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On the Acceptability of the Ambient Tax Mechanism: An Experimental Investigation

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Abstract

Our objective in this paper is to assess the acceptability of the ambient tax. Concretely, we ask subjects to choose between (A) an ambient tax and (B) an individual tax system. In case (A), they actually participate in a game in which their payoff depends on all participants' decisions and on natural variability as would be the case in the real world if an ambient tax was implemented. In case (B) they simply earn a sure payoff, which is supposed to reflect their maximal profit under the individual tax system. We take the percentage of agents preferring the ambient tax to a given sure payoff level as an indicator of the acceptability of the ambient tax given this sure payoff level. Our experimental results mitigate the common belief that ambient taxes are totally unacceptable. If the "sure" alternative to the ambient tax policy is very costly for the polluters, for example because it involves high inspection costs, polluters might eventually prefer being liable to an ambient tax.

Keywords: Nonpoint Source Pollution; Group Decision Making; Experiments; Acceptability of fiscal instruments.

JEL Classification: C92, H3, Q5.

1 Introduction

Regulation of non-point emission problems such as pesticide and nitrogen pollution of lakes and ground water is a major policy challenge. The emissions-based instruments that economists usually

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advocate for cost-effective pollution control are not feasible since emissions are unobservable (for surveys, see for example Xepapadeas, 1999, Shortle and Horan, 2001). Among the policy instruments suggested by the theoretical literature on non-point management, the tax schemes applied to ambient concentrations ("ambient taxes" for short) have drawn particular interest. Under such a fiscal instrument, each polluter pays a tax which depends on the ambient pollution level resulting from the emissions of all polluters, from natural sources and from the weather conditions in the area. The implementation of such an ambient-based instrument is possible because in many non-point source pollution situations, the regulator is able to meter the ambient pollution level at a given point at a reasonable cost (even though he cannot observe individual emissions). Ambient tax schemes contrast sharply with the traditional pigovian tax, which depends on individual emissions. They are calibrated to implement the social optimum as a Nash equilibrium of the game among polluters. Segerson (1988) first proposed a linear ambient tax scheme such that each polluter pays a marginal tax corresponding to total marginal environmental damage caused by changes in the ambient concentration. More precisely the instrument is a tax/subsidy, since the amount polluters have to pay is positive if ambient pollution exceeds a specified target, and negative in the opposite case.

To the best of our knowledge, no real world implementation of an ambient tax scheme to regulate nonpoint source pollution has ever been reported. The only available empirical evaluation of the ambient tax scheme has been carried out in the laboratory. Broadly speaking, the existing controlled laboratory experiments on the ambient tax scheme conclude that though the polluters' emissions do not maximize the social net benefit, a second-best level of social welfare is achieved as the observed total pollution level matches the specified target (see Vossler, Poe, Schulze, and Segerson, 2006, Cochard, Willinger, and Xepapadeas, 2005, Alpizar, Requate, and Schram, 2004, Poe, Schulze, Segerson, Suter, and Vossler, 2004, Spraggon, 2004, Spraggon, 2002). In particular, ambient taxes seem to be implementable even when each polluter has limited information on the objective function of the other polluters (Cochard, Ziegelmeyer, and BounMy, 2007).

While the efficiency of ambient taxes has been demonstrated experimentally, there is a capricious aspect to the instrument that would likely limit its acceptability by the group of potential polluters. In particular, individuals who take costly actions to improve their environmental performance could find themselves subject to larger rather than smaller penalties due to environmental shirking on the part of others, natural variations in pollution contributions from natural sources, or stochastic variations in weather. Conversely, individuals who behave badly may end up being rewarded by the good actions of their neighbors or nature.

Our objective in this paper is to assess the acceptability of a standard ambient tax/subsidy scheme. Concretely, we ask subjects to play the role of polluters that would have to choose between (A) an ambient tax scheme and (B) an individual tax system. In case (A), they actually participate in a game in which their payoff depends on all participants' decisions and on natural variability as would be the case in the real world if an ambient tax was implemented. Due to the presence of the ambient tax, the unique Nash equilibrium of the game is also the social optimum (i.e. the regulator's objective). In case (B) they simply earn a sure payoff, which is supposed to reflect their maximal profit under the individual tax system. Obviously the agent's choice of (A) or (B) is strongly related to the level of this sure payoff. Thus we consider twelve values of the sure payoff level, ranging from 40% to 95% of an agent's expected payoff under the ambient tax system if the social optimum is achieved. The relevant value of the sure payoff level is mainly an empirical question, and we acknowledge that other values might have been implemented. However an ambient-based scheme should be less costly for society than an individual regulation scheme because it requires less information (the regulator only needs to meter ambient pollution at one given measuring point and not to monitor each polluter's emission). It seems therefore reasonable to assume that polluters should at least partially support the extra cost of the individual regulation, and thus that their social optimum profits should be higher under the ambient tax than under the individual tax system. Such a line of explanation justifies why the highest sure payoff level that we consider is worth 95% of an agent's expected payoff under the ambient tax system if the social optimum is achieved. We take the percentage of agents preferring the ambient tax to a given sure payoff level as an indicator of the acceptability of the ambient tax given this sure payoff level.

By choosing between a sure payoff and participating in the ambient tax game, subjects are lead to reveal their certainty equivalents for a "risky" situation. Knight (1921) was the first to distinguish between two kinds of uncertainty or risk: exogenous uncertainty when the probabilities of all possible states of the world are well known and endogenous uncertainty when they are not well known. The behavior of other players in a game, or "strategic uncertainty", is such an example of endogenous uncertainty. Our experiment is therefore one of the first attempts to elicit the certainty equivalents of people for situations in which subjects face both sorts of uncertainty, as in our ambient tax game.[1]

We focus in this study on the *ex ante* acceptability of the instrument, i.e. whether polluters find it acceptable or not after having the opportunity to familiarize with it, but before having experienced it in interaction with other polluters. To our knowledge, ambient taxes have never been implemented so far, so that an *ex ante* evaluation of the instrument is particularly relevant. Assessing the acceptability of ambient taxes after several periods of implementation could also be interesting, but we think that if the instrument is too unpopular before it is implemented, then the regulator will probably not be able to enforce it in the field. One could argue that acceptability could increase over time, which would mitigate the seriousness of early rejections of the instrument. Nevertheless, even if the instrument becomes more popular as time elapses, the serious acceptability problems that can occur during the intermediary period are likely to result in a premature cancelling of the policy. Assessing the *ex ante* acceptability of the instrument is also more relevant due to the experimental methodology. Indeed, if a few periods of interactions were carried out before the evaluation of acceptability, then subjects would have the possibility to learn about the group's behavior. This means that strategic uncertainty could be reduced, enhancing the acceptability of the instrument.[2] But we suspect that this would be an artificial enhancement of the acceptability

[1]Heinemann, Nagel, and Ockenfels (2006) explore various aspects of strategic uncertainty in one-shot coordination games with multiple equilibria, and measure subjects' certainty equivalents for a class of coordination games and a lottery.

[2]Learning would be actually more important with partners than with strangers interactions. In a partner design, subjects interact with the same subjects at each period, whereas in a strangers design, they are rematched in different

of the instrument because strategic uncertainty would probably decrease less in the field than in the laboratory. Therefore, an assessment of acceptability before any interaction between subjects seems preferable. It preserves strategic uncertainty at its maximal level, which is likely to be closer to the situation in which firms actually are in the field.

We consider an environment in which polluters have limited information. This means that each polluter only knows his own payoff function but does not know those of his counterparts. However, he knows the number of polluters in his group. This is similar to the "limited information" treatments of the experiment presented in Cochard, Ziegelmeyer, and BounMy, 2007. We choose to focus on a limited information framework for two reasons. First, this assumption is likely to be closer to the natural environment, in which firms have very little information. Second, it should be noticed that the instrument we consider is not collusion-proof as polluters may increase the sum of their profits by excessively reducing their emissions. As has been verified in the previous experiment, collusion is less likely to occur under limited information than under full information. Therefore, considering a full information condition might have artificially increased the acceptability of the instrument.

We observe that the larger the level of the sure payoff the smaller the acceptance rate of the ambient tax. Interestingly enough, average acceptance rates are high (60%) even when the sure payoff equals 95% of the social optimum payoff under the ambient tax system. This suggest a majority of the subjects think they can earn at least 95% of the social optimum payoff if the ambient tax is implemented. Our experimental results mitigate the common belief that ambient taxes are totally unacceptable. If the "sure" alternative to the ambient tax policy is very costly for the polluters, for example because it involves high inspection costs, polluters might eventually prefer being liable to an ambient tax.

In the next section, we suggest a measure of the acceptability of the ambient tax mechanism. The experimental procedures are explained in section 3. Section 4 is devoted to the results. Section 5 concludes.

2 The ambient tax game and the acceptability of the mechanism

A set $N = \{1, \ldots, n\}$ $(n \geq 2)$ of polluters emit pollutants to the same recipient and individual emissions cannot be observed by the environmental regulator unless costly investigations are carried out. Environmental damage in the recipient is a function of the ambient pollution level at one given measuring point.

Each polluter $i \in N$ knows its own profit function which is defined as a function of emission levels that are a by-product of the polluter's production: $\pi_i(e_i) = \gamma_i - \alpha_i(e_i - e_i^{max})^2$ where $e_i \in [0, e_i^{max}]$ denotes the emissions of the ith polluter, e_i^{max} denotes polluter i's maximal amount of emissions, $\gamma_i > 0$ and $\alpha_i > 0$. In the absence of any environmental control, polluter $i \in N$ releases pollution up to e_i^{max} which we refer to as the uncontrolled level of emissions.

For simplicity, the ambient concentration of the pollutant is given by $\sum_{i \in N} e_i + \epsilon$, which is assumed to be non-negative, and where ϵ is a stochastic environmental variable with null expecta-

groups at each period. But even in the latter, subjects learn about the overall behavior of the population.

tion.[3] The economic costs of damages caused by pollution are given by $\left(\sum_{i\in N} e_i + \epsilon\right)^2$, meaning that damages from total emissions are a convex function of total emissions. We assume that the damage function is common knowledge. Assuming that the environmental regulator or social planner is risk-neutral, he seeks to maximize total profit less expected environmental damages, i.e., he chooses the socially optimum emission level for each polluter such that the expected net profit is maximized. The expected net profit of resource allocation decisions by nonpoint sources is given by $\sum_{i\in N} \pi_i(e_i) - E\left[\left(\sum_{i\in N} e_i + \epsilon\right)^2\right]$ where E denotes the expectations operator over the stochastic environmental variable. Hence the socially optimal level of emissions for each polluter is obtained by solving

$$\max_{\{e_1,\ldots,e_n\}} \quad \sum_{i\in N} \pi_i(e_i) - E\left[\left(\sum_{i\in N} e_i + \epsilon\right)^2\right]$$

which we refer to as the planning problem.

The environmental regulator has to design a mechanism that gives incentives to the polluters for optimal emission levels. Hansen (1998) and Horan, Shortle, and Abler (1998) have shown that the environmental regulator can impose a damage based tax mechanism on each polluter in order to implement the socially optimal level of emissions. After the mechanism has been introduced, a risk-neutral polluter $i \in N$ chooses e_i so as to maximize $\pi_i(e_i) - E\left[\left(\sum_{i\in N} e_i + \epsilon\right)^2\right] + K$, where $K > 0$ is a lump-sum subsidy determined by the regulator. Assuming interior solution, Nash equilibrium first order conditions are given by $\alpha_i\left(e_i^* - e_i^{max}\right) + e_i^* + \sum_j e_j^* = 0$ leading to $e_i^* = (\alpha_i e_i^{max} - \sum_j e_j^*)/(1+\alpha_i)$, for $i, j \in N$ where $i \neq j$.[4] Under the assumption that he knows the distribution of the polluters' profit functions, the regulator could determine the "ideal" level of the lump-sum subsidy K^* so that polluters would not incur expected taxes at the social optimum, i.e., $K^* = (\sum_i e_i^*)^2 + Var[\epsilon]$ where Var denotes the variance operator over the stochastic environmental variable. Given n, $(\gamma_i, \alpha_i, e_i^{max})_{1\leq i\leq n}$, ϵ and K, the ambient tax game corresponds to the situation where polluters emit pollutants after the mechanism has been introduced.

The damage based mechanism is information efficient as the solution of the planning problem is decentralized to polluters. But the fact that the optimum is implemented as a Nash equilibrium entails that polluter i's response to the damage based mechanism will depend on its conjectures about the other polluters' emission choices. In other words, the consistency requirement in Nash equilibrium requires knowledge of other polluters' Nash equilibrium emissions for polluter i to determine its own Nash equilibrium strategy.

Measuring the acceptability of the ambient tax mechanism

Assume that the regulator can carry out perfect inspections of each polluter in order to monitor its individual emissions. These inspections are obviously costly because of the "nonpoint source" nature of pollution and the inspection costs should be, at least partially, supported by the polluters. Consequently, a polluter's *sure* payoff under the individual tax mechanism is only a fraction of the

[3] We shall ignore the non-negativity constraint $\sum_{i\in N} e_i + \epsilon \geq 0$ for ease of exposition. This problem is handled in Cochard, Ziegelmeyer, and BounMy (2007).

[4] Due to our convexity assumptions, second order conditions are trivially satisfied.

polluter's expected Nash payoff when playing the ambient tax game.

Since the ambient tax game involves both strategic and natural uncertainties, a polluter asked to choose between the ambient tax mechanism and the individual tax mechanism might prefer the sure payoff to the uncertain payoff associated with the outcome of the game. The strength of this preference is likely to depend on the difference between the sure payoff obtained under the individual tax mechanism and the expected Nash payoff of the ambient tax game, i.e. on the cost of inspection. Assuming that polluters assign well-defined probabilities to the strategy profiles of others, the cost of inspection is a risk-premium. For given costs of inspection, a natural measure of the acceptability of the ambient tax mechanism is the proportion of polluters preferring to play the ambient tax game rather than receiving the sure payoff.

3 Experimental design and procedures

In our laboratory environment, subjects are partitioned into groups of six polluters and they go through two phases: a training phase and a decision phase. In the training phase, subjects do not interact with each other but they are endowed with a *payoff calculator* which enables them to compute their payoff for a given profile of emissions in the ambient tax game. After having completed the training phase, subjects either decide to receive a sure payoff or they decide to play the ambient tax game once and receive the resulting payoff. In this section, we first describe our experimental implementation of the ambient tax game. Second, we detail the training and decision phases and, third, we discuss our practical procedures.

3.1 Design

When playing the ambient tax game, subjects take the role of polluters whose decisions correspond to the level of emissions. The larger the decision number the more emissions the polluter releases up to some maximum decision number which corresponds to the polluters uncontrolled level of emission, i.e., to the subject's endowment (in tokens).[5] In each group of six subjects, one subject is endowed with 23 tokens, four subjects are endowed with 31 tokens and one subject is endowed with 45 tokens. From now on, we will refer to the subject whose endowment is the lowest as the small polluter, the subject whose endowment is the highest as the large polluter and the four remaining subjects in the group as the medium polluters. Subjects are told that their total payoff will be the sum of a private payoff and a group payoff. The private payoff, which is analogous to the polluters' before-tax profit function, is found by looking up their decision number on a payoff table. A different payoff table is associated to each polluter's type, small, medium or large, as the private component of the payoff function differs. Subjects have no information about the endowments and private payoff tables of other group members. They are only informed that not all group members have been provided with the same endowment and private payoff table. The group payoff depends on the group total. Subjects are informed that the group total is the sum of the decision numbers of all

[5] Emissions are restricted to integer values.

of the subjects and a random variable which follows a triangular distribution.[6] The group total is analogous to the ambient level of pollution in the nonpoint source pollution case. Adding a random variable to the sum of the decision numbers allows us to investigate the effects of the ambient level pollution being observed with error, or being affected by stochastic factors like weather conditions.

Two positions of the socially optimal level in the polluter's emission interval are considered. In the *low position of the social optimum* condition each polluter's socially optimal level of emission is between 30% and 40% of its endowment depending on its type. In the *high position of the social optimum* condition each polluter's socially optimal level of emission is between 60% and 70% of its endowment depending on its type. There are two levels of the lump-sum subsidy. Instead of assuming that the regulator can determine the level of the lump-sum subsidy which corresponds to no tax/subsidy at the social optimum, we investigate whether a miscalculation has an impact on subjects' behavior. In the *Kinf* condition the regulator under-evaluates the level of the lump-sum subsidy which implies that polluters pay taxes at the social optimum whereas in the *Ksup* condition the regulator over-evaluates the level of the lump-sum subsidy which implies that polluters are subsided at the social optimum. The two positions of the socially optimal level are combined with the two levels of the lump-sum subsidy to generate four parametrizations of the ambient tax game. Table 1 provides the key parameters of the four experimental games.

Social optimum's position	Low			High		
Under-evaluated lump-sum subsidy (*Kinf*)	4200 (85% of 4922.5)			12300 (85% of 14462.5)		
Over-evaluated lump-sum subsidy (*Ksup*)	5700 (115% of 4922.5)			16700 (115% of 14462.5)		
Random variable's support	{-9,-6,-3,0,3,6,9}			{-15,-10,-5,0,5,10,15}		
Random variable's probs.	(1/16) {1,2,3,4,3,2,1}					
Polluter's type	Small	Medium	Large	Small	Medium	Large
Endowment	23	31	45	23	31	45
Value of γ	2645	3363.5	5062.5	7935	9610	15187.5
Value of α	5	3.5	2.5	15	10	7.5

Table 1: Parameters of the ambient tax games.

The training phase

Subjects start by practicing the ambient tax game for about half an hour. With the help of the payoff calculator, they compute their payoffs in the ambient tax game for each possible value of the random variable and given their own emission level as well as the emission levels of the five other members of their group. The training phase is composed of two stages. In the first stage, the investment of the five other members of the group is a preprogrammed number. Thus each

[6]The triangular distribution is a good approximation of the normal distribution and it is easy to explain to subjects.

subject has to enter his token investment given this preprogrammed number of tokens displayed on screen. Each preprogrammed number of tokens is submitted to the subject for five periods in a row, allowing him to investigate the impact of various decision numbers. In total each subject participates in ten five-period simulations, providing him the opportunity to experience a wide range of others' preprogrammed number of tokens. In the second stage, each subject has to enter both his token investment and the number of tokens invested by the other members of his group. The second stage is limited to ten minutes.

The decision phase

In the decision phase, subjects choose between being paid according to the outcome of the one-shot ambient tax game and receiving a sure payoff which either takes a low, medium or high value.[7] The sure payoff corresponds to a fraction of the social optimum payoff under the ambient tax scheme. Each subject therefore faces a series of three choices between participating in the ambient tax game and earning one of the following twelve fractions of the social optimum payoff: {.40, .45, .50, .55, .60, .65, .70, .75, .80, .85, .90, .95}. To reduce order effects, no feedback between choice situations is provided to the subjects and sure payoffs are not presented in increasing or decreasing order: Subjects first face the medium sure payoff, then the high sure payoff, and finally the low sure payoff. Each parametrization of the ambient tax game involves four groups of six subjects with each group of six subjects facing a specific sequence of three sure payoffs as shown in table 2. At the end of the three choice situations, each subject is presented with a recap screen which displays the three decisions of each the six members of the group. To avoid hedging, subjects are informed, before making their choices, that only one of the three choice situations will be effectively implemented. Concretely, after all choices have been made, one of the 24 subjects selects randomly one of the three choice situations.

	Group 1	Group 2	Group 3	Group 4
Medium sure payoff	.75	.70	.65	.60
High sure payoff	.95	.90	.85	.80
Low sure payoff	.55	.50	.45	.40

Table 2: Fractions of the social optimum payoff in each group of polluters.

To avoid subjects misrepresenting their preferences, we rely on the *random dictator rule* which is theoretically incentive compatible: in each group, one of the six members is randomly selected, the so-called *dictator*, and the dictator's choice is implemented for all six members of the group. Since each member has the same chance of being the dictator but only one actually determines the group outcome, strategic considerations are eliminated (see also Rutström and Williams, 2000). Though the same choice situation applies to all 24 subjects, different outcomes may prevail for different groups, depending on the respective dictator's actual choice. Those group-members whose dictator

[7] Since subjects do not interact with each other in the training phase, none of the strategic uncertainty has been resolved when they enter the decision phase.

chose the sure payoff in the randomly selected choice situation earn their respective sure payoffs whereas those group-members whose dictator chose to play the ambient tax game participate in the interaction situation.

3.2 Procedures

The experiment was run on a computer network in October 2003 using 96 inexperienced students at the Max Planck Institute in Jena. Four sessions were organized, one session per parametrization of the ambient tax game, with four groups of six subjects per session. Each subject was allocated to a computer terminal, which was physically isolated from other terminals. Communication, other than through the decisions made, was not allowed. The subjects were instructed about the rules of the game and the use of the computer program through written instructions, which were framed in neutral language and read aloud by a monitor (instructions are available in Appendix A). A short control questionnaire followed.[8] Each session took between $1\frac{1}{2}$ and $2\frac{1}{4}$ hours. In addition to the earnings related to their performance (on average 16.6 euros with a standard deviation of 9.3 euros), subjects received a show-up fee of 2.5 euros.[9]

4 Results

In this section, we first study the ambient tax/subsidy acceptance rates, and second, the number of tokens invested by subjects (polluters' emissions) whenever the ambient tax is effectively implemented.

4.1 The ambient tax acceptance rates

Figure 1 on the next page depicts the average acceptance rates per type of polluter and per interval of sure payoff levels (.40-.55, .60-.75, .80-.95). As expected, average acceptance rates tend to decrease with the level of the sure payoff (the slope coefficients are significantly negative at the 5% level only for large and medium polluters). More precisely, small polluters' acceptance rates decrease slowly with the sure payoff and remain at a high level even when the sure payoff is high, medium polluters' acceptance rates decline linearly with the level of the sure payoff, and large polluters' acceptance rates are at a high level only when sure payoffs are low and then decrease sharply when the sure payoff is higher than .55. Interestingly enough, average acceptance rates are relatively high (50% or more) even when the sure payoff is high. A large proportion of subjects choose to play the ambient tax game even when the sure payoff is almost equal to the social optimum payoff. This could indicate that subjects expect to earn higher payoffs than the social optimum payoff with the ambient tax, or equivalently that they expect investments to be lower than the socially optimal

[8] Approximately 30 subjects were invited for each session. Subjects who did not answer correctly the control questionnaire were not allowed to take part in the experiment.

[9] We did not endow subjects with a starting cash balance to cover potential losses. In case of negative payoffs at the end of a session, subjects just received the show-up fee.

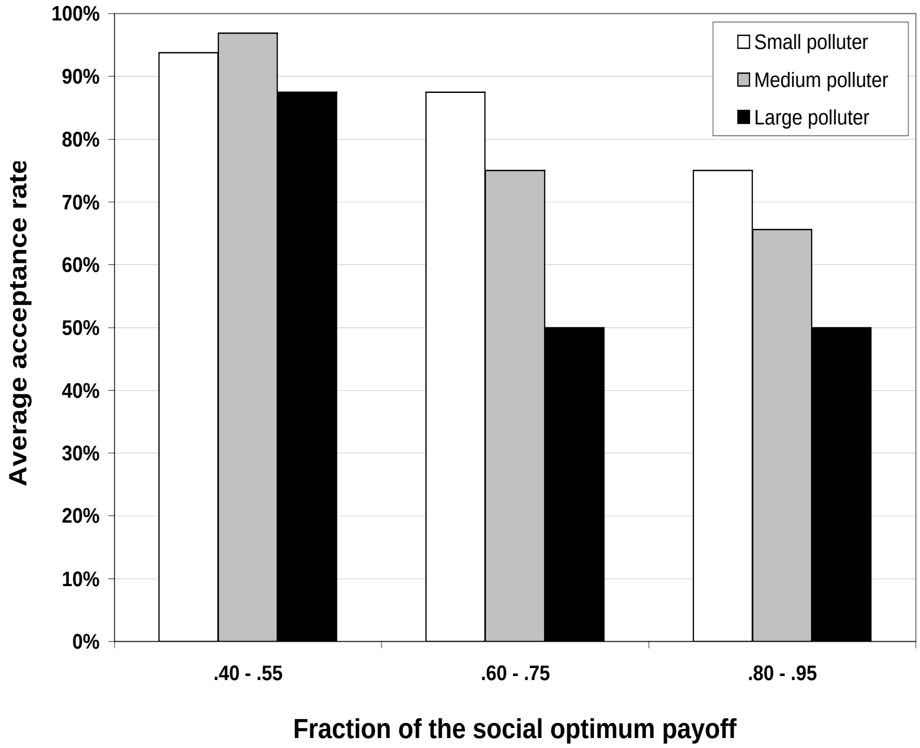

Figure 1: Average acceptance rates.

investments. In the next section, we investigate whether this expectation proves correct or not. Overall, the acceptability of the ambient tax is rather high in our experimental setting.

In order to substantiate the previous descriptive analysis, we estimate the probability of choosing the ambient tax given the level of the sure payoff, and we test for differences between treatments and polluters' types. The observations can be treated as cross-sectional time series (or panel) data. There is a total of 96 subjects and 3 choice situations. Assume that the acceptance decision of subject i ($i \in \{1, ..., 96\}$) in choice situation t ($t \in \{1, 2, 3\}$) is given by:

$$y_{it}^* = \beta' x_{it} + u_i + \epsilon_{it}, \tag{1}$$

where y_{it}^* is an unobservable variable representing subject i's utility level at period t, x_{it} is a $(k \times 1)$ vector of k explanatory variables, β is the $(k \times 1)$ regression vector to be estimated, u_i is a normally distributed random variable that measures the individual random effect, and ϵ_{it} is an idiosyncratic error term. Let $p(.)$ denote probability. The model assumes $p(y_{it} = 0/x_{it}) = p(y_{it}^* \leq 0/x_{it}) = F(-\beta' x_{it})$ and $p(y_{it} = 1/x_{it}) = p(y_{it}^* > 0/x_{it}) = 1 - F(-\beta' x_{it})$, where $F(.)$ is the cumulative normal distribution, $y_{it} = 0$ if the ambient tax is rejected and $y_{it} = 1$ if it is accepted. We include the following explanatory variables (fixed effects): *sure* (level of the sure payoff), *high* (equals 1 in the high social optimum condition), *ksup* (equals 1 in the high lump-sum subsidy case), t (choice period), *small* (equals 1 for a small polluter), *large* (equals 1 for a large polluter), and all interactions terms among these effects. The combination low position of the social optimum-under evaluated lump-sum subsidy constitutes the reference parametrization of the ambient tax game and medium constitutes the reference type. We start by estimating the model with all interaction terms and then subsequently drop insignificant effects on the basis of likelihood ratio tests.

The final result of the random-effects panel regression are summarized in table 3 on the following page. The Wald test shows that the model is globally significant. The random individual effect is significant (the variances of u_i and ρ are significantly positive). An increase in the sure payoff has a negative and significant impact on the acceptance probability of the ambient tax. Hence, the econometric analysis validates the hypothesis that the probability of acceptance is decreasing with the level of the sure payoff.

The acceptability of the ambient tax is neither affected by the level of the subsidy K nor by the position of the social optimum. One could have expected the acceptability to be higher when K is large than when it is low. Indeed, a higher K allows subjects to earn higher payoffs at the social optimum. However, subjects' expectations are also affected by the level of K. Since they anticipate lower payoffs when K is low, subjects may also anticipate that token investments will be lower. The contrary holds when K is high. Thus, in practice, a low K might be as acceptable as a high K.

There are no large differences between polluters' types. Still, large polluters are less prone to accept the ambient tax than medium or small polluters. When choosing between the ambient tax and the sure payoff, subjects do not know the types of their counterparts. Even though they know that there are different types in their groups, subjects probably assume that other types are not very different from theirs. Therefore, large polluters expect high investments, and thus big losses, whereas small polluters expect low investments, and thus important gains. Accordingly, it is not surprising that large polluters are less prone to accept the ambient tax.[10]

4.2 The token investments (polluters' emissions)

In this subsection, we analyze the number of tokens invested (i.e. the polluters' emissions or input use) by subjects when the ambient tax is actually implemented. The Nash emissions in the low (respectively high) social optimum condition are given by 9 (respectively 15) for the small polluter, 11 (respectively 19) for the medium polluters and 17 (respectively 29) for the large polluter.

The ambient tax has effectively been implemented (after the random drawings) in 11 of 16 groups. Table 4 on the next page displays the invested tokens for each type of polluter and for the group averaged over all treatments (see Appendix B for a more detailed overview). Clearly, average levels of investment are smaller than the socially optimal investments in all treatments (no clear differences between types are observed). We hypothesized that subjects chose the ambient tax because they anticipated relatively small investments, and thus relatively high payoffs. If this is the case, then this anticipation proves right. Actual earnings are much higher than the social optimum earnings, and thus much higher than the sure payoff levels.

[10]Surprisingly enough, polluters are more likely to accept the ambient tax in latter choice situations though the effect is weak.

Table 3: Probability of choosing the ambient tax.

Random-effects probit		Number of obs		=		288
Group variable : i		Number of groups		=		96
Random effects u_i	Gaussian					
		Wald $\chi^2(3)$		=		30.59
Log likelihood = -116.13027		Prob > χ^2		=		0.0000
	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sure	-4.605757	.9803446	-4.70	0.000	-6.527197	-2.684317
large	-1.16244	.5949456	-1.95	0.051	-2.328512	.0036319
t	.4918927	.1834667	2.68	0.007	.1323046	.8514808
_cons	4.069089	.9137912	4.45	0.000	2.278091	5.860087
$ln(\sigma_u^2)$	1.066615	.3501706			.3802934	1.752937
σ_u	1.704561	.2984436			1.209427	2.402401
ρ	.7439527	.066703			.5939439	.8523229

Likelihood ratio test of ρ=0: $\overline{\chi}^2(01) = 39.67$ Prob $\geq \overline{\chi}^2 = 0.000$

Hence, on average, subjects were right in choosing the ambient tax. However, did it pay for all participants to play the game? In other words, when a subject played the game and wanted to do so, was his payoff higher than the highest sure amount he refused to get? Over the 54 subjects who voluntarily played the game, 46 (85%) earned more than the highest payoff they refused (the rates are almost similar in every treatment). This shows that for a large majority of subjects, playing the game was the right decision.[11]

Table 4: Average amount of invested tokens (all treatments).

	Small	Medium	Large	Group
Nb. of observations	11	44	11	11
Average observed Investment in % of Soc. Opt.	0.53	0.76	0.71	0.72
Payoff Euros (% Soc. Opt.)	21.29 (1.77)	20.86 (1.74)	15.91 (1.33)	120.64 (1.67)

[11]Investments are surprisingly low compared to the first period of Cochard, Ziegelmeyer, and BounMy (2007). One might argue that subjects perceive the decision phase as cheap talk. Indeed, before playing the game, subjects observe the choices of the other group members (between the sure payoff and the ambient tax). Since collusion in the ambient tax game provides high payoffs, choosing the ambient tax game may be interpreted as a (non binding) commitment of collusive behavior. This line of argumentation turns out to be wrong. Indeed, the correlation coefficient between the "degree of collusion" (difference between the social optimum investment and the observed investment, divided by the difference between the social optimum investment and the collusive investment) in each group and the number of subjects having chosen the ambient tax is very low (0.0097) and non significantly different from 0 (Student test, p=.9774).

5 Conclusion

This paper has assessed the acceptability of a damage-based ambient tax mechanism. Such a mechanism can handle nonpoint source pollution problems by rewarding polluters for environmental quality above a given standard and penalizing them for substandard levels of the ambient residual concentration. Though theoretically the ambient tax mechanism is an effective social institution devised to solve group moral hazard problems, this economic instrument is not used in any location at the present time. The main reasons that can account for the unpopularity of the instrument are that it relies both on natural and strategic variability, and that it can lead to unfair outcomes. We assess the acceptability of the ambient tax mechanism by asking subjects to choose between playing the ambient tax game once and earning a sure payoff. We vary the magnitude of the sure payoff which corresponds to a fraction of the social optimum payoff in the ambient tax game. In line with Cochard, Ziegelmeyer, and BounMy (2007), we assess the acceptability of the ambient tax mechanism by considering heterogenous polluters who have limited information about the payoff functions of the other members of their group and interact in different parametrizations of the ambient tax game.

The rate of acceptance decreases with the level of the sure payoff which comes as no surprise. More interestingly, the parametrization of the ambient tax game does not seem to influence the individual acceptability of the economic instrument, acceptance rates remain high even when the sure payoff is almost as high as the social optimum payoff and large polluters are less likely to accept the ambient tax mechanism than small and medium polluters.

The effect of assessing the acceptability of the ambient tax mechanism on polluters' emissions is however the most striking result of this paper. Indeed, emissions are observed to be much lower than the socially optimal levels and also lower compared to those observed by Cochard, Ziegelmeyer, and BounMy (2007) in similar parametrizations of the ambient tax game. Consequently, subjects earn much higher payoffs than the social optimum ones which helps understanding why acceptance rates are so high. Additional research on this issue is required to understand the link between individual acceptance of collective punishment and individual propensity to collusion.

All in all, our experimental results mitigate the common belief that ambient taxes are unacceptable. If the "sure" alternative to the ambient tax policy is sufficiently costly for the polluters, for example because it involves high inspection costs, polluters might eventually prefer being liable to an ambient tax.

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Supplementary material (for referees' use)

The following appendices are not meant for publication but could be made available on a web repository. Appendix A contains a translated version of the instructions (originally in German). We document here the instructions used in the *LowKsup* treatment for a small polluter. Appendix B contains an additional table which summarizes the number of tokens invested by subjects for the actually implemented ambient tax games.

Appendix A. Translated instructions for a small polluter in the *LowKsup* treatment

Welcome

In the following you will take part in a decision-making experiment. You will receive a fixed amount of 2.50 euros for arriving on time and participating in this experiment. Please read these instructions carefully.

Once you have finished reading the instructions, we will ask you to answer a questionnaire testing your understanding of the rules of this experiment. You can only take part in this experiment if your questionnaire shows that you fully understood the instructions.

General Instructions

You will interact in a group consisting of 6 participants. The composition of the groups will be determined randomly at the beginning of the experiment and will remain unchanged until its end. You will not be able to identify those five other participants that have been assigned to your group, neither during nor after the experiment. During the experiment you and each of the other members of your group will be referred to by a number. The numbers are assigned randomly. You will be informed at the beginning of the experiment which number has been assigned to you. In the course of this experiment you will acquire experimental points. The experimental points that you receive will be converted into euros at the end of the experiment. The conversion rate according to which this is done is provided to you in the last section of these instructions. We will now describe the experimental procedure. But before doing so, we provide you with a description of an interaction situation you may be confronted with and your understanding of which is a necessary requirement for taking part in this experiment.

The Interaction Situation

When in this situation, each participant receives a certain number of tokens, which we will in the following refer to as "endowment". **You receive 23 tokens. Different group members will be endowed with a different amount of tokens**. You may be the only participant of your group that has received an endowment of 23 tokens.

You decide how many tokens you want to invest. You obtain a payoff (only) for invested tokens. Furthermore, the payoff you receive does not only depend on how many tokens you invested yourself but also on the number of tokens that have been invested by the other members of your group as well as on the outcome of a random event. Note that the payoff you attain in the interaction situation may be positive (gain) or negative (loss). Hence, it is not excluded that you do not make any gain or even incur a loss. If your experimental account shows a loss at the end of the experiment, you will only be paid the promised fixed amount of 2.50 euros for your participation in this experiment.

Your payoff in the interaction situation is composed of two parts, namely an individual and a group component:

- Individual Component: The individual component of your payoff is given by a credit (in experimental points) where the size of this credit only depends on the number of tokens that you have invested yourself.

- Group Component: The group component of your payoff depends on the sum of tokens (including your own) that your group invests in total and the value of a randomly generated number.

Individual component of your payoff

For each token you invest (and only for those tokens you invest), you will be directly credited a certain number of experimental points. The table provided at the end of the instructions (see table 5, page 18) summarizes how many experimental points are credited to you for the different possible individual investments. According to this table, you will be credited with 440 experimental points if you invest 2 tokens, where you receive a credit of 225 experimental points for the first token invested and respectively 215 experimental points for the second token, i.e., you are credited a total of 225 + 215 = 440 experimental points.

Please note that the tables received by the different members of your group differ. Moreover, it is not excluded that you are the only member of your group that has received exactly your payoff table. Consequently, other members of your group will be credited with a different number of experimental points for investing 2 tokens. In order not to favor or discriminate any participant we have adapted the individual conversion rates accordingly.

Group component of your payoff

The group component of your payoff depends on the investment decisions of all members of your group (including your own) and is hence identical for all group members. Effectively, the group component can turn out as a credit or a point deduction and is derived according to the following rule: The computer determines the sum of the tokens invested by all group members (including your own). To this sum the computer adds a randomly drawn number (see the following remarks on the random draw) and multiplies the result attained from this by itself. The group component now is attained by subtracting the result from 5700 experimental points.

Formally:
Group component of your payoff = 5700 - [(Sum of all tokens invested in your group + randomly drawn number) * (Sum of all tokens invested in your group + randomly drawn number)]

The randomly drawn number can take one of the following seven values: (-9), (-6), (-3), 0, +3, +6, +9. The likelihood with which the number takes one of these values is summarized in the following table. The likelihood that the randomly drawn number takes e.g. the value (-6) equals $\frac{2}{16}$.

Random number	-9	-6	-3	0	$+3$	$+6$	$+9$
Likelihood	$\frac{1}{16}$	$\frac{2}{16}$	$\frac{3}{16}$	$\frac{4}{16}$	$\frac{3}{16}$	$\frac{2}{16}$	$\frac{1}{16}$

According to this rule it is not excluded that the sum of all tokens invested in your group and the randomly drawn number is negative. If this is the case, the computer sets this sum to zero, which then results in a group component of 5700 experimental points.

Example:

*- Assume your group invested total number of tokens amounts to 50 and the randomly drawn number takes the value 3. In this case the group component of your payoff equals 2891 experimental points [5700 - (50 + 3) * (50 + 3)].*

*- Assume your group invested number of tokens amounts to 110 and the randomly drawn number takes the value (-6). Here the group component of your payoff equals (-5116) experimental points [5700 - (110 - 6) * (110 - 6)].*

Experimental Procedure

The experiment consists of two phases:

First Phase

In the first phase of this experiment you have the possibility to calculate your payoff in the interaction situation for different hypothetical constellations of your own investment, the total group investment and the randomly drawn number. In order to do so you are provided with a payoff calculator which determines your payoff given a certain own investment and a certain overall sum of investments of the other five members of your group for all possible values of the randomly drawn number.

In a first step, the computer fixes a certain hypothetical sum of the investments of the other five group members. You then have to enter how many tokens you would invest given the respective assumed scenario. When you click on ‘Calculate’ the device returns your payoff for the considered case.

In a second step, you yourself enter an own hypothetical investment as well as the sum of investments of the five other members of your group. Again, if you then click on ‘Calculate’ on the device, it returns the payoff you would receive in the assumed scenario.

This first phase of the experiment is a training phase, in which you can check out the payoff implications of different constellations of your own decision to potential decisions taken by the other members of your group and different possible values of the random number in the above described interaction situation.

Second Phase

In the second phase of the experiment you will take three decision rounds. Concretely you will three times decide which of the following two options you want to choose:

- **Option A**: If you choose option A and your decision is realized you receive a sure payoff of a certain size. You are informed about the size of the sure payoff before you actually choose an option.

- **Option B**: If you choose option B and your decision is realized, you will interact with the five other members of your group in the interaction situation that has been described above.

If all 24 participants present in this experiment have three times chosen between option A and option B, one of the 24 participants will be drawn randomly to conduct two raffles.

In the first raffle, one of the participants will draw which of the three decision round taken in the second phase of the experiment will be the one that is decisive. For this the participant draws a number between 1 and 3 out of an urn. Consequently, the result of the first raffle is either 1, 2 or 3. If number 1 is drawn, the first decision round taken in the second phase of the experiment is decisive. If the number drawn is number 2, then the second decision round taken in the second phase is decisive and respectively, if number 3 is drawn, the third decision round taken in the second phase of the experiment is decisive.

The second raffle determines the option that will be realized. In the second raffle one of the participants draws a number between 1 and 6 out of an urn. Hence the result of the second raffle can be number 1, 2, 3, 4, 5 or 6. Each participant has been assigned a number at the beginning of the experiment. If the number drawn in the second raffle is number 1, the option chosen by group member 1 in the round which has been determined as decisive in the first raffle (round 1, 2 or 3), will be realized for all the members of his group. If a number different from the one that has been assigned to you at the beginning of the experiment is drawn in the second raffle, the option you have chosen in the decisive decision round is not relevant. On the contrary, if the number you have been assigned is drawn, the option you yourself have chosen in the decisive decision round is realized for all members of your group (including you yourself).

If the group member drawn in the second raffle has chosen option B in the decisive decision round, you and all members of your group will in the following in fact be once confronted with the above described interaction situation. Here you will choose the number of tokens you want to invest. You can decide to invest any number between zero and your complete endowment. Hence, you can invest either 0, 1, 2, 3, etc., 20, 21, 22 or 23 tokens. All members of your group enter their investment decision simultaneously. When you take your decision you do not know how many tokens the other members of your group have invested.

Once all group members have taken their investment decision, the computer randomly draws one of the possible numbers between (-9) and 9. Each group members will then be informed about her resulting payoff.

If on the other hand, the group member whose chosen option is implemented for the whole group has chosen option A in the decisive decision round, all members of her group receive the sure amount that has been offered in the respective decisive decision round.

Your conversion rate from experimental points into euros is the following: 1000 experimental points exchange for 4.90 Euros.

Once you have read these instructions we will ask you to fill in a questionnaire. Please take your time for answering the questions. If you make too many mistakes in the questionnaire you cannot take part in this experiment. If you have any questions now or during the experiment please raise your hand. Please do not ask questions loudly at any time.

Table 5: Table of individual payoff for a small polluter

Number of tokens invested	Additional gain or loss generated by the last token invested	Total individual payoff
0 token	-	0 point
1 token	225 points	225 points
2 tokens	215 points	440 points
3 tokens	205 points	645 points
4 tokens	195 points	840 points
5 tokens	185 points	1 025 points
6 tokens	175 points	1 200 points
7 tokens	165 points	1 365 points
8 tokens	155 points	1 520 points
9 tokens	145 points	1 665 points
10 tokens	135 points	1 800 points
11 tokens	125 points	1 925 points
12 tokens	115 points	2 040 points
13 tokens	105 points	2 145 points
14 tokens	95 points	2 240 points
15 tokens	85 points	2 325 points
16 tokens	75 points	2 400 points
17 tokens	65 points	2 465 points
18 tokens	55 points	2 520 points
19 tokens	45 points	2 565 points
20 tokens	35 points	2 600 points
21 tokens	25 points	2 625 points
22 tokens	15 points	2 640 points
23 tokens	5 points	2 645 points

Appendix B. Subjects' invested tokens

Low Social Optimum	Small	Medium	Large	Group
Socially optimal investment	9	11	17	70
Treatment *LowKinf*				
Nb. of observations	3	12	3	3
Average observed Investment (% Soc. Opt.)	2.33 (0.26)	6.50 (0.59)	17.33 (1.02)	45.67 (0.65)
Payoff Euros (% Soc. Opt.)	22.51 (1.88)	24.08 (2.01)	20.64 (1.72)	139.17 (1.93)
Treatment *LowKsup*				
Nb. of observations	4	16	4	4
Average observed Investment (% Soc. Opt.)	2.75 (0.31)	10.94 (0.99)	7 (0.41)	53.5 (0.76)
Payoff Euros (% Soc. Opt.)	17.88 (1.49)	21.07 (1.76)	13.60 (1.33)	115.76 (1.61)
High Social Optimum	Small	Medium	Large	Group
Socially optimal investment	15	19	29	120
Treatment *HighKinf*				
Nb. of observations	3	12	3	3
Average observed Investment (% Soc. Opt.)	13.33 (0.89)	14.25 (0.75)	17.67 (0.61)	88 (0.73)
Payoff Euros (% Soc. Opt.)	24.7 (2.06)	19.51 (1.63)	13.89 (1.16)	116.63 (1.62)
Treatment *HighKsup*				
Nb. of observations	1	4	1	1
Average observed Investment (% Soc. Opt.)	18 (1.2)	7.75 (0.41)	36 (1.24)	85 (0.71)
Payoff Euros (% Soc. Opt.)	21.05 (1.75)	14.39 (1.20)	17.94 (1.49)	96.56 (1.34)