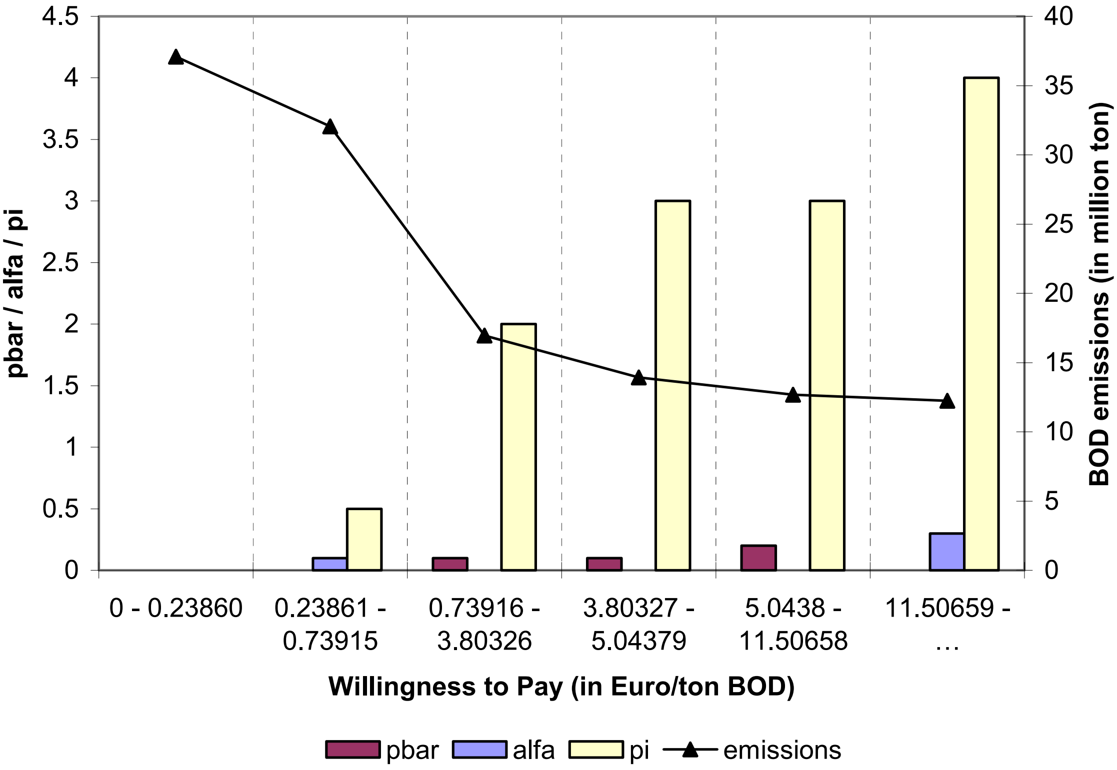

Figure 2: Results for given WTP and $\overline{E}$ = 260 mg/l

Moreover, we notice that the penalty parameter never equals its highest possible value, i.e. 5. This is partly due to our assumption that, for equal levels of social welfare[4], the lowest value of the parameter under consideration is taken. We assume that the lower the penalty, the more easily it is implemented and/or the less it costs. This result refines the well-known result of Becker (1968). Becker claims that the fine should be set as high as possible and the probability of detection should be as low as possible in order to obtain a given level of deterrence at the lowest cost. This result depends crucially on the assumption of being able to levy fines at zero cost. However, in this paper, we do assume that levying fines involves costs for society as well as for the targeted firm. These costs include, among others, costs for legal representation, possible court costs, administrative costs

[4] It is possible that several – different – monitoring and enforcement policies give the same overall welfare. For example, if the WTP equals 12 Euro, then welfare is the same for both π equal to four and π equal to five.

and time costs. The results of this model are therefore closer to reality since we do not observe maximum fines for all offences.

We also see that the stringency of the monitoring and enforcement policy increases with increasing WTP. If people are willing to pay more for a cleaner environment, it pays for the government to enforce an emission standard more seriously. More stringent monitoring and enforcement leads, after all, to lower BOD emissions and therefore higher social welfare. Notice that both the inspection and the fine variables increase with a more stringent policy. This confirms our result that monitoring and enforcement are complementary tools for an effective policy.

WTP given

Suppose we only know what the willingness to pay for an improvement in water quality is. We now want to determine the optimal emission standard and the optimal monitoring and enforcement policy given this WTP. The optimal environmental regulation is the one that maximises social welfare. The optimal policy for a given WTP maximises the difference between the gain in environmental quality by increasing emission reductions and the decrease in social welfare by costs associated with the increase in policy stringency. The results of these calculations can be found in figure 3, figure 4 and the exact numbers in the appendix. If, for example, the WTP is equal to 1.4 € per ton BOD, we see that the highest welfare level is obtained by choosing the emission standard equal to 200 mg/l and selecting the monitoring and enforcement parameters such that the fixed inspection frequency (pbar) equals 0, the variable inspection parameter (alfa) equals 0.1 and the sanctioning parameter (pi) equals 1.5. This will result in total BOD emissions of approximately 13.9 million ton in the economy.

In general we see that the higher the WTP, the more stringent the environmental regulation is and the lower the resulting BOD emissions. When people are willing to pay for cleaner rivers, it is optimal for the government to design and enforce more environmental laws. As in the previous case we also find that it does not pay to formulate an environmental policy if the WTP for a cleaner environment is too low. Moreover, we can say that, in general, the more stringent the emission standard the more stringent the monitoring and enforcement strategy will be.

Again we find that it is not optimal to maximise the fine and keep the inspection level as low as possible. Both fine level and inspection level turn out to be equivalent instruments in building an optimal monitoring and enforcement policy.

This scenario clearly demonstrates the importance of knowing the willingness to pay for environmental improvements by the community. Estimating this WTP is no easy and clear-cut job.

Several techniques[5] have been developed but very few – consistent – empirical estimates exist. For Flanders we do not know of any study considering the willingness to pay for BOD reductions in Flemish rivers.

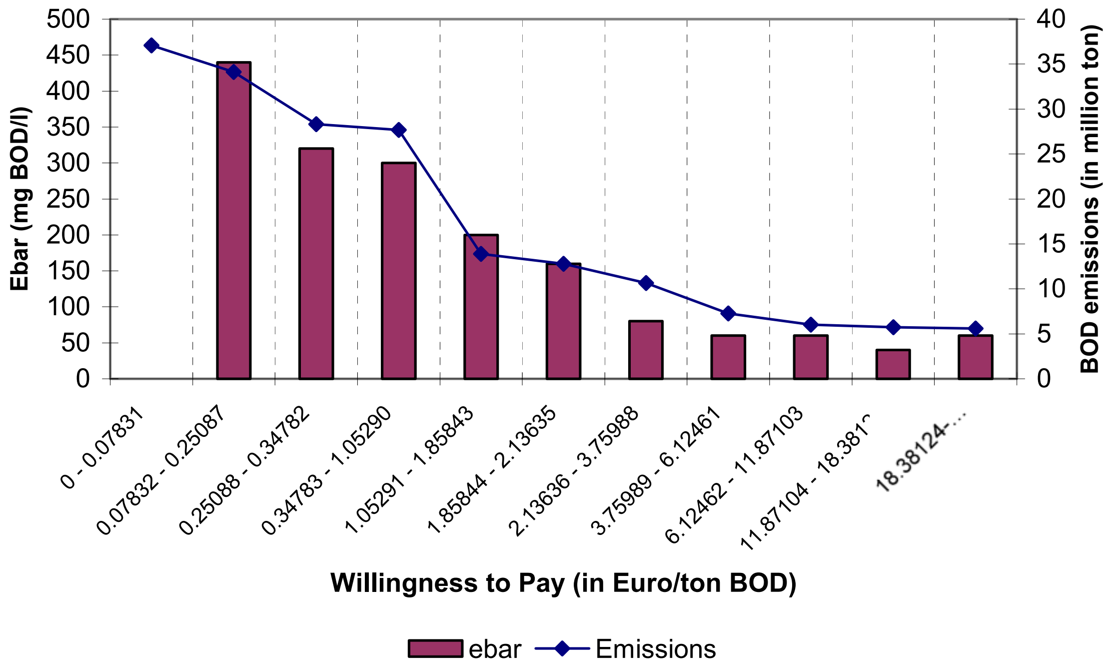

Figure 3: BOD emissions and emissions standard for given WTP

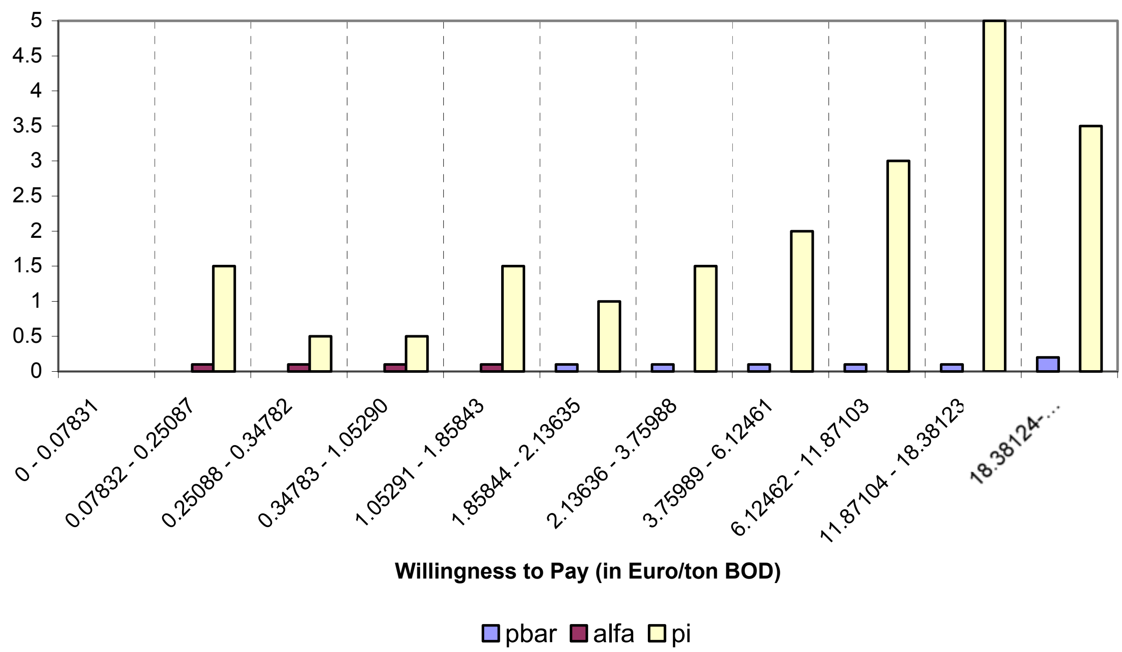

Figure 4: Monitoring and enforcement variables for given WTP

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5 For instance, the travel cost method (TCM) or contingent valuation (CVM). For an overview of this literature see, for example, Freeman (1993).

Emission target given

Finally we are also able to answer the following question: if you want to obtain a certain level of BOD emissions, which environmental policy will give you the highest possible welfare level (see figure 5)? For example, if the regulator wants less than 25 million ton BOD emissions released in Flemish rivers by the textile industry, it should set its emission standard for that industry equal to 200 mg/l. The associated monitoring and enforcement policy would then be $\overline{p}$ equal to 0, α equal to 0.1 and π equal to 0.5 (see appendix). Figure 5 shows only part of the results. The complete results can be found in appendix.

Again we see that the more emissions the regulator wants to reduce, the more stringent the environmental policy it should set. This confirms our intuition. However the relation is not completely straightforward.

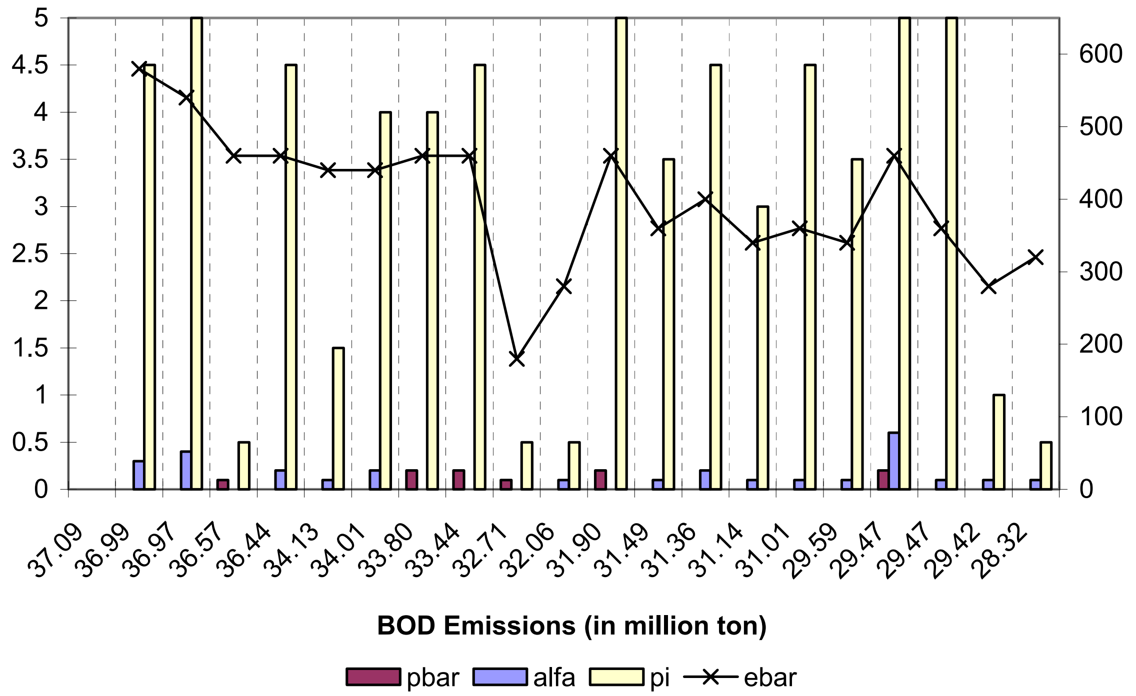


Figure 5

An emission reduction target is selected up front and can be influenced by the WTP but this is not necessarily so. We would also like to point out that overachievement by firms is valued at the WTP. If firms abate more than required, the extra emission reductions are valued as an increase in social welfare.

V. CONCLUSION

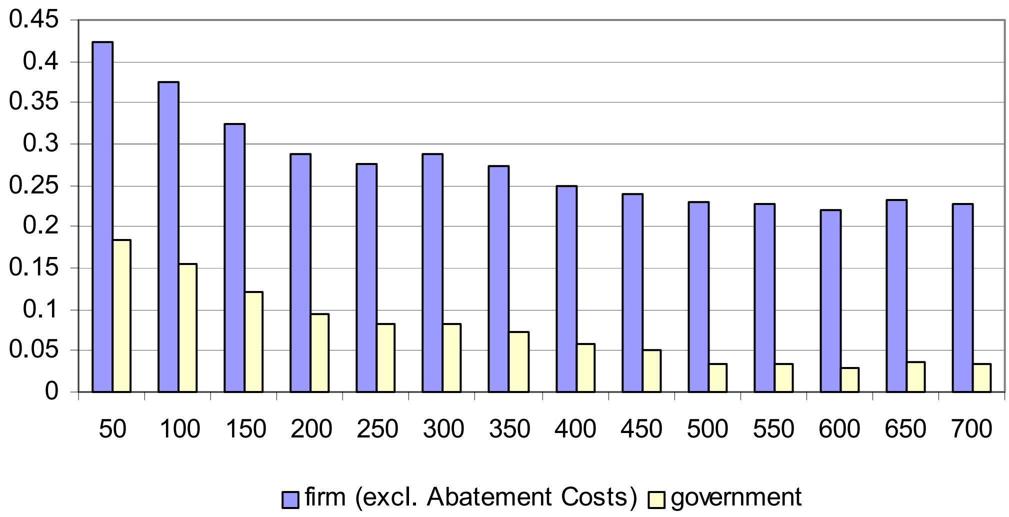
In this paper we have shown that the Becker result ("maximal fine / minimal inspection") does not hold if we include rule making, implementation and enforcement costs into the model. We find that there is a balance between the fine and the inspection variables. Making enforcement more stringent does not mean to put the fine levels as high as possible and only then increase the inspections. Both inspections and fines are increased at the same time. This is an important result as it refines one of the most important results in law & economics literature.

We have also shown that is extremely important to have correct estimates of people's willingness to pay for environmental improvement. These WTP estimates determine in great part the optimal environmental strategy and its associated optimal monitoring and enforcement policy. If the WTP is very low, the costs of implementing environmental regulation are not fully compensated by the corresponding environmental improvement. However, the higher the WTP for emission reductions, the more it pays to develop more stringent environmental regulation (emission standard plus monitoring and enforcement policy).

Moreover, it really pays off to optimise the monitoring and enforcement strategy associated with an emission standard. This optimisation does not necessarily mean that monitoring and enforcement should be as stringent as possible. It is often possible to obtain the desired result by some intermediate value of the monitoring and enforcement parameters. This is due to the balancing of costs and benefits associated with monitoring and enforcement.

APPENDIX

A. Detail of figure 1



B. Results for given WTP and $\overline{E}$

WTP €/ton BOD between	and	Ebar (mg/l)	pbar	alfa	pi	Emissions (ton BOD)
0	0.23860	260	0	0	0	37 089 413
0.23861	0.73915	260	0	0.1	0.5	32 060 321
0.73916	3.80326	260	0.1	0	2	16 958 181
3.80327	5.04379	260	0.1	0	3	13 930 028
5.04380	11.50658	260	0.2	0	3	12 668 667
11.50659		260	0	0.3	4	12 250 297

C. Results for given WTP

WTP €/ton BOD between	and	ebar (mg/l)	Pbar	alfa	Pi	Emissions (ton BOD)
0.00000	0.07831	-	0	0	0	37 089 413
0.07832	0.25087	440	0	0.1	1.5	34 132 318
0.25088	0.34782	320	0	0.1	0.5	28 322 988
0.34783	1.05290	300	0	0.1	0.5	27 677 109
1.05291	1.85843	200	0	0.1	1.5	13 894 641
1.85844	2.13635	160	0.1	0	1	12 786 423
2.13636	3.75988	80	0.1	0	1.5	10 659 359
3.75989	6.12461	60	0.1	0	2	7 273 985
6.12462	11.87103	60	0.1	0	3	6 012 624
11.87104	18.38123	40	0.1	0	5	5 718 244
18.38124		60	0.2	0	3.5	5 597 254

D. Results for given emission target

emissions	Ebar	pbar	alfa	pi	emissions	ebar	pbar	alfa	Pi
37 089 413	-	0	0	0	18 324 070	320	0.1	0	4
36 989 154	580	0	0.3	4.5	18 200 080	320	0	0.2	4
36 965 424	540	0	0.4	5	18 030 083	300	0.1	0	3.5
36 565 105	460	0.1	0	0.5	17 906 094	300	0	0.2	3
36 441 116	460	0	0.2	4.5	16 970 059	100	0.1	0	0.5
34 132 318	440	0	0.1	1.5	16 958 181	220	0.1	0	1
34 008 328	440	0	0.2	4	16 938 719	320	0	0.3	5
33 796 625	460	0.2	0	4	16 644 733	300	0	0.3	4
33 444 732	460	0.2	0	4.5	16 644 339	320	0	0.6	5
32 706 201	180	0.1	0	0.5	16 350 353	300	0	0.5	4.5

32 060 321	280	0	0.1	0.5	13 930 028	280	0.1	0	4
31 899 889	460	0.2	0	5	13 894 641	200	0	0.1	1.5
31 487 827	360	0	0.1	3.5	13 806 038	220	0	0.1	2.5
31 363 837	400	0	0.2	4.5	13 542 748	60	0.1	0	0.5
31 135 934	340	0	0.1	3	12 786 423	160	0.1	0	1
31 011 945	360	0	0.1	4.5	12 668 667	240	0.1	0	5
29 591 090	340	0	0.1	3.5	12 544 677	240	0	0.1	5
29 470 350	460	0.2	0.6	5	12 250 297	240	0	0.2	5
29 467 101	360	0	0.1	5	10 866 488	200	0.1	0	2.5
29 415 830	280	0	0.1	1	10 742 498	200	0	0.1	2
28 322 988	320	0	0.1	0.5	10 659 359	80	0.1	0	1.5
27 870 987	260	0	0.1	1	10 514 595	160	0	0.1	1
27 677 109	300	0	0.1	0.5	10 390 605	180	0	0.1	1.5
27 161 552	400	0.1	0	3	10 110 163	200	0.1	0	3
27 037 563	340	0	0.1	4	9 758 270	160	0.1	0	2
26 442 197	460	0.7	0	5	9 634 281	120	0	0.1	1
25 678 498	320	0	0.1	2	9 605 127	200	0	0.6	0.5
25 441 448	280	0	0.1	1.5	9 481 138	200	0	0.1	3.5
25 317 459	280	0	0.1	3	9 253 234	180	0	0.5	0.5
25 032 618	300	0	0.1	1.5	9 186 757	200	0	0.2	3
24 807 447	200	0	0.1	0.5	9 129 245	180	0	0.1	2.5
24 222 933	140	0.1	0	0.5	8 848 802	200	0.1	0	4.5
24 133 399	340	0.1	0	5	8 834 864	180	0	0.1	4.5
24 009 409	340	0	0.3	4	8 724 813	200	0.1	0.1	2.5
23 781 761	320	0	0.1	2.5	8 496 909	180	0.1	0	4
23 487 775	300	0.1	0	1	8 430 432	200	0.1	0.1	3.5
22 748 049	360	0	0.6	5	8 372 920	160	0	0.1	2.5
22 716 986	440	0.8	0.5	5	8 078 540	160	0	0.1	3.5
22 453 668	340	0	0.8	5	7 631 205	140	0.1	0	3
22 413 295	280	0.1	0	3.5	7 273 985	60	0.1	0	2
22 377 909	200	0	0.1	1	6 369 845	140	0.1	0	3.5
22 289 306	280	0	0.1	4.5	6 245 855	80	0	0.1	1
22 026 016	180	0	0.1	0.5	6 075 464	100	0.2	0	3
21 352 223	320	0	0.1	3	6 012 624	60	0.1	0	3
21 228 233	320	0	0.1	3.5	5 951 475	120	0	0.1	3.5
21 058 236	300	0	0.1	2	5 888 635	60	0	0.1	0.5
21 027 945	280	0	0.2	4.5	5 718 244	40	0.1	0	5
20 934 247	300	0	0.1	3	5 594 254	60	0.2	0	3.5
20 733 565	280	0	0.4	4					

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