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

THIS IS A VERY PRELIMINARY VERSION INTENDED FOR DISCUSSION

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Abstract

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 advocate for cost-effective pollution control are not feasible since emissions are unobservable. 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. While the relative efficiency of ambient based taxes has been demonstrated experimentally, the instrument may raise serious acceptability problems. 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. 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.

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 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, 2005).

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. Eliciting the polluters' opinions about the ambient tax could be carried out by various methods. We resort to the experimental methodology, which allows us to study the acceptability issue in a controlled environment and to focus on polluters' choices rather that on simple stated opinions. We provide monetary incentives for truthfully revealing the willingness to accept or not the instrument.

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.

Our goal in this study is to investigate 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.[1] But we suspect that this would be an artificial enhancement of the acceptability 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, 2005. We choose to focus on a limited information framework for two reasons. This assumption is likely to be closer to the natural

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

environment, in which firms have very little information.

To summarize, our experimental subjects have to choose between the ambient tax and the sure payoff in a very diffuse environment, since they have limited information and no experience of interaction with the group. One could argue that in such an environment, making a "correct" decision is almost impossible, and choosing the socially optimal emission is totally impossible. Firstly, we think that this is the very situation in which firms are, the first time the instrument is implemented, and we want to assess acceptability at that specific moment. Secondly, we think that the effect of providing full information is unsure. This would increase the length of the instructions and might add to rather than remove complication. Third, again, subjects are offered the opportunity to practice the ambient tax during a long training phase before playing the real game.

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. 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 present the theoretical background on which our study is based and suggest a measure of the acceptability of the ambient tax. The experimental procedures are explained in section 3. Section 4 is devoted to the results. Section 5 concludes.

2 Theoretical background and acceptability of the ambient tax

In this section, we present the theoretical framework on which our experiment is based, and then describe our measure of the acceptability of the ambient tax.

2.1 Description of the environment

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 expectation.[2] 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 $e_i^* = (\alpha_i e_i^{max} - \sum_j e_j^*)/(1 + \alpha_i)$,

[2]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, 2005.

for $i, j \in N$ where $i \neq j$.[3] 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.

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. A necessary condition for polluters to anticipate the others' equilibrium strategies is the knowledge of their profit functions. However, even the common knowledge of rationality and complete information is generally not sufficient in this class of game because many strategies may still be rationalizable.[4] Hence in this experiment we give up the complete information assumption and turn to a more realistic framework in which each polluter is assumed to know only its own profit function (though the number of firms is known).[5] This is what we call a "limited information" condition.

2.2 A measure of the acceptability of the ambient tax scheme

Our objective in this study is to investigate the acceptability of an ambient tax/subsidy scheme. We do this by asking polluters to choose between being submitted to (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 regulator's objective (i.e. the social optimum). In case (B) they simply earn a *sure payoff*, which is supposed to reflect their maximal profit under the individual tax system. Of course this implies that an individual taxation is possible in practice, even though it is costly because

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

[4]For example, while the Nash equilibrium is the only rationalizable outcome in a Cournot duopoly, it is not necessarily so when there more than two firms.

[5]Each firm even does not know the distribution of other firms' profit functions, meaning that we cannot rely on the concept of Bayesian Nash equilibrium to derive a solution.

of the "nonpoint source" nature of pollution. Hence we assume that the regulator can carry out perfect (costly) inspections of each polluter in order to monitor its individual emission. Because the individual tax system requires costly individual inspections, it seems reasonable to assume that these costs are at least partially supported by polluters, and therefore that a polluter's *sure payoff level* is lower than the payoff he can expect under the ambient tax/subsidy scheme, that is, his expected payoff under the ambient scheme at the social optimum. 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 at the social optimum. 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.

It should be noticed that the cost of inspection can also be regarded as a risk-premium. Because of strategic and natural uncertainties, choosing the ambient tax game can be regarded as a risky choice. Thus the basic idea of this experiment is to make subjects choose between a risky situation and earning a sure payoff.

3 The experiment

3.1 Procedures

The experiment was run on a computer network[6] in October 2003 using 96 inexperienced students at the Max Planck Institute in Jena. Four sessions were organized, with four groups of six subjects per session.[7] Subjects were randomly assigned to groups of six players, where 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. A short questionnaire followed. 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

[6]Based on an application developed by Bounmy (2003) designed for Visual Basic.

[7]Around 30 subjects were invited for each session to be able to select subjects and make sure all of the participating subjects had understood the game.

euros with a standard deviation of 9.3 euros), subjects received a show-up fee of 2.5 euros.[8]

At the beginning of the instructions, subjects are informed that they may be involved in an "*interaction situation*" (pertaining to the case where the ambient tax/subsidy scheme is implemented) during the experiment, so that they have first to perfectly understand its rules before getting more information on the rest of the experiment. In the following we adopt the same structure, presenting first the ambient tax game, and then the proceeding of the experiment (the instructions are available on page 27).

3.1.1 The interaction situation (the ambient tax game)

The interaction situation is based on the same environment as in Cochard, Ziegelmeyer, and BounMy (2005) which was designed to test the efficiency of the ambient tax/subsidy we study here. 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).[9]

Subjects are not informed of endowments of the other group members. In each group, 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. They 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 (see table 3 on page 15). The group payoff depends on the group total. Subjects are informed that the group total is the sum of the decision numbers of all of the subjects and a random variable which follows a triangular distribution.[10] 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

[8]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.

[9]Emissions are restricted to integer values.

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

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.

3.1.2 The proceeding of the experiment

After describing the interaction situation, the instructions inform subjects of the proceeding of the experiment, which is composed of two phases.

a. **The training phase.** Subjects start by practicing the interaction situation (the ambient tax/subsidy game) for about half an hour. To this end, each subject is provided with a *Payoff Calculator* available on the screen of his computer. The Calculator computes, given the subject's investment and the hypothetical investments of the five other members of his group, his total payoff for each possible value of the random variable. 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 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.

   We would like to emphasize that during this training phase, subjects do not interact with each other. Instead, they use the Calculator to make simulations, and observe the impact of their decisions, of hypothetical decisions of their counterparts, and of "natural variability" on their earnings in euros. These simulations give subjects the opportunity to learn much about the ambient tax/subdidy scheme. However, they do not learn anything about the behavior and types of their counterparts. Put differently, they are left in the same state of strategic uncertainty. This would not be the case if real interactions took place during this training period. Subjects would then have the possibility to learn about the average behavior in the population of players.

Again, our objective is to evaluate the acceptability of the ambient tax *before* any interaction is experienced.

b. **The decision phase.** After completing the training phase, subjects are asked to choose between a sure payoff in euros (decision A) and participating in the interaction situation (decision B). An important specificity of our protocol should now be presented. In order to collect more data, we submit subjects to a *sequence of three choices*, and inform them that only one of these choices will be selected randomly and effectively implemented. For ease of exposition we refer hereafter to these choices as "choice periods", even though these are not interaction periods. At the end of the three choice periods, each subject is presented a recap screen displaying his three decisions and the three decisions of each the five other members of his group.

   One subject in the laboratory is then designated to pick randomly up one of three papers from a box. Each paper has a number (1, 2, and 3) corresponding to a choice period. The paper which is drawn determines which choice period will be implemented for all subjects in the laboratory. Therefore at this point of the experiment, a total of six individual decisions have been collected for each group of subjects. A technical problem is that the whole group has to be submitted to the same decision: either each one gets his sure payoff, or all participate in the interaction situation, but it is not possible to let some get their sure payoff and others participate in the interaction situation, because the latter requires exactly six players.[11] This generates a social choice problem, which is typically addressed by voting. However, voting systems have long history of theoretical and experimental scrutiny questioning their ability to appropriately induce subjects to reveal their true preferences, and thus suggesting that they should be chosen with great care. Therefore we resort instead to a theoretically incentive compatible mechanism, the so-called "*random dictator rule*". Under this scheme, everyone has the same chance of dictating the outcome for the group, whereby strategic considerations are eliminated. After subjects have taken their decisions, one of them (the dictator) is drawn randomly, and his decision is implemented for all members of his group. Because only one individual's choice determines the

[11] Obviously it is not the same for a polluter to be submitted to an ambient tax scheme when there is for example only one other polluter and when there are five other ones. The number of interacting subjects increases strategic uncertainty, so that it is likely to influence the acceptability of the instrument. Hence we decided that the ambient tax/subsidy would only be implement with the whole six-subject group.

outcome, subjects cannot gain by engaging in strategic behavior. This mechanism has already been used in other environmental settings (see Rutström and Williams, 2000, 2002, Büchner and Dittrich, 2002, Anderhub, Dittrich, Güth, and Marchand, 2002).

Here is how the random dictator rule is implemented in our study. Each subject in each group is assigned a number from 1 to 6. Six papers, numbered from 1 to 6, one for each subject, are introduced into a box. Then a paper is drawn at random from the box in order to determine the dictator, which choice (A or B) will be implemented for his respective group. To summarize, the same choice period applies for all subjects in the lab, but a different option (A or B) may apply for each group, depending on the respective dictator's actual choice. Those groups in which decision A has been taken by the dictator in the drawn choice period earns the sure payoff that has been up for choice in the relevant choice period, and the experiment ends. Those groups in which decision B has been drawn participate in the interaction situation.

It should then be noticed that subjects play the ambient tax game—whenever they play it—for only one period. This one-shot feature is chosen because we need to introduce high monetary incentives in this experiment in order to be able to assess the acceptability of the ambient tax, otherwise subjects will not be induced to make thoughtful choices or might simply gamble. Since there is only one period of play, subjects have to make their choice between the ambient tax and the sure payoff very carefully. Allowing for more periods would have made the choice of the ambient tax less risky and diluted the incentives. Of course, subjects know that the game will be played only once. In other words, we choose a one-shot game in order to approximate the high stakes that are present in the field. Another reason can account for our choice of considering a one-shot game. A repeated game is likely to be regarded as more attractive than a one-shot game by subjects. Thus, if we would have implemented a repeated game, then subjects might have chosen the ambient-tax game just to have a good time. This could have artificially increased the acceptability of the instrument.

At the end of the session, subjects are paid their accumulated payoffs, converted from laboratory points to euros. Conversion rates differ between sessions and polluters' types so that, in case of perfect individual compliance with the social optimum in the interaction situation, payoffs are identical (they are actually equal to 12 euros at the social optimum).

3.2 Treatment variables and experimental parameters

There are three treatment variables in our experiment: the level of the sure payoff, the position of the socially optimal emission level in the strategy space, and the level of the lump-sum subsidy K of the ambient tax/subsidy scheme. Only the first of these treatment variables is specific to this study. The two latter ones are similar to the ones in Cochard, Ziegelmeyer, and BounMy (2005) on which this study is based. We now describe each of these treatment variables and the corresponding experimental parameters subsequently.

In this experiment, subjects have to choose between the ambient tax scheme and a sure payoff. The level of the sure payoff is thus our first treatment variable. We consider twelve levels of sure payoff, defined in percentages of the social optimum payoff under the ambient tax scheme (i.e. 12 euros) from the set {40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%}. Each subject is faced with a sequence of three choices between participating in the ambient tax game and earning a sure payoff from the previous set. Therefore, each subject experiences only three of the twelve previous sure payoff levels: one relatively low, one relatively medium, and one relatively high. To reduce order effects, these sure payoffs are not presented in increasing or decreasing order. Instead, the subjects are first submitted the medium sure payoff, then the high one, and then the low one. Each six-subject group is faced with a specific sequence of three sure payoffs. Since there are four groups in each treatment, we are able to investigate the effect of each of the twelve payoff levels. The sure payoffs sequences are displayed in table 1 on the following page.

The two other treatment variables that we consider here are similar to the ones introduced in Cochard, Ziegelmeyer, and BounMy (2005). However, contrary to this study, we restrict ourselves to the *limited information* condition, in which 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. Cochard, Ziegelmeyer, and BounMy (2005) also consider a *complete information* condition, in which subjects know the endowments and private payoff tables of the other people in their group.

The position of the socially optimal level in the polluter's emission interval is also investigated.

Table 1: Sure payoff sequences per group in each treatment.

	Group 1	Group 2	Group 3	Group 4
Choice no. 1	75%	70%	65%	60%
Choice no. 2	95%	90%	85%	80%
Choice no. 3	55%	50%	45%	40%

Note: The percentage is the percentage reduction with respect to the social optimum payoff (12.00€). For example, each member of Group 2 has first to choose between playing the ambient tax game and earning 70 % of the social optimum gain under the ambient tax, then to choose between playing the ambient tax game and earning 90 % of the social optimum gain under the ambient tax, and finally to choose between playing the ambient tax game and earning 50 % of the social optimum gain under the ambient tax.

Two positions of this level 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 (see table 3 and table 4 below for more details).[12]

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 ($K^* = (\sum_i e_i^*)^2 + Var[\epsilon]$), 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. In the experiment, we set $K = 0.85K^*$ in the *Kinf* condition, and $K = 0.85K^*$ in the *Ksup* condition.

The two positions of the socially optimal level factor is combined with the level of the lump-sum subsidy factor in a complete 2×2 factorial design. Table 2 summarizes our experimental design and table 3 provides the key parameters of the experiment.

[12]Recent experimental literature on public good games has shown that the level of the equilibrium (here, the social optimum) in the strategy space has an impact on the subjects' contributions as moving the equilibrium level of contribution closer to the collusive decision leads to a decrease in average over-contribution with respect to the equilibrium (see, among others, Isaac and Walker, 1998 and Willinger and Ziegelmeyer, 2001). By considering two different levels of the social optimum, we study whether these findings can be confirmed in a "public bad" setting (recall that in our experiment the social optimum is the Nash equilibrium of the stage game). In the high social optimum condition, the distance between the social optimum and the collusive outcome is much larger than in the low social optimum condition. Therefore, if past results can be generalized, we should observe average decisions to be closer to the social optimum in the latter case (as is the case in Cochard, Ziegelmeyer, and BounMy, 2005).

Social optimum's position	Lump-sum subsidy	Treatment
Low	Kinf	*LowKinf*
Low	Ksup	*LowKsup*
High	Kinf	*HighKinf*
High	Ksup	*HighKsup*

Table 2: Experimental design.

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 3: Parameters of the experiment.

3.3 Theoretical benchmarks

Our experimental data can be compared to the two following quantitative benchmarks: the social optimum and the (fully) collusive outcome. Table 4 summarizes our theoretical predictions for the two positions of the socially optimal level in the strategy space.[13] Total socially optimal emissions released by a group of six polluters composed of one small polluter, four medium polluters and one large polluter equal 70 (respectively 120) in the low (respectively high) social optimum condition. Total collusive emissions released by the same group of polluters equal 17 (respectively 42) in the low (respectively high) social optimum condition.

[13]Given the parametrization of the experiment, Nash equilibrium emissions are integer values. However, the collusive emissions reported in the table have been computed under the additional assumption that emissions are restricted to integer values.

Social optimum's position		Low			High	
Polluter's type	Small	Medium	Large	Small	Medium	Large
Socially optimal emission	9	11,11,11,11	17	15	19,19,19,19	29
Collusive emission	3	3,2,2,2	5	6	6,6,6,6	12

Table 4: Emissions at the social optimum and the collusive outcome.

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/subsidy acceptance rates

4.1.1 Descriptive analysis

Figure 1 on the next page depicts the average acceptance rates per type of polluter and per interval of sure payoff levels ($40\% - 55\%$, $60\% - 75\%$, $80\% - 95\%$). Two remarks can be formulated:

- The average acceptance rates tend to decrease with the level of the sure payoff (the slope coefficients are significantly negative at the 5% level for Large and Medium polluters, though not for Small ones). This is what we would expect. Provided that subjects' utility functions are increasing in their monetary payoffs, then, whatever their attitude with respect to ambiguity, acceptance rates cannot increase with the level of the sure payoff.
- The average acceptance rates are relatively high (50% or more), even when the sure payoff is high. Thus, subjects choose the ambient tax even when the sure payoff is almost equal to the social optimum payoff under the ambient tax. This may suggest that subjects expect higher earnings than the social optimum ones.

The figure clearly shows that when the sure payoff is low (40% to 55%), all types of subjects have similarly high acceptance rates. For higher sure payoff levels, Small polluters tend to choose the ambient tax more frequently than Medium and Large polluters, and Medium polluters more frequently than Large ones. Put differently, Small polluters' acceptance rates decrease slowly with sure payoff

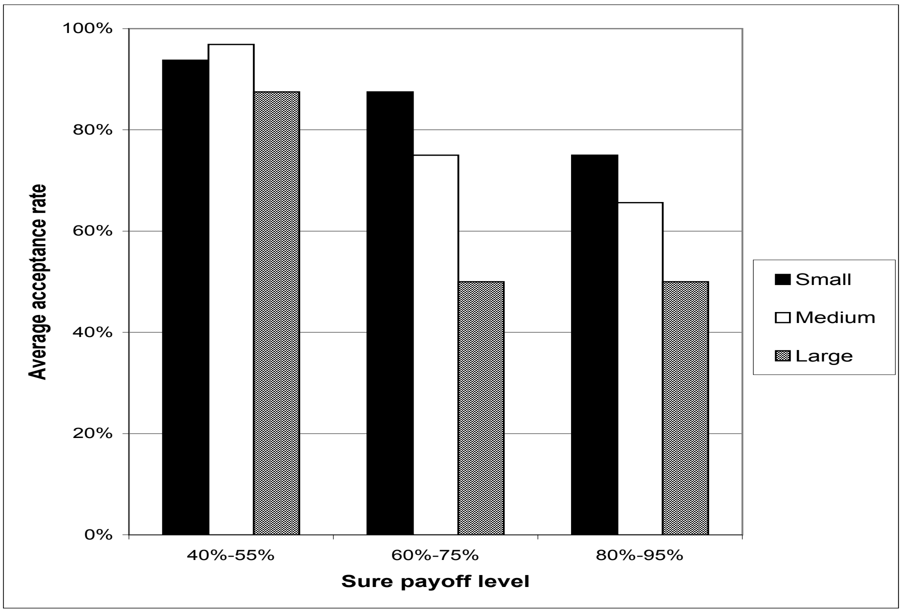

Figure 1: Average acceptance rates per intervals of sure payoff.

and remain at a high level even when the sure payoff is high. Large polluters' acceptance rates are at a high level only when sure payoffs are low, and then decrease steeply when the sure payoff is higher than 55%. Medium types' acceptance rates are in between, and seem to decline linearly with the level of the sure payoff.

Figure 2 on the following page depicts the average acceptance rates per type for each treatment. Average acceptance rates are almost always decreasing with sure payoff. It is however difficult to investigate the difference among treatments on the basis of these diagrams. Accordingly, we further investigate our data set by resorting to econometric regressions.

4.1.2 Econometric analysis

In this subsection, we intend to substantiate those observations drawn from the previous descriptive analysis. To this end, we estimate the probability of choosing the ambient tax given the level of the sure payoff, and test for differences between treatments and types.

The observations can be treated as cross-sectional time series (or panel) data. There is a total of

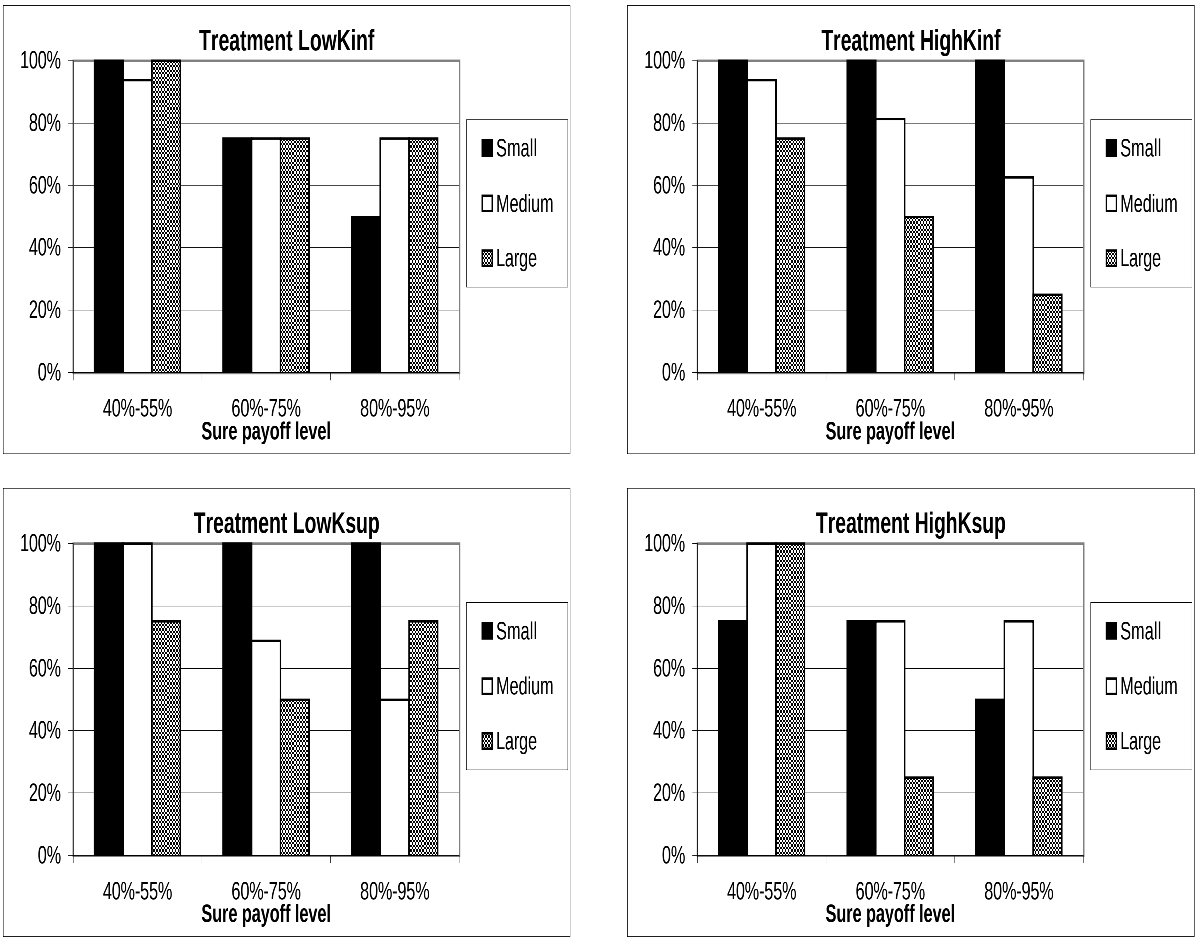

Figure 2: Average acceptance rates per treatment.

96 subjects and 3 "choice periods". Assume that the acceptance decision of subject i ($i \in \{1, ..., 96\}$) in choice period 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. For comparisons between treatments and between types, we need to define a reference treatment and a reference type. Let us set treatment *LowKinf* as the reference treatment, and Medium as the reference type. The choice of *LowKinf* is arbitrary. The choice of Medium-type is due to the fact that there are more Medium than Small and Large polluters. The explanatory variables (fixed effects) we can use are therefore: *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. 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 5 on the next page. The Wald test shows that the model is globally significant. The random individual effect is significant (the variance 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 choice period coefficient is significantly positive. This suggests that subjects are more prone to accept the ambient tax in the second than in the first choice period, and in the third than in the second choice period. This is rather surprising at first glance to the extent that we took care not to have the sure payoff levels monotonically decrease over choice periods. A possible explanation is that the subjects' minimum requested sure payoff levels decreased over choice periods because subjects progressively thought that it could be a pity to miss the opportunity to experience the interaction situation. It should however be noticed that this coefficient is of relatively small magnitude. No significant difference is detected between treatments. The Large polluters' coefficient is significantly different from 0 at the 5% level. Since it is negative, this confirms that the Large polluters' acceptance probability is significantly lower than that of the Small and Medium polluters.

Table 5: Result of the Probit regression.

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 $\geq \overline{\chi}^2 = 0.000$

4.1.3 Acceptability of the ambient tax: Discussion

Let us summarize the previous results:

a. The average acceptance rates decrease with the level of the sure payoff, which is what one would expect.

b. The average acceptance rates are high even if the sure payoff is high. 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 investments. In the next section, we investigate whether this expectation proves correct or not. This observation leads us to conclude that the acceptability of the ambient tax is rather high in our experimental setting.

c. No clear treatment effects have been detected. This means that the acceptability of the ambient tax is neither affected by the level of the subsidy K nor by the position of the social optimum. This result is of interest. First, one could have expected 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 they will get 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. In our experimental setting, we have $Kinf = 0.85K^*$ and $Ksup = 1.15K^*$. A question is whether a smaller $Kinf$ and a larger $Ksup$ would have produced the same results. Second, one could have expected acceptability to be higher when the social optimum is high than when it is low. Indeed, as was observed in Cochard, Ziegelmeyer, and BounMy (2005), investments were relatively lower than the social optimum in the high social optimum treatments than in the low social optimum treatments. This is not the case here. This could indicate that subjects did not anticipate lower investments in the high social optimum treatments in the present experiment.

d. Large polluters are less prone to accept the ambient tax than Medium and 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 relatively higher emissions, and thus larger tax payments, whereas Small (and Medium) polluters expect relatively lower emissions, and thus lower tax payments (or even subsidies). Accordingly, it is not surprising that Large polluters are less prone to accept the ambient tax.

4.2 The token investments (polluters' emissions)

In the experiment, the ambient tax is effectively implemented (after the random drawings) in 11 of 16 groups.[14] Therefore, we collect quite a lot of data concerning the ambient tax game. In this section, we analyze the number of tokens invested (i.e. the polluters' emissions) by subjects when the ambient tax is actually implemented.

Table 7 on page 23 displays the average amount of invested tokens in each treatment. All data are aggregated in table 6 on the next page. As can be noted, the average levels of investment are smaller than the socially optimal investments in all treatments (no clear differences between types are observed). A hypothesis we formulated previously is that subjects chose the ambient tax because they anticipated relatively small investments, and thus relatively high payoffs. If this is the case, then this

[14] The ambient tax is implemented in 3 groups in treatment *LowKinf*, in 4 groups in treatment *LowKsup*, in 3 groups in treatment *HighKinf*, and in 1 group in treatment *HighKsup*.

anticipation proves right. Tables 7 on the following page and 6 show that actual earnings are much higher than the social optimum earnings, and thus much higher than the sure payoff levels.

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 sure 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.

Table 6: 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.	53%	76%	71%	72%
Payoff Euros (% Soc. Opt.)	21.29 (177%)	20.86 (174%)	15.91 (133%)	120.64 (167%)

Investments are surprisingly low when compared to the first period of Cochard, Ziegelmeyer, and BounMy (2005). A hypothesis to account for this observation is that our design has the same effect on behaviors as a cheap talk. Before playing the game, subjects observe the choices (between the sure payoff and the ambient tax) of the other group members. Since collusion in the ambient tax game provides high payoffs, choosing the ambient tax game might be interpreted as a (non binding) commitment of collusive behavior. Thus, if many of the group members have chosen the ambient tax game, subjects might be confident that playing the game will be worthy because of collusion. To check this hypothesis, we computed the correlation coefficient between the "degree of collusion"[15] in each group and the number of subjects having chosen the ambient tax. If our hypothesis was true, then this correlation coefficient would probably be significantly positive and high. However, the correlation coefficient is very low (0.0097) and non significantly different from 0 (Student test, p=.9774), which leads to a rejection of the previous hypothesis.[16]

[15] We define the degree of collusion as the difference between the social optimum investment and the observed investment, divided by the difference between the social optimum investment and the collusive investment.

[16] The average degree of collusion is equal to .3076 when all subjects chose the ambient tax, and to 0.4557 when at least one subject chose the sure payoff.

Table 7: Average amount of invested tokens per treatment.

Low Social Optimum Treatments	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 (26%)	6.50 (59%)	17.33 (102%)	45.67 (65%)
Payoff Euros (% Soc. Opt.)	22.51 (188%)	24.08 (201%)	20.64 (172%)	139.17 (193%)
Treatment *LowKsup*				
Nb. of observations	4	16	4	4
Average observed Investment (% Soc. Opt.)	2.75 (31%)	10.94 (99%)	7 (41%)	53.5 (76%)
Payoff Euros (% Soc. Opt.)	17.88 (149%)	21.07 (176%)	13.60 (133%)	115.76 (161%)
High Social Optimum Treatments	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 (89%)	14.25 (75%)	17.67 (61%)	88 (73%)
Payoff Euros (% Soc. Opt.)	24.7 (206%)	19.51 (163%)	13.89 (116%)	116.63 (162%)
Treatment *HighKsup*				
Nb. of observations	1	4	1	1
Average observed Investment (% Soc. Opt.)	18 (120%)	7.75 (41%)	36 (124%)	85 (71%)
Payoff Euros (% Soc. Opt.)	21.05 (175%)	14.39 (120%)	17.94 (149%)	96.56 (134%)

5 Conclusion

This experiment aimed at studying the acceptability of the ambient tax. Our starting point is that 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. Accordingly, we offer subjects the opportunity to choose between playing a game with an ambient tax, and earning a sure payoff. We consider several levels of the sure payoff, but these levels are always smaller than the social optimum payoff under the ambient tax. When making their choices, subjects are in a situation of limited information, since they do not know the payoffs of the other members of their group. They know that the ambient tax game will be played only once—if at all. Two treatment variables are introduced: the level of the ambient tax subsidy K (low or high) and the location of the social optimum in the strategy space (low and high). Groups are heterogeneous: there are Small, Medium, and Large polluters.

We study the acceptance rates of the ambient tax as a function of the sure payoff level, and test for differences between treatments and types. The rate of acceptance decreases with the level of the sure payoff, which is as expected. What is more striking is the fact that acceptance rates remain high even when the sure payoff is almost as high as the social optimum ambient tax payoff. No treatment effects is observed. Large polluters are less likely to accept the ambient tax than Small and Medium polluters. We also analyze the subjects' investment decisions (polluters' emissions) whenever the ambient tax is effectively implemented. Investments are observed to be lower than the socially optimal levels, which allows subjects to get higher payoffs than the social optimum ones, and thus than the sure payoff levels.

The reason why acceptance rates are so high is unclear. Subjects might have correctly anticipated that investments would be relatively low, allowing for high earnings. What is however surprising is that they take a great risk by choosing the ambient tax. Moreover, why do subjects pollute so little if they expect others to do so in a one-shot interaction? Our hypothesis was that our protocol enhances collusion in the same manner as a cheap talk. But we were able to reject this hypothesis on the basis of our data set.

All in all, 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.

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Translated Instructions

The following instructions were originally written in German. We document here the instructions used in the LowKsup *treatment, for a Small polluter. The instructions for the other treatments were adapted accordingly. In particular the individual payoffs for Medium and Large polluters can be found respectively in tables 9 on page 32 and 10 on page 33.*

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 8, page 31) 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 8: 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

Table 9: Table of individual payoff for a Medium polluter

Number of tokens invested	Additional gain or loss generated by the last token invested	Total individual payoff
0 token	-	0 point
1 token	213.5 points	213.5 points
2 tokens	206.5 points	420 points
3 tokens	199.5 points	619.5 points
4 tokens	192.5 points	812 points
5 tokens	185.5 points	997.5 points
6 tokens	178.5 points	1 176 points
7 tokens	171.5 points	1 347.5 points
8 tokens	164.5 points	1 512 points
9 tokens	157.5 points	1 669.5 points
10 tokens	150.5 points	1 820 points
11 tokens	143.5 points	1 963.5 points
12 tokens	136.5 points	2 100 points
13 tokens	129.5 points	2 229.5 points
14 tokens	122.5 points	2 352 points
15 tokens	115.5 points	2 467.5 points
16 tokens	108.5 points	2 576 points
17 tokens	101.5 points	2 677.5 points
18 tokens	94.5 points	2 772 points
19 tokens	87.5 points	2 859.5 points
20 tokens	80.5 points	2 940 points
21 tokens	73.5 points	3 013.5 points
22 tokens	66.5 points	3 080 points
23 tokens	59.5 points	3 139.5 points
24 tokens	52.5 points	3 192 points
25 tokens	45.5 points	3 237.5 points
26 tokens	38.5 points	3 276 points
27 tokens	31.5 points	3 307.5 points
28 tokens	24.5 points	3 332 points
29 tokens	17.5 points	3 349.5 points
30 tokens	10.5 points	3 360 points
31 tokens	3.5 points	3 363.5 points

Table 10: Table of individual payoff for a Large polluter

Number of tokens invested	Additional gain or loss generated by the last token invested	Total individual payoff
0 token	-	0 point
1 token	222.5 points	222.5 points
2 tokens	217.5 points	440 points
3 tokens	212.5 points	652.5 points
4 tokens	207.5 points	860 points
5 tokens	202.5 points	1 062.5 points
6 tokens	197.5 points	1 260 points
7 tokens	192.5 points	1 452.5 points
8 tokens	187.5 points	1 640 points
9 tokens	182.5 points	1 822.5 points
10 tokens	177.5 points	2 000 points
11 tokens	172.5 points	2 172.5 points
12 tokens	167.5 points	2 340 points
13 tokens	162.5 points	2 502.5 points
14 tokens	157.5 points	2 660 points
15 tokens	152.5 points	2 812.5 points
16 tokens	147.5 points	2 960 points
17 tokens	142.5 points	3 102.5 points
18 tokens	137.5 points	3 240 points
19 tokens	132.5 points	3 372.5 points
20 tokens	127.5 points	3 500 points
21 tokens	122.5 points	3 622.5 points
22 tokens	117.5 points	3 740 points
23 tokens	112.5 points	3 852.5 points
24 tokens	107.5 points	3 960 points
25 tokens	102.5 points	4 062.5 points
26 tokens	97.5 points	4 160 points
27 tokens	92.5 points	4 252.5 points
28 tokens	87.5 points	4 340 points
29 tokens	82.5 points	4 422.5 points
30 tokens	77.5 points	4 500 points
31 tokens	72.5 points	4 572.5 points
32 tokens	67.5 points	4 640 points
33 tokens	62.5 points	4 702.5 points
34 tokens	57.5 points	4 760 points
35 tokens	52.5 points	4 812.5 points
36 tokens	47.5 points	4 860 points
37 tokens	42.5 points	4 902.5 points
38 tokens	37.5 points	4 940 points
39 tokens	32.5 points	4 972.5 points
40 tokens	27.5 points	5 000 points
41 tokens	22.5 points	5 022.5 points
42 tokens	17.5 points	5 040 points
43 tokens	12.5 points	5 052.5 points
44 tokens	7.5 points	5 060 points
45 tokens	2.5 points	5 062.5 points